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THE ABIDJAN CONFERENCE 1968

VOLUME I

NATIONAL ACADEMY OF SCIENCES

NATIONAL RESEARCH COUNCIL

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CONFERENCE ON AGRICULTURAL RESEARCH PRIORITIES FOR ECONOMIC DEVELOPMENT IN AFRICA

Colloque sur les Priorités de la Recherche Agricole
Dans le Développement Economique de L'Afrique

ABIDJAN, IVORY COAST
April 5-12, 1968

VOLUME I

REPORT OF THE CONFERENCE

Volume II

Contributed Papers:
Soil and Water Management:
Crop Production and Protection

Volume III

Contributed Papers:
Animal Production & Health
Economics; Farming Systems;
Education, Research & Institutions.

Organized by the US National Academy of Sciences in cooperation with the Food and Agriculture Organization of the United Nations and the Government of the Republic of the Ivory Coast, and with the financial support of the US Agency for International Development.

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M.G.C. McDonald Dow
Washington, D.C.
December, 1968

Foreword

Over the centuries the people of Africa have adapted themselves to the forces of nature. It is primarily in the settler areas, such as Kenya, Rhodesia, and South Africa that attempts have been made to apply science and technology to agriculture. For the rest of Africa, Ritchie Calder's expression "men against the jungle" provides an apt description of subsistence agriculture.

One of the paradoxes of developing countries, and of Africa in particular, is that their societies, although predominantly agricultural, are becoming acutely short of food. This is partly because the encouragement of agriculture by the colonial powers was directed almost exclusively towards the production of export crops. Such a policy can, to a limited extent, be justified because colonial territories have to earn external resources to pay for the cost of administration and the skeletal system of social services introduced by the metropolitan powers.

After the second World War, there was a noticeable attempt to provide a scientific and technological base to agriculture in the dependent territories of Africa. The Commission for Technical Cooperation in Africa South of the Sahara (CCTA) organized scientific conferences and sponsored research work. A chain of agricultural research stations began to appear in the various parts of the continent. These were staffed and partially financed by the colonial powers. The CCTA has now been replaced by the Scientific, Technical and Research Commission under the auspices of the Organization of African Unity (STRC/OAU). Most of the scientists who had gained some experience of agriculture under African conditions have returned home since African

territories became independent. The newly independent states, however, do not command the personnel or the financial resources to maintain scientific work, even at the colonial level.

In the past, the metropolitan powers organized training courses and meetings for scientists – French under the French Government, and British under the British. Later, the CCTA provided an opportunity for multinational meetings. Africa, therefore, has two levels of needs – to fill the research gap which has been created since the attainment of independence, and to raise the level and scope of activities to meet the growing needs of its populations.

The *Conference on Agricultural Research Priorities for Economic Development in Africa* held in Abidjan, Ivory Coast, in April 1968 under the auspices of the United States National Academy of Sciences, in cooperation with the Food and Agriculture Organization of the United Nations and the Government of the Ivory Coast, brought together scientists in similar fields from adjacent countries and gave them an opportunity to meet for the first time. The decision of the Conference to form an Association for the Advancement of Agricultural Sciences in Africa, with membership open to all agricultural scientists on a voluntary basis, may turn out to be a decisive step. It may mean the acceptance of science and technology as effective instruments in meeting the immediate needs of the growing populations of Africa and in revolutionizing agriculture.

I feel happy and honored to contribute this foreword to the report of a conference of such significance.

R.K.A. Gardiner
Executive Secretary
UN Economic Commission for Africa

Postscript

Professor Akin Mabogunje, Chairman of the Special Seminar on Agro-Climatology and Water Resource Development, in his article in the BULLETIN OF THE ATOMIC SCIENTISTS* evaluated extremely well the achievements of the Conference on Agricultural Research Priorities for Economic Development in Africa. He states ". . . the Abidjan conference represents a veritable milestone in the history of agricultural development in Africa. This is not only because of the consensus arrived at with regard to research priorities but especially for the opportunity provided for the establishment of the Association for the Advancement of Agricultural Sciences in Africa. This continental organization is meant to provide an invaluable medium for keeping a continuous overview on the extent to which the research priorities so ably formulated at Abidjan are achieved."

The conference comprised eleven commissions, each involving participants of widely divergent backgrounds and interests, deliberating over research priorities in a continent heterogeneous in terms of its ecology and its ethnic relationships. Nevertheless, the commissions successfully focused attention on the most urgent problems in need of intensified agricultural research.

Certain broad research needs stood out in bold relief against a mass of specific priorities. The understanding of soil and water management in Africa was considered woefully inadequate, yet this is probably the most important

*April 1969.

specific research area in tropical Africa. Soil improvement constitutes the basis for any dramatic change in food production or in other types of agricultural production.

Important research currently being carried out in maize, millet, and sorghum should be continued according to the Commission on Food Production but it is essential that rice production also be intensified in West Africa. Legumes and root crops are another priority area for research. Root crops are widely produced and consumed and they will continue to be, irrespective of their low nutritional status yet they receive little attention from the research workers. Legumes should be produced and consumed more widely to elevate the level of protein the people consume.

As yields, diversity and quality of products increase and as transportation and marketing possibilities improve, protection of growing crops and storage and protection of harvested crops must also improve.

The principal management problem in animal production is proper nutrition. The Commission on Animal Production and Health pointed out the great need for research on fodder production in both humid and dry tropics, to exploit the ecological potential of the continent to produce food as efficiently as possible in a great variety of environmental conditions.

The research needed in marketing, mechanization, growth of farm and non-farm population, varietal improvement and many other aspects of agriculture were similarly emphasized. The relative importance of each of these general priority areas will, however, vary according to local conditions.

Generalizations do not substitute for the Commissions' deliberations; the Commissions' reports must be referred to for elaboration of the priorities as they were set forth by the Commission members.

Most of the participants viewed the Abidjan conference as but the first of a series filling a real need. Future conferences will probably be held at appropriate times and places under the aegis of the newly-formed AAASA. Not only may they define research priorities and build stronger lines of communication among research workers; they may also serve to develop better understanding among scientists and economic planners who in cooperation can promote the most effective action programs in agricultural development based on sound research.

Those who participated can take great pride in the outcome of the conference. The *ad hoc* committee consisting of African and expatriate agricultural leaders greatly contributed to its success. The support of FAO, the work of the National Academy staff together with Ivorien officials concerned with local arrangements and with hospitality constituted key elements that made the conference a productive stimulating experience.

John J. McKelvey, Jr.
Chairman, Organizing Committee
Rockefeller Foundation, New York

The Conference

Background and Synopsis

Since the Abidjan Conference was the first meeting of its kind in Africa, it is useful to record in some detail certain aspects of its background and organization.

The concept of holding a conference which would review existing knowledge about the technical aspects of food production in Africa originated in 1966 from informal discussions between members of the Africa Science Board of the US National Academy of Sciences (NAS), prominent African agriculturalists, planners and educators, and representatives of the Agency for International Development (AID), the Rockefeller Foundation, the International Bank for Reconstruction and Development, the Food and Agriculture Organization of the United Nations (FAO) and other interested organizations. As a result of the interest generated, AID asked the Academy to undertake formal exploratory discussions on the desirability, objectives, agenda and participation in such a conference.

PLANNING MEETING AT THE UNIVERSITY OF GHANA

Accordingly an Academy Organizing Committee, chaired by Dr. John J. McKelvey, Jr. of the Rockefeller Foundation, was created and this Committee invited an *ad hoc* group of distinguished African scientists to a planning meeting with NAS, AID and FAO representatives at the University of Ghana in March, 1967. The Ghana meeting agreed that there was need for a

conference at which agricultural scientists, as individuals rather than government representatives, could discuss the priority areas of agricultural research to which more emphasis should be given toward finding solutions of problems restricting increases in food or export crop production. It was also agreed that for the first meeting of this type participation should be broad geographically and representative of the various academic disciplines. In addition, it should include not only the university and research institute scientists and economists, but also representatives of the ministries of agriculture, in recognition of the dependence on government funding of research in Africa and the need for ministries and non-governmental agencies to work together more closely.

This kind of participation would stimulate communication and cooperation among the scientists, economists, educators, planners and administrators, working on similar problems in different countries in an informal way not possible at meetings of government delegations.

It was envisaged that the information provided by the Conference would be of use to governments and national and international technical agencies for more effective deployment of agricultural research resources to improve agricultural production. The congregation of a broadly representative group of agriculturalists from a large number of African countries would also provide an opportunity for them to form an association as a permanent mechanism for maintaining contact and communication and stimulate more effective research on Africa's crop and animal production problems.

The planning group also prepared a provisional agenda and compiled a list of possible participants.

THE PARIS MEETING

The agenda and participation were also the subject of a June, 1967, Paris meeting between NAS, FAO and AID officials and representatives of the French specialized research institutions dealing with tropical agriculture and Belgian and British Government technical cooperation agencies, at which the purpose of the Conference was explained and their support and advice solicited.

COSTS OF THE CONFERENCE

Costs of the Conference totalling $250,000 were borne by AID, including travel and subsistence expenses for participants from African countries and from private institutions in Europe and the United States. FAO provided a team of eight interpreters and two translators at cost, in addition to technical personnel.

PARTICIPATION

Participants were invited individually by the NAS and ultimately totalled approximately 200 from 32 countries.

PRE-CONFERENCE DINNER

Participants met at the Hotel Ivoire for a pre-conference dinner on April 5th. After dinner, Mr. Ola Vincent delivered a statement* on behalf of President Mamoun Beheiry of the African Development Bank.

In his statement, Mr. Beheiry noted that the objectives of the Conference and the problems it is facing are of particular interest to the African Development Bank, and expressed the support of the Bank for this initiative and for application of practical results in the future.

The Bank and the Conference have the common objective of economic development. The agreement through which the Bank was created has been signed by 30 independent African countries to date, and the membership and capital is entirely African. It finances investment projects or programs of member countries giving priority to those which are multinational. Agricultural and industrial development are the fundamental constituents of economic development; they are complementary and their interaction is clear particularly in exports and imports. If 80 percent of the population is involved in agriculture, progress in agricultural development will increase not only their standard of living but also their effective demand for industrial production.

One particular problem resulting from the low level of income in many African countries is that much of any increase in per-capita income is required for buying food. Increased industrialization, on the other hand, needs more and more production of industrial raw materials. The priority objectives should therefore be: food production in sufficient quantity to supply the needs of the continent and accelerated production of other agricultural output and raw materials to meet the needs of the industrial sector. This production will enable exports to be increased and reduce the demands of the agricultural sector for foreign exchange.

Research is an integral part of this, but it is important to orient the research appropriately to ensure the resulting technical innovations are easily adopted by the farmers. Multinational research efforts, where appropriate, should be stressed. African countries should employ joint efforts in

*Complete texts are included in this report on pp. 73–103.

establishing effective research programs in a number of areas: seed selection, cultivation, improvement in equipment, irrigation and flood control. The results ought also to be exchanged extensively and effectively between the various African research institutions.

Apart from production, storage, distribution and marketing are also problems as are credit policy, land-tenure and the expansion of extension services. Thus it is most encouraging to see agriculturalists, economists and administrators represented at this meeting. In closing Mr. Beheiry hoped that the relations established through this meeting would persist and that regular meetings of this kind would be held. The deliberations would be followed with great interest and he wished them every success.

Dr. McKelvey then introduced Mr. Robert Gardiner, Executive Secretary of the UN Economic Commission for Africa (ECA). Mr. Gardiner, in a keynote address, pointed out that science is not the monopoly of any social system, and that every state could, no matter how poor or small, train enough of its citizens to ensure its entry into the domain of scientific thought and action necessary to control their resources – this ability characterizing the independent from the dependent economies. Africa has approximately 280 scientific institutions dealing with agriculture and natural resources and a reassessment of the concept of research, possibly on the basis of ecological zones, was of the greatest interest. There is, furthermore, a great contrast between the ability of the sub-continent to produce agricultural products, and the drain on foreign exchange reserves for importation of cereals, sugar and dairy products. These problems require urgent solution, through a coordinated and rational approach to technical assistance on the one hand and the development of appropriate institutional capability on the other. ECA would wish to play a positive part in institutional activities concerned with furthering research in the field of agriculture. Recognizing that research, while costly, pays handsome dividends – the Rockefeller crops research programs in Mexico, India, Pakistan and Turkey are supreme examples – a similar effort in food crop and livestock production in Africa might well result in her becoming a net exporting rather than deficient continent.

Finally, he strongly recommended the development of a continuing dialogue between African agricultural scientists through creation of an Association for the Advancement of Agricultural Sciences in Africa, which ECA would strongly support. ECA or some other appropriate body might also be selected as a focal point for the dissemination of research results. Concluding, Mr. Gardiner paid tribute to the late Dr. Martin Luther King in the following words:

> The outcome of the deliberations of this conference and, particularly, the results of follow-up actions will not be unrelated to the solution of what I believe to be, a

major problem of our age – the avoidable poverty and social handicaps of 'the third world' and the underdeveloped countries. La Fontaine's fables illustrate the notion that 'the poor are always wrong'. Some of the hostility of the privileged is derived from this wrong notion. The poor and handicapped minorities and nations, if their existence were to be taken for granted, would become the outcasts of the 20th Century world community. On Oscar Wilde's tombstone one reads that 'outcasts always mourn'. Today we have cause to mourn. Another champion of the poor, the handicapped and the underprivileged has fallen victim to human folly. Yesteryear it was John F. Kennedy and this year, Martin Luther King. The outcasts must continue to mourn.

Mr. Chairman, Ladies and Gentlemen, the challenge to us is not confined to work in laboratories and farms. It concerns a vital element in the search for peace and human dignity. 'The wars of the future', the late Lord Keynes stated, 'may start not from disputes about sovereignty and frontiers but from the problems of fuel, transport and food.'

OPENING CEREMONY

The official opening ceremony took place at 9:00 a.m. April 6th in the Cinema of the Hotel Ivoire, presided over by the Ivoirien Minister of Agriculture, His Excellency Abdoulaye Sawadogo.

In his opening address, Mr. Sawadogo welcomed participants on behalf of President Houphouet-Boigny who would have wished to open the Conference in person had not affairs of state taken him out of the country at the time. He described the aspiration of all African countries, of whatever location or economic system, as emergence from underdevelopment, or achievement of economic independence through development of modern economies. These should have substantial recourse to science and technology of which agricultural research was most important. In the Ivory Coast, agriculture must have priority in development efforts and agricultural research must relate to development planning. This is achieved through technical committees and has led to great efficiency in the research institutes which have produced valuable results already serving the 1960-1970 economic plan of diversifying the economy.

He then called for increases in productivity, to combat dropping world market prices for raw materials, and for greater efforts in the increase of value of exports through industrial processing prior to exportation. These guidelines give impetus to research in the various fields, through exchange of knowledge and materials, and to international collaboration as an absolute necessity for the contribution of the richer countries to the progress of the poorer. Here, formation of a scientific association could only stimulate such collaboration through technical assistance. The questions arising from different

methods of organization of cooperation in research – bilateral, multilateral, under national or supranational control on an ecological basis – can be settled through a conference such as this. The case of the Ivory Coast merits study. The joint Ivoirien-French institutes have accomplished much, and while this relationship reflects a tradition of cooperation between the two countries, the Ivory Coast also seeks new relationships with all organizations – private, national or international – willing to contribute to the advancement of science in the Ivory Coast. The Government of the Ivory Coast regards the choice of Abidjan for the Conference as a privilege and an honor.

Replying on behalf of the US National Academy of Sciences, Dr. Edward Knipling pointed out the tremendous return on investment in research in agriculture in the United States. The Academy's role in this has been limited primarily to the activities of its advisory committees. However, in more recent years it has come to reflect increasing interest of the US scientific community in problems of development in other countries, and in particular in the Africa Science Board undertaking the organization of this Conference. Describing the genesis of the meeting, he concluded by saying that the fundamental principle that technological and scientific research is an essential component of economic development, in the Academy's view is just as true for Africa as it has been for the United States. Hoping that this would be but the first of many meetings, and that it might also provide for the establishment of a permanent mechanism for continuing discussion and increasing communication and cooperation, he was delighted to welcome so many distinguished colleagues to the Conference.

Dr. Otto E. Fischnich, on behalf of the Director-General of FAO, expressed the pleasure of his organization in being invited by the US National Academy of Sciences to cooperate in the organization of the Conference. Its aim, he continued, is of prime importance for Africa's future, and the need for the development of food and agricultural resources is very urgent. The development of science and technology and the ever-increasing problems facing agriculture call for intensification of efforts and closer cooperation at all levels. The Conference is a fine example of this type of cooperation, and it is hoped that the recommendations and conclusions will be followed by positive action. FAO will give full support in serving the needs of member nations. He wished the Conference every success.

Dr. J.J. McKelvey Jr. prefaced the opening of the first plenary session by remarking that his impressions from the Rockefeller Foundation sponsored conference on the "Strategy for the Conquest of Hunger" which had just

been held in New York, were that the emerging nations had made a tremendous amount of progress in the previous twenty years. The facts and figures presented by eminent public servants from many parts of the world showed that great increases in yield were being obtained through the use of new varieties of wheat, "miracle" rice, and fertilizers, as a result of work that has been done in these countries. However it was also clear that although much had been done, more attention needed to be given to the research priorities for the future. He hoped that the Conference would provide an opportunity for participants to return to their countries with clear, honest evaluations of these priorities. The distinguished chairmen had been left as free as possible in the organization of their commissions which were expected to produce objective resolutions or recommendations.

Dr. McKelvey then introduced Dr. Francis LeBeau of AID to indicate what the Agency hoped to achieve through its financial support of the Conference. Dr. LeBeau pointed out that African agricultural problems had been the subject of a substantial research effort over the past two decades. This research is still being carried out in the independent countries of Africa largely by expatriate research personnel, and although efforts are being made to train Africans it is likely that for some time there would be heavy dependence on external sources for both financial and technical assistance. Research, furthermore, is being carried out by a variety of entities – ministries, universities, research institutes – and there would seem to be a need for closer cooperation and coordination of efforts to avoid duplication and to afford the most rapid translation of research into practical application. In addition the similarity of problems in similar ecological settings in different countries would appear to offer an opportunity for research organizations to cooperate and improve the quality and quantity of research supported from local and external sources.

Dr. LeBeau then stressed the need for examining mechanisms for the exchange of information and for translating research information into farming practice. Many meetings have been held on these subjects which have proposed ways of tackling the problems. AID believed that the primary responsibility for seeing that the research necessary for their agricultural development is carried out in the most appropriate, effective and economic manner should rest with the agricultural scientists, workers and administrators of the African countries themselves. As one means of stimulating this activity AID provided the US National Academy of Sciences with the financial resources necessary to hold the Conference at which as broad and general a group of these individuals could discuss their common problems. It was felt that at this stage this use of funds would produce greater benefits in the long run than if they were used to undertake a specific research project.

One of the more significant aspects is the actual assembly of such a group to discuss problems and develop personal relationships from which wider communication and exchange of information will follow. It was hoped that this meeting would be but the first of many, perhaps on a more specialized basis, and that these meetings would provide a mechanism to provide valid technical foundations for policy determinations by the governments as well as mechanisms to deal with the problems of agricultural research on a regional basis.

On Sunday afternoon April 7th participants visited "Expo-Cocody", an exhibition of locally manufactured products. In the evening, Mr. Sawadogo presided at dinner after which Dr. Fischnich and Professor René Dumont gave addresses.

Dr. Fischnich, Assistant Director-General of FAO, delivered a message on behalf of the Director-General, Mr. Hendrik Boerma. He stressed the contribution of research to the development of agriculture, one of the more interesting aspects of which had been the self-generating increase in research in Europe and North America as production and yields of agricultural produce increased. The implications of the success of this research for rapid progress in agriculture in Africa are profound. They are all the more profound when considered in the light of the requirement for a sound and vigorous agriculture as the essential basis of social and economic development. Agricultural research, furthermore, can show progress through cooperation not only between the different kinds of scientists but also between countries, in making their knowledge available for the benefit of all. A sound basis for progress in agricultural research in Africa is already in existence represented by the centers and institutions many of which have been established for some considerable time, and have attained world-wide reputation. Although much has been done, it is little in comparison to the needs, and a main objective of the Conference is to see what can be done to build on existing institutions and programs, and what new facilities and programs should be arranged. In assessing priorities, first is the utilization of existing knowledge and experience not only from within Africa, but that available from other parts of the world, of which the Rockefeller Foundation programs are an outstanding example. FAO is working closely with these and a number of other programs and organizations on these problems, and is planning to extend its African activities through its "Working Group on Measures for the Closer Cooperation in the Provision of Aid to African Countries in Agricultural Research" and through further meetings in agricultural research on a sub-regional ecological basis in Africa.

Second on the priority scale is sharing the work-load – the need to work out better cooperative arrangements for complementary research

activities to make best use of available resources and avoid unnecessary duplication. It is important also that adequate emphasis be placed on research to develop new ways and means of adapting and adjusting rural Africa to technological progress. Direct practical approaches, such as the successful fertilizer program of the Freedom from Hunger Campaign, can ensure that the farmer takes advantage of the results of research to meet the urgent needs of developing countries for increased production.

In conclusion, Dr. Fischnich expressed, on behalf of Director-General Boerma, appreciation for the hospitality of the Ivory Coast Government and for the cordial cooperation of Mr. Robert Gardiner and again wished the Conference every success.

In a paper entitled "The Ivory Coast has not 'Made a False Start' But. . .", Professor Dumont referred to his book, *L'Afrique Noire est Mal Partie,* and other reports in which he had been involved warning of the serious problems facing agriculture in Africa and other countries as a result of the European ex-colonial powers and the new leaders avoiding their responsibilities. Although he hoped to be proven wrong, unfortunately this has not happened. While it is true the problems of food production are less serious in inter-tropical Africa than elsewhere, food production is increasing less rapidly than population growth. Agricultural exports have risen much faster than food production but world market prices for these products are falling. Africa, without the pressures of overpopulation seen in Southeast Asia, should increase food production faster than population growth. Without such an increase the food position in tropical Africa would be in danger of deteriorating quickly. In Professor Dumont's view, contrary to that of the Paddock brothers, the danger of famine is not inevitable and may be averted through a general mobilization of world resources, such programs as FAO's Indicative World Plan and birth control programs. World Bank reports urge the advantages of a complete transformation of agriculture, through mechanization, fertilizer and selected seed in settlement schemes, all of which have had, to date, poor results. Introduction of mechanization has been particularly unfortunate and is best suited to large efficient operations when high returns have been already achieved and manpower is limiting. Irrigation, also requiring a high technical level, should only be used when absolutely necessary.

Greater attention should be given to economic ways of passing from shifting to intensive farming systems; long research delays progress, and development of leadership and education on which many of these techniques depend, is slow. Top priority should be given to rural sociology and psychology, making use of Africans who understand rural traditions, to better

understand the mechanism of mental development and resistance to innovation and other forms of development.

The Ivory Coast provides a happy exception from the general deteriorating economies and political instability of other African countries; industrial crop production is progressing particularly well. However food imports are increasing, other economic indicators are not favorable, and there are problems of finding increasing numbers of Ivoiriens to teach in schools. Graduates trained abroad seldom return. The white collar contempt for labor is as strong as ever and corruption is not a thing of the past. These shortcomings would be gradually overcome in an expanding economy but there are problems, not only of production, but also from social inequalities which may lead to semi-stagnation of the economy. As pointed out in his book, the two dangers for African progress are premature socialism and South Americanization. The Ivory Coast has been able to avoid the former and reduce some of the abuses of liberalism, but needs to steadily eliminate the most serious social inequities. Advance from underdevelopment is no easy task, but the Ivory Coast has more chance than any other country provided it comes to grips with its problems and no longer counts too much on the capital and technical assistance from abroad.

WORKING SESSIONS OF THE CONFERENCE

Eleven Commissions were charged with reviewing problems and assessing priorities in the following areas:

I Soil and Water Management
II Animal Health
III Animal Production
IV Cereal Crop Production
V Industrial Crop Production (Savannah Zone)
VI Economics of Agricultural Production and Marketing
VII Grain Legume and Root Crop Production
VIII Industrial Crop Production (Humid Tropics)
IX Education
X Crop Protection and Storage
XI Research Institutions

In addition there were plenary sessions on:

1 Ecological Cases for Regional Research Programs
2 Farming Systems in Africa – Mechanization and Innovation and a special seminar on agroclimatology and water resource development.

The appended reports of these discussions form the bulk of the direct results of the Conference.

With the diversity of topics, participation, styles of presiding over and reporting discussion, inevitably these reports reflect the variety of approach to the task. Chairmen were given the widest latitude in running the Commissions and reporting in the way they felt to be the most appropriate.

The priorities of research detailed in the reports represent the consensus of a prestigious group of agriculturalists, probably the largest of its kind to be assembled at one time in Africa.

In addition to these priorities, emphasis was given to a number of areas common to many or all of the Commissions. Foremost of these was the generally expressed need for the rapid increase in the number of agriculturalists in all fields, coupled with the need for more coordination of research whether on a national, regional or ecological zone basis, and in particular better facilities for the exchange of information, especially between anglo- and francophone countries. It was also widely felt that agricultural research should be organized towards solution of specific problems, or achievement of a particular objective, rather than fragmented into its component specializations. In this way it would be more easily adapted for practical use by the farmer, since it is often necessary to provide information in a number of fields simultaneously to achieve success with a new practice. An example is the introduction of improved varieties of crop requiring also improved fertilization, spraying against pests, improved storage and protection after harvest.

This view of research was also reflected in the generally accepted need to develop intensive, integrated systems of farming, for which it is necessary not only to organize inter-disciplinary research efforts within the various agricultural disciplines, but also to include research in rural sociology and psychology, to gain an understanding of the motivation and attitudes of the farmers.

ESTABLISHMENT OF AN ASSOCIATION

One promising accomplishment of the Conference was the establishment of the Association for the Advancement of Agricultural Sciences in Africa (AAASA). A group of approximately 60 participants, at a special meeting, took the initiative in forming the association, and later obtained the adherence of nearly 40 more at a general meeting. At this meeting a steering

committee was elected, by a total of 97 valid ballots cast by 103 participants present, with the following membership:

Dean Victor Oyenuga, University of Ibadan, Nigeria (President)
Monsieur Louis Sauger, CRA, Bambey, Sénégal (Vice-President)
Dr. Melak H. Mengesha, Haile Sellassie I University, Ethiopia (Secretary-Treasurer)
Monsieur Leonard Mukendi, Director, INEAC, Congo-Kinshasa
Dean Peter Nderito, University College Nairobi, Kenya
Monsieur N'Guetta Bosso, SNRA, Bouaké, Ivory Coast
Dr. Hilton Jarrett, Njala University College, Sierra Leone
Monsieur Gabriel Ramalanjaona, Tananarive, Madagascar

Between 70 and 90 participants ıed up as founder members, and were to solicit additional founding members in their countries after the conference.

MEETING OF THE INTERIM COMMITTEE

A meeting of the Committee was held in early August in Addis Ababa, at which the constitution of the Association was drafted. This is being circulated to members. It was also decided to inform Member Governments of the Organization of African Unity of the formation of the Association and solicit their moral and material support. A membership drive is to be started in all OAU member countries.

His Imperial Majesty the Emperor of Ethiopia has graciously consented to become the Association's first Patron.

Persons interested should write to the Secretary-Treasurer at the following address: Dr. Melak H. Mengesha, Director of Research, Agricultural Experiment Station, Haile Sellassie I University, P. O. Box 32, Debre Zeit, Ethiopia.

It was generally agreed that a major accomplishment of the Conference was to bring together francophone and anglophone research workers. Many of them although were working in the same field had never met; thus the Conference afforded increased opportunities for communication and cooperation. It is also clear that much of the work carried out by each group is unknown to the other. The language barrier cannot be overestimated, and the possibility of a bi-lingual journal and future meetings which the Association may hold, would be major steps in overcoming it.

CLOSING CEREMONY

On the evening of Thursday, April 11, Dr. McKelvey presided over the closing dinner at which Mr. Sawadogo and Mr. R. Peter Strauss of AID were guests of honor.

After dinner, Mr. Moise Mensah, on behalf of FAO, gave a brief closing statement commenting that he felt the meeting had been extremely useful for all types of people represented. Priorities had been defined and communication established between those people engaged in all aspects of carrying them out. He was particularly pleased with the stress laid on increasing cooperation in research, and that the need was felt for programming on a regional level from the point of view and approach of ecological zones. FAO was particularly looking forward to the first ecological zone conference on research in the Sudan-sahel zone, and in due course to one on the humid tropics.

The launching of the AAASA is extremely important for the future in enabling research workers throughout Africa to exchange ideas. He expressed appreciation to the NAS for associating FAO with the Conference, and to the Government of the Ivory Coast for hosting it.

Mr. Leonard Mukendi, Director of the National Research Institute of the Congo, INEAC, made a plea for all the participants to increase their efforts to carry Africa forward out of intellectual and economic underdevelopment. Science and technology are essential ingredients in this process, and Africa should become a "science-producing" rather than a "science-consuming" continent. He thanked the organizers and the host government for providing the opportunity for all the participants to assemble and discuss these problems for their mutual benefit and the benefit of the continent.

Mr. John de Wilde of the International Bank for Reconstruction and Development then delivered the main closing address, in which he made a critical appraisal of the results of the Conference. His remarks are reproduced in full on the following pages.

CLOSING ADDRESS BY MR. JOHN C. de WILDE

When Dr. McKelvey asked me to make some remarks this evening I accepted with some diffidence and reluctance. With diffidence because I am not an expert in the agricultural sciences. I am a development economist, and, like many others in this field, I have had to become a "jack-of-all-trades" with the attendant risk of being considered an amateur by all disciplines. But an

economist is supposed to be something of an integrator and to concern himself above all with priorities, with the best use of scarce resources. And it is perhaps for this reason that I have been asked to reflect aloud on the outcome of this conference.

I speak also with some reluctance, partly because it is difficult to evaluate a conference of this sort and especially because I must admit to some prejudice – a prejudice against conferences. Sometimes I have suggested – and only semi-facetiously – that one of the best things that could happen in this world would be the conclusion of an international agreement for the drastic limitation of conferences. We are developing a new race of peripatetic professional congress goers; and I can only hope that this particular conference will not prove to be for many of you the beginning of such a career.

One always says that the redeeming quality of conferences are the personal contacts one makes. In this respect this conference has been successful. It has brought together all disciplines concerned with agricultural development – not only the various disciplines within the agricultural sciences proper but also the administrators of research, agriculturists concerned with the implementation of research, and even the social scientists. I might say in this connection that I have particularly appreciated the hearing which the social scientists have obtained at this conference. For I would like to think that in considering agricultural research we must always keep to the fore the object of all our efforts, namely, the farmer, who is after all a human being whose reactions are very much governed by the values and the structure of the society in which he lives.

The Conference has been particularly important in bringing together research workers in the francophonic and anglophonic areas of Africa. Since approaches to the organization of research work in these two zones of Africa have in many respects been different this has been an especially valuable experience which we can all hope will be intensified in the future, particularly within the framework of the Association which we have agreed to establish at this Conference. Unfortunately, these contacts, particularly the direct person-to-person contacts, are still seriously handicapped by a language barrier. One would wish it were possible to subject all research workers to a process of intensive and accelerated language instruction which we in English call "total immersion". Some of us are perhaps too old to add another language to our accomplishments but we may hope that in the training of future generations of scientists great importance will be put on acquiring competence in both English and French.

There have been many papers, and I suspect only a few of us have been able to digest all of them. A hasty reading of the majority of these papers have impressed me with the fact that they have given us a basis for appreciating what is being done and what has been accomplished over much

of Africa. It is evident that research has produced a number of practical and profitable innovations that have been and are being applied effectively. Moreover, there are already available technical means which could gradually enhance the output of African agriculture in the future, even though their adoption may not, under existing conditions, be practicable or profitable. On the basis of past accomplishments and the production potential that can be realized, I do not share the pessimism of some whose dreams are apparently haunted by the spectre of hunger stalking the continent.

However, when we consider the fundamental objectives of this conference – the determination of research priorities – I suspect that many of us are not wholly satisfied. This is not to say that the various commissions have not done some useful work in this direction. But I wonder whether our list of research priorities is not far too long, considering the limited resources available. I do not contest that agricultural research should cover a very large range of problems. The particular need, however, is to determine how much emphasis and how much personnel and financial resources must be devoted to each problem. I believe we have not given very much guidance in this respect.

First of all, I doubt if we have taken adequate account of the scarcity of resources, and particularly the limited personnel, available for research. I believe the shortage of personnel may well grow more acute over the next decade. The loss of experienced expatriate scientists will probably tend to out-balance the new supply of agricultural research workers, all the more so because African governments have not yet adequately addressed themselves to the need for making research, including research in agricultural economics, an attractive life-long career.

Secondly, I consider it extremely difficult to define research priorities for all of Africa or even for all of tropical Africa. True, there are many common problems, but their relative importance to economic development is likely to vary remarkably from country to country and from region to region. For example, in view of the importance of rice as a staple food in West Africa and the dependence of West Africa on considerable imports of rice, research on the whole complex of problems relating to rice is certainly of paramount importance to that part of Africa. But for other regions and countries, except perhaps Madagascar, it is of much smaller importance. This example could be multiplied. Thus, more attention should be paid to determining priorities in the light of the actual and potential importance of different types of grouping and livestock activities to the economies of the various countries or regions.

Any general statement of priorities tends also to ignore important socio-economic variables which limit the profitability and practicability of "research solutions". One of these variables which limit the types of research that are

likely to be applicable and that therefore should be undertaken, is that of price. We must remember that much of African agriculture and livestock production takes place far from markets. The resulting high cost of transport limits the price that farmers and livestock holders receive and increases the cost of cash inputs. Under such conditions the types of research that must receive priority should focus on innovations that are relatively cheap and that can be supported under prevailing farm prices.

Another important determinant of research priorities, and one that varies in all ecological zones, is the population pressure on land. There are widespread disparities in population pressure, and this conditions both the nature of the problem that must be resolved by research and the receptivity of the farmers to various innovations. When land is relatively scarce, greater priority must obviously be given to research and extension work focusing on the restoration and improvement of soil fertility than when land is still relatively plentiful. Similarly, where population is dense there is much greater receptivity to intensive methods of cultivation requiring a lot of labor. In my opinion this factor of differential population pressure is one that we have been unable to consider fully in fixing research priorities on a continental basis.

At the same time we must recognize that these parameters governing research priorities – especially the socio-economic factors – change over time. There is every reason to believe, for instance, that the rate of population growth will increase over the next decade or two. Many of the sociological limitations on innovation will also grow less important, for much of African society is in a dynamic process of transformation. And if, indeed, with growing population pressures food shortages do threaten, then one can also anticipate that the farmers' term of trade will improve, that farm prices will rise and that many methods of increasing production now too expensive to adopt will become profitable and therefore applicable. It is up to the social scientists to give the agricultural research scientists the long-term prospectives toward which they must orient their work. We cannot forget the priorities of the immediate future, but, as has been repeatedly pointed out, we must keep in mind that much research takes a long time and must, therefore, focus on long-term requirements.

In my opinion the only way to obtain a careful appraisal of priorities is to have a number of studies in depth, each confined to a region but with the full realization that within each region, no matter how defined, there are a wide range in conditions that research must meet. Each such study should determine:

1) the extent to which they are really valid, profitable and practical research solutions that have been devised but not applied;

2) the extent to which research is really directed to the problems encountered at the farm level, taking also into account the extent these problems are actually changing; and

3) the need for, and methods of accomplishing, international cooperation in research, considering the shortage of research personnel and the degree of common interest in certain problems.

Such studies carried out by inter-disciplinary teams would then provide a basis on which regional conferences might be able to arrive at more meaningful conclusions about research priorities.

Let me end up on an optimistic note. This conference has again demonstrated that we have a reservoir of research findings on which we shall be able to draw in the future, particularly in the light of changing conditions affecting the applicability of research. With a continued and well focused research effort we shall undoubtedly be able to add to this reservoir. On the basis of past experience and the unrealized potential for substantial increase in agricultural output, I feel we can be reasonably optimistic about the future development of agriculture in Africa.

Reports of the Plenary Sessions and Commissions

First Plenary Session

The Development of Regional Research Programs on the Basis of Ecological Zones

Mr. R. Devred presented a paper on the above subject in relation to the need for strengthening cooperation in research; and Mr. G. Dubois reported on a project for cataloguing agricultural research data undertaken by FAO's Documentation Centre.

Mr. Devred stressed the need for greater organization on research across national lines and on a multi-disciplinary basis. This was above all necessary to make the best use of scarce research personnel and to avoid duplication. He suggested that more research be organized along ecological lines since problems encountered in similar ecological regions even going beyond Africa were much the same. The development of regional or ecologically-based research programs and the exchange of information among countries and between national institutions could be very fruitful.

Mr. Dubois, in a complementary paper, described first of all that FAO had undertaken to compile an index of FAO documents and papers, and secondly, the project it had recently launched to prepare and keep up-to-date an inventory of agricultural research projects, completed and underway, of agricultural stations in Africa. The latter in particular was designed to keep research people abreast of work going on and to facilitate coordination.

The First Plenary Session took place on Saturday morning, April 6, under the chairmanship of His Excellency Abdoulaye Sawadogo, Minister of Agriculture of the Republic of the Ivory Coast. The rapporteur was John C. de Wilde, International Bank for Reconstruction and Development, Washington, DC.

The ensuing discussion produced general agreement that more coordination of research and better facilities for the exchange of information were clearly necessary. There was considerable difference of opinion, however, on the exact means which should be adopted to achieve these objectives.

In principle the proposed catalogue of research was recognized to be useful and could, among other things, help the researcher to look for relevant material in abstracts on which he placed his principal reliance. However, some fear was expressed that a catalogue might become a "laundry-list" without much value. It was considered important, for example, that some distinction be made between major and minor research projects. Problems of classification would also have to be carefully considered. Care would have to be taken to ensure that projects were classified by subject rather than by title. Projects that were not very specifically defined in terms of purposes and methods might have to be excluded. Mr. Dubois indicated some of the ways in which he hoped to meet some of these comments and promised to give careful consideration to others.

The exchange of research findings among countries, and particularly between francophone and anglophone Africa, was recognized to be highly desirable; and it was readily acknowledged that research in one ecological zone in one country would well be relevant for the same or similar ecological zones in another country. However, some reservations were expressed. Some countries producing the same products for a highly competitive international market might even wish to put limits on the exchange of research findings. The degree in which research ought to be organized along international and ecological lines as distinct from national lines was very much disputed. By no means all research should be ecologically oriented. Research in animal health, for example, would cut across ecological lines. The types of required research were only partially determined by ecological requirements. There were, for instance, also economic and social determinants, and national research institutions could more properly take that into account. In the end, it appeared to be a question of balance. It was suggested that the more fundamental or basic oriented research lent itself better to international organizations along ecological lines, but that applied (adaptive) research fell more clearly within the province of national research institutions. Thus research on range management, soil fertility and varietal improvement might to a large extent be entrusted to regional, ecologically-oriented programs.

Mr. Devred pointed out that it was not the intention of FAO of putting major emphasis on internationally organized research and considered that perhaps as much as 80 percent of research activities would have to be conducted on a national basis. It was generally agreed, in conclusion, that the appropriate division of responsibility between regional and national research programs should be further considered by Commission II which was concerned with agricultural research institutions.

Commission I

Soil and Water Management

Attention was focused on the need for continued study and research into soil and water management practices within countries in Africa, based on the development of coordinated regional research programs. Agricultural research undertaken in Africa should be of high quality, and based on the most advanced methods and techniques. It should be of such design and modality as to yield fruitful results easily adaptable by farmers in countries within an ecological zone.

SOIL SURVEY

Due attention was given to the very valuable work already carried out by Dr. J.L. D'Hoore and others in providing a 1:5,000,000 soils map of the African continent, the work being carried out under the auspices of the Commission for Technical Cooperation in Africa.

As to the future, the Commission was pleased to note that after a short period of suspension, the Inter-African Bureau for Soils and Rural Development (B.I.S.) is resuming its functions. The hope was expressed that future regional research programs will be coordinated by this body or a similar organization.

Commission I met on Saturday afternoon, April 6, under the chairmanship of Professor George Aubert, Head of the Pedology Section, ORSTOM, France. The rapporteur was Hilton Jarrett, Njala University College, Sierra Leone.

The more urgent need in the area of soil surveys was felt to be the establishment of regional soil maps giving more details of soil family characteristics and their potential uses to farmers. These soil maps can best be established as part of the integrated regional surveys in which agro-climatic features within the ecological zones assume primary importance.

SOIL CONSERVATION

Some more studies have to be conducted on the different factors of soil erodibility in the field, and these should be based on rain simulator methods. At the same time farmers must be made aware of the fact that the improved soil and water conservation practices are often the most efficient and economic farming methods.

WATER MANAGEMENT

There is need for more knowledge of the water resources in Africa, which can be used more effectively for a number of functions: chief among which are domestic and agronomic (irrigation) uses.

Studies are required of river basins and watersheds incorporating observations which are now available from already managed catchment areas and irrigated lands. Research of this nature should be the concerted effort of hydrologists, agro-meteorologists, soil scientists, agronomists and silviculturists.

WATER BALANCE IN SOILS

Intensive studies are to be made on the water regime throughout the year in the various units of soil families within the different ecological zones in Africa.

The methodology of various procedures for better seed-bed preparations and root zone development, based on the water regime, will require careful study. The establishment of root systems and their attendant functions in the soil will have to be determined either by ordinary methods or the use of isotopes.

A thorough investigation of the potential and real evapo-transpiration will be one of the most important bases for water regime studies in any given region. More information on soil moisture characteristics (pF curves) would be of considerable value in assessing water balances.

SOIL NITROGEN DYNAMICS

Soil nitrogen dynamics and particularly nitrogen fixation require more attention.

HERBICIDES

Weed infestation is one of the factors seriously limiting the use of soil water and nutrients particularly within an intensive crop production system and hence its control should form an important study in any management practice.

The introduction of herbicides offers opportunities for the removal of major power and labor bottlenecks in land preparation and cultivation besides offering beneficial side effects in soil conservation and fertility. Comparative studies of conventional methods with minimum cultivation techniques involving the use of herbicides should be investigated from both agronomic and socio-economic points of view.

BURNING OPERATIONS

The effect of burning, as part of soil management practices in very many areas of Africa, has received some attention in the past, but more intensive investigation is required in order to be able to realize the effect of this operation on soil fertility with particular regard to the physical characteristics of surface soils and the development of microbiological life.

SOIL UTILIZATION

1. It will be of significant importance to determine more closely the maximum potential productivity of each unit of soil family in each ecological zone, using the best and most improved varieties of crop in combination with the most up-to-date farming techniques and control measures against diseases and pests.

2. In order to approach maximum potentials under the most economic conditions in a given ecological zone, important changes must be made in the various soil characteristics for such high levels of production to become effective and lasting. Progressive studies should be made of the evolution of these characteristics under such conditions.

3. Among the most important methods for the attainment of maximum potential yields, the use of chemical fertilizers is one of the practical approaches. Studies must be made on soil nutrient deficiencies (using chemical and biological methods) incorporating the best ways of correcting them.

4. Before an actual appraisal of the significant effects of fertilizers from the above studies can be made, it will be necessary to obtain more precise calibration of known soil analytical methods in use, by comparison with results of field trials.

5. Other studies of high priority include the precise role of organic matter in the soil with special regard to its effects on nitrogen transformations and the release of other plant nutrients. These revelations, together with the possible improvement of the physical properties of soils, due to organic matter incorporation, should be correlated with yield data.

TIMING AND SPACING

Attention should be devoted to finding out the reasons for the good results obtained, in some cases, due to early planting and plant population densities insofar as they relate to soil properties, water cycle, nitrogen metabolism, etc.

HYDROMORPHIC SOILS

Priorities have also been accepted for studies to be made of plant nutrient dynamics in hydromorphic soils which are of such importance for food production, especially rice, throughout the African continent.

Commissions II & III

Animal Production and Health

Believing that health and production aspects of animal science ought not to be considered separately, the Commissions decided to produce a joint report for the two sessions.

ANIMAL HEALTH

Considering the importance of animal health as a basis for any development of animal production, and further the fact that much research work has been done in the field of animal diseases and that excellent results have already been obtained in the control of some major diseases, the Commission made a detailed review of other diseases which still constitute an obstacle to animal production and classified these into four groups. On this basis, and bearing in mind the results already obtained, the Commission recommends:

A. For diseases which constitute a handicap to international trade

Commissions II and III met on Saturday afternoon, April 6, and Sunday morning April 7, under the chairmanship of Dean Peter Nderito, University College, Nairobi, and Dr. Hervé Michels, Lovanium University, respectively. The rapporteurs were Dr. I. Konate, Livestock and Animal Health Service, Bamako, Mali, and Dr. A.K. Mariko, Union Nigérien pour Crédit et de la Coopération, Niamey, Niger.

1. Rinderpest

a) Further research should be undertaken with the aim of producing vaccines that keep well at high temperatures.

b) Further research should be undertaken concerning differential diagnosis in rinderpest and mucosal diseases.

c) Study should be continued concerning rinderpest and its relationship with small domestic ruminants and wild game.

In the field of disease prevention, the Commission noted with satisfaction the very gratifying results in the joint campaign against rinderpest in West Africa. This effort must be continued in countries already covered by this program, and in particular by annual vaccination of the calves. The Commission was also pleased to learn that this joint program will shortly be extended to countries of Eastern Africa.

2. Contagious Bovine Pleuropneumonia

a) As regards this disease, the Commission took cognizance of the Working Party recommendations of the Joint Working Group on contagious bovine pleuropneumonia of FAO/OIE/OAU held in Khartoum in February 1967.

b) In the light of those recommendations, the Commission placed special emphasis on the necessity for continued research in the field of epidemiology, immunology and pathogenesis of this disease and production of effective vaccines that keep well at high temperatures.

c) Considering that some localized mass vaccination experiments have already been done with success, the Commission recommends starting of mass vaccination campaigns based on international cooperation.

3. Foot-and-Mouth Disease

As regards this disease it was recommended that further research be pursued with a view to the production of vaccines, if possible polyvalent, and obtained from local strains.

4. African Swine Fever

Since this disease is potentially one of the most dangerous for the entire world and presents very complex problems in immunology, the Commission

recommends that research be pursued and intensified on the following points:

a) immunity mechanism
b) development of a vaccine
c) improvement of diagnostic procedures
d) typing of different virus strains
e) mechanism of transmission of this disease from wild pigs to domestic pigs, and the role of different vectors.

5. African Horse Sickness

Considering the worldwide importance of this disease and its possible spread to all parts of Africa, the Commission recommends continuation of research in the following fields:

a) typing of various virus strains
b) improvement of vaccines
c) study of vectors

B. For diseases that constitute a handicap to the development of animal production in Africa

1. Trypanosomiasis

The Commission noted that this disease covers almost one third of the continent of Africa and is therefore a major obstacle to permanent animal husbandry in the areas involved. Furthermore, because of the permanent trend towards demographic growth and, as a corollary, to the increasing demand for meat, it appears that the control of this disease and its vectors is essential.

The Commission therefore recommends that research efforts be pursued in the zones where this disease occurs in:

a) Control of vectors by already accepted methods and emphasizing the promising experimental results obtained by radio-sterilization of the tse-tse fly.

b) Studies on the pathogenesis and immunology of this disease which may eventually lead to the production of vaccines.

c) Research in chemotherapy in order to produce new prophylactic and curative means.

2. *Theileriasis*

The Commission considers that fundamental research is still necessary on:

a) The life cycle of the parasite in both the vector and the bovine host, referring particularly to *Theileria parva.*

b) Studies on the pathogenesis and immunology with the aim of producing a vaccine should be continued.

c) Research in chemotherapy in order to produce prophylactic and curative means.

3. *Streptothricosis*

The Commission noted the importance of this infestation which annually causes serious losses in the hides and skins trade, particularly in West Africa.

It therefore recommends that additional research be undertaken on its etiology and pathogenesis with a view to devising an effective method of prophylaxis and treatment.

4. *Helminth Diseases*

Considering the economic importance of this group of parasitic diseases, which are a definite obstacle to development of animal husbandry, the Commission, although aware that these diseases are rather well-known, nevertheless recommends additional research on the intermediary hosts of some of these helminths.

C. Nutritional and deficiency diseases

The Commission noted with concern that such diseases constitute a problem that becomes more serious as new methods of stockraising are applied and with the introduction of improved breeds as well as the settling of nomadic herds, especially in West Africa.

It is therefore recommended that work already underway in certain laboratories be pursued diligently in this field.

D. Public Health

Considering the growing importance of anthropo-zoonoses, the Commission recommends that pertinent research be continued.

ANIMAL PRODUCTION

Starting from the premise that while unremitting attention is needed in this respect in Africa, we have today methods for controlling animal diseases, the Commission feels a second premise should be borne in mind before determining research priorities in the field of animal production in Africa.

The Commission therefore recommends that all competition between human beings and animals, with respect to food resources and potentialities, should be avoided. This means that food resources which can be consumed by humans should be included as little as possible in animal feeds.

The present aim of Animal Production in most of the African countries should therefore be the transformation of otherwise non-productive areas into production of animal proteins in the most efficient way.

PRIORITIES

Considering the premises mentioned above, the Commission recommends the following steps:

1. considering research on ruminants as a priority study before research on monogastric animals;
2. determining the best species of ruminant in each ecological area by comparing their capacity for converting pasture-land into animal protein, per hectare and per year;
3. studying the conformation of the best breeds within a species, utilizing selection methods based on the criterion of the best biological equilibrium in each ecological area;
4. continuing improvement of the nutritional and bioclimatological environment.

The improvement of the environment should be based on the quantitative and qualitative improvement of animal feeding in the light of ecological and economical requirements. In order to achieve this aim the Commission recommends:

1. the inventorying and exploiting of natural pastures, looking for the best methods: rotation, periodical mowing, improvement by leguminous species (in particular, Stylosanthes): pastures with browse shrubs, optimal carrying capacity per hectare;
2. utilizing available water resources in the most efficient manner possible;

3. studying the possibilities of forage crops;
4. studying nutritional deficiencies (nitrogenous substances, water, minerals, vitamins);
5. studying the respon' of animals to different types of pastures and fodders, with respect to stage of plant growth, digestibility and net energy value;
6. carrying out all types of research which could promote mixed crop and stock farming, utilizing animal draft power in crop farming, with a view to obtaining optimum returns from the soil and water resources and from pastures while aiming at intensification of African farming systems;
7. studying monogastric animals in accordance with the premise and objective mentioned above.

Such research can lead to large scale application of findings, to the extent that problems relating to the economics of animal production, particularly through adequate marketing systems, are solved, thus guaranteeing the profitability of livestock production.

GENERAL RECOMMENDATIONS

The Commission stresses the urgency of training competent African research workers, this being one of the most important factors in the conduct of long-term research programs for the optimal improvement of livestock and the African environment in which the industry operates.

Research workers have always to bear in mind the principle that the adoption of new techniques by farmers poses psychological problems, whence the need for preliminary work in the field of human sciences, especially with respect to the psychological and sociological background and the economic motivations of livestock farmers, and finally their relationship with extension service officers all to precede any action.

The necessity of organizations and extension services that fully understand social conditions, in the broad human sense, appears then to be of primordial importance.

It appears to be equally important to develop by all possible means co-operation among African countries in the field of animal production. This cooperation should be especially considered on an ecological basis and between researchers working in the same disciplines.

In any case it is up to the responsible authorities to define the order of priority within the list of the proposed research programs.

Commission IV

Major Problems Affecting Cereal Production

PAPERS PRESENTED

1. Rice Production in Africa, H. D. Jordan
2. Priority Research in the Field of Food Crop Protection in Francophone Countries in Africa South of the Sahara, H. Barat
3. Problems Affecting the High Productivity of Cereals in the Highlands of Ethiopia with Special Reference to Wheat, Barley and Teff, Dr. Melak H. Mengesha
4. Some Problems of Sorghum and Millet Production in Africa, Dr. B. N. Majisu and H. Doggett
5. Problems Relating to Grains – Maize, IRAT
6. Problems Relating to Grains – Pearl Millets and Sorghum, IRAT
7. Major Problems Affecting Productivity of Maize, N. Harrison
8. Major Problems Affecting Productivity of Cereals – The Pest Problem, Dr. T. Ajibola Taylor
9. Agricultural Research in Tropical Rice Production, R. Chabrolin
10. Research on Rice in Madagascar, IRAT/IRAM
11. The Improvement of Rice-Growing in the Malagasy Republic, IRAM
12. Varietal Improvement of four Food Crops in the Malagasy Republic: Rice, Cassava, Maize, Sorghum – Present Situation and Prospects, IRAM

Commission IV met on Sunday afternoon, April 7, under the chairmanship of H. Doggett, EAAFRO Serere Research Station, Soroti, Uganda. G. van Poorten, Deputy Director of IRAT, was rapporteur.

The Chairman gave a rapid introduction on the subject to be dealt with by the Commission, and underlined several points he thought should be dealt with by the speakers, namely:

1. the marketing, handling, distribution, processing and storage of the crop harvest;
2. the need to maintain in the field sufficient scientific research workers actively engaged on crop improvement with good continuity of research programs;
3. the means of improving crop yields by
   a) improved agronomy including fertilizer use,
   b) improved genotypes, including resistances to pests and diseases,
   c) control of pests, including birds,
   d) the better matching of the crop to its appropriate ecological zone;
4. quality improvement, including flavor, appearance, and improved nutritional value. Higher protein content and better amino acid balance were involved here;
5. Improved extension and seed production.

The Chairman opened the discussion by requesting that each cereal be treated in turn, and called on some authors to present a summary of their papers: Mr. Jordan for paper No. 1; Mr. Chabrolin for papers No. 9, 10 and 11 (paper 12 was not presented); Dr. Melak H. Mengesha for paper No. 3; Dr. Majisu for paper No. 4; the Rapporteur for papers No. 5 and 6; and Dr. Sprague for paper No. 7.

Dr. Webster was invited to speak about his regional program for the improvement of sorghum and millet in West Africa paralleling the regional program for maize put forward by Mr. Harrison in English-speaking East Africa.

The Chairman accepted the motion of Mr. Sauger that papers concerning the protection of standing crops and crops in storage (papers No. 2 and 8 as well as No. 13 presented by Mr. Max Diaw) should be passed to Commission X.

The Rapporteur made a rapid survey of the general agricultural and human situation at the present time in intertropical Africa in its relation to the problem of cereal crops and their development, due regard being paid to demographic growth and the food and nutritional requirements of the African populations.

On the basis of the papers presented, statements made to the Commission and the discussion on them the following conclusions can be drawn concerning research priorities in cereal production in Africa:

A. General conclusions of common interest;
B. Research topics:
   1. common to various cereals;
   2. specific to a particular cereal;
C. Conclusions concerning means and structures (rural institutions).

A. GENERAL CONCLUSIONS

1. Priority in general should be given to research on the problems of all cereal crops, especially rice, but without neglecting maize, millet and sorghum, or teff for Ethiopia. There is a need to strengthen research efforts on all cereals throughout Africa.

2. The concept of ecological regions can generally be employed in drawing up and carrying out research programs on individual cereals, but it must not be the only concept. The national character of certain programs should be retained. Regional interstate programs should be carried out and developed with the fullest possible coordination, especially between English-speaking and French-speaking countries.

3. Research work should not be divided up by scientific discipline and for each product; there should be a true interdisciplinary integration so as to obtain technical and practical solutions leading to agricultural progress.

B. RESEARCH TOPICS

1. Common to various cereals.
   a) resource inventorying:
      i) agroclimatic
      ii) soil
      iii) hydrological
      iv) distribution of natural flora
      v) range of parasites and predatory pests (insects, nematodes, birds, etc.).
   b) general agriculture:
      i) land tenure surveys
      ii) socio-economic studies with a view to the adaptation of cultivation methods

iii) economics of improved farms
iv) study of farming and crop rotation systems and the advisability of maintaining or reducing fallow
v) general study of soil fertility and the soil development under cultivation.

2. Specific to particular cereals.

a) *Rice*

i) General topic: investigation of intensification of rice growing, bearing in mind local, social and economic conditions – as already demonstrated by Madagascar (two cropping cycles, heavy application of fertilizers, etc.).

ii) soils: application, placement and timing of fertilizers (mainly nitrogen);
study of toxicity (swamp soils, for example);

iii) water: water control;
study of water needs, methods of irrigation, flooding systems;
coordination of the study of hydrological data;

iv) plant: broadening of the bases of collections by introducing new varieties to enrich genetic stocks;
setting of priority on obtaining varieties having broad ecological adaptability (temperature, light) and responding well to available and added fertilizers;
creation of varietal series adapted to each small region;
obtaining of high yield varieties, resistant to lodging, diseases, and pests;

v) crop-growing techniques: study of the crop protection against weeds (chemical or mechanical protection);

vi) types of rice growing: promote the improvement of upland (rainfed) rice;

vii) technology: improvement of parboiling;

viii) basic research: in physiology, genetics, etc. Such research must be amplified for comprehension of biological phenomena;

ix) agricultural economics: study the economics of rice-growing at all social and economic levels.

b) *Millets and Sorghum*

i) General topic: intensify research principally to increase yields. Each region should lay down its own priorities in relation to ecological, economic and human criteria.

ii) plants: complete local programs of improvement by regional, inter-state programs;
set up a gene bank with as much plant material as possible brought together in a central collection, perhaps with secondary collections in various ecological sites;
on a regional basis, extend projects on basic genetics (reduction of the straw/grain ratio) and physiology (photoperiodism, thermoperiodism, photosynthetic balance, carbon and mineral nutrition);

iii) soils and techniques: expand studies on the fertilization of soils;
protection against parasitic plants (Striga);
protection against insects and diseases;
protection against birds;
study of agricultural mechanization in tillage and maintenance work, especially with use of animal draft power;

iv) technology: on a regional basis, develop the study of technological standards, of methods of analysis and measurement of these standards, and of the methods of crop processing;

v) agricultural economics: extend studies on the economics of peasant farming that includes millet and sorghum in the cropping system.

c) *Maize*

i) General topic: to develop the study of maize adaptation on the various ecological sites where the cultivation of maize is possible;

ii) plant: follow the example of the regional program for East Africa (Kenya) as regards methods combining both basic and applied research;
genetic improvement of the original plant material;
make a central regionwide collection, a real gene bank, and later secondary collections in two or three different ecological sites;
on a regional basis, expand genetics and physiology research;

iii) soils and techniques: intensify agriculture by a study of soil fertilization; study of crop parasites, diseases and means of control;

iv) technology: on a regional basis, develop technological studies on maize, particularly as regards protein content and problems of texture (mealy or horny) and preservation;

v) economics: develop local studies on economic profitability of the crop in various farming systems.

vi) Generally, research on cereal food crops should be oriented to providing extension workers with a package of recommendations to advise farmers which improved varieties to grow and how to grow them.

d) *Wheat, Barley and Teff*

i) General topic: to study how these cereals can be developed in an intensive farming system, and particularly with reference to land tenure pattern so as to rise above the present level of yield per hectare;

ii) plant improvement: make the maximum use of available germ plasm resources and build up a gene bank at some central point;

iii) soils and techniques: study of the best methods of soil protection and erosion control; fertilization studies; study of storage methods and protection of stored grains.

C. CONCLUSIONS AS TO MEANS AND STRUCTURES

1. Prior to research and for its execution, requirements are:

a) better exchange of information between research workers through a wider distribution of the available documents in the main working languages; in particular, the distribution in English-speaking countries of works in French and vice versa;

b) improved coordination in planning and project programming between the various countries concerned;

c) equipping cereal research with all facilities and staff (scientific instruments, high calibre research workers);

d) more frequent international meetings between research workers and visits to research stations where programs are underway;

e) the setting up of panels of research workers, specialists on individual crops, for example in regional research centers for each cereal with liaison and coordinating offices for the whole of Africa.

f) It was pointed out that the setting up of the African branch of the International Rice Commission as agreed in principle by FAO would meet this need for rice.

2. Post-research requirements:

a) organization of production and the distribution of selected seeds;

b) coordination of all operations in the technical and economic spheres indispensable for crop improvement;

c) arranging or promoting of effective dissemination of research findings;

d) taking of protection measures for crops in stores or in granaries;

e) improving of agricultural commodity marketing.

The opinion of the meeting was therefore summarized by the chairman as follows:

1) Plant breeding, agronomy studies, and quality studies should be continued and extended on all the cereal crops. This implied the importance of maintaining an adequate staff of specialists of high calibre for each cereal crop, with special stress on the need for continuity of research programs.

2) The greatest expansion of effort should take place in research on the rice crop.

Commission V

Major Problems Affecting the Production of Industrial Crops in the Savannah Zone

PAPERS PRESENTED

1. The Activities of CFDT in the Francophone Countries of Black Africa, P. Lombard
2. Problems of Peanut Production, IRAT
3. Agricultural Problems of Peanut Production in the Savannah zone: Results obtained, Research in Progress, Objectives, J.C. Mauboussin
4. Intensification of Cotton Growing in Africa and Its Impact on the Development of African Agriculture, L. Richard.
5. IRHO Research and Development Results on Peanuts in Upper Volta, A. Bockelée-Morvan
6. IRHO Research and Development Results on Peanuts in Senegal, A. Bockelée-Morvan
7. Organization in Research Goals in Tropical Africa and Madagascar, J. Lhuillier
8. Economic Feasibility of Mineral Fertilization of Peanuts in Senegal, A. Bockelée-Morvan
9. The Development of Peanut and Sorghum Yields Through Fallow or Green Manure, A. Bockelée-Morvan
10. Drought Resistance of Peanuts, J. Gautreau, P. Prevot, M. Ollaginier & M. Gillier

Commission V met on Monday morning April 8, under the chairmanship of J. Lhuillier, formerly Director-General, IRCT, Paris. C. Charreau, IRAT, Senegal, was rapporteur.

Traditionally, agriculture in savannah countries is characterized by the restricted trading of commodities. An equilibrium has been achieved between soil fertility, farming conditions and population requirements on the lowest level.

The opening of these regions to the outside world and their population explosion have impinged on this equilibrium so that no favorable trends may be expected unless the cycle of self-sufficiency is broken. Industrial crops (peanuts and cotton) now produce a cash income which these populations never had before and have led to the introduction of new means of productio by which all crops are affected, thus initiating a transition from a subsistence economy to market economy.

A. RESEARCH PRIORITIES FOR BOTH CROPS

1. Economic marketing studies, essential for promotion of long-range upward production trend.

2. Agronomic and economic interaction between cash crops and food crops. Intensification of industrial crop-growing also produces higher yields of the food crops associated with them in rotations as a result of the application of mineral fertilizers and the use of more scientific production techniques. It is therefore essential to induce the most desirable interaction and to study their economic repercussions.

3. Study of the possibility of continuous cropping without fallow periods, since both crop stabilization and demographic growth tend to restrict or even entirely eliminate fallowing, except in cases where the feeding of the livestock on the farm have to be taken into consideration. This trend is normal but appropriate techniques for application of fertilizers, methods of working the soil, and suitable rotations that will maintain high soil fertility need to be studied.

4. Trends as regards mineral requirements of industrial crops. Study of standard fertilizers (nitrogen, phosphates and potassium) is continuing satisfactorily but special attention must be paid to the dynamics of sulphur in soil and to possible trace element requirements of crops.

5. Mechanization of industrial crop-growing. The term "mechanization" is taken to cover manual labor, manual labor with the use of draft animals, or use of machinery. Multiple trials have to be made before recommending to farmers implements or equipment that meet all three purposes: technological, economical, and social.

PRIORITIES FOR RESEARCH ON PEANUTS (GROUNDNUTS)

1. Development of drought-resistant varieties. Research along these lines is underway in Sénégal and the first achievements under this highly specialized program need to be disseminated widely because of the importance of such varieties in the Sahelian and Sudanian zones – the least favored from the climatic standpoint.

2. Research on aflatoxine. Toxicity attributable to aflatoxine is always a serious handicap in marketing of peanuts and peanut products.

Research begun a few years ago indicated the complexity of this problem and has so far only given partial results. It appears desirable to have this work given high priority in order to find ways of preserving peanuts against this serious type of spoilage.

3. Breeding for varieties resistant to rosette (Cercospora personata) and leaf-spot.

PRIORITIES FOR COTTON

1. Establishment of an inter-state quarantine service. Such a service, which must above all be very strict and efficient, is indispensable in order to provide full guarantee of safety in seed exchange and distribution.

2. Examination of ways and means for setting up combined observation and notification outpost networks.

Such networks would study the biology of the main pests of cotton and give useful advice to control agencies on seasons for insecticide treatment, the results being increased efficacy of, and savings in, application of pesticides.

3. Systematic research for rapid detection of possible acquisition of resistance of pests to pesticides.

Research along these lines would be greatly aided by a network of observation outposts.

4. Study of possibilities of biological pest control.
   a) research on the morphological, physiological, or chemical characteristics conferring resistance on plants or making them pest tolerant.
   b) reconnoitering of areas in order to isolate entomopathogens (viruses, bacteria, fungi) that could be used if an integrated control campaign were undertaken.
   c) genetic and cyto-genetic research for improvement of the technological priorities of fibres to make them competitive with synthetic fibres.

Contacts between geneticists, economists and industrial technicians is deemed advisable for such research.

d) development of a program in genetics starting with the creation of glandless cotton varieties. The flours derived from such seed are of exceptionally high protein content and may become a valuable addition to the list of human foods.

The demographic importance of the savannah zone, where over three-fourths of the population of tropical Africa lives, together with the fact that the farmers of this zone have at the present time only two cash crops (peanuts and cotton), led Commission V to urge that the above priorities be given the utmost attention. It is also urged that work on the introduction of new crops should be undertaken, because of the dependence on these two crops.

Commission VI

Economic Aspects of Agricultural Production and Marketing

This Commission was charged with the responsibility of considering the research priorities involved in the theme: *Economic Aspects of Agricultural Production and Marketing.* Background papers by Carl Eicher, John de Wilde, and D.G. Belshaw were discussed. We cannot do justice to these valuable papers in this short summary. We urge members of the Conference to read the originals. In addition to the papers a statement was prepared by Mrs. Rowena Lawson emphasizing the importance of research into marketing and the need to give greater attention to the analysis and interpretation of government statistics, in particular data on prices, foreign trade and population, which could yield useful information relating to agricultural policy and planning.

MAJOR THEMES

Five major themes raised in these background papers provided an orientation to discussion and generated a number of hypotheses and suggestions for further research.

Commission VI met on Monday morning, April 8, under the chairmanship of Professor Bruce F. Johnston, Stanford University Food Research Institute. Dr. V.C. Uchendu, then of the University of Ghana, was rapporteur.

1. The importance of agriculture in the economies of African countries and the interdependence between the agricultural and industrial sectors, which is increasingly appreciated by policymakers, implies that more resources and greater incentives should be given to the agricultural sector where most Africans are presently engaged, and will be engaged for many decades. Although the population data are far from being accurate, there are clear indications that African populations are growing rapidly and that the capacity of the nonfarm sector to absorb labor is distinctly limited. These give rise to an important challenge to increase food production.

Other important aspects of the interdependence between agriculture and the rest of the economy were also stressed. The industrial sector can increasingly play a key role in providing agriculture with inputs such as improved equipment, fertilizers, and insecticides. Likewise, the growth of the nonfarm sector means an increase in the internal market for purchased food which will become an increasingly important means for enlarging farm cash income, thereby making possible greater use of purchased inputs in farming as well as enlarged purchases of consumer goods that provide a stimulus to industrial growth. The growth of nonfarm employment is also important in initially slowing the growth of the farm labor force and eventually making possible a reduction in its absolute size with the increased scope for raising farm labor productivity which that implies.

2. The need to view the farming system as a whole rather than as isolated units of different crop enterprises was emphasized. This whole farm approach has three major research implications. First, there is the need for more knowledge of the prevailing farming systems and patterns which case studies and farm management surveys can reveal. Second, there is the challenge, in research on the process of diffusion, of adapting farm innovations to farming systems so as to make them more readily acceptable to the farming population. Third, it makes agricultural research, planning and extension work more realistic as both become increasingly based on an understanding of the range of possibilities within the existing farm structure.

The receptivity of the African farmer to farm innovations which make only modest demands for additional labor or modifications of his prevailing farming system is no longer in doubt. Case studies have demonstrated over and over again that innovations which are profitable, practicable, and reflect the farmer's "felt needs" are often accepted. But much more knowledge is needed about why certain innovations fail and others succeed within a relatively short time among the same community of farmers.

3. The consensus of opinion in the Commission was that the amount and the type of incentives required by the small farmer are sometimes underestimated. Change involves risk-taking and change for its own sake is

never attractive. There is need in a number of countries to review the prevailing taxation and fiscal policies as well as the activities of the state or parastatal marketing bodies which in many instances seem to exert a great disincentive effect on production and labor utilization.

It was emphasized that a small percentage increase in production frequently does not provide a sufficient incentive, whereas innovations which result in a substantial and visible increase in output and net returns are readily adopted. Priority should therefore be given to the most profitable innovations in order to reinforce the farmer's basic securities and increase his trust in and dependence on the market system. It was fully appreciated by the Commission that the transition from subsistence production to production for the market should be encouraged.

4. The need to coordinate technical and economic knowledge in the service of a productive development program was emphasized. Development planning is a recent innovation in African national economies, but it is an innovation which has been accepted as a necessary tool for development. This development goal cannot be achieved unless the economists who provide and sometimes guide the policy ideas are increasingly understood by, and make the necessary effort to understand, their technical counterparts—mainly agriculturalists—who implement development programs on the ground. Errors in planning and waste and inefficiency in plan execution could be reduced by improving communication between the development economist, on the one hand, and the agricultural scientist and administrator on the other hand. Both should be concerned with the "opportunity cost" of alternative projects proposed for implementation at the national, regional, and local level. If agricultural planning is to identify major constraints to economic growth, while insuring maximum returns to investment, it must be based on solid data, usually supplied by the agricultural scientists and administrators who must look beyond what is technically possible to what is economically sound.

Planning without data has been the usual practice in many African countries. The result has not always been successful. It is no wonder that in the absence of data, alternative projects are not considered in the planning process, and the cost-benefit criterion of the economist is not applied. There is need, therefore, to collect basic data on actual farming conditions and to guide major development projects with the data obtained by means of preinvestment surveys and pilot schemes. It is worthwhile insisting that government-sponsored projects and schemes keep and maintain detailed records of costs and returns so that schemes can be re-evaluated and the experience gained used in assessing future projects.

Making research relevant to development needs was an important issue discussed. But there was no consensus on the criteria for ranking research priorities. The cost-benefit approach, which is attractive to the economist, is often resented by the agriculturalist who argues that since the gestation period for research projects differs and the outcome of research is uncertain, the "payoff" criterion would be likely to discourage long-term and basic research. There was, however, a measure of agreement that long-term research projects should be balanced by short-term projects of an applied nature and more certain payoff.

GENERAL SUGGESTIONS

Among the suggestions made by the Commission the following appear to be of particular importance:

1. The need for research on the relation between conditions of health and labor productivity in various farming situations.
2. The need for pilot schemes to avoid waste of scarce resources in the implementation of major projects.
3. The need to communicate farm innovations through the "appropriate" and "required" channels of communication.
4. The need for a market intelligence service to explore promising outlets for both traditional and new products.
5. The need for economic studies of the scope that may exist for expansion of intra-African trade in agricultural products.
6. The need for innovations that enhance the productivity of the existing and relatively abundant farm resources of labor and land and which make small demands on particularly scarce resources, notably capital and foreign exchange.
7. That agricultural economists, who are "practical and non-pontifical," should be posted to major research stations to help insure that technical recommendations are feasible and economically attractive to practicing farmers.

RESEARCH PRIORITIES

The following research priorities were stressed as deserving urgent attention:

1. Research into the prevailing farming systems and the kinds of innovations which are best adapted to them.

2. The strong need for farm management studies of a micro-economic nature, based on actual farming conditions.

3. The need for research on the economics of systems for the maintenance or improvement of soil fertility that are profitable and feasible at the farm level.

4. A study of the various factors that motivate the African farmer.

5. A study of the effects of state marketing monopolies and other quasi-monopolistic institutions on investment, incentives, and farm output. There is also need for a greater understanding of the contribution that agriculture can and should make to government revenue and of the forms of taxation that minimize the disincentive effect of taxes levied on agriculture.

6. Study of problems of food marketing and why prices in the markets do not always reflect demand and supply situations in the economy.

7. A study of the population problem and its long-term implications, including an assessment of the growth of the total farm and nonfarm labor force to be expected in the next 25 to 50 years.

8. Study of regional programs in agriculture within the ambit of the diversification of trade and of African countries supplementing each others needs.

9. An economic evaluation of government services and autonomous bodies in agricultural production.

Commission VII

Major Problems Affecting Legume and Root Crop Production

LEGUMES

The Commission noted that, except in a few particular cases, very little had so far been done as regards research on legumes.

Within the framework of the current campaign to free the world from hunger and also in order to bring about an improvement in the often far too monotonous diet of rural people of Africa, the Commission recommends that priority should be given to the organization of research of as wide a scope as possible in the sector of grain legumes. Such research should include a study of the food value of each legume and even fodder legumes.

The work should be undertaken in the following order of priority:

1. A survey preparatory to the setting up of a legume gene plasm bank in West Africa, which is considered a secondary diversification center for these species; attention should be given to the establishment of a sub-regional center somewhere in Eastern Africa.
2. Research by hybridization and selection of a range of varieties adapted to the various ecological situations of Africa;

Commission VII met on Monday morning, April 8, under the chairmanship of Professor E. Collart, Lovanium University. Dr. G. Cours-Darne, founder and formerly director of the Institut de Recherches Agronomiques de Madagascar (IRAM) was rapporteur.

3. Inventory and study of insect pests in the main ecological environments: use of the optimum control methods;
4. Genetic control of virus diseases;
5. Study of toxic residues on crops according to the different techniques used;
6. Study of plant resistance to drought and devising of early tests to judge such resistance;
7. Determination of mineral fertilizers to be used for each ecological site;
8. Continuation of studies already initiated on photosynthesis of different varieties.

ROOT CROPS

The Commission emphasized three points of particular importance that require priority action.

1. *Research on types of cassava*
   a) resistant to mosaic diseases. The yield from this plant, the staple food of many African peoples, is often so low because of this parasitism as to raise the spectre of famine;
   b) well adapted to various ecological environments, of high yield, with roots containing little water (density over 1.15) and low glucoside content, short and stocky so as to make possible the rooting up by machines;
   c) easy to propagate by cuttings and moisture resistant so that they can be grown on both heavy soils and low-lying lands;
   d) with leaves of higher nutritive value.
2. *Research on yams,* the cultivation of which would be unlikely to be of great interest unless a thorough study makes clear what it has to offer: Such research could include:
   a) experimentation in single cropping on ridges with a study of supports;
   b) gathering a large collection of assorted varieties from a survey on the uses of varieties grown;
   c) studies prior to genetic improvement; research on fertile varieties, methods of inducing blooming, study of compatibility of inter-variety and inter-species crossings;
   d) varietal improvement, first through selection among varieties grown, then by genetic means;
   e) physiological studies, particularly of dormancy.

3. *Research on mechanization* of various operations in the cultivation of root crops and in particular the harvesting of cassava, yams and sweet potatoes.

The Commission wished to emphasize the problems involved in the storage of tubers although it recognized that this was a subject that came within the terms of reference of Commission X.

Commission VIII

Major Problems Affecting the Production of Industrial Crops in the Humid Tropics

A total of twelve papers were presented to the Commission. The papers highlighted the rather impressive research activities that are being conducted on the major industrial crops in the various countries in the humid tropics. The Commission took note of the limitation of staff, especially Africans and financial resources in some cases for the execution of worthwhile research projects. These research projects were generally well directed and given high priorities commensurate with the problems they represent.

Attention was directed to market institutions whose policies often led to damping down of farmers' enthusiasm for increased production. In this regard there exists a body of research findings which is not reaching the farmers, and which it appears does not contribute to bringing about institutional changes connected with effective utilization of extension services with a minimum of hardship to the farmers.

Attention was drawn to the almost complete absence of research activities on the better or rather alternative uses of these industrial crops and their by-products. It is strongly felt that research directed towards this goal can yield handsome returns and generate further incentive for increased production.

Commission VIII met on Monday afternoon, April 8, under the chairmanship of L. Mukendi, Director-General, INEAC, Kinshasa. Dr. L.K. Opeke, Director of the Cocoa Research Institute of Nigeria, was rapporteur.

Attention of the Commission was drawn further to the value of mechanization in the efficiency of production and processing of these industrial crops.

Having regard to the foregoing, the Commission *RESOLVED* to table the following priorities in research on these crops before the Plenary Session for consideration.

Priority No 1: As most of Africa has–

(a) considerable material resources well adapted to industrial crop production, and

(b) a long documented capacity to be a net exporter of agricultural products, be it resolved that: As much effort as possible should be directed to support research on these industrial crops in order that Africa may compete efficiently for her full share in the world market.

Priority No. 2: As current research activities are yielding information, some of which is not effectively getting to the farmers, that research activities be directed towards the:

(a) investigations of the best ways of presenting research information to the farmers, vis-a-vis the problem of application of research findings in the field.

(b) investigations on how institutional changes can be brought about without causing too much hardship to people.

(c) investigations on the most beneficial market institutions for these industrial crops.

Priority No 3: As it is not enough for African countries to remain perpetually the exporters of raw materials only, it is highly recommended that priority be given to the processing of the raw farm products to a semi-finished state for export.

Priority No 4: As it is realized that some of the presently wasted by-products of these industrial crops could find valuable uses in industry, it is recommended that first priority be attached to research activities directed towards the finding of uses for these presently wasted but valuable by-products.

Priority No 5: As it is appreciated that the germ plasms for these industrial crops exist in scattered pockets all over the world, it is revolved that immediate effort be made towards the creation of their gene-pools (collections) at appropriate centers in Africa.

Priority No 6: As a few industries springing up in some countries of Africa* are seriously competing with farm labor and as labor costs are increasing, it is recommended that research activities aimed at the mechanization of some stages in the production of these industrial crops be embarked upon as a matter of urgency.

Priority No 7: In view of the uncertain future for some of the industrial crops – notably sisal, wattle and coffee – it is recommended that research be directed toward developing new crops and diversified production of processed fruits, nuts, oil, etc. under optimal conditions.

*(e.g. textile industries, oil refineries, cement factories, breweries, vegetable oil industries in Nigeria, Ghana and the Ivory Coast).

Commission IX

Education: The Role of Universities and Schools of Agriculture in Research and Manpower Production

The following are the conclusions and recommendations of this Commission:

1. The number of African agricultural research workers must be increased as rapidly as possible, in order to build up, throughout tropical Africa, an African cadre of agricultural research workers who can identify and solve the problems of agriculture in tropical Africa.

2. Since throughout tropical Africa, as in many other regions, the need for trained men and women in all fields is very great, agricultural research is in competition for able people with many other activities. It is therefore likely that expatriate agricultural research workers will be needed in Africa for some time to come. These workers must regard the training of African research workers as an urgent and continuing part of their duties in the service of Africa. They must be encouraged when necessary to serve in Africa for longer periods than is often usual at present, and they must be enabled to work in stable and continuing organizations.

The Commission urges donor agencies and countries providing technical assistance to adopt policies which will enable such expatriates to accept extended assignments in Africa without losing tenure and other privileges of their permanent appointments in their home countries.

3. African universities, and the universities of foreign countries which wish to help to advance African agriculture, must strive to produce more

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Commission IX met on Monday afternoon, April 8, under the chairmanship of Professor A.H. Bunting, Dean of the Faculty of Agriculture, University of Reading (U.K.). Dr. S.T. Matturi, Principal of Njala University College, University of Sierra Leone, was rapporteur.

African agricultural scientists and technologists, trained to internationally acceptable standards. Their training must orient them towards change and innovation and must not be exclusively directed towards the current practice of African agriculture.

4. At the present time, African agricultural scientists should wherever possible receive their first training in African universities, and it may be useful in many cases for them to receive part at least of their specialist and post-graduate training in the more developed countries. Since, however, this may tend to hold back the growth of post-graduate schools in African universities, the latter should associate themselves with universities in more developed countries to ensure a two-way flow of post-graduate students.

5. African students should be selected for post-graduate work in ways that will ensure so far as possible that they have a real and continuing interest in agriculture, that they are sufficiently mature in outlook, and that, if they are sent overseas, they will return to serve African agriculture when their training is complete.

6. African universities and governments must satisfy themselves that the overseas training of African post-graduates is appropriate to the work they are to do when they return to Africa. They will be helped in this if the institutions to which their students go have an active interest in African agricultural progress and are associated with corresponding institutions in African countries.

7. When the student returns home, he should be able to enter a stable, well organized and continuing professional structure, in which his duties and responsibilities as well as his privileges are clearly defined and in which he has the support and collaboration of competent senior colleagues.

8. Research in subjects related to agriculture in African universities (in faculties of arts and science as well as of agriculture) should be prepondently such as to contribute wherever possible, in the longer or shorter term, to the needs of local agriculture. Most scientists working in African universities, we believe, already accept such marginal limitations on their academic freedom of choice in research.

9. Agricultural research (and related research in pure science and in the social sciences) in the universities should become associated with similar research in government institutions, other educational institutions, and independent (including commercial and industrial) research organizations. All these interests should be represented in national and regional agricultural research authorities in which they can make their contribution to, and take their share in, the common effort. Such authorities, through financial support of research, could assist universities and other institutions to play a fuller part in the agreed program. Indeed, in some countries it has proved

advantageous for universities to take responsibility, under the guidance of appropriate national authorities, for large sectors of the national program of agricultural research.

10. The resources, both for teaching and research, of the African universities will be materially increased by associations with other research institutions – and these institutions will benefit also by closer links with the universities.

11. Generally, in agricultural research in Africa, there is an extreme shortage of competent, reliable and experienced technical assistants. A competent research worker can normally employ as many as three or four technicians, who can multiply many times the range and effectiveness of his work. It is therefore urgently necessary to organize the training of technicians on the necessary scale, in universities and technical colleges as well as in research institutions.

Special Seminar on Agroclimatology and Water Resource Development

PAPERS PRESENTED

1. Agroclimatology and Scientific Research in Africa, J. Cochemé, (presented by M. Dagg)
2. Suggestions for Research in Some Problems Related to Water Resources Development, G. Dekker
3. Water Resource Opportunities and Problems Presented by Large-Scale Man-Made Lakes, T. Scudder

The participants in this seminar were concerned with the maintenance and development of African water resources in the broadest sense. The papers and discussions dealt primarily with two foci: agroclimatology and river basin development. Priorities stressed related to agricultural and other economic systems, to domestic water use, and to health, pointing up the complexity and interdisciplinary nature of effective water resource research and development.

The following research priorities were stressed:

1. Provision of adequate data for the preparation of relevant agroclimatological classifications and maps. Special emphasis should be

The Special Seminar was held early in the evening of Tuesday, April 9, under the chairmanship of Professor Akin Mabogunje, Head of the Geography Department and Dean of the Faculty of Social Sciences, University of Ibadan, Nigeria. Professor Thayer Scudder, California Institute of Technology, was rapporteur.

placed on the collection of those data important for the calculation of actual and potential evapo-transpiration. The seminar also calls attention to the importance during agronomic experimentation of noting and recording the status of the soil water balance and of bearing this in mind in the interpretation of experimental results.

2. Collection and storage of available data in a form that permits easy access to those interested in local, regional and broad ecological correlations.

3. Interdisciplinary research concerned with maximizing the agricultural development potential of river basin systems. Alternate uses must be carefully assessed in terms of the varying (and often conflicting) domestic and economic needs of urban and rural populations. Where new water resources are to be created, it is important that both opportunities and problems be carefully assessed so as to ensure the full realization of potential benefits. This is especially the case with the large-scale man-made lakes that are changing the African landscape. To date insufficient attention has been paid to the implications for development presented by such lakes as opposed to the dams that create them.

4. River Basins are dynamic systems which are currently being degraded by indiscriminate land use in catchment areas and along river banks. Survey is needed to determine the extent of this deterioration and to serve as a basis for better management.

5. In recent years many water points have been constructed in rural areas to provide water for domestic use, livestock, and small scale irrigation. In many cases water points have had deteriorating effects on the rural environment which were not anticipated. It is to be expected that the construction of such points will be continued. Nonetheless, it is urged that studies be made of their effect on human welfare and on total productivity in rural areas. Areas to be covered in particular are the Sudan-sahel zone and Eastern Africa. Such studies, which should be interdisciplinary should greatly assist the formulation of rational programs of rural water development aimed at increasing the social and economic welfare as well as ensuring the continuous productivity of rural resources.

Second Plenary Session

Farming Systems in Africa: Mechanization and Innovation

Having heard the summaries of the various papers, the meeting:

A. emphasized that work in agricultural research had shown that the agricultural potential of African soils was, except for the marginal zones, comparable in level to that of temperate countries, and that a considerable rise in the productivity of African farmers, and consequently of their standard of living, was technically possible;

B. took note that one of the essential objectives of agricultural development is constant innovation bringing considerable increase in productivity and in the gross returns on family farms, which for a long time to come will constitute the backbone of the agricultural economy of Africa;

C. and further noted that development activities covering whole regions and based on the application of research findings had already been undertaken and had achieved satisfactory results.

D. Taking into account the previous considerations, the meeting drew attention to the following points:

1. *In the special field of agricultural mechanization as a means to development.*

   a) The need for well-planned and technically sound mechanization (involving the introduction of farm implements and machinery)

The Second Plenary Session was held on Wednesday morning, April 10, under the chairmanship of L. Sauger, Director, Centre de Recherche Agronomique, Bambey, Senegal. L. Mukendi, Director-General, INEAC, Kinshasa, was rapporteur.

carried out gradually over a period of years, in keeping with the best farming systems (application of fertilizers and irrigation) and combined with a system of agricultural credit, which is absolutely necessary to development under present conditions in Africa in order to raise productivity of African farmers and contain nomadism.

b) The need to organize and continue research in Africa on both national and regional bases so as to ascertain which types of machines and tools are the most suitable (a working group put forward the recommendation attached to the present report).

c) The fact that a number of countries and organizations engaged in research and implementation in the field of farm mechanization lack adequate information and documentation about the experiments of others with the consequent risk that they may be induced to redo them unnecessarily with loss of time and money or ultimate discouragement of the farmers in case of failure.

2. *In the more general realm of putting into practice innovations leading to more intensive farming systems.*

a) The need for thoroughgoing research in rural sociology in order to understand the attitudes and motivations of the farmers and to discover new methods of applying the results of research in farming areas.

b) The need for agricultural economics research at the level of the farmers themselves.

c) The importance of integrating crop production and animal production in the farming system and solution of the resultant problems.

d) The need for research with the object of developing more intensive types of farming systems against the background of all agricultural, economic and sociological factors, in particular by making use of innovations in various cultivation systems. There is consequently a need to perfect new methods for applying research findings in farming areas (see (a) above).

e) The advisability in savannah country of studying new systems of cultivation and of micro-improvements leading to better utilization of rain water, particularly through the technique of controlling runoff.

f) The usefulness of perfecting, under certain conditions, of completely controlling water use (supply and drainage) for intensive farming systems leading to a maximum output in one and the same year.

g) The important problem of development structures and institutions. Research should be undertaken in this field, in conjunction with the authorities responsible for development who should be consulted about extension work, farmer training and the organization of technical cadres.

A certain amount of work on these two subjects has already been undertaken in some countries. Now is the time for the study and scientific analysis of the methods employed so as to permit the greatest possible extrapolation with a view to systematic dissemination of research results in rural areas.

RECOMMENDATION OF THE PANEL ON MECHANIZATION

The introduction of mechanization in its various forms (implements and machinery for hand-use, animal-drawn or motorized), from the initial land clearing to processing the products, is necessary to provide the farmer the possibility of making a greater contribution to the economic development of the countries, while also reducing his workload and improving his existence.

For many years research, trials and experiments have been carried out in various regions under the aegis of different specialized organization. It is now essential that the published results in the practical application of specialized research be made known to all those concerned.

1. For this purpose mutual contacts must be developed between individual research workers and the various specialized organizations, both anglophone and francophone, and particular existing organizations provided with additional means to improve their effectiveness.

2. In the light of the results obtained there might later be considered the need for new mechanisms for developing international cooperation in this field.

To implement the first recommendation it would seem desirable to set up, immediately, a small committee, composed of an economist from the Ford Foundation and two engineers (one anglophone, one francophone) familiar with tropical agricultural engineering, whose object would be to implement the recommendation and eventually, following this, suggest further actions envisaged in the second recommendation.

The panel on mechanization was composed of W.K. Agble, Crops Research Institute, Ghana; W. Boshoff, Makerere University College, Uganda; R. Devred, FAO; B.F. Johnston, Stanford University; G. Labrousse, CEEMAT, France; M. Morel, BNETD, Abidjan.

Commission X

Crop Protection and Storage: Prevention of Waste

PAPERS PRESENTED

1. Major Problems Affecting Productivity of Cereals. The Pest Problem, T. Ajibola Taylor
2. Crop Protection, M. Diaw
3. IRHO Contribution to the Problems of Coconut Palm Crop Protection, D. Mariau
4. IRHO Contribution to the Problems of Oil Palm Crop Protection, J. Dubois
5. Prevention of Waste with Special Reference to Agricultural Engineering, J. Rawnsley
6. Priority Research in the Field of Food Crop Protection in Francophone Countries South of the Sahara, H. Barat

The papers listed above and others presented to previous commissions on the crop protection aspects of production formed the basis for a stimulating discussion on the issue of priorities in crop protection, storage and prevention of waste. It is significant to note that throughout the Conference the problem of crop protection has featured in the work of all commissions on the improvement, production and management of crops.

Commission X met on Wednesday afternoon, April 10, under the chairmanship of M. Luc, Director, Adiopodoumé Center, ORSTOM, Ivory Coast. Dr. T. Ajibola Taylor, University of Ibadan, Nigeria, was rapporteur.

This indicates a full awareness of the limitations which pests and diseases in the field and store can impose on efforts at increasing productivity and emphasizes the need for urgent simultaneous action.

The pests reviewed in the papers and discussions included insects, birds, rodents, nematodes; and the diseases included virus, fungal and bacterial diseases. The achievements and problems in relation to these pests and diseases were discussed and valuable information exchanged.

The attention of the Commission was drawn to the fact that as tropical Africa was beginning to enter into its own era of chemicalization of agriculture, extreme caution was necessary to avoid the same pitfalls which characterized this era in the developed countries, and the use of chemicals in crop protection must not be regarded as an absolute panacea.

It was emphasized that it is *urgent* and *top priority* to undertake biological research to obtain the necessary data on which sound pest control programs could be based, and an integrated approach or pest management system which utilizes all suitable techniques–cultural, biological, ecological and chemical–was advocated.

The following areas and undertakings of research were designated as priorities in the field of crop protection and storage in tropical Africa, and it was emphasized that these could be carried out on a regional basis with the cooperation of a number of neighboring countries.

Priority 1: Fundamental studies on the biology, ecology and population dynamics of the pest/parasite complex on the major food and cash crops in tropical Africa to provide a basis for sound integrated control programs. The major crops to receive priority include Cereals, Cocoa, Coffee, Cotton, Coconut, Cowpea and Oil Palm, Cola Nuts.

Priority 2: Studies on the control of the major pests and the effects of chemicals on the vertebrate and invertebrate fauna of agroecosystems in Africa.

The Commission urges the initiation of studies to ascertain the magnitude of pesticide residues following the use of agricultural chemicals in the protection of food and feed crops with special reference to whether such constitute a health hazard or may prejudice the position of crops in world trade channels.

In connection with (1) and (2) above, the Commission considered that cooperation in the identification of pests and pest problems and the exchange of valuable biological data among the establishments in similar ecological zones would be valuable.

Priority 3: Studies on the ecology and operational control of grain-eating birds especially *(Quelea quelea)* throughout the range of its distribution in tropical Africa.

The Commission suggested that an attempt be made to achieve a collaboration of all efforts in the solution of this problem.

Priority 4: Studies on the control of rodents and other vertebrate pests of economic importance.

Priority 5: Studies aimed at the development of improved grain storage techniques, in particular drying methods which could enable earlier harvesting and avoid pest problems altogether.

The Commission noted that the prevention of waste could be effected by the application of processing and preservation in addition to disease and pest control. It also observed that the improvement of quarantine regulations and facilities would be desirable.

Commission XI

Agricultural Research Institutions—National and Regional. The Problem of Increasing Effective Research

PAPERS PRESENTED

1. The Development of Agricultural Research and Education, A. H. Bunting
2. The East African Agricultural and Forestry Research Organization – Priorities and Problems, O. Starnes
3. Arabica Coffee Research in Africa, P. A. Huxley
4. Agricultural Research Priorities for Economic Development in Africa, Yuen-liang Ku
5. Role of IRHO in Agricultural Training and Education, P. Renault
6. Development of African Institutions of Agricultural Education and Training in Relation to Urgent Priority Needs in Agricultural Research, F. B. Wilson
7. Agricultural Research Programs on Ecological Bases, R. Devred

As a result of the papers contributed and the discussions arising therefrom, the following emerged as matters of high priority and are recommended by the Commission for acceptance by the Conference:

1. National and regional organizations, where they exist, should restrict themselves to research directed towards finding solutions to problems limiting agricultural productivity. While national and regional programs may,

Commission XI met on Wednesday afternoon, April 10, under the chairmanship of Dr. E.J. Asomaning, Director, Cocoa Research Institute, Ghana. Dr. Ordway Starnes, Director, EAAFRO, was rapporteur.

and do, differ in their terms of reference, purposes, resource structure, and the way in which their findings are extended, three recognized activities of common interest are:

a) deciding research priorities;
b) performing the research; and
c) ensuring that the results are applied.

2. A mechanism, such as governing councils, must exist whereby the need of the community may be expressed, and technical and scientific competence must be the basis for deciding what research will be undertaken. It was agreed that cost/benefit analyses should precede the initiation of applied research projects.

Once a research program is underway it is essential to keep it under constant review and if need be to terminate it before too many resources have been dissipated.

3. The Commission agrees that research on problems that are common to two or more countries, or which require a commitment of specialized talents, expensive facilities, or a period of time exceeding that which national governments can conveniently commit, lend themselves to regionalization, a factor to be considered in the allocation of limited agricultural research resources.

4. Problem-solving research is not complete until results have been published, if warranted, and these reflected in the welfare of the people. The mechanism for disseminating the findings accruing to effort in the national and regional research stations differ, and most regional stations have no mechanism for disseminating results directly to farmers but make results available to national organizations for use in their extension programs.

The Commission proposes that appropriate mechanisms for the dissemination of research findings be employed by all agricultural research institutions.

5. The Commission notes and commends the OCAM proposal to develop collaborative inter-territorial research within the framework of present research organizations.

6. The Commission notes that the Development Assistance Committee of the OECD is giving special attention to the problems of assistance to agricultural research and has concluded that:

a) every effort should be made to ensure the continued viability of Africa's national and regional research programs and institutions;
b) the replacement of career colonial civil servants by technical assistance personnel has often not assured the continuity so vital to sustained and productive research effort;

c) donor countries, in their awareness of the need to expand research services, emphasize the need for regional programs;
d) it is essential that there be established and maintained continuing communication between English-speaking and French-speaking countries in Africa; and
e) donor countries need the basis of a working relationship, particularly in matters pertaining to regional programs, and suggest therefore that where new institutional arrangements must be found, that regional or sub-regional councils be formed to consult with interested bilateral and multilateral donors.

7. The Commission has noted with great interest the initiative taken by FAO in the field of documentation, and particularly the proposals made for the establishment and maintenance of an "Index of Agricultural Research Projects in Africa," of which sample issues were presented to the Conference.

Considering that up-to-date information in this field is of key importance for the intensification of contacts between research workers and institutions and constitutes an essential tool for the organization and management of research activities, the Commission warmly endorses the proposal and expresses the hope that FAO will obtain the more active collaboration of governments and other interested bodies for the collection of the necessary data, as well as adequate support for the production of this Index at an early date.

8. The Commission shares the intention of FAO to convene conferences on the establishment of agricultural research programs on an ecological basis in Africa with all member countries, research organizations and institutions and donors already interested in agricultural research, and proposes that the ecological approach to the solution of agricultural problems in the first place be attempted in the Sudanian zone as a pilot program. Additional programs may be decided when the mechanism for work on an ecological zone basis is working satisfactorily and as the need arises.

9. The Commission notes the mutual enrichment derived as a result of associations between certain research organizations and universities through which university researchers are encouraged to utilize facilities for the conduct of work within the programs of research institutes and institute staff are afforded an opportunity to offer seminars, lectures, supervise the dissertation work of graduate students and otherwise contribute to the training of potential research workers. The Commission endorses and encourages this sort of relationship between research institutes and universities, and suggests that when new national or regional research institutes are established that they be located in association with and in close proximity to faculties of agriculture.

10. The Commission recommends that a study Commission be convened to determine factors associated with the recent decline of regional research

programs in Africa following national political independence, and factors attributable to the effective functioning of remaining regional research programs.

In conclusion, the Commission recommends that agricultural research programs be designed to undergird national development goals and agrees that with consideration to economy and efficiency, the following combinations of alternatives should be employed when feasible:

a) the strengthening of national program;
b) the further development of national programs of unique strength and extending these to serve additional countries in the same ecological zone;
c) the strengthening of existing regional programs to more effectively meet present commitments and expanded to meet the needs of the ecological area.

11. The Commission recognizes the competition for limited funds and manpower between regional and national research organizations. It is recommended that this should be taken into account upon the expansion of existing facilities as contemplated.

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His Imperial Majesty Haile Sellassie I with Members of the Interim Committee of the Association for the Advancement of Agricultural Sciences in Africa (AAASA):

left to right: Dean Peter Nderito, M. Gabriel Ramalanjaona, Dr. Melak H. Mengesha (Secretary-Treasurer), Dean V.A. Oyenuga (President), Dr. M.G.C. McDonald Dow (NAS), His Imperial Majesty, Mr. Frank Pinder (ECA), M. Louis Sauger (Vice-President), Dr. Gerard Dekker (ECA), M. J. Dubois (ECA), Mr. St.G. Cooper (ECA).

Photograph courtesy Ethiopian Ministry of Information – August, 1968

Texts of Addresses

HIS EXCELLENCY ABDOULAYE SAWADOGO
MINISTER OF AGRICULTURE
REPUBLIC OF THE IVORY COAST

Your Excellencies, Ladies and Gentlemen:

The Conference on Agricultural Research Priorities for Economic Development in Africa, the opening ceremony of which I have the honor of presiding at now, is of great interest to the Ivory Coast both for the importance of its purpose and for the great assembly of renowned scholars and famous agronomists that it has gathered together, thus making our capital of Abidjan for a few days a metropolis of science for the whole of Africa.

The Head of our State, His Excellency President Houphouet-Boigny, who personally approved the holding of this Conference here, would have dearly loved to preside here today and to tell you what great value he attaches to scientific research. Speaking on 20 December 1959 at the opening of the Abidjan-Dakar Seminar on Scientific and Technical Research and the Economic and Social Development of African Countries, he said, and I quote:

> It is with great emotion that I speak to you today, for this symposium, being as it is a meeting where the experience of many specialists from all the realms of science, of applied research and of the high echelons of administration comes into direct contact with the realities of Africa, represents an absolute revolution in the methods of work followed up until now in scientific and technical research and warrants hope of swift and immense progress in the economic and social development of our States.

Your purpose in being here, Ladies and Gentlemen, which is to decide on priorities in agricultural research, assumes that such research has already been integrated into the progress of the economic development of Africa.

And this thought leads one to ask what are the means, not only financial but above all in manpower, for setting to work, and to speculate on the place of international cooperation in the realm of science.

Your indulgence and your patience lead me to speak to you on the philosophy and the practices and policy of the Government of the Ivory Coast.

The final aim and the justification for the actions of the States of Africa are the same, be they in the north or south, east or west, with a planned economy or under free enterprise, and speaking any and all tongues: to instruct, to nourish, to clothe and to care for – to make of the African an equal, and therefore a brother, of the most advanced peoples of the world; in a word, to emerge from underdevelopment, an objective that is better known here by the phrase 'achievement of economic independence.'

In point of fact, the concept of economic independence should not be interpreted to mean a desire to return to national self-sufficiency, to shrink within oneself in a rejection of the modern economic world, which above all implies trade and interdependence. It must be looked upon as a battle between two forms of dependence: the dependence of national economies on external trade and the dependence on one or more raw materials from the vegetable, animal or mineral kingdoms.

Thus our States wish to ensure the primacy of their economies and to place them on solid foundations, which is, after all, a wish to build up modern economies.

Now life teaches us the primordial, basic tole of science and technology in the phenomena of the flowering and progress of what are now fully developed countries. For Africa, then, as for all emerging countries, there will be no growth, no take-off of their economies without substantial recourse to science and technology, which thus find themselves in the forefront of the battle for the better life.

Agricultural research is in the very forefront, since agriculture is the livelihood of an average of over 85 percent of the population of Africa and their main source of employment and goods.

We in the Ivory Coast know well that, although the developed countries are all industrialized, it is agriculture that must have priority in our development efforts. The objectives and topics of agricultural research must be so chosen that, when dealt with on a short or even long-term basis, they bring about quantitative and qualitative improvement in production and a

rise in productivity. And here the necessary relationship between research priorities and development planning becomes apparent. Either the National Development Plan lays down objectives for the nation, so that agricultural research may apply itself to the solution of the difficulties that need to be overcome before it can be implemented, or the Plan, in determining its basic options, takes into account the main fruits of past research. There is give and take between the director and the practitioner, the man of action and the scholar, the agronomist and the man in the laboratory.

In the Ivory Coast such exchanges take place through very flexible bodies named technical committees, whose members are chosen from all the sectors interested in the progress of science: politics, administration, the professions, the scientific world.

This collaboration makes for great efficiency in the 11 research institutes in our country that are devoted to basic and applied agriculture and has already produced very valuable results: on them have been based the Government's objectives for the Ten-Year Plan 1960-1970, summed up in a single word: Diversification.

By making methodical use of scientific discoveries, the Ivory Coast has been able not only to maintain its level of coffee productions, but also to launch ambitious and successful programs for export crops (cocoa, oil palm, coconut, banana, pineapple and rubber) as well as of industrial crops such as cotton, and cash food crops (rice, and the products of industrial small-scale fisheries, aviculture and ranching), making use of original methods well adapted to the country and co-ordinating the activities of management, research institutes and development companies.

But if diversification was the slogan of the first Plan, today it is the battle for Productivity that we ask our farmers to wage and win.

I call upon all the farmers of the Ivory Coast – the young people as well as trained technicians and responsible authorities – to think from now on in terms of productivity and yields, rather than total output or areas under cultivation.

With the same (or almost the same) amount of work and more application of scientific findings, we can and we must raise yields: for coffee, from 300 kilograms to two tons per hectare, for cocoa from 400 kg to one tone or even two, for rain-fed rice from one ton to three, for swamp rice from two tons to eight, and so on.

For in the world in which we live, where the terms of trade are steadily worsening for us through the continuous drop in the world market prices for raw materials – a fact that no verbal magic can conjure away – an increase in productivity is a powerful means of self-defense for the masses of our farmers.

And another, complementary step has been proposed and taken by the Government of the Ivory Coast, the inclusion of the value added by industrial processing of crops prior to their exportation. Much remains to be done in this context for the products of our forests and our food crops.

Ladies and Gentlemen, these are the guidelines for future activity in agricultural development. At present they lead us to research. They call for an increased effort towards advance in farming technology, oceanography, agricultural hydraulics, intensive mineral fertilization, and genetics; the problems of basic research will be set before us clearly. In solving them we shall have the advantage of a greater collaboration with ORSTOM – a first-rate organization for the purpose – of assistance from the laboratories of the University and the leading schools, including the Ecole Nationale Supérieure Agronomique (National School of Agriculture).

We hope that for a large number of doctorate theses our students will choose subjects of basic science whose solution will further progress in applied research.

Ladies and Gentlemen, that is the broad outline of how priorities in agricultural research are defined in the Ivory Coast.

We have pointed out the capital importance of the advancement of science and technology to the success in our efforts towards development. But this progress in science nevertheless requires considerable resources in money and, especially, in manpower, out of all proportion to the modest means of African States.

The Ivory Coast between 1960 and 1967 spent eight thousand millions of CFA francs, that is the equivalent of 32 million dollars, on agricultural research. Now this sum, considerable though it is for us, represents only half of the actual cost of running our institutes.

International cooperation thus seems to be an absolute necessity and provides one of the most effective formulae by which the richer countries can contribute to the progress of the poor ones. Such cooperation can assume very many forms:

a) exchange: of knowledge, techniques, experience, material – leading to economies of every kind. It is evident that the foundation of interstate scientific associations of scientists cannot but stimulate this beneficial type of cooperation.

b) sending of complete teams to work in various countries for periods of a certain length.

But whatever form it may take, scientific cooperation should concern itself with training of national groups of scientists under the sponsorship of the laboratories of the rich countries.

It remains to be seen whether cooperation in science and agricultural technology ought to be bilateral or multilateral, and whether research centers

should be under the authority of the nation in which they work or whether, on the other hand, they should come under that of all the States in the climatic zone in question.

Meetings like this one today will enable us to settle this question.

In any case the example of the Ivory Coast merits study. The joint Franco-Ivory Coast institutes of agricultural research have done devoted work and have reflected that cooperation between France and the Ivory Coast whose exemplary nature was recently praised by the President Houphouet-Boigny.

But this cooperation, which has now become a tradition, does not exclude that of other countries. While consolidating our ancient friendships we also seek new ones with all countries and all organizations (be they private, national or international) willing to contribute to the advancement of science in the Ivory Coast.

Ladies and Gentlemen, as I said at the beginning of this address, the Government of the Ivory Coast feels the choice of Abidjan as the seat of your Conference to be a privilege and an honor.

In the name of the President Houphouet-Boigny, I have the pleasure of welcoming you to Abidjan.

I sincerely hope that your Conference. launched under the most propitious circumstances, will meet with complete success.

I make a special welcome to those of you who, like myself, have had the honor of being students under *inter alia* Professors Aubert, Dumont and Pagot.

Thank you, Your Excellencies, Ladies and Gentlemen, whose very presence ornaments our ceremony.

I hereby declare the Conference on Agricultural Research Priorities for Economic Development in Africa officially open.

MR. R.K.A. GARDINER
EXECUTIVE SECRETARY
UN ECONOMIC COMMISSION FOR AFRICA

Your Excellencies, Ladies and Gentlemen:

The National Academy of Sciences is to be congratulated on at least two scores. First, on their tenacity of purpose, which has culminated this evening in the assembly of a body of Agricultural Scientists here in Abidjan,

whose names and areas of specialization are known throughout the length and breadth of this and other continents. Secondly, the National Academy is also to be congratulated on the choice of the Conference theme, which has been titled, and I think very appropriately at this point in time, "Agricultural Research Priorities for Economic Development in Africa."

In an age of vast conceptual changes and spectacular technology, Africa cannot afford to lag further behind in generating and controlling its energy resources, conserving and utilizing its water, combating its diseases, and fructifying its land – these are the inequalities and disparities which characterize the dependent from the independent economies.

Research of the quality required to make a break-through is impeded by lack of basic technological skills, of power and transport, and of the social and economic infrastructure necessary for a technological society. But science is not a monopoly of any social system. Every state, however small or poor, can train enough of its citizens to ensure its own entry into the domain of scientific thought and action.

You are all aware, I am sure, of the stimulus derived from a meeting of minds, of the opportunity which Conferences such as this offer as a means to communicate with people with like interests, conceptions, and ideas.

Organized on the widest possible agricultural front, I fully expect that when deliberations are completed, with minds enriched and stimulated, you will return safely to your bases to tackle the multitude of tasks which lie ahead. By the time this Conference has completed its deliberations, it is the hope of the Organizers that work priorities will have been clarified, re-defined, and oriented more specifically towards Africa's immediate and more urgent needs.

The papers contributed to the Conference, and the discussions which naturally will follow, fall within four broad fields of endeavor, which are covered by the physical, biological, chemical and socio-economic sciences. In essence, these scientific disciplines cover the use of the essential components which collectively give rise to the term Agriculture. The Conference papers encompass studies concerned with the formation and use of Africa's soils, and the environmental considerations which include precipitation, water use, humidity, and temperature, and seek to define the ecological conditions in which man has to pit his wits to win more production for his essential and ever growing needs.

Africa, according to estimates of U.N. bodies, has approximately some 250-280 scientific institutions dealing with agricultural research and natural resources. For a continent of limited resources, this is an impressive number. I am, therefore, particularly interested in that body of opinion concerned with the re-assessment and re-evaluation of the whole concept of

research, organization and policy in Africa at the present moment. There would seem, therefore, to be much sense, in terms of the known and likely resources of trained manpower and money, in accepting the idea that research should be developed in the future on an ecological zone basis.

Permit me now to focus your attention for a few moments on some of the *more obvious agricultural deficiencies in Africa,* which in my view, should have a bearing on the direction of the research priorities which will be considered in this Conference.

The U.N. 1965 trade figures available for the countries of the West African sub-region, for example, indicate an adverse trade situation in cereals involving 700,000 metric tons, of which rice imports represent approximately 50 per cent, maize and other cereals making up the balance. In money terms, these imports cost the West African Governments concerned approximately 86 million U.S. dollars. This is a very heavy drain on countries striving to build up their foreign currency reserves which are urgently required for development purposes.

In the same year, sugar imports cost $44 million, and dairy products, 30 million U.S. dollars. These three commodity groups alone, cost Governments the equivalent of 160 million U.S. dollars. This is a staggering total for a sub-region blessed with favorable climatic conditions, good soils, and plentiful human resources. Surely, this is a challenge which statistics and technicians cannot ignore.

I raise the questions – are our plant-breeding and seed multiplication facilities adequate? Are the farmers being offered the means and the advice necessary to secure sufficient balanced fertilizer? And what of the losses which occur between time of harvest and the time when grains have to be prepared for human food? I recognize, gentlemen, the magnitude of the problems involved in raising these questions, from the point of view of finance, organization, and skilled manpower, but I feel sure that proposals for their solution are not beyond the competence of this distinguished body of scientists.

I would like to cite another example, which I consider to be of the highest priority. I refer to the meat situation in Africa, where large areas are, I believe, eminently suited for the rearing and fattening of cattle to provide meat for the mass of the people. What do we find? Beef herds providing an annual take-off of 8 per cent, compared with 25 - 30 per cent in the Argentine and Western Europe. Beef cattle requiring 5 - 7 years to reach slaughter weight, compared with 3 years in Western Europe. Carcass weights representing only 60 per cent of the weights attained by beef cattle in Argentine, Britain and many other countries.

The means of producing beef cattle in West Africa has changed little since early times. Now it becomes inevitable and urgent that application of science and technology must be brought to bear on the problem.

Whether we like it or not, we now live in a money economy. Cattle numbers in themselves mean little; what is required, and required urgently, is an increase in quality production from a given area of land considered suitable for the rearing and feeding of cattle. In a nutshell, the needs are better breeding – better pastures and feed – better control of animal disease. Again, I recognize that there is no single simple solution to these problems, as they form part of an interlocking complex that calls for a multi-disciplinary approach.

I recognize that in some countries, work is already proceeding in organizing and establishing controlled fattening ranches, which will act as a link in the production chain and which suggests that the Conference might consider range management research as an issue of high priority.

Let us have a look at another example – the North African sub-region. Here, the challenge to science and technology is equally acute. In this sub-region in 1965, the adverse trade situation in wheat and wheat flour was equivalent to approximately 3 million tons of wheat grain, or, at current levels of production, including irrigated areas, the utilization of 3.7 million additional hectares. Much of the production of wheat in North Africa is the concern of traditional farmers, who as yet have failed to make contact with the knowledge and products of science and technology. Here I refer specifically, to the extended use of improved cereal varieties, use of fertilizer, extension of irrigation facilities, and greater application of modern farm mechanization. Failure to meet the current demand for wheat production in the North American sub-region, involves Governments in import expenditures approximating 220 million U.S. dollars annually.

The same general situation holds good also for such commodities as raw sugar and dairy products. Imports of raw sugar, for instance, are now running a little short of one million metric tons annually.

It is obvious from the situation just cited, considerable efforts will have to be made to close the food production gap. In this connection, the role to be played by agricultural scienctists, is, I think, clearly indicated and defined.

I can further indicate to you similar situations in the East African sub-region, where, apart from Kenya, a considerable annual deficit in cereal production is recorded. In 1965 for example, there was a deficit of six million metric tons. In the Central African sub-region, Cereal supply in 1965 was short by two million tons.

I would hope that my remarks have focussed sufficient attention on the urgency for a co-ordinated rational and effective approach to be made by

the entire spectrum of foreign aid – bilateral, multilateral, foundations and other private sources, to the solution of these problems, which seem to me to be of the highest priority, in our economic and social development programs in Africa. The Economic Commission for Africa, in their role as catalysts in African economic affairs, would wish to play a positive part in institutional activities concerned with the furthering of research in the field of agriculture.

I believe that most of us realize that a serious gap exists between the research scientist and the working farmer in the field. Somehow this gap must be narrowed, and in this connection, I suggest that it might be fruitful to consider the possibilities of institutional change in the African setting, such as the Land Grant College system which has served the United States of America so well. In such institutions, as you are all aware, the basic philosophy and working pattern is to achieve a welding and co-ordination between research, teaching and extension interests, so that research findings may be rapidly translated into practice in the field.

I wish now to make a special plea for financial and technical support to enable selected research institutions, concerned with improved agricultural practices, to play their proper role in developing the agricultural resources of Africa.

I recognize that the cost of research is enormous, but I also recognize that handsome dividends can be obtained from investment in research, which is properly conceived, efficiently directed and effectively applied. In Northern Nigeria, in Ghana and Liberia, in Senegal and in East Africa, we are all aware of the contributions made by research, which have resulted in significant increases in the volume and yields of ground nuts, rubber, cacao, maize and coffee. In Mexico, India, Pakistan and Turkey, we are also aware of the excellent results achieved from the research carried out by the Ford and Rockefeller Foundations on wheat, rice and maize. I believe that a similar effort mounted for the food crops and livestock of Africa might well result in Africa becoming a food exporting rather than a food deficit continent.

And now a final word. I would like to make two suggestions. One – I think the Conference would fail in its purpose, if it permits this gathering to be an end in itself. I, therefore, strongly recommend that there should be a continuing dialogue between scientists, and this could best take the form of an Association for the Advancement of Agricultural Sciences in Africa.

The Economic Commission for Africa would strongly support such a body, provided it were organized on an ecological zone basis. Secondly – there is a considerable amount of agricultural research, past and present, that has been assembled in Africa, but unfortunately, there is no focal point for disseminating the results. In this connection, may I suggest that ECA or

some other appropriate body be selected as a clearing house, provided the additional overhead costs, resources and personnel are borne by either government aid donors, foundations, or private sources.

I have attempted, Mr. President, Gentlemen, in this brief address, to give a synoptic picture of only some of the research issues faced by the continent of Africa. I do not pretend that it is an exhaustive scientific review. I consider that my role has been to indicate the realities which face this vast continent of ours, and I have endeavored to suggest a few general guidelines, which I trust will be taken into account in your deliberations. I thank you for your kind patience and I close with the words of a famous scientist, Henry Fabre, who wrote "History celebrates the battlefields whereon we meet our death, but scorns to speak of the ploughed fields whereby we live; but cannot tell us the origin of wheat. This is the way of human folly."

DR. EDWARD F. KNIPLING
MEMBER
U.S. NATIONAL ACADEMY OF SCIENCES
DIRECTOR
ENTOMOLOGY RESEARCH DIVISION
U.S. DEPARTMENT OF AGRICULTURE

Your Excellencies, Ladies and Gentlemen:

The U.S. National Academy of Sciences has been involved with domestic agricultural research programs since the formation of the Agricultural Board in 1944. The 25 years since then have been notable for the tremendous advance in techniques and production in agriculture for which research has provided continual stimulus. Indeed it has been estimated by economists at the University of Chicago that the return on money invested in research in agriculture in the United States has been of the order of 100 per cent per annum.

The Academy cannot take credit for contributing a great deal to this success story since it does not actually carry out research. It was chartered by the Congress of the United States in 1863 to advise the government on scientific matters upon request. It has contributed to agricultural development principally through the activities of its advisory committees on such subjects as foot and mouth disease, animal health, animal nutrition, plant and

animal pests, and veterinary drug efficacy. In recent years another aspect of the work of the Academy has been to provide outlets for the rising number of American scientists whose interests lie not only in the fields of science in foreign countries but in the larger issues of economic development, international relations, food supply – including, of course, the scientific and technological components of these. The Academy now has boards whose members represent a wide variety of academic discipline united by a common interest in Africa, Latin America and the Pacific. Under their direction studies have been made on animal diseases and agricultural development schemes in Africa.

In 1966 members of the Africa Science Board of the Academy paid an extensive visit to Africa to establish contact with the new African Academies of Science and other scientific bodies, and to explore ways of improving communication and cooperation with African scientists. Discussions also inevitably involved agricultural topics, and these continued, on the return of the members to the United States, with officials of the Bureau for Africa of the Agency for International Development, the Rockefeller Foundation, the Department of Agriculture, the World Bank, and many others, on what the Board and the Academy might be able to do to assist their scientific colleagues toward the development of African agriculture. At this time, the possibilities of an international center for agricultural research and of an international conference on agricultural research were the most prominently developed ideas. With the decision of the Ford and Rockefeller Foundations to support the former, AID agreed to provide the Academy with funds to carry out more formal consultations on the need for and aims and objectives of a conference. Accordingly a Committee of the Africa Science Board, chaired by Dr. John McKelvey of the Rockefeller Foundation, was formed to oversee the project, and decided that the first step in any planning should be to consult with a representative group of African agriculturalists. In March 1967 the Academy staff met, appropriately in the Faculty of Agriculture at the University of Ghana, Legon, with scientists from Senegal, Mali, Ghana, Nigeria, Kenya, Uganda, the Sudan, and the Congo, and representatives of AID. This meeting laid the foundation for the type of conference which has emerged, since the recommendations, subsequently endorsed by the Academy Committee, were for a broad representative conference with scientists, planners, economists and social scientists, as well as government officials from throughout tropical Africa, dealing with agriculture in its broadest sense, from climatology, soils and water, to crops, crop protection and storage, animals and their health, economics and marketing, sociological aspects, education, training manpower and extension.

Inherent in the meeting, and in its objectives, is the fundamental principle which we in the Academy believe holds just as surely for Africa as it has been observed to do in the United States, that scientific and technological research is an essential component of economic development. We also believe that personal contact is just as important a stimulus to research as communication through scholarly journals and for these reasons we are particularly pleased that so many of our distinguished colleagues from so many countries of Africa and elsewhere have accepted the Academy's invitation to meet and discuss this most important subject. We hope that this will be but the first of many meetings, and that it may also provide the opportunity for African scientists to arrange for the establishment of a permanent mechanism for continuing discussions and increasing communication and cooperation among themselves.

On behalf of President Seitz and the National Academy of Sciences, I am very glad to welcome you all to the Conference.

MR. MAMOUN BEHEIRY
PRESIDENT
AFRICAN DEVELOPMENT BANK

Your Excellencies, Ladies and Gentlemen:

It gives me very great pleasure to be with you this evening and to address this assembly of eminent scientists and agricultural economists. The objectives of the Conference and indeed the fact that such a large number of scientists and agricultural experts are meeting to consider one of the most important and pressing problems facing Africa are of very great interest to the African Development Bank which I have the honor to represent here.

Your Conference has not come a day too soon. In effectively planning any concerted efforts it is useful to pause and choose priorities so that the maximum benefits could accrue from a given amount of efforts. You have taken a wise course by convening this Conference. And I must say that we in the African Development Bank congratulate you and would like to assure you of our interest and support for the initiative you have taken and the realization of your objectives here and thereafter in the field.

The meeting point between the objectives of this Conference and those of the Bank is the common interest we have in economic development. The Agreement establishing the African Development Bank came into force in

September 1964. At the moment 30 independent African states are members of the Bank and its capital is exclusively owned by African countries. We formally started operations on 1st July 1966.

The purpose of the ADB is to contribute to the economic development and social progress of its members – individually and collectively. It is the Bank's function to use the resources at its disposal for the financing of investment projects in African member countries giving priority to projects or programs of multinational nature and those designed to make the African economies increasingly complementary.

Both agricultural and industrial developments are the essential ingredients of economic development. It is now generally speaking accepted that industrial and agricultural developments are not alternatives but complementary and are mutually supporting with respect to both inputs and outputs. In particular, if as it has been estimated, 80 per cent of the people on the African continent are engaged in agriculture, increasing agricultural productivity is not only increasing the standard of living of those people on the land but also increasing the effective demand for industrial output and supply of inputs for further industrial development.

As you are well aware, the agricultural sector occupies a pivotal position in Africa's economic development. It is not my intention to dwell upon the importance of agriculture in economic development, particularly in Africa. But a few issues are worth mentioning here. Because of the prevailing low levels of income in many African countries, a larger part of a given increase in per capita income is spent on food. Moreover, acceleration of the process of industrialization needs increasing amount of agriculture-based raw materials. The immediate goal should be one of attaining self-sufficiency in food products so as to feed the population to an adequate extent and of increasing the production of other agricultural products and raw materials to meet the requirements of the industrial sector. Increased production, moreover, needs to be accompanied by quality improvements. In the long run agricultural production needs to be accelerated and diversified so as to increase the export capacity and to reduce the adverse effects of dependence on few primary products and of deterioration in terms of trade of the agricultural sector.

The African Development Bank subscribes to the proposition that the fundamental task of economic development is that of increasing society's productive capacity and thereby economic and social well being. If agriculture is to play a dynamic role in the process of economic development and meet the goals mentioned above, productivity changes leading to increase in production and improvement in quality need no emphasis. Obviously enough agricultural research needed to bring about required productivity changes in the agricultural sector assumes prime importance.

In order that efforts in the direction of agricultural research yield maximum benefits, priority needs to be given to those types of research and those types of agricultural techniques that are best suited for the solution of the problems peculiar to African agriculture. The application of better techniques already evolved elsewhere will need suitable orientation to make them useful for African agriculture. Thus great ingenuity and imagination will be required not only in evolving new techniques most suitable to African conditions but also in adapting the known techniques.

But this is not the whole story. It is equally important that such techniques which will be the fruits of research should be placed more easily in the hands of the farmers who will ultimately make use of the techniques in day-to-day life. The workers on the land should be enabled to put into practice the perfected techniques effectively without delay and loss. This calls for an efficient network for transferring the scientific knowledge to the village level and for a system through, for example, extension services to teach African farmers the practical application of knowledge and the use of better techniques and practices. Thus the need for training of both agricultural research workers and field agriculturists assumes equal and simultaneous importance.

Another aspect of agricultural research that needs explicit reference is the importance of multinational approach to research in Africa wherever possible. African countries need to make collective and concerted efforts in instituting effective research programs covering the problems of better seeds and techniques, better tools and implements, pest control, irrigation and flood control, etc., and in promoting agricultural research and practical training programs. There should also be more widespread and effective exchange of research findings between various African research centers.

There are some other problems of agricultural development besides the problem of production and productivity to which I shall briefly refer. One of these is the problem of distribution and marketing. It is believed that not all the surplus marketable agricultural products, especially food crops for local consumption get to the centers where they are needed and in good condition. This inability to sell all their products is a source of frustration to the farmers. The inadequate storage and marketing arrangements are said to exert disincentive effects on production. Then there are other related questions of adequacy of credit systems for agriculturists and appropriate land tenure systems and extension services that can have such favorable incentive effects on production.

It is very encouraging that here present in Abidjan are the concerned scientists, agricultural experts, economists and administrators fully skilled and experienced in their respective fields to be able to come up with effective answers to the various problems of agricultural development in Africa.

I feel certain that you will devise a system of placing as early as possible the conclusions of your discussions and future research efforts in the hands of the appropriate agencies which are in direct contact with the technicians and farmers in the field. We would like to see that the contacts being established here would be maintained and that a meeting of agricultural experts working on African problems would become a regular feature of your activities. Such a development should help in diffusing existing and new knowledge of agricultural sciences and thus promote the improvement of agricultural practices and output in Africa which is an urgent necessity.

I leave you with the note that all of us involved in the economic development of Africa will follow your deliberations with keen interest and will be forever grateful not only to those who organized this Conference but also to the distinguished delegates who have taken time off from their numerous other engagements to participate in this all important Conference

I wish you every success.

DR. OTTO E. FISCHNICH
ASSISTANT DIRECTOR GENERAL
FOOD AND AGRICULTURE ORGANIZATION
OF THE UNITED NATIONS

Your Excellencies, Ladies and Gentlemen:

It is a great honor and pleasure for me to deliver to you all a message on behalf of the Director-General of the Food and Agriculture Organization of the United Nations on the occasion of the Introductory Session of this Conference.

During the last decade a large number of conferences and meetings organized by various bodies have dealt with many different aspects of agricultural research and development in Africa. Usually only limited technical and scientific features of Africa's agriculture were discussed. Here it became increasingly evident that a broader approach, on the basis of agriculture as a whole in all of tropical Africa, was necessary if a full perspective was to be obtained of the priorities in agricultural research that are needed to solve the challenging agricultural problems involved in the economic and social development of Africa. Accordingly, the Director-General has warmly welcomed this opportunity for FAO to cooperate with the United States

National Academy of Sciences and the Government of the Ivory Coast in the holding of this important Conference.

The contribution of research to the development of agriculture

In the development of agriculture, research plays an absolutely invaluable and essential role, as other speakers have already pointed out.

Examples of the contribution that research can make to the development of agriculture can be provided from the spectacular advances that have been achieved in the yields of cereals in certain countries. In the 25-year period between about 1925 and 1950 grain yields in North America more than doubled, whilst in Africa the increase was around 20 percent, and in Asia a barely perceptible 7 percent. More recently in the United States of America the trend has been towards a doubling of acre yields every 15 years, with an annual rate of increase as high as nearly 5 percent. Whilst various interlocking factors such as average income per person, a market-oriented rather than subsistence-type of agriculture, favorable prices for farm products, and the level of development of the non-agricultural supporting sector of the economy all influence the ability of a country to raise output per acre, a very advanced agricultural technology based on the results of research on plant breeding, fertilizers, fungicides, insecticides, weed-killers and improved cultivation practices has played a major part in those yield increases.

One most interesting feature of recent studies of agricultural development has been that the magnitude of yield increases, once established in a country, tends to grow rather than to decline or level off, as shown by the situation in the United States which I have mentioned. Moreover, in countries such as those of Western Europe, the United States, Australasia and Japan, where agricultural productivity is already high, there is not the slightest sign of any lessening of their agricultural research activities, but on the contrary there is a consistent intensification of research effort.

The implications of this for African agriculture are highly encouraging. Japan's industrial and economic development, for example, is only of recent origin. That country's rice yield per acre has just about doubled over the past 80 years, and is now over three times the average of the rest of Asia. Comparable progress in agriculture can be anticipated in any country in Africa on the basis of a similar intensive application of the results of agricultural research. With the amount of scientific and technological knowledge now available, progress can be even more rapid in Africa.

The role of agricultural research in general social and economic advancement

Agricultural research, however, is not only the starting point and life-blood for the development of agriculture. It is more than this, for it can be the starting point for development of the whole economy.

In recent years it has come to be realized that a sound and vigorous agriculture is an essential basis for the general social and economic advancement for which Africa, like all developing regions, is striving. Throughout the world there has been a close inter-dependence between the development of agriculture and the development of urban industry in modern expanding economies. The demand for farm products is mainly governed by the level of national income, and as the resulting income of farmers rises, it in turn absorbs more industrial output, and thus helps to accelerate the expansion of the entire national economy.

As just one example, the breeding of the early-maturing and high-quality Narquis variety of wheat in the early years of this century enabled most of Western Canada to be opened up for cereal cultivation. This led to the development of towns and cities in that part of the country. That variety of wheat was said to be worth 100 million dollars a year to Canada for at least a 15-year period, until it succumbed to the ravages of a new strain of the rust disease. Then the plant breeders again had to come to the rescue with the creation of new disease-resistant varieties. Parts of Western Canada are now amongst some of the most highly developed areas of the world, so that the breeding of Narquis wheat provides an example of the basic contribution that agricultural research can make, not only to agriculture, but also to eventual overall industrial and economic development. The way in which this valuable variety of wheat eventually fell to the ravages of epidemic disease; and itself had to be replaced, is also an example of the fact that, as I have already mentioned, agricultural research never comes to an end – that even in the most advanced of agricultural systems there is always a vital need for agricultural research.

The need for co-operation in agricultural research

Agriculture is by nature an integration of many skills. Its development likewise is a multidisciplinary exercise which calls for the application of knowledge in a wide range of subject-matter fields in the physical, biological, social and economic sciences.

Evidently agricultural research can be a complex and costly undertaking. Today it is realized, that no single country should stand alone in the field of agricultural science. Progress can be more certain and more rapid

through cooperation – firstly, cooperation between the many different kinds of scientists concerned, and secondly, cooperation between countries, in making their scientific knowledge available for the benefits of all, and in showing and learning from one another how that knowledge can best be used.

The comprehensive program that has been placed before us shows that this Conference will make a valuable contribution to the strengthening of both of those kinds of cooperation with respect to agricultural research and development.

A sound basis for progress in agricultural research in Africa already in existence

Africa is not an area where it can be said that agricultural research has been neglected. General studies on soils, climate, vegetation and ecology have been carried out in practically all of its countries, and this work still continues under the auspices of national, bilateral and international programs. Agricultural research centers and institutions, many of which have acquired a world-wide reputation, have been established throughout Africa. Some of them are of a general nature, such as INEAC, the National Institute for Agricultural Investigations in the Congo; EAAFRO, the East African Agriculture and Forestry Research Organization in Kenya; and the ORSTOM system with its associated chain of research institutes in francophone Africa. Many other research institutes of more restricted and sometimes highly specialized nature in various African countries have been outstandingly successfully concerned with research on a multitude of local problems in such subjects as wheat, maize, sorghum, rice, coffee, cocoa, cotton, oil palm, sisal, rubber, locust control, livestock husbandry, general veterinary science, specific animal diseases including rinderpest and trypanosomiasis, fisheries and human nutrition. The accomplishments in these many fields have been indeed impressive.

Thus it will be seen that in all parts of Africa experimentation has been and is still being conducted on food and industrial crops, animal husbandry, land and water resources, soil conservation, fertilizers, pesticides, the control of diseases, and general farming techniques and cultivation practices.

However, although in total so much has already been done, it is but little in relation to the needs. Clearly, with ever-growing world populations outpacing the agricultural production that must satisfy their demands for food, clothing and shelter, agricultural research must have high priority in plans for overall social and economic advancement.

A main objective of this Conference will therefore be to see what can be done to build still further on the basis of existing institutions and programs, and what new research facilities, programs and other arrangements should be established.

As research topics are legion, and resources in money and trained manpower are limited, there is no other alternative but to assess priorities and to share the work through cooperative arrangements.

The first priority in agricultural research in Africa – the utilization of existing knowledge

I believe that two basic lines of action are needed in current research activities.

As a first priority, the fullest possible use should be made of existing knowledge and experience from all sources. That which has already been obtained under African conditions is particularly valuable. Much of it has already been published. Much, perhaps even more, is still in unpublished documents and archives in various African research institutions. All possible effort should be made to see that this material is not lost, but becomes available to the scientific community and is adapted to practical application in present-day agricultural development in Africa.

In addition, the vast amount of knowledge and experience available from other parts of the world must continue to be put to the fullest possible use in Africa. Whilst much of this research information can be directly transferred and applied under African conditions, other parts of it will need to be adapted and supplemented by further research in African countries. As an example, spectacular advances in the productivity of wheat and rice have been achieved in recent years through intensive research directed towards the breeding of improved varieties with special morphological and physiological characteristics enabling them to tolerate and respond to heavy applications of fertilizers. The work on wheat improvement in Mexico and on rice improvement at the International Rice Research Institute in the Philippines, both of which programs have been made possible through the initiative and generous support of the Rockefeller and Ford Foundations, have led to high-yielding varieties of wide adaptability. These may well lead to dramatic increases in cereal production in developing countries where they are suitable – and indeed they are already beginning to do so. However, they are more demanding than the old varieties in their requirements for good husbandry, improved cultivation practices and generally favorable environmental conditions, and may turn out to be susceptible to local pests and diseases which they have not previously encountered. Much care is

therefore needed before such new varieties are introduced on a large scale into new areas, for whilst in some countries they may by chance be well adapted, in others, if unsuitable, they could lead to catastrophic failure.

Nevertheless, even in such cases the great potential benefit from the remarkable basic improvements in the characteristics of these new varieties can eventually be realized through further plant breeding and crop husbandry research. These examples show, on the one hand, the immediate value that can sometimes be derived from the direct introduction of research results from other countries, and on the other hand, the frequent need that exists for further adaptive research under local conditions.

In addition, under local conditions, there will also be the need for long-range research. However, just as in agricultural education, so also in agricultural research, it should be ensured that the agricultural sciences serve a policy for social and economic development, rather than a policy for scientific development. This emphasis on applied research, for action, does not of course exclude the need for continuing and expanding research for basic scientific knowledge in certain selected fields. It is a pre-requisite for further progress and development, that research must maintain its position well ahead of general practice. To argue the merits of basic and applied research, and the proper balance between them is academic, and does not serve any useful purpose. Both basic and applied research are required for the effective solution of most complex agricultural problems. Moreover, to the young agricultural scientist, I should like to take this opportunity of saying that research on economic crops and livestock, on problems of direct practical importance, can be just as exciting and as intellectually rewarding as any other kind of research – with the added satisfaction of knowing that only through such research can economic and social progress be achieved.

FAO interest and action in agricultural research

It is for this reason that, whilst the headquarters staff of FAO are not themselves personally engaged in research, the Organization devotes much of its resources to various ways of encouraging agricultural research and its practical application, especially in the developing countries. This is done both on a national and regional basis, through such means as policy advisory meetings, technical meetings, training courses, fellowships, and publications, and through direct "technical assistance" and "Special Fund" projects financed from the United Nations Development Program, or through the Freedom from Hunger Campaign, or in cooperation with various private non-governmental bodies. Amongst these, the Rockefeller Foundation and the

Ford Foundation have made particularly valuable practical contributions to agriculture through research, and FAO appreciates the many opportunities it has had to cooperate with them.

Reference has already been made to the work of these Foundations on wheat in Mexico and on rice in Asia, and FAO looks forward to the successful establishment by the Rockefeller and Ford Foundations, in co-operation with the Nigerian Government, of the proposed International Institute of Tropical Agriculture at Ibadan.

FAO is also closely associated in the relatively recently established United Nations Economic and Social Council's Advisory Committee on the Application of Science and Technology to Development. That important Advisory Committee, now entering into its fifth year, is preparing a World Plan of Action for the Application of Science and Technology to Development, which is closely related to FAO's own World Indicative Plan for Agricultural Development. This is an international attempt to measure and anticipate the needs of the peoples of the world in terms of food, trade and development 20 years from now, when the world population will have risen some 50 percent above its present level. Just as the United Nations Advisory Committee's World Plan of Action will provide a focus for inter-governmental action across the whole field of science and technology, so also will FAO's Indicative World Plan provide a focus for FAO activities in the food and agriculture sector of overall economic development.

Within the framework of the United Nations Advisory Committee on Science and Technology, FAO is also associated with its studies on such subjects as measure for "increasing the production and use of edible protein" and "the development and rational utilization of natural resources."

Just as the United Nations Advisory Committee has special regional working groups, including one in Africa, so also FAO has plans for extending its work in the African region through such activities as the Working Group on Measures for Closer Co-operation in the Provision of Aid to African Countries in Agricultural Research, and is planning to organize further meetings on the establishment of agricultural research programs on a sub-regional ecological basis in Africa.

The second priority in agricultural research in Africa – the sharing of the work-load

It will be seen that the long-existing trend towards international cooperation in agriculture is becoming more and more intensified, and this brings me to the second priority which I wish to emphasize, the need to work out better

cooperative arrangements for complementary research activities so that the vast amount of research that has to be done can be shared, thus making the best use of available resources by avoiding unnecessary duplication of effort.

This present Conference will provide an opportunity for discussing the factors that must be taken into account in the establishment of agricultural research programs, identifying objectives and priorities, and sharing the work on a cooperative basis.

Whilst particular attention and concerted effort must be placed on the technical aspects of production and development research, it is important that adequate emphasis also be placed on research to develop new ways and means of adapting and adjusting rural Africa, economically and socially, to technological progress. One of the main needs in Africa is to demonstrate to traditional farmers the advantages of changing over from their subsistence shifting cultivation system to stabilized and intensified modern agricultural methods of farming. How to break the social and psychological constraints of the rural population and encourage them to move from the former to the latter systems, should be given high priority in research and development programs in Africa today. For this reason adequate institutional and organizational arrangements for liaison between research and extension are essential, so that research findings can be translated into a language that appeals to farmers. A good example of what is needed and can be achieved is shown by the Freedom-from-Hunger Campaign Fertilizer Programme, launched by FAO in cooperation with the world fertilizer industry. Through this program demonstrations and simple fertilizer trials are laid down on farmers' fields and supplemented by economic studies on local fertilizer marketing and profitability. Pilot schemes for fertilizer distribution and credit have also been included in order to make fertilizers more readily available to small-scale farmers. In this way small farmers have seen with their own eyes what fertilizers can do to increase yields and profits on their own land. In countries participating in this program, now in its eighth year, fertilizer sales have increased more than three times faster than the average in other developing countries. It is through direct, practical approaches of this kind to the farmer that the results of agricultural research can most quickly be used to meet the urgent needs of the developing countries for increased agricultural production.

Conclusion

The Government of the Republic of the Ivory Coast, in extending its generous hospitality to this Conference, has shown a deep understanding of the

importance of the problems with which we shall be dealing here, and on behalf of the Director-General of the Food and Agriculture Organization of the United Nations which is associated with the National Academy of Sciences of the United States of America in convening this Conference, I should like to express our deep appreciation for this hospitality. On behalf of the Director-General, I also wish to express sincere appreciation of the cordial cooperation that FAO has received from Mr. Robert Gardiner, Executive Secretary of the United Nations Economic Commission for Africa.

Excellencies, Distinguished Delegates, Ladies and Gentlemen, it is a matter of great satisfaction to me to see here today that the assessment of agricultural research priorities to solve rural development problems is receiving attention simultaneously from various sides by the governments and agriculturists of Africa.

On behalf of Mr. A.H. Boerma, Director-General of FAO, and myself, I should like to express my sincere hope that this Conference will prepare the way for further cooperation and concerted action for the benefit and well-being of all the peoples of Africa, and I wish this Conference every success.

PROFESSOR RENE DUMONT
INSTITUT NATIONAL AGRONOMIQUE DE PARIS

The Ivory Coast Has Not Made a 'False Start' But... Africa South of the Sahara, as a Whole, Has.

When I wrote *False Start in Africa* in 1961-62, my purpose was to shake up European opinion, which had not recognized all its responsibilities for this false start: for those of the past (slavery and colonization) and for those of the present (neo-colonialism and deterioration of the terms of trade). Another purpose was to bring African leaders face to face with their new responsibilities arising from independence and the achievement of adulthood. I was already apprehensive about unproductive expenditures, hasty Africanization, a certain premature socialism, the appearance and growth of a more or less parasitical middle-class in politics and the administrative sector and a lack of the spirit of enterprise. I took my decision to write this book at Brazzaville in the middle of May 1961, under a particularly corrupt and inefficient government.

When our report of April 1959 to the United Nations on *Community Development in India* pointed out the danger of a general scarcity and regional famines in that immense country at the end of the Third Plan in 1966 or 1967, that too was a serious warning. We wrote that "if the present mistakes continued there would be serious dangers." Events have proved us right, although we hoped that we would be wrong. It was the same for Africa South of the Sahara in 1962. My greatest hope then was that I would be given the lie direct on the widest possible scale.

And for the whole continent, alas, that did not happen. From Morocco to the United Arab Republic the food situation is even worse in the north of Africa than in the Africa between the tropics. The latter country, by making a great effort, just succeeded in improving its food supply to keep pace with its population growth. But since independence, agriculture in Morocco has stagnated. The modern sector is deteriorating in Algeria in recent years and everywhere food imports have increased greatly.

It is true however that the food situation seems less serious in Africa between the tropics. Nevertheless figures published by the Economic Commission for Africa and by FAO show that, for the sub-continent as a whole, *food production has advanced less rapidly than population growth* since 1959. Fortunately there are not such serious famines as in India or in certain regions of Latin America (the Andes mountains and in north-east Brazil). But droughts in East Africa still lead to very serious shortages, as in 1961 and 1965. Qualitative undernourishment remains very evident in the poorest strata of the population, even among the peasants who generally have no opportunity of getting sufficient animal proteins.

Elsewhere imports of food continue to rise steadily: in Tanzania, for example, by 16.5 percent in one year, between 1965 and 1966. And this of course greatly reduces its capacity to purchase equipment and thus to develop. The Belgian economist Paul Bairoch considers that the productivity per head among agricultural workers in the generally retarded Afro-Asian complex has fallen by about 20 percent during the last 50 years. Even if such a percentage may be challenged it seems difficult to deny that there has been a fall. It is easily seen in Asia in the reduction in the area cultivated by each peasant, if one bears in mind that the agricultural population doubles in 50 years, but that the cultivated land does not.

This situation is more difficult to understand in Africa, where land is generally not scarce. But newly worked land is not always as fertile as land already cultivated, and the diminution of fallow land, insufficiently fertilized also decreases fertility. Africa, however, has been able to increase its agricultural exports to a large extent very much faster than its food production.

But here the deterioration in terms of trade has not permitted it to increase its income to the same extent. Coffee exports are now limited by international agreement, the cocoa marketing is becoming saturated, and the prices for hard fiber are going down. The same applies to sisal, to which the competition of a synthetic fiber may prove fatal in the long run. No one can forecast with certainty what will be the future of cotton or of wood paper pulp at the end of this century. Even palm oil, which for so long had a remarkably stable price, has dropped dangerously in price these past months.

Population increase and food requirements

Africa between the tropics, like America and Australia as a whole, is sparsely populated except for a few sectors at present of limited extent. It has the greatest interest in rapidly increasing its population for speeding up its economic and general development. In this respect its position is basically different from that of South-East Asia, which is already very much overpopulated. But such a growth in population should not increase its dependence in the matter of food. For this reason its food production ought to increase perceptibly faster than its population growth: if the latter increase averages 2.6 percent yearly the former ought to be 4 percent. This would permit a swift reduction of both food insufficiencies and of food purchases from outside Africa.

Without such advances the food position of the developing countries in tropical Africa as a whole would be in danger of deteriorating very quickly. The Paddock brothers, one a diplomat and the other an agronomist from the United States, have written a rather strange book entitled *Famine 1975*, with the subtitle "America's decision who will survive". Their conclusion is that a general famine in the developing countries seems to be absolutely *unavoidable:* tens of millions of men are going to die of starvation. They suggest that the United States make use of this time of famine by a "plan of selection" that decides which countries are worth being helped by the United States. This book should make our African friends thoughtful. If they do not balance their diet they run the risk of becoming dependent on those who make it up for them. As for us, we drew their attention to the seriousness of the situation a year previously in our study *"Nous allons à la famine"*. (1) However, unlike the Paddock brothers, although we tried to emphasize the *danger* of famine we still refuse to believe that is is inevitable. On the contrary, we called for a *general mobilization of all world resources* to increase food production *more rapidly*. The FAO tries to make its own

contribution, especially by its Indicative World Plan. Clearly a speedup in *birth control* is also necessary.

"Transformation" or "Improvement" approach

Having been called on to study the agricultural development programs of Zambia (March-April 1967) and of Tanzania,* (August-September 1967) we studied the various reports of the World Bank on agriculture in these countries, issued in 1961 - 1964. They urge the advantages of a complete "transformation" in agriculture, arising chiefly from its mechanization in Africa, the creation of villages, the employment of fertilizers and selected seeds, and so on. This advice has been generally (and sometimes unfortunately) followed.

Two-thirds of the resources devoted to the development of agriculture of Tanzania in its First Plan 1965-70 have been devoted to *"Settlement Schemes"* – with very middling results. All these schemes are very largely deficient, the loans are badly repaid, and the increase in output thus obtained at great cost has been very modest. On the other hand the old-established types of agriculture, with *"Improvement approach"*, have shown much better results. Copper treatment on coffee (Kilimanjaro), fertilizers and insecticides on cotton (Sukumaland), and other projects have made possible some rapid and considerable increases in output.

A cooperative in south Zambia, near Livingstone, which asked for a loan to buy 12 span of oxen and the same number of small ploughs, got from the authorities a tractor and all its equipment instead. When I passed through (in the busy season) that tractor had been under repair already for 40 days. "If we had had an accident to an ox we would still have had 23 left for work" said the chairman, a real peasant. How right he was. De Wilde and others, in their study *Agricultural Development in Tropical Africa* published for the World Bank in 1967, emphasize with good reason all the difficulties that arise from premature mechanization. The Bank however has not drawn attention to the fact that it had so unwisely advised that policy. This must be simple forgetfulness, which we hope to remedy here.

Outline of Priorities in Agricultural Advance

A large plantation, privately or publicly operated, may be motorized successfully if it is very well organized. This is specially true of permanent

*As a result of the English version of my book False Start in Africa (London, A. Deutsch, 1966)

plantations with a large output, such as (once again) the *Sodepalm* in the Ivory Coast. It seems to be very often useful for annual crops, whether of food or even for industrial purposes, in the peasant context, to adopt the following course, which is of course not laid down dogmatically:

1. Choice of agriculturally useful land to be brought under cultivation, reasonably grouped, near to an existing road and with access to water.
2. Preparation of the soil and weed eradication early and carefully, and especially *early sowing,* which command the profitability of all other techniques.
3. Insecticides and fungicides when necessary.
4. And only afterwards, animal drawn cultivation (carts, fodder, manure, good use of oxen and material) and *chemical fertilizers.*
5. When high returns have thus been achieved, and there is lack of manpower or this manpower can find productive work enough elsewhere, *motorization.*
6. *Irrigation,* which should be given a high priority only when of overriding necessity (the Aswan dam in the desert of the United Arab Republic). Like the tractor, it requires a very high technical level.

The threat of a general famine in the developing countries necessitates greater attention being given to *food production* and not merely to the crops for export. It leads on a study of intensive techniques that are nevertheless economic: which is not always agreeable. We must search for paying ways of passing from shifting cultivation to permanent cultivation of the soil, especially through a more economic supply of humus and other fertilizers. Long research will delay progress, and also the demographic explosion impedes any quicker advance. The outline above implies a numerous leadership, instilled dynamism and general education (which will have to be slow). It took centuries in Europe for the use of animal power to spread and thousands of years for its arable land to be "built up".

It seems to me that today what ought to have *top priority* are more far-reaching studies in rural psychology and sociology, making use of African psychologists and sociologists who have been brought up in rural tradition and who are thus more sensitive to it than we palefaces are. We must get a better understanding of the mechanism of mental development, of the causes of resistance to innovation and other forms of development. We must find out why some Africans prefer leisure to greater comfort, administrative work to dynamically productive work. How could the interest of the general public and of the workers (which are often confused together) better be safeguarded?

"Rely on Your Own Strength" or the Scandal of New Delhi

"Rely first of all on yourselves and find out what unrevealed productive strength you have" was the advice given to the Africans by their Chinese friends. Certainly they show them an example of very active leadership – something like a brotherhood of monks of the new regime. When he came back from China in June 1967 the President of Zambia, Kenneth Kaunda, told his friend Julius Nyerere of Tanzania: "The Chinese are remarkable workers, they are very devoted to their community, to their country – it looks as if they must be Christians! " However, we must see whether the conditions for an economic take-off are present today in the majority of the countries of tropical Africa.

Paul Bairoch had already shown us in one of his studies (4) that the real basis of the English Industrial Revolution at the end of the eighteenth century was *the growth that had already taken place in agricultural output* in that country. He put it at about forty percent in 50 years – which is three times greater than in the preceding half-century. Now the productivity per agricultural worker in Africa and in southern Asia in 1968 must be about half of that in England around 1780. And, as we have already seen, during the past half-century that productivity seems to have definitely fallen. Only China is "taking off" without foreign aid, but with a very exceptional effort.

Europe has made its contribution in demolishing the traditional economy of Asia and Africa. European civilization, like that of its overseas White branches, thus bears a very heavy responsibility for the present situation of the backward countries which is so difficult. The rich world hardly seems to be aware of its responsibilities, or of its long range interests. For the first time the rich really have an interest, if they wish to safeguard their own civilization, in being more generous. And not only at the level of private charity, which has never proved adequate to solve any serious economic problem, any rather pressing social question.

The master manufacturer in Europe in the nineteenth century paid his workers badly; his wife's charitable contributions did not solve social problems. Because purchasing power was badly distributed the economy passed from expansion into recession, and this impeded progress in general. The demands of trade union and socialist workers forced the employers to raise wages – which aided capitalism, in spite of itself. But recessions began to loom up. The chief demand that will be made at the end of the twentieth century will come from the backward countries, for the worst social injustices are now at the international level and grow worse each day. The poor countries therefore, in order to make their voice heard, ought to present a united front (which would benefit the rich countries in spite

of themselves). This was attempted at Geneva in June 1964 by the "Group of 77", and again at Algiers in October 1967.

Like the émigrés who returned to France in 1814, the rich countries seem to have learned nothing and forgotten nothing. As Jean Lecerf of the *Figaro* has said, their attitude at New Delhi in March and April of this year was quite simply scandalous. And yet the demands made by the developing countries were very reasonable. A contribution of 1 per cent of the national income of a rich country given for the advancement of the developing countries is far from being an impossible demand: in 1959 France allocated 2 per cent of its income to *official* assistance to the Third World. Since then, says Gilbert Mathieu in *Le Monde,* the percentage has been reduced to 0.85 for 1968. Other rich countries have similarly reduced their aid very considerably.

The developing countries demand a worldwide organization of agricultural markets and of raw material, without which they will continue paying higher and higher prices for their equipment requisites. They ask for favored marketing conditions for their processed agricultural commodities – instant coffee from Brazil or the Ivory Coast, fruit juices, canned fish, and so on. But the United States wish to make its own instant coffee keeping to itself the most profitable sectors – a very short-sighted policy.

The Ivory Coast Has Made Quite a Good Start, but . . .

In Africa as a whole, where economies tend rather to deteriorate and where national unity and political stability are so difficult to achieve or maintain, the Ivory Coast provides a happy exception. Samir Amin has illustrated the advances made and that seemingly will continue. Light industry is developing and the output of coffee, cocoa, wood and pineapple increases steadily. It would seem at first glance that the conditions necessary for an economic take-off, for a self sustaining development, are now within reach. Above all it would seem that the large plantations of oil-producing trees (the oil palms and the coconut palm of the Sodepalm, industrial and village plantations) will become the source of new wealth during the coming decade. The excessive use of unproductive administrative expenses has been slowed down a little. The Africanization of staffs has not been premature.

It must not be thought however that the country has resolved all its difficulties. Imports of foods (rice, meat, vegetables and fruit) have not ceased to increase, except for rice since 1966. The nutritional level of the ordinary people is generally adequate in quantity but not in quality. Imports of goods for light industries are also on the increase because there are no basic industries. The latter (basic chemicals, for example, which is more

urgent than metallurgy) cannot be economically developed except on a West African scale, as has been urged for several years by the Economic Commission for Africa. The export of capital in the form of profits of foreign firms and savings from wages seems excessive. The country's debt is growing rapidly. The best secondary school graduates go abroad to finish their studies and a large proportion never returns.* Five thousand French teachers are expected to be working in 1975 as compared with 1500 in 1968 because the number of Ivory Coast secondary school teachers is not growing fast enough; the number at the Lycée at Abidjan has decreased. Out of the 200 pupils at the agricultural school at Bingerville, only ten have agreed to spend their holidays as trainees in the villages. The clerk's and civil servant's contempt for manual labour, specially on the land, seems as strong as ever. And one cannot assert that corruption is a thing of the past. All these shortcomings however will gradually be overcome in an economy that was in constant and rapid expansion. But in this respect also there are certain worries.

The market for coffee is governed by an international commodity agreement; poor cultivation practices deplete the soil which is the basic natural heritage. Fortunately more intensive cropping is developing with new plantations (oilpalm, rubber, coconut and bananas). Lumbering companies are culling the precious woods from the stands, a high proportion still being exported as timber logs. But saw mills are developing; there is a project for a pulp and paper plant and reforestation is being speeded up. The positive economic elements are certainly keeping the upper hand.

Social inequalities however also continue to deepen, as Samir Amin shows us, and they are bound to have repercussions in the economic and political fields. Industry in Mexico and Brazil use only a part of their production capacity because purchasing power in the rural areas is generally insufficient. Now the peasants in the savannah in the northern parts of Ivory Coast, Malinké or Senoufo, could make a considerably larger contribution to the food supply of the towns and planters in the south in the form of vegetables, fruit, milk, meat and cereals. But he cultivates mainly tobacco and cotton and goes in for rice on a far too restricted scale to become really worthwhile to modern industry. The town grows rich more quickly than does the countryside and the administrative sector tends to become that privileged *minority* lacking in enterprise, the dangers of which Yves Lacoste has emphasised (5). Quite close to the Ivoire Hotel at Abidjan every night more than a hundred workers sleep in the open air on the banks of the lagoon, lying on the ground along the one main street of the village called Blockhaus.

*When a student at the University of Hanoi has finished his studies he vows to "serve his country *anywhere, and in any capacity, for any remuneration*".

All this, if it goes on, might lead insidiously towards a *semi-stagnation* of the economy of the Ivory Coast such as that already manifest from Ghana to Senegal, and in a number of countries in South America, even in those among the better-off as regards agriculture, as is true of Uruguay and Argentina. In August 1968 Italconsult and Fiat asked me to take part in a symposium on the causes of the economic semistagnation. In my book *False Start in Africa,* I drew attention to two serious dangers before it: premature socialism and South Americanization. The Ivory Coast has been able to avoid the former and to reduce *some* abuses of liberalism, especially through State control. But it cannot avoid all risk of South Americanization without training more devoted technical cadres and steadily eliminating the most crying social inequities that slow down economic development. (Sodepalm has not even a single Ivorian "assistant" on its plantations – it is a hard job.)

So one must always keep a lookout for squalls, for to advance from a state of underdevelopment is certainly no easy task. If there is one country of West Africa that has more chances of advancing before the others it is the Ivory Coast, provided it looks its difficulties squarely in the face, comes to grips with obstacles to its development (whether social or economic) and no longer counts too much on the capital and technical assistance from overseas.

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List of Contributed Papers in Volumes II and III

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Improving the Fertility of Tropical Soils, a Prerequisite for Establishing Intensive Farming Systems – R. Chaminade

Soil Investigation and Land Improvement as Aids to the Economic Development of Agriculture in the African Tropics – Hilton O. Jarrett

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Soil and Water Management for Cultivation of Oil Palm – R. Ochs

Fertilizer and Fertilizer Policy – S. Bouyer

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Orientation of Research on Water Management and Use in Africa – Jean Bazin

Suggestions for Research in Some Problems Related to Water Resources Development – Gerard Dekker

Farming Systems - Rational Use of Water – R. Sordoillet

Cereal Production

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Problems Relating to Cereals - Maize – IRAT

Some Problems of Sorghum and Millets Production in Africa – B.N. Majisu & Hugh Doggett

Problems Relating to Cereals - Pearl Millets and Sorghum – IRAT

Problems Affecting the High Productivity of Cereals in the Highlands of Ethiopia with Special Reference to Wheat, Barley and Teff – H. Melak Mengesha

Research on Tropical Rice Production – R. Chabrolin

Research on Rice in Madagascar – IRAT & IRAM

The Improvement of Rice Growing in the Malagasy Republic – IRAM

Varietal Improvement of Four Food Crops in the Malagasy Republic: Rice, Cassava, Maize, Sorghum – IRAM

Crop Protection

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Priority Research in the Field of Food Crop Protection in Francophone Countries in Africa South of the Sahara – H. Barat

Crop Protection – Max Diaw

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The Development of Peanut and Sorghum Yields Through Fallow or Green Manure – A. Bockelée-Morvan

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The Intensification of Cotton Growing in Africa and Its Impact on the Development of African Agriculture – L. Richard

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Research on Root Crops – P. Silvestre

Tree Crops

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Arabica Coffee Research in Africa – P. Huxley

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Animal Production & Health

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The Need for Research to Assess the Production Potential of African Livestock – M.H. French

Animal Production and Veterinary Medicine in the Tropics – J. Pagot

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Education, Research and Institutions

Development of African Institutions of Agricultural Education and Training in Relation to Urgent Priority Needs in Agricultural Research – Fergus Wilson

The Development of Agricultural Research and Extension – A.H. Bunting

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Organization of Forestry Research in Francophone Africa by Ecological Zones – R. Catinot

General Forestry Research Corresponding to the Ecological Zones of Francophone Tropical Africa – R. Catinot

The East African Agriculture and Forestry Research Organization – Tecwyn Jones & O. Starnes

Organization and Research Goals in Tropical Africa and Madagascar – J. Lhuillier

Agricultural Research Priorities for Economic Development in Africa – Yuen-Liang Ku

Conference Program

FRIDAY, APRIL 5

Registration		Foyer
6:30 p.m.		
Informal welcome cocktails hosted by the U.S. National Academy of Sciences		Pavillon
8:30 p.m.		
Pre-Conference Dinner		Colombier
Chairman:	J. J. McKelvey, Jr., Rockefeller Foundation	
Statement:	M. Beheiry, President African Development Bank	
Address:	R. Gardiner, Executive Secretary UN Economic Commission for Africa	

SATURDAY, APRIL 6

8:00 a.m.		
Meeting of chairmen and rapporteurs		Tropicana
Chairman:	J. J. McKelvey, Jr., Chairman US National Academy of Sciences Organizing Committee	

9:00 a.m.

Formal Opening Ceremony — Cinema

Under the Distinguished Patronage of His Excellency the President of the Republic of the Ivory Coast

His Excellency Abdoulaye Sawadogo
Minister of Agriculture of the Republic of the Ivory Coast

The Honorable George A. Morgan
United States Ambassador to the Republic of the Ivory Coast

O. E. Fischnich
Assistant Director-General
UN Food and Agriculture Organization

Robert Gardiner
Executive Secretary
U.N. Economic Commission for Africa

E. F. Knipling, Member
US National Academy of Sciences

10:45 a.m.

First Plenary Session — Cinema

Chairman: His Excellency Abdoulaye Sawadogo
Minister of Agriculture of Republic of the Ivory Coast

Rapporteur: J. de Wilde
International Bank for Reconstruction and Development

Introductory remarks: J. J. McKelvey, Jr.
F. LeBeau, Chief
Agriculture Division
Bureau for Africa
Agency for International Development (AID)

The Development of Regional Research Programs on the Basis of Ecological Zones

Summary presentations: R. Devred
Rural Institutions & Services Division, FAO

G. Dubois, Chief
Documentation Center, FAO

2:30–5:30 p.m.

Commissions I & II

Commission I – Soil and Water Management — Cinema

Chairman: G. Aubert, ORSTOM, France
Rapporteur: H. Jarrett, Njala, Sierra Leone
Summary presentation: M. Dagg, EAAFRO, Kenya

Commission II – Animal Health — Tropicana

Chairman: P. Nderito, University College, Nairobi, Kenya
Rapporteur: I. Konaté, Bamako, Mali
Summary presentations: H. E. Lépissier, OAU/STRC, Dakar
J. Orue, IEMVT, Dakar

SUNDAY, APRIL 7

10:30–1:00 p.m.
Commissions I (concluded) & III — Tropicana

Commission III – Animal Production
Chairman: H. Michels, Lovanium University
Co-chairman: G. Jourdain, Ministry of Animal Production
Rapporteur: A. K. Mariko, Union Nigérien pour Crédit et de la Coopération
Summary presentations: P. J. Auriol, Animal Production Division, FAO
J. Pagot, IEMVT, France
R. Rose-In[illegible], Legon, Ghana
V. A. Oyen[illegible]a, Ibadan, Nigeria

2:30–5:30 p.m.
Commission IV — Cinema

Major Problems Affecting Cereal Production
Chairman: H. Doggett, EAAFRO, Soroti, Uganda
Rapporteur: G. van Poorten, IRAT, Paris
Summary presentations: H. D. Jordan, U.K.
M. Harrison, Kitale, Kenya
B. N. Majisu, EAAFRO, Soroti, Uganda
Melak H. Mengesha, Debre Zeit, Ethiopia

6:00–7:30 p.m.
Visit to "Expo-COCODY"

8:30 p.m.
Plenary Dinner — Colombier

9:30 p.m.
Evening addresses
Chairman: His Excellency Abdoulaye Sawadogo
Minister of Agriculture of Republic of Ivory Coast
Speakers: O. E. Fischnich
Assistant Director-General, FAO

Professor René Dumont
Institut National Agronomique, Paris

MONDAY, APRIL 8

8:30–10:30 a.m.
Commission V — Tropicana

Major Problems Affecting the Production of Industrial Crops in the Savannah Zone
Chairman: J. Lhuillier, IRCT, Paris
Rapporteur: C. Charreau, IRAT, Sénégal
Summary presentations: C. Charreau for J. C. Mauboussin
A. Bockelée-Morvan, IRHO, Sénégal
L. Richard, IRCT, Paris
A. Angelini, IRCT, Bouaké, Ivory Coast

8:30–12:30 p.m.
Commission VI — Cinema

Economic Aspects of Agricultural Production and Marketing
Chairman: B. Johnston, Stanford University, USA
Rapporteur: V. Uchendu, University of Ghana
Summary presentations: C. Eicher, Michigan State University, USA
J. de Wilde, International Bank for Reconstruction and Development

10:45–12:30 p.m.
Commission VII — Tropicana

Major problems Affecting Grain Legume and Root Crop Production
Chairman: E. Collart, Lovanium University, Kinshasa
Rapporteur: G. Cours-Darne, IRAT, France
Summary presentation: G. Cours-Darne, IRAT, France

2:30–5:30 p.m.
Commissions VIII & IX

Commission VIII – Major Problems Affecting the Production of Industrial Crops in the Humid Tropics — Tropicana
Chairman: L. Mukendi, INEAC, Yangambi, Congo Kinshasa
Rapporteur: L. Opeke, NCRI, Nigeria
Summary presentations: G. Johnson, Michigan State University, USA
E. Asomaning, GCRI, Tafo, Ghana

Commission IX – Education: The Role of Universities and Schools of Agriculture in Research and Manpower Production — Cinema
Chairman: A. H. Bunting, Reading University
Rapporteur: S. Matturi, Njala, Sierra Leone
Summary presentation: H. Darling, Ahmadu Bello University, Nigeria

6:30 p.m.
Cocktail-Reception hosted by the Government of the Republic of the Ivory Coast — Salle des Fêtes

TUESDAY, APRIL 9

8:00 a.m.

Visits to agriculture research stations

Centre ORSTOM d'Adiopodoumé

Centre de Recherches de L'Institut Français du Café et du Cacao (IFCC), Bingerville

Station experimentale de Port-Bouet (IRHO)

Centre d'Elevage de Bingerville

L'Institut pour le Technologie et l'Industrialisation des Produits Agricoles Tropicaux d'Abidjan (ITIPAT)

5:00–7:00 p.m.

Special Seminar on Agroclimatology and Water Resource Development — Tropicana

Chairman: A. Mabogunje, Ibadan, Nigeria

Rapporteur: T. Scudder, California Institute of Technology, USA

Summary presentations: J. Cochemé, FAO
G. Dekker, ECA

WEDNESDAY, APRIL 10

8:30–12:30 p.m.

Second Plenary Session — Cinema

Farming Systems in Africa: Mechanization and Innovation

Chairman: L. Sauger, CRA, Bambey, Senegal

Rapporteur: L. Mukendi, INEAC, Yangambi, Congo Kinshasa

Summary presentations: F. Bour, IRAT, Paris
R. D. Bradfield, IRRI, Philippines

11:00 a.m.–1:30 p.m.

Commission X – Crop Protection and Storage: Prevention of Waste — Tropicana

Chairman: R. Luc, Adiopodoumé, Ivory Coast

Rapporteur: T. Ajibola Taylor, Ibadan, Nigeria

2:30–5:30 p.m.

Commission XI – Agricultural Research Institutions – National and Regional. The Problem of Increasing Effective Research — Tropicana

Chairman: E. Asemaning, Tafo, Ghana

Rapporteur: O. Starnes, EAAFRO, Kenya

THURSDAY, APRIL 11

Third Plenary Session — Cinema

Chairman: F. Pinder, ECA

8:30 a.m.–12:30 p.m.

Reports of the Commissions

2:30–5:30 p.m.
Third Plenary Session — Cinema

7:30 p.m.
Aperitif — Salle des Fêtes

8:30 p.m.
Closing Dinner — Salle des Fêtes

Chairman: His Excellency Abdoulaye Sawadogo
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Closing remarks: J. C. de Wilde, IBRD

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Glossary of Acronyms and Abbreviations relating to African Agriculture

ADB	African Development Bank (Ivory Coast)
ADC	Agricultural Development Council
AID	Agency for International Development (United States) Agence International pour le Développement (Ivory Coast)
ARCCA	Agricultural Research Council of Central Africa
BAD	Banque Africaine de Développement
BDPA	Bureau pour le Développement de la Production Agricole
BIRD	Bureau Internationale pour la Reconstruction et le Développement (Ivory Coast)
BIS	Bureau Interafricain des Sols
BNETD	Bureau National d'Etudes Techniques de Développement (Ivory Coast)
CBD	Coffee Berry Division
CBPP	Contagious Bovine Pleuropneumonia
CCTA	Commission for Technical Cooperation in Africa South of the Sahara Commission de Coopération Technique en Afrique au Sud du Sahara
CDC	Cotton Development Corporation (United Kingdom)
CEA	Commission Economique de l'Afrique des Nations-Unies
CEEMAT	Centre d'Etudes et d'Expérimentation du Machinisme Agricole Tropicale
CEK	Centre d'Elevage de Korhogo (Ivory Coast)
CFDT	Compagnie Française pour le Développement des Fibres Textiles
CFRB	Centre de Formation Rurale de Bingerville
CGOT	Compagnie Générale des Oléagineux Tropicaux
CIMMYT	Centro Internacional de Mejoramiento de Maïz y Trigo
CMAOM	Comité du Machinisme Agricole d'Outre-Mer

CNRST	Comité National de la Recherche Scientifique et Technique (Madagascar)
CNZRS	Centre National de Recherches Zootechniques de Sotuba (Mali)
COMACI	Commission et Approvisionnements de la Côte d'Ivoire
COMEX	Comité d'Expérimentation pour le Mécanisation des Cultures (Ivory Coast)
CRA	Centre de Recherches Agronomiques de Bambey (Sénégal)
CRAC	Centre de Recherches Agronomiques de N'Kolbisson au Cameroun
CRC	Cotton Research Corporation (United Kingdom)
CRI	Coconut Research Institute (Ceylon)
CRIG	Cocoa Research Institute of Ghana
CRIN	Cocoa Research Institute of Nigeria
CRST/OUA	Commission de la Recherche Scientifique et Technique de l'Organisation de l'Unité Africaine
CSA	Scientific Council for Africa Conseil Scientifique pour l'Afrique
CSNRD	Consortium for the Study of Nigerian Rural Development
CSSV	Cocoa Swollen Shoot Virus
CTAB	Centre Technique d'Agriculture de Bingerville (Ivory Coast)
CTFT	Centre Technique Forestier Tropical
DRPLC	Départment des Recherches des Plantations Lever au Congo
EAAFRO	East African Agriculture and Forestry Research Organization
EACSO	East African Common Service Organization
EASIR	East African Institute of Social Research
EATRO	East African Trypanosomiasis Research Organization
EATU	East African Testing Unit
EAVRO	East African Veterinary Research Organization
ECA	Economic Commission for Africa of the United Nations
ECGC	Empire Cotton Growing Corporation
EFSA	Ecole Fédérale Supérieure Agronomique
ENCR	Ecole Nationale des Cadres Ruraux
ENSA	Ecole Nationale Supérieure Agronomique
ENSG	Ecole National Supérieure Agronomique de Grignon (France)
ETSSA	Ecole Technique Secondaire Supérieure d'Agriculture
FAC	Fond d'Aide et de Coopération
FAO	Food and Agriculture Organization of the United Nations Organisation pour l'Alimentation et l'Agriculture (ONU)
FED	Fond Européen de Développement
FEG	Fonds d'Entraide et de Garantie
FIDES	Fonds d'Investissement pour le Développement Economique et Social des Territoires d'Outre-Mer
GAS	Ghana Academy of Sciences
HSIU	Haile Sellassie I University (Ethiopia)
IBAH	Inter-African Bureau of Animal Health (Bangui, CAR)
IBRD	International Bank for Reconstruction and Development

IEAAC	Institut d'Etudes Agronomiques d'Afrique Centrale
IEMVT	Institut d'Elevage et de Médecine Vétérinaire des Pays Tropicaux
IFAC	Institut Français de Recherches Fruitières Outre-Mer
IFCC	Institut Français du Café, du Cacao et Autres Plantes Stimulantes
INADES	Institut Africain pour le Developpement Economique et Social
INEAC	Institut National pour l'Etude Agronomique du Congo (Kinshasa)
INRA	Institut National de la Recherche Agronomique
IRAM	Institut de Recherches Agronomiques de Madagascar
	Institut de Recherches Agronomiques de la Republique Malgache
IRAT	Institut de Recherches Agronomiques Tropicales et Cultures Vivrières
IRCA	Institut de Recherches sur le Caoutchouc en Afrique
IRCT	Institut de Recherches du Coton et des Textiles Exotiques
IRHO	Institut de Recherches pour les Huiles et Oléagineux
IRLCS	International Red Locust Control Service
IRRI	International Rice Research Institute (Philippines)
IRSAC	Institut pour la Recherche Scientifique en Afrique Centrale
ISABU	Institut des Sciences Agronomiques du Burundi
ISAR	Institut des Sciences Agronomiques de Rwanda
ITEPAT	Institut pour la Technologie et l'Industrialisation des Produits Agricoles Tropicaux
ITERG	Institut des Crops Gros (Paris)
IUCN	International Union for the Conservation of Nature
LDC	Less-Developed Country (ies)
MRS	Maize Research Station (Kenya)
MSIRI	Mauritius Sugar Research Institute
MSU	Michigan State University (United States)
NARS	National Agricultural Research Station
NAS	National Academy of Sciences (United States)
NRC	National Research Council
OAU	Organization of African Unity
OCAM	Organisation Commune Africaine et Malgache
OCDE	Organisation de Coopération et de Développement Economique
ODM	Ministry of Overseas Development (London)
OECD	Organization for Economic Cooperation and Development
OICMA	Organisation Internationale contre le Criquet Migrateur Africain
OIE	Office International des Epizooties
ONI	Office National des Irrigations
ORANA	Organisme de Recherche pour l'Alimentation et la Nutrition en Afrique
ORSTOM	Office de la Recherche Scientifique et Technique Outre-Mer
PNUD	Programme des Nations-Unies pour le Développement
PPR	Peste des Petits Ruminants
PVD	Pays en Voie de Développement

REMVPT	Revue de l'Elevage et Médecine Vétérinaire des Pays Tropicaux (Paris)
RTAC	Regional Technical Aids Center
SAG	Station Agricole de Guetalé
SAL	Scott Agricultural Laboratories
SAP	Société Africaine de Prévoyance
SHMD	Sociéte des Huileries Modernes du Dahomey
SNAHDA	Société Nationale des Huileries du Dahomey
SODEFOR	Société pour le Développement et l'Exploitation des Forêts
SODEPALM	Société pour le Développement et l'Exploitation du Palmier à l'Huile
SOGETA	Société Générale des Techniques Agricoles
SOMALAC	Société Malgache d'Aménagement du Lac Alaotra
SOSUMAV	Société Sucrière de la Mahavavy (Madagascar)
SOTROPAL	Société Tropicale des Allumettes
SPROA	Société des Plantations Réunies de l'Ouest Africain
SREA	Station Régionale d'Expérimentation Agricole
SRU	Soils Research Unit
STRC/OAU	Scientific, Technical and Research Commission of the Organization of African Unity
TPI	Tropical Products Institute
TPRI	Tropical Pesticides Research Institute
TRIEA	Tea Research Institute of East Africa
TSGA	Tanzania Sisal Growers Association
UNCC	Union Nigérien pour Crédit et de la Coopération
UNDP	United Nations Development Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
USAID	United States Agency for International Development
WAIFOR	West African Institute for Oil Palm Research
WAITR	West African Institute for Trypanosomiasis Research
WAMRU	West African Maize Research Unit
WASPRU	West African Stored Products Research Unit
WHO	World Health Organization
WMO	World Meteorological Organization

Conversion Tables

CURRENCY

US $1.00	245 CFA francs or FMG or 4.94 NF or 492 FM
	8.33 UK shillings, 7 Nigerian or East African shillings
	1.02 Ghanaian New Cedis
100 CFA francs	40.51 US¢, 3/4d UK or 1.85 Nigerian or East African shillings

AREA

1 hectare	2.471 acres
1 acre	0.4047 hectares
1 sq. km	0.3861 sq. miles
1 sq. mile	2.59 sq. km

DRY MEASURE

1 liter	61.02 US cu. in.	0.908 US quart
100 liter	3.53 US cu. ft	2.84 US bushels
1 US bushel	2150.42 US cu. in.	35.238 liters
1 Imp. bushel	2219.36 US cu. in.	0.036 cu. m.

LIQUID MEASURE

1 liter	1.057 US quarts	0.22 Imp. gallon
1 Imp. gallon	1.2 US gallons	4.545 liters
1 US gallon	0.833 Imp. gallon	3.785 liters

WEIGHT

1 kilogram	2.2046 lbs	
1 lb	0.4536 kg	
1 US short ton	2000 lbs	0.907 metric ton
1 US long ton	2240 lbs	1.016 metric tons
1 metric ton	2204.6 lbs	1.1 US short tons
		or 0.984 US long ton
1 US short cwt	100 lbs	45.359 kg
1 US long cwt	112 lbs	60.802 kg
1 quintal	100 kg	220.56 lbs

RATIOS

1 quintal/ha	89.2 lbs/acre
1 long ton/acre	4.11 metric tons/ha
1 metric ton	892 lbs/acre
100 persons/sq. mile	38.6 persons per sq. km
100 persons/sq. km	259 persons per sq. mile

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Agricultural Research Priorities for Economic Development in Africa

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THE ABIDJAN CONFERENCE 1968

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CONFERENCE ON AGRICULTURAL RESEARCH PRIORITIES FOR ECONOMIC DEVELOPMENT IN AFRICA

Colloque sur les Priorités de la Recherche Agricole
Dans le Développement Economique de L'Afrique

ABIDJAN, IVORY COAST
April 5-12, 1968

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MAJOR PROBLEMS TO BE INVESTIGATED IN MANAGING TROPICAL SOILS

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SUMMARY

Good soil management involves the preparation of a suitable seed bed, the provision of a satisfactory environment for roots, the suppression of weeds, the maintenance of fertility and the prevention of accelerated soil erosion. Research work in various categories is required in each phase and advances in research that make an impact on the economy must be on a broad front culminating with imaginative thinking at the extension level. All soil management practices must take account of the high crop water requirement and high rainfall intensities in the tropics and techniques for seed bed preparation that conserve water, such as stubble mulch and tied ridge systems, should be given high priority in agronomic trials. Minimal cultivation methods with or without herbicides offer new opportunities to make mechanized agriculture more of an economic success in areas where the date of planting is severely restricted. Field trials are required to determine how best to deal with the inherently fertile, but, as yet, under-developed black clay soils. Cultivating twice for one crop is a serious disadvantage in alternate fallow farming but the use of herbicides to control the fallow makes the system more attractive economically. Techniques for weed control must especially conserve water towards the end of the season when crop water requirement is highest. Here again herbicides would appear to fulfill most of the technical requirements including the maintenance in the rich top soil of fine feeding roots that are damaged by conventional clean weeding techniques. Thus there is a strong case for more thorough economic studies of the potentialities of herbicides at all levels of agriculture. The traditional methods of maintaining fertility by shifting cultivation are giving way to planted ley systems. More extensive trials in a wide range of climatic conditions are required to test the efficiency of these systems. Such trials should be thorough enough, with nutrient balances and full ecological descriptions, to enable the conclusions to be used rationally over a wide area. Accelerated soil erosion can be minimized by diverting surplus runoff water along gently graded channels but measures to improve the rainfall acceptance rates of the soil are more constructive under dry tropical conditions. Internationally co-ordinated trials are required to test the efficiency of soil and water conserving cultivation techniques under African conditions, to have valid advisory data available when land pressures and new systems of land tenure make conservation measures more relevant to peasant farmers. The maximum value of basic research effort will only be realized when there is an adequate background collection of ecological data to enable the results to be interpreted widely. Research effort is also required into which data is most relevant. Throughout all aspects of soil management there is an outstanding need for better training of extension workers and more communication research on how best to present concepts and advice to farmers.

INTRODUCTION

Soil management constitutes one of the complex of factors that control the economic development of African agriculture. The environment provided by the soil is not at all simple, with strong physical, chemical and biological interactions that are far more completely understood. However, empirically, good soil management involves the preparation for a suitable seed bed, the provision of a satisfactory environment for roots, the suppression of weeds, the maintenance of fertility and the prevention of accelerated soil erosion.

The crop must be adequately supplied with water at all stages of growth and in the drier parts of Africa, water is often the dominant factor in crop productivity. Consequently, it is not possible to consider soil management in isolation from the atmospheric environment of the plant, which in tropical Africa imposes very high levels of transpirational demand on the growing crop, and aspects of the water supply from rainfall, frequently of high intensity, continually impinge on soil management practices. It has not perhaps been realized in the past that the annual evaporation rates in tropical Africa are characteristically 3 to 4 times higher than, say, in U.K.

Research activities proceed in various categories within each aspect of soil management and an effective impact on the economic development of a country only follows an advance on a broad research front, finishing with imaginative thinking in the field of communications on how to put the point across to the farmer. Other elements in the research chain, (following Pereira, 1964) include the agronomists to test under local conditions, successful methods from similar ecological regimes, specialists with mainly advisory and diagnostic duties and a further corps of specialists seeking the fuller understanding of basic mechanistic relations through longer term experiments. The conclusions of the latter group are usually linked to various ecological parameters to enable the results to be applied over a wide range of conditions. Their work is therefore ineffective unless backed by a team responsible for mapping the relevant parameters. Finally, the university worker, free from the pressing needs of immediate application, can pursue details of a problem in depth to reach a more complete scientific understanding. No specific attempt is made here to assign research need into each class but it is clear that priorities for special research effort in different phases of soil management will fall into different categories.

PREPARATION OF THE SEED BED

Ignoring other considerations, the immediate environment of the seed should insure an intimate contact between seed and soil, adequate aeration and moisture, a favorable temperature and little mechanical resistance to the emergent shoot and roots. Thorough plowing and discing with rolling to consolidate the soil if necessary, has generally been found to provide excellent conditions for the seed. Unfortunately, these operations are not often compatible with other aspects of good soil management in the tropics. The frequent disturbance of the soil and the pulverizing action of the harrow exposes the organic fraction of the soil to rapid oxidation to the detriment of the structure and stability of the surface soil. High intensity rain storms then break down the fine soil crumbs and seal off the surface, encouraging water loss and subsequent soil erosion.

The water loss is particularly critical in areas where the rainfall is already marginal for crops and the transpirational demand is very high. Hudson (1957) found runoff rates of 30% of the total season's rain not uncommon from a 3% slope under sunhemp in Rhodesia, and in Central Tanzania runoff rates of 40% at moderate rainfall intensities up to 80% at intensities of about 40 mm./hr. were observed from 1% slopes on a sandy loam. These represent very large losses of water where rainfall is frequently the limiting factor in crop productivity and the prevention of such water loss must rate as one of the most important objectives in soil management in the marginal areas that must in due course be brought into production.

The general solutions are evident once the problem is clearly recognized and defined. The soil should be distributed as little as is consistent with satisfactory crop growth; soil stability and structure should be maintained; mechanical impedance to runoff should be incorporated into the cultivation methods to allow more time for water to infiltrate into the soil and in particular, the soil should be protected against the impact of rain drops by a cover of some sort. However, it is not apparent that the problem is recognized in the cramped instruction courses for extension workers and, if water conservation is treated at all, the susceptibility of the crop to the very high water requirements in the tropics does not seem to receive much stress and it is not related to seed bed preparation. Some preliminary educational work is indicated even before starting the difficult task of communicating the cardinal concepts to the farmer.

Many practical methods of land preparation for water conservation have been proposed (Edminster & Miller, 1959) but few have been given extensive field trials in Africa. The tied ridge or basin listing system has perhaps had the widest trials (Boa, 1966) and a fully mechanized set of equipment has been designed for it (Cashmore and Hawkins, 1957), which certainly succeeds in conserving water. The system holds great promise but other proven methods including stubble mulch cultivation techniques deserve much more study and there is still considerable scope for new ideas.

Thorough cultivation systems may be by-passed however by the introduction of minimal tillage techniques in conjunction with the new herbicides. Planting into a micro seed bed within a mulch of killed weeds or grass sod requires the minimum of soil disturbance and provides protection for the soil surface. This technique also opens up prospects of cultivating slopes previously considered closed to mechanized methods. As the need to kill and bury all weeds during land preparation recedes, the necessity for moving around large amounts of soil and producing a very fine seed bed is being questioned closely. Much semi-empirical work (for instance, Brill, et al., 1966) suggests that a very rough seed bed is adequate for many crops but that others definitely require finer conditions. There remains a need for more basic research work on the micro environment of the seed and the small scale mechanics of root penetration into soils. The detailed type of work being carried out for instance by Taylor, et al., (1966) in the U.S.A. on the mechanical impedance of the soil and the penetrating power of machinery for seed bed preparation in tropical Africa.

Mechanization and date of planting

The optimistic introduction into tropical Africa of mechanization on a large scale such as at Kongwa in East Africa and Mokwa in West Africa, threw up several intractable problems that are still with us. One of these concerned the length of time available for seed bed preparation. It was discovered then (see Baldwin, 1957) and has been demonstrated widely since, (e.g. Akehurst and Sreedharan, 1965), that in a region with markedly seasonal rains, the yield of annual crops can be very critically dependent on the date of planting. A variety of reasons for this effect have been advanced in different climatic regimes but whatever the reason the fact remains that there is generally a very limited time for land preparation and planting, such that it is extremely difficult to use tractors efficiently in relation to the area planted. A system of minimum tillage, either plow plant or the production of a micro seed bed in otherwise undisturbed soil, requires fewer operations or less draught and promises a significant improvement in the economic chances of mechanization in these areas. Few field tests have yet been carried out although some experiments are in hand in Tanzania, where the lighter draught makes dry planting an attractive possibility with reasonably small tractors, but more properly costed trials are required to see if these techniques offer a real solution to a difficult economic problem.

An alternative approach is to elucidate fully the reasons for the acute dependence of yield on date of planting, in the hope of ameliorating the situation. The pieces of evidence at present seem to be conflicting with the needs to match the crop development to water availability, to utilize the flush of nutrients at the onset of the rains and to avoid the build up of pests later in the season, all playing a part.

PROVISION OF A SATISFACTORY ENVIRONMENT FOR ROOTS

The positive target of achieving optimum levels for all facets of the root environment is unrealistic, and the ideal is best defined negatively as avoiding all the conditions that are inimicable to plant growth. Thus it is necessary to avoid harmful ranges of pH, of oxygen and carbon dioxide concentrations, of soil moisture, of salinity and of nutrient concentrations, (although the last factor might be expressed more positively).

Root structure

Frequently the scope of the root environment of a crop is inadequately known and observational studies of root systems can be extremely useful and sometimes vital in understanding the pattern of crop response to a special situation. (One can begin to appreciate why Buffel grass (Cenchrus ciliaris) can stay green in a relatively harsh environment when it is observed that newly planted splits can extract water from a depth of 20 ft. within 9 months (E.A.A.F.R.O. Record of Research). In tropical areas, the ability of the plant to utilize appreciable quantities of stored water in a relatively short drought is often critical to its well-being. The primary technique of root washing from trenches is relatively simple and the

opportunity to carry out these studies before the cost of labor becomes prohibitive should be taken.

pH

pH can be measured reliably today and its relation to nutrient availability, etc. are moderately well understood as are the measures to counteract unfavorable conditions. However, the relationships between pH, crop and soil type are still not at all easy to explain in detail to an extension worker with little scientific training.

Aeration and drainage

Poor aeration in the soil is almost always due to waterlogged conditions brought about by poor internal drainage or a high water table. This being a very well known problem in temperate climates, the practical solutions in terms of improved drainage are well known and documented. Applications of these techniques in African developing countries may be delayed because of cost or because other, better drained, land is easily available, but land pressure will in due course force remedial measures to be taken. Of special interest is the utilization of the heavy black montmorillonitic clay soils developed in areas of impeded drainage. These soils are difficult to work and are often seasonally waterlogged but they are generally of high potential chemically, particularly in older landscapes due to the concentration of nutrients leached out of the surrounding soils higher in the catena. A specific effort is required to determine how best to bring these soils into production against the day when land pressure will make reclamation economically attractive. Several alternative methods are available from the wealth of experience elsewhere, for instance, in the Southern U.S.A. and the West Indies.

Individual situations such as Lawes (1961) describes at Samuru, may require measures to combat poor internal drainage early in the crop season combined with the strictest water conservation towards the end of the season and peak water demand. Particular solutions must depend on the local ecological conditions and the advisory services must have adequate diagnostic tools to delineate the troubles.

Moisture conservation

The problem of maintaining a moist enough environment for the roots is more frequently encountered in Africa than the need for drainage. It is a continuation of the problem in seed bed preparation of avoiding surface runoff, with the additional problem of reducing evaporation from the soil during the growing season. The same considerations apply, maintenance of stable and open soil structure, provision of mechanical impedance to runoff, surface mulch to protect the soil and reduce evaporation, etc. Tied ridges offer a solution in some cases, stubble mulching in others and there is a wealth of literature from the western part of the U.S.A. on this general problem, (e.g. McCalla and Army, 1961). The essential point is that where water conservation is important, something should be done

to reduce losses by soil management, and peasant farmers should be made aware that the real problem is often not shortage of rain but shortage of effective rain.

The water requirement of seasonal crops increases with the degree of cover and often reaches a peak after the main rains have ceased. Thus at Muguga, much of the April-May rain passes beyond the 6 ft. range of the maize while the crop frequently fails through lack of water in the following months of peak demand (Dagg, 1965). The necessity for water conserving measures depends therefore on thé relation of probable monthly rainfall to monthly transpirational demand and the soil moisture storage in the root range. Some survey of these parameters is therefore necessary in the rational planning for crop production.

Wider spacing of plants in marginal areas may make more moisture available to each plant. For instance, cashew nut trees need a very wide spacing to enable them to make full use of their habit of extending their lateral roots over an area four times that of the tree canopy, so reducing their effective areal transpirational rate by four. Leaf drop and loss of crop results if the spacing is such that the canopy can begin to close, (Dagg and Tapley, 1967).

Many marginal areas could be cropped reliably if alternate bare fallows, preferably in strips, were used to conserve some of one season's rainfall for the next. The trouble and cost of cultivating twice for one crop is a serious disadvantage and there is a risk of erosion from the bare soil. Pereira, et al., (1958) showed that a heavy sowing of teff grass was effective both in conserving water and preventing erosion at Kongwa and recent trails in Tanzania have shown that contact herbicides give as effective a control of weeds and erosion as conventional cultivation techniques for a much smaller expenditure of time and money. Further development could make alternate fallow farming a much more attractive proposition than in the past.

Salinity and alkalinity

Problems arising from salinity and alkalinity are readily recognized and have been thoroughly studied in the U.S.A. (Richards, 1954). Treatments are well-known but most are costly.

Nutrient status

Problems of nutrient status of the soil is due to be dealt with in other papers. Two points however, have a special relevance to cultivation practice and the root environment. Some nutrients, phosphorus in particular, do not move far in the soil: therefore roots must move to the nutrients. If this is largely associated with the organic matter in the immediate topsoil, the fine roots in the topsoil should not be chopped up by frequent cultivation. Secondly, if the top soil dries out excessively, the rich nutrient store may become unavailable to the crop and the surface roots will die back. A mulch can insulate the top soil from excessive

drying and perhaps thereby leave these nutrients available to surface roots. Much more definitive work should be carried out on these topics as current clean weeding practices could possibly be seriously detrimental.

SUPPRESSION OF WEEDS

Ideally, the soil should only grow the crop wanted and any other plants that compete for nutrients, water and sunlight should be completely excluded. Frequent clean weeding between row crops, however, leaves the soil in a finely divided state, bare and unprotected, which encourages water loss and erosion. Formerly it was thought that cultivation per se was desirable in loosening the top soil, providing a surface soil mulch and improving aeration. Except possibly for a few tropical soils that cap very severely, and in the absence of waterlogging, aeration is not a first magnitude problem, and under tropical evaporative conditions, whether the top few inches is cultivated or not matters very little in the water loss in the top foot of soil. Rough cultivation with the minimum of disturbance, leaving the soil in a cloddy tilth, has been found to do least damage to the structural characteristics of the Kenya coffee soil (Pereira and Jones, 1954) and stubble mulch cultivation techniques are undoubtedly very successful in leaving the soil in a state to accept rainfall.

However, the advent of effective herbicides promises to revolutionize weeding practices both in efficiency and labor costs: the tea industry in the Kericho area of Kenya claims to have halved the weeding costs by changing to herbicides. Besides controlling the weeds and providing a killed cover as a protective mulch the system has the added advantage, in a perennial crop, of avoiding bringing new weed seeds to the surface, which over the course of a few years greatly reduces the cost of weed control. The sophistication and present cost of herbicide techniques should not discourage experimental work into devising methods for peasant farmers. Spray equipment for insect control will almost certainly become commonplace in the future and spray techniques may well prove far more attractive to the farmer than tedious hand hoeing, thus insuring better weed control and possibly a greater area cultivated. (The decision taken in the early 1930's to exclude fertilizers from experimental work in Uganda, because there was no likelihood of peasant farmers ever being able to afford them, seriously held back fertility studies in that country). Clearly the research effort needed in this field is very wide, ranging from extension programs to persuade peasant farmers to consider new techniques to, for instance, detailed biochemical studies of decomposition products under tropical conditions and the continuing search for new herbicides.

MAINTENANCE OF FERTILITY

Ideally, soil and crop management should maintain or increase fertility; the land should be left in at least as productive a state as when cultivation started. Continued cropping diminishes fertility, resting under vegetation restores it. In the long run nutrients from outside the system must be applied to replace those removed in the crop but Nye and

Greenland (1960) have shown that the traditional methods of shifting cultivation with a short cropping break and a long rest under heavy forest can very nearly maintain the level of fertility. Increasing population pressure and the introduction of mechanization is bringing about the end of the traditional system and the progression is towards continuous cultivation with added fertilizers, or to shorter resting periods under established grass leys that can be made to be productive in themselves through animal products, following the pattern of development in western Europe. The economic value of ley farming in the tropics is not yet proven and short term leys in drier areas are very unlikely to maintain fertility without liberal additions of fertilizers or manure.

The general physical and chemical processes involved are broadly understood (Russell, 1963) and it is clear that the variable part of soil fertility depends critically on the level of the organic matter in the soil; the physical status on the mere presence of organic matter and the nutrient status on the rate at which organic matter decomposes and releases inorganic ions into the soil solution. The detailed understanding of the role of organic matter in terms of the likely chemical constituents, the location of the nutrient elements within them, etc. is still very far from complete and no more than partial advances in this extremely complex field of study can be anticipated for some time to come. However, it is known that the humic level of soil depends on the balance in the rates of addition and depletion and Nye and Greenland have shown how through detailed nutrient balances, it is possible to arrive at a rational structure relating likely rates of change in fertility under different cropping patters to the intrinsic productivity governed by the climatic and soil regime. Such basic research work deserves every encouragement to provide, if not complete understanding, at least guiding lines on which to plan more empirical studies.

The pressing demand for more extension advice must place heavy reliance on empirical trials to find suitable components of the ley and appropriate resting periods. It should perhaps be stressed that such trials should be carried out in some detail with adequate peripheral measurements to enable the conclusions to be translated to other places where conditions are different. For instance, the findings from the complex fertility trial at Serere, Uganda, (Jameson and Kerkham, 1960), begun in 1936 and now in its sixth cycle, refer to the local soil type, the crop consequence chosen, the type of volunteer fallow and even, presumably, the organic content of the farmyard manure, that has given the remarkable conclusion that the effects of such a light dressing, 2½ tons per acre every five years, are cumulative over 20 years. It is perhaps a lot to ask for more detailed climatic data and nutrient studies of the crops and drainage water, in an already complicated trial, but Nye and Greenland have shown that such data must be available for the conclusions from the empirical systems under test to have more widespread application.

The soil structural aspect of soil fertility is better understood than nutritional. The benefits of a higher level of organic matter are better rainfall acceptance and working qualities of the soil: an increased erosion hazard is the main consequence of structural deterioration which is much more rapid than in temperate climates. Erosion following the break

from a fallow can be particularly serious if the nutrients have been concentrated in the top soil. This can be combatted by the measures mentioned previously to maintain infiltration rates.

PREVENTION OF ACCELERATED SOIL EROSION

Under normal conditions, the slope of the ground is so graded as to match the infiltration rate of the soil, the degree of cover and the likely rainfall intensities, and any soil erosion proceeds quite slowly. On clearing for cultivation, the cover is reduced and the intrinsic infiltration rate of the soil declines. Conventional mechanical soil conservation measures are generally aimed at safeguarding the soil by removing the consequent surplus runoff water along gently graded channels, so reducing its erosive action. It has already been explained that water loss in itself is serious in many parts of the tropics and the present trend in soil conservation practice is to emphasize the importance of maintaining a protective cover against the destructive impact of rain drops. For instance, Hudson (1957) demonstrated a reduction of runoff from 41% and soil loss of 60 tons per acre on bare soil to 1% and 2 tons per acre by suspending a mosquito gauze over the soil.

Techniques and formulae for the construction of various terraces are well known and well documented but rely on some knowledge of the soil characteristics and rainfall intensity which is all too often not available in Africa, leaving the whole operation rather less of a science than an art based on experience. Furthermore, the quantity of soil to be moved on steeper slopes is rather large and the resulting maldistribution of fertility has given rise to such opposition from some peasant farmers in Kenya that soil conservation laws are flatly ignored. Whilst some mechanical structures are necessary to cope with the exceptional storm, perhaps more positive advice on cultivation methods to improve infiltration may be a better approach and permit wider vertical intervals between terraces than the formulae specify. All the measures mentioned previously for water conservation are, of course, relevant to this situation.

The outstanding needs for investigation therefore are for more extensive large scale trials of cultivation methods for water conservation, backed by adequate soil and climatic surveys and research into ways of impressing the need for soil conservation measures on peasant farmers. Detailed experiments on soil and water loss tend to be very expensive as large plots are usually necessary to carry out truly representative farming operations. There is, therefore, perhaps a strong case for a carefully coordinated series of experiments carried out in various parts of Africa, where promising techniques could be compared under different ecological conditions but with closely similar operational conditions. If the operational details differ widely it is difficult to make any valid comparison of the results (Menne, 1959).

A final point, peasant farmers are unlikely to adopt costly soil conservation techniques while fallow land is freely available to move to

after they have exhausted the fertility of their present plots. A greater awareness of the need for soil conservation will only arise with increasing population densities and changes in the system of land tenure. The same consideration applies to measures to maintain fertility: when a farmer clears a new area for cultivation he cannot be expected to be very interested in improving the value of the fallow period on the land he has left, unless he has a vital stake in the ownership of the land. More constructive and responsive attitudes are already evident in Kikuyuland, Kenya, following land consolidation and the issuing of title deeds.

SURVEY RESEARCH

In each phase of soil management it is clear that the maximum value of much of the research effort will only be realizable against a background collection of ecological data that will enable the results to be interpreted over a wide area. It is possible, for instance, from appropriate rainfall, evaporation and soil data to make a fair estimate of the likely crops that can be grown, the relative importance of soil and water conservation and thus the cultivation techniques that might be appropriate.

The major research problem is the definition of the relevant set of parameters, which stems from an appreciation of the most critical variables in the field situation. (For instance, the seasonal rainfall total should not be expected to describe the drought hazard for a crop: a combination of weekly rainfall and evaporation to yield a seasonal pattern of moisture stress can lead to a far more realistic estimate). The next stage might be the creation of a network of stations to take the necessary measurements followed by the mapping of the information. Alternatively, it might be more appropriate to devise a field test to yield a value within a range of classes that has been pre-calibrated in terms of field performance, (e.g. erosion potential). Seasonal functions like temperature or evaporation would be appropriately presented on maps, whereas the rate of infiltration or the rainfall acceptance of a soil would be better tested in the field and placed into a particular class.

Parameters of particular relevance to soil management would include rainfall amount, intensity and probability distribution, and evaporation in the atmospheric environment, and soil "erodibility" (compounded, for instance, from slope, infiltration rates and stability) depth and water holding capacity besides the data usually included in soil survey. It is difficult to make a very long list because the basic research has not yet been done to define adequately the most suitable measurements for several of the limiting factors, such as the mechanical impedance of the soil to roots, or soil aeration. The lack of realistic test procedures is still a fundamental limitation in the diagnosis of field problems in soil management.

CONCLUSIONS

Water conservation must be a cardinal consideration in all cultivation practices because of the high crop water requirement towards the middle and end of the season. Apparently suitable cultivation techniques

have been developed elsewhere but have been inadequately tested in Africa. Tests should include large scale erosion studies on an internationally co-ordinated basis. The introduction of effective herbicides for weed control presents such extensive advantages in soil management practices that a very thorough testing of their potentiality is essential despite their relatively high present cost. Realities of water and soil conservation in relation to soil cultivation practices should be given a more prominent place in the education of extension officers.

The economic introduction of large scale mechanization into areas with markedly seasonal rainfall is limited by the very short period for planting. Minimal cultivation and micro seed bed techniques offer opportunities for more rapid seed bed preparation with lighter tractors, which should be carefully tested and costed. On the other hand, large scale methods with heavy equipment to bring the inherently fertile heavy clay areas into production should be examined.

The shifting cultivation system of maintaining fertility is being replaced by shorter term planted leys on the European pattern. The system has yet to be proved satisfactory under a wide range of tropical conditions and more thorough tirals with more nutrient balances and ecological descriptions are urgently required.

A great deal of knowledge and technical understanding cannot be applied at present because of the lack of background ecological data or relevant field tests. There is a need for more collection and mapping of appropriate data and also for basic research towards selecting suitable planning parameters.

Present farmers are unlikely to adopt improved, but costly, methods of soil conservation and maintenance of fertility while land is plentiful and ownership is general. More interest is probable as land pressures increase and new systems of land tenure come into being. There is a great need for communications research into more imaginative ways of presenting better soil management methods to peasant farmers.

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IMPROVING THE FERTILITY LEVEL OF TROPICAL SOILS A PRE-REQUISITE FOR THE ESTABLISHMENT OF INTENSIVE FARMING SYSTEMS

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SUMMARY

Establishing intensive farming systems is only possible when the productivity of the soil is sufficiently high.

Generally, this condition does not prevail at present among the soils of the tropical regions.

The role of agricultural research is to analyze the causes for this low soil productivity, point out the limiting factors and suggest solutions for correcting the problem.

The poorness of these soils in mineral elements indispensable to the healthy growth of plants seems to be the major limiting factor. In this regard, fertilization seems to be an extremely efficient way to elevate the productivity level of these soils.

The rational use of fertilizers requires that there be exact knowledge of the nature of the soil environment and its deficiencies.

The study of such a problem entails a logical sequence for agricultural research which can be summarized as follows:

1) Diagnosis of deficiencies of the soil - Several techniques can be used in revealing the mineral deficiencies of the soil: chemical analysis, foliar analysis, tests on potted plants. This latter technique has been widely employed by IRAT to determine the extent and relative amounts of the deficiencies.

2) Correcting the deficiencies - Experimentation at this stage should determine the levels of fertilizer (P, cations) to correct the deficiencies of the soil.

The "response curve" technique, consisting of testing plants with different levels of one isolated nutrient (the other factors being supplied in sufficient quantities), makes such an analysis possible.

This type of experimentation provides fundamental data making possible determination of the maximum production capacity or potential fertility of the soil.

It shows the framework within which agricultural production can vary,

taking all the ecological conditions into consideration.

Improvement of the productivity level of soils by the use of "corrective fertilizers" should be regarded as a capital investment. This fact should be taken into consideration when profitability is being calculated.

For economic reasons, the correction of soil fertility can be spread out over a number of years.

3) Maintaining acquired fertility - The aim of fertilization in this third phase is to maintain the fertility level by trying to compensate for the factors causing soil fertility loss (removal of nutrients by crops, loss through drainage, etc.)

Here we are speaking of maintenance fertilizer, and its profitability must be calculated annually.

Thus the role to be played by agricultural research for the intensification of tropical agriculture appears to be essential. The deep change in traditional methods, which will be an inevitable consequence of the application of the results of research to the rural environment, will require the cooperation of extension [illegible]ts and the rural technical infrastructure, but we feel that it is safe to assert that agricultural intensification will only be possible if the fertility level of the soils is improved.

INTRODUCTION

In tropical agriculture, with the exception of a few industrial crops, yields appear to be particularly low.

Agronomic research should be primarily concerned with the analysis of the underlying causes of low yields, the determination of the limiting factors and the working out of solutions which could correct such factors and thereby increase soil productivity.

I. Limiting Factors

When analyzed, limiting factors can be classified into two categories:

- some factors remain beyond man's reach and cannot be corrected, e.g., soil texture, soil depth, slope, lack or faulty rainfall distribution;

- other factors directly related to plant nutrition can be corrected to a large extent.

Although carbon remains quantitatively the most important element for plants, carbon nutrition is almost always largely assured. Carbon

nutrition is achieved through photosynthesis, from carbon dioxide contained in the air. It is dependent on external conditions, namely light and temperature.

However, in addition to carbon, a number of elements are also required by the plant, in particular nitrogen which, in association with carbon, hydrogen and oxygen, produces protein compounds which are of considerable biological importance, since they are the only source of nitrogen for animals and man alike.

Mineral elements are also required, such as phosphorus, potassium, calcium, magnesium, sulphur; they are trace elements with various physiological roles, either as constituting elements of the plant constituents or as catalysts for enzymatic reactions.

Finally, water plays a part in plant nutrition, not only through its constituent elements, hydrogen and oxygen, but also as a carrier for various substances. Thus, the plant absorbs a large amount of water which is then transpired by the leaves. The accumulation of one kilo of dry matter may require absorption of up to 300 to 500 kilograms of water.

Except for carbon and, in the case of legumes, nitrogen, all the above elements must come from the soil.

It is precisely their deficiency which, in most cases, is the limiting factor in plant development. And, in this field, man's action can be considerable in bringing about a radical transformation in soil fertility.

II. Moisture Requirements

We are considering in this paper only the case of dry cultivation, in which the source of moisture is rainfall. Research should aim at optimum use of water received by the soil.

Such research deals essentially with improvement in physical environment; condition and stability of structure, permeability, depth of soil reached by roots, field capacity of soil, weed control, etc.

Depending on the area, the problems take on different forms: either control of excess moisture, or maximum retention of moisture in the soil. The means of action deal essentially with soil management, often performed with rudimentary tools. The use of draft animals is an objective which should represent a considerable improvement over present conditions. It raises problems of general agriculture relating to the integration of animal husbandry and the inclusion of feed crops in the rotation system.

Provision of water is often mentioned as a limiting factor to production. It is certainly so. However, it should not be forgotten that, contrary to what happens in connection with mineral nutrition mentioned below, water is an intermittent limiting factor. Even in areas with low, badly distributed rainfall (600 mm. in 3 months), there are periods

during which adequate moisture is assured. For the plant to be able to make the best use of water in the soil, there should be at that time no other limiting factors. Thus, the correction of mineral deficiencies is an indirect means of alleviating limitations due to shortage of water.

III. Mineral Nutrition

This is undoubtedly the factor upon which man's action can have the most spectacular results. In most cases, due to their stage of development, tropical soils are extremely poor.

Soil improvement requires two steps: identification of the deficiencies and corrective measures in the field.

a) Detection of deficiencies

Several methods can be used to detect mineral deficiencies in soils: soil analysis, leaf analysis, direct tests in the field, tests on potted material.

IRAT has made extensive use of the latter method, the principle of which is very simple: a comparison is made, on small plant containers, between the reactions of test plants to complete fertilization and to a fertilizer regimen deficient in one mineral element (P, K, Ca, Mg, S, trace elements). Through this method, it becomes possible to detect deficiencies, to measure their relative importance and to classify the limiting factors.

The method is primarily qualitative in nature and its objective is to collect information on soil conditions and thereby open the way for experiments in the field.

b) Deficiency Correction

Once the limiting factors are known, as well as their order of importance, field trials are aimed at determining the amount of fertilizer to be applied to the soil in order to correct the deficiencies.

Here again, several experimental procedures are available. IRAT has used the method of "response curves" with one variable. For example, if experiments in plant containers have shown P, K, and Mg deficiencies, a phosphorus response curve will be established by adding to the soil N, K and Mg in sufficiently large amounts, as well as six different amounts of P. The amount of P corresponding to the maximum in the yield curve represents the amount necessary for complete correction of phosphate deficiency.

N, K and Mg response curves are established by the same procedure.

Through such experiments, it is possible to determine the "soil productive capacity." The test-plant used for the experiment depends on the climatic conditions of the area. In Madagascar, in the area of Tananarive, use is made of maize, which reacts very well to changes in soil fertility.

It may be objected that the results depend on the nature of the test-plant. In fact, it must be remembered that the trials do not aim at devising the optimum fertilization mix for a given species, but at correcting soil deficiencies. We are dealing here with the problem of adapting fertilization to the soil, and not to the plant.

If the soil is to be devoted to a single crop, the plant under consideration may then be used as test-plant. In the general case, when various crops are to be arranged under a rotation system, the yearly maintenance fertilization should be adapted to the special requirements of each crop.

Information on "productive capacity" of the soil is an essential goal of agricultural research. It will enable the agricultural engineer to know the limitations within which fertility may vary.

Two observations must be made on the "productive capacity" of the soils.

On the one hand, such capacity will vary considerably in relation to the nature of the soil and the climatic conditions.

On the other hand, the amounts of elements to be used to correct deficiencies; in other words, the fertility capital to be invested in the soil, will exhibit considerable variations from one soil to the next.

For example, in tropical ferruginous soils in Upper Volta, a serious deficiency in phosphoric acid is corrected with 50 to 75 kg. of this element per hectare. In the ferrallitic soils of the Malagasy Highlands, the amounts required may reach 350 to 400 kg.

Tests conducted by IRAM on gneiss-derived ferrallitic soils in Madagascar have given a spectacular example of improvement in soil fertility through deficiency correction.

These soils have at present no fertility at all. When maize is sown, the plant reaches a few centimeters, then disappears. Soil examination in plant containers revealed P, K, Ca, Mg and S deficiencies. Once the deficiencies were corrected, response curves showed yields exceeding 8 tons of maize per hectare.

Similarly, deficiency correction of rice beds led to crops of 10 tons of paddy (in the Tananarive plain, the average yield is 2 to 2.5 ton/hectare).

For economic reasons, it is possible to adopt provisionally a fertility level less than maximum. Since response curves give continuous information on variations in soil fertility during deficiency correction procedures, it is possible to evaluate the amounts necessary to obtain intermediate fertility levels. It should be observed that, since response curves are similar to MITSCHERLICH curves, a yield equal to 60% of the maximum, for example, will be obtained through use of an amount of elements clearly less than 60% of the amount necessary to completely correct the deficiency.

The development of "small fertilization" procedures should fall under basic research on fertility potential of soils.

Small fertilization may be an essential step in the evolutionary process of tropical agriculture. It does not seem advisable that experiments on this point should constitute the main research activity. When the use of fertilizers amounting to a total of 100 to 150 kilos per hectare is the immediate objective, knowledge of soil deficiencies and the type of crop should be sufficient to determine, within reasonable limits, the composition of fertilizer application. In such case, a few verification trials should be enough. According to A. Demolon[1], a fertilizer test with variable amounts of a given element can only be meaningful if the amounts involved show differences of at least 25 kilos per hectare. In view of the very small amount of fertilizer and of the generally very high margin of error under tropical experimental conditions, it would be illusory to endeavor to determine within a few kilos the amounts of each element.

IV. Maintenance of Fertility

Once soil fertility is increased through corrective fertilization, such capital is then to be maintained in the soil under cultivation.

This point still raises numerous research problems. As a first approximation, a working hypothesis might be that fertility will be maintained if the elements taken away by the crops are put back in the soils, possibly in addition to those lost through drainage. This is, of course, a mere hypothesis. Certain mechanisms may bring about, in the case of phosphoric acid, an irreversible transformation into a non-assimilable form. Although experiments conducted on this point seem to show that the consequences of such mechanism may have been sometimes exaggerated, further research is necessary.

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1. Croissance des végétaux cultivés (Growth of cultivated crops).

When crop rotation is practiced, the yearly maintenance fertilization should be adapted to the cultivated crop. The best solution appears to be to give in advance to the plant the amount of elements which will be required for the expected yield, the latter being determined in relation to fertility.

Unfortunately, data on the amounts of elements consumed by tropical plants are still quite imprecise. Figures to be found in the literature show considerable variations; research should be undertaken on this point also.

In connection with problems of fertility maintenance, the evolution of the physical properties of the soil should also be examined. In particular, the process of development of organic matter, as well as changes in structural stability. Consideration could possibly be given to a rotation system with one crop improving the agricultural profile (feed crop or improved fallow).

V. Conclusion

Agricultural research has a basic part to play in the study of problems raised by the development of tropical agriculture. So much is at stake that daring solutions are justified, and even required.

In countries with a primarily agricultural economy, the problem is to insure an acceptable standard of living and, in the first place, to provide for a quantitatively and qualitatively satisfactory food supply.

It must be realized that such a goal will never be achieved as long as tropical soils have their current low productivity. There should be a massive increase in fertility capital.

True, difficulties are many. Although many solutions seem clear from a technical point of view, many problems are raised by the practical application. With his very limited resources, the African farmer cannot make this investment. He is unable to examine the financial mechanisms involved. Consideration must also be given to providing sufficient leadership so as to make possible, at the farmer's level, the technological revolution involved by the use of methods which differ so widely from traditional practices.

Much time will be obviously needed in order to overcome these difficulties. Possibly the long road ahead should be traveled in stages. However, the agricultural engineer should keep as an objective the establishment of intensive agriculture through the correction of factors which limit agricultural production.

SOIL INVESTIGATION AND LAND IMPROVEMENT AS AIDS TO THE ECONOMIC DEVELOPMENT OF AGRICULTURE IN THE AFRICAN TROPICS

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SUMMARY

There is need for a study and appraisal of land and its use in the countries of Tropical Africa. This is of greatest importance to the future economic development of the agricultural industry of the region since this industry is basic, and will continue to be the major source of foreign exchange earnings of nations. The rapid rate of population growth and the accelerated rise in living standards of the peoples of this region will demand a change in the production trends of the nations if economies are to remain stable and buoyant.

Planned systems of land use should provide grass and forage for livestock, arable crops, forest reserves, and town planning in the most suited areas. These will have to be laid out permanently on well-considered conservation patterns.

In order to achieve desired goals there will be need for trained man-power, the use of modern technology and improved system of farming. There will also be need for every assistance and encouragement to the nations of the region in their endeavor to improve their living standards.

INTRODUCTION

Tropical Africa presents widely varying ecological and socio-economical systems which are manifested in the agricultural problems of the countries comprising the regions (6). An inventory of the agriculture in this land area indicates a tremendous need for the appreciation of basic policies which will cover the territories' agricultural potential and development. Such policies should be geared to the general long-term interest of nations, while at the same time be adaptable to changing circumstances in their applications.

There is need for a new outlook in respect of agriculture. This is necessary because the industry is basic, and those concerned in crop and livestock production must be given ample assurances that the programs they propose to undertake are likely to be worthwhile.

With the achievement of independence in the various countries of tropical Africa came the awareness of the need for a stable and buoyant economy in their future programs. The general policies of the African governments will have to take cognizance of the need for a raise in the general efficiency of production by systems of farming and produc-

tion methods which will result in the increase and efficient use of land resources without much increase in labor and capital. This will have to be the case, since most of the countries in this region of Africa depend on agriculture for a national income, although light industries and mining are assuming increasing shares in the maintenance of the nation's economy.

Agriculture employs approximately 60-70% of the available labor forces of the nations, and it is responsible for about 75% of their gross national income. Because of the important contribution the industry will have to make towards national economics, a major source of foreign exchange earnings, the region's land potential and fertility status are vital assets which must be very carefully protected and progressively developed to the best advantage of the countries.

Patterns of land-use in the past allowed for random demarcations by individuals. In a few cases, teams of government officers comprised of agronomists, foresters and executive officers proposed and carried out plans for land development with some measure of success. Except in very rare cases, there was usually a pronounced absence of soil scientists. Areas were set aside for town planning and development, mining, forestry and agriculture, and those operations were performed with little assessment of the value of soils of the region.

With respect to agriculture, some early progress was achieved, but after a period administrators became aware of certain menaces, evinced by erosion and declining fertility of the land, caused by operators who failed to take into account some of the basic problems associated with land-use (8). Public attention was then focused toward the need for soil surveys and conservation measures.

Soil Survey and Classification for Agricultural Development Schemes

Soil surveys are usually carried out in order to provide basic information which will lead to an orderly development of soil resources, and provide the fundamental knowledge in every research study relating to agricultural development. Soil mapping and classification were virtually absent in tropical Africa until very recent times. With the exception of a few soils studies carried out between the wars (3) (4) (7), no material in the light of present day concepts was available for the region. Within the last two decades, however, the appreciation of soil surveys and classifications have become very popular, and are now being considered as essential, preliminary undertakings to the planned development of the African countries. At present, soils surveys are proceeding at a relatively rapid rate, because international organizations (2) and governments have realized that the information contained therein will lend value to the planning of orderly systems of land-use and conservation. Previously, the pronounced absence of such basic information in the region had hindered research and the application of results to practical agriculture, and made its development more difficult and slow.

As more agricultural problems become noticeable, it has been necessary to try to develop inventories of soil resources either on broad national resource bases with semi-detailed soil mapping and classification for those areas where priorities are placed on agricultural improvement, or in detailed surveys in the case of special development projects.

In regard to special projects, soil surveying has progressed tremendously within the last few years. This is due to the fact that governments, farming organizations, engineers and other technical bodies are themselves becoming more and more dependent on the use of soil maps and soil data. In the specific field of crop production, this progress has certainly contributed greatly toward the economy of countries and has assisted in the overall appraisement of agricultural endeavors.

The future for agricultural development, based on the evaluation and allocation of land among the various farming enterprises, looks good. It is only when agriculturally-suited lands are put into full production under a sound knowledge of their properties and functions that farmers of these regions can begin to find much greater returns from their agricultural pursuits. The policy of carrying out soil surveys will have to be followed by intensive educational and development work.

Agricultural development schemes should seek to provide farmers with technical knowledge and assistance in order that they might be able to plan and carry out full agronomic programs on their farms in strict accordance with land capability and evaluations. At the present time, the governments of these African countries are faced with extreme shortage of trained man-power which can be applied to such projects as soil survey and classification. Efforts are being made to secure the services of experts from developed countries to assist in undertaking various survey projects, while at the same time training programs are conducted for local inhabitants. This is necessary since it is hardly likely that any precise and reliable program will succeed without the basic knowledge which surveyors will provide for future agricultural development.

In order to meet the requirements of an agricultural development program, sound interpretations will have to be given to the results of soil surveys, as these will bring out more effective realizations of the properties and functions of soils of a single family or closely related soil families. This will be necessary since it is at family levels that most of the soils' broad characteristics are portrayed, revealing such important properties as the degree of soil moisture and its associated fertility status.

Land Capability and Use

In endeavoring to classify soils under capability units, attention should be devoted to grouping those suitable for plant growth that will

respond similarly to the same management system, even though such soils may have different series differentiations. In terms of agricultural development programs, land-capability classification should be based on the suitability of the various soil groupings for the production of arable crops, tree-crops, and for grass and forage production. Due care and attention should be given to possibilities of increased erosion and flood hazards.

In the past, land-capability studies have been virtually absent in the region. There is now an increasing emphasis on the use of land for increased food and fibre production and for recreation parks and game reserves within national development plans.

In the African tropics, there are limitations to what could be described as good agricultural land. Such lands are scarce and constitute small farm holdings of sizes up to ten acres and are often isolated as small parcels of land. More of these agriculturally-suited lands should be demarcated within soil provinces and used effectively on an optimal land-use pattern, in keeping with the principle of utilizing land for its highest income value; this would be crop production or improved grassland/livestock production.

As a result of present commercialization of agriculture and increased worldwide demands for agricultural products, it is reasonable to assume that land at present under forest cover, as reserves, will be shifted to crop and pasture production. Governments of the various countries will be forced to maintain a reasonable distribution of land between agriculture and other land operations. Expert knowledge and advice, based on research and experimentation, will have to be sought in order to bring such agriculturally-suited lands into optimal use. Conversely, lands which are now in use for crop production and which pose threats of serious hazards will have to be taken out of production and put under reasonable conservation practices more commensurate with their grouping.

In the above assumptions, the increase or decrease in crop or grassland production will be realized. It is necessary to research actively the economic factors related to land-use management, in order to investigate the effective use of productive soils under systems of crop rotation and the economic viability of small-sized farm holdings in remotely located sites, since these continue to be important obstacles to higher and better farm production in countries of the African tropics.

Soil Fertility in Relation to Future Needs

The system of "shifting cultivation," as practiced over large areas of agricultural lands in tropical Africa, has been adopted because other systems cannot maintain the level of productivity needed within such limited resources. The effectiveness of such a system reached its peak when virgin forests and regenerated high bushes were available for

clearing, and production capacity limited to sustaining a relatively thin local population was prevalent. (5)

Executive bodies in the various countries now have a tremendous urge to increase production, due to rapid increases in population and the need to increase their foreign exchange earnings.

Large-scale clearings with the aid of modern technology have accounted for increased production in several localities in the region, but sustained higher levels have not been maintained, and the exhaustion of such lands has often been rapid.

There are known systems of maintaining soil fertility through stable systems of farming and rotational cropping patterns, and these have been practiced in the developed countries of the world over a great many years. Such systems might well gain ground in the African tropics, but advisably their introduction should be backed by sound research and experimentation data, especially where they might cover large tracts of land. Experiments of this nature will have to be conducted by trained agriculturists on the different soils mapped out in the soil amendments. The need and importance of such experimentation has been clearly stated by Charter (1): "It is no use merely mapping the soils; we must know a great deal about their crop responses and, most important of all, about their interactions with different systems of farming designed to maintain or even to augment soil productivity. If a program of soil surveys is to achieve its aims, it must be accompanied by efficiently organized agronomic work, and the two must be intimately related."

Farmers in the tropics of Africa are now beginning to appreciate the value of fertilizers in the overall production economy of their lands, through governmental support in some of the countries, and more recently from the ogranization of fertilizer distribution and use by various foreign aid bodies, including the United Nations Food and Agriculture Organization "Freedom from Hunger" campaigns. The principal need will be to provide means of getting the greatly increasing amounts of fertilizers and soil amendments required into use on farmers' lands. There will also be the need for providing farm education, agricultural credit and the marketing and distribution systems of farm products.

Future Outlook and Capital Requirements

With thoughts towards an expanding production capacity there will have to be plans for further investment in the agricultural industry. Most of these will have to come from private, governmental and quasi-governmental sources of the various territories which will supply needed capital to keep pace with foreseeable development.

The immediate needs of the countries of tropical Africa are calculated on the maintenance of their present living standards. There are

signs indicating a more rapid rise in living standards and dietary habits than is generally predicted, and pressures from the peoples of the region will force governments to devote more attention to agricultural development and provision of food. Production will have to be increased more than is currently planned, otherwise, foreign exchange will dwindle in an effort to import food to feed the nations.

Although the present investment patterns in agriculture seem to be improving, there is, and will continue to be, accelerated needs for various aid programs to give more help to the industry. Good working relationships must be provided whereby such assistance from aid programs could be effectively utilized to the maximum advantage of the developing countries.

Since the various regions of African countries appear to have competitive advantages in crop and livestock production, adjustment to future changes and control programs should not be difficult, provided improved technology and sound management systems are introduced into the various production provinces.

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SOIL SURVEY AND MAPPING IN RELATION TO AGRICULTURAL DEVELOPMENT

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SUMMARY

I. DESIRABILITY OF SOIL STUDIES

Summary of conditions specific to Africa:

- population with low average but very uneven density, with some heavily populated areas with poor and degraded soils, and thinly populated areas where the soils are sometimes unusable (laterite) or sometimes chemically very rich (vertisols).

- most soils have a fragile structure and are relatively poor chemically, sometimes very deep, but harden easily and are generally poor in humus.

- special geographical characteristics, with very dense forests and also a shoreline with deltas having very saline or alkaline soils.

- severe economic conditions, with very expensive power and transportation, high-cost land clearing, development projects, agricultural mechanization, justifying detailed preliminary studies on soils.

II. USERS

The users are almost always government agencies; the documents required are either surveys are large or medium scale maps (extension services) or small scale maps (planning services).

III. STATUS OF PROJECTS

In the last analysis, the mass of data, reports and maps appears to be quite large in all the African countries, although map coverage is rather unevenly distributed. However, several countries have more than 50% of their area covered by 1/200,000 maps, while 1/1,000,000 or 1/500,000 maps are becoming quite common (more than 12 countries).

Finally, Africa is covered by a comprehensive 1/5,000 000 map drawn up after coordination of all studies by soil specialists and following agreement on a common nomenclature.

I. DESIRABILITY OF SOIL STUDIES

It would appear unnecessary to stress the desirability of soil studies, i.e., soil characterization studies, with or without maps, for the sound growth of agricultural improvement and research. However, in the case of tropical areas, such studies present from the human, pedological, geographical and economic points of view some rather peculiar aspects which should be stressed or specified.

A) Africa is a continent with a low average population density, but with areas with a very high population density where agricultural practices often trigger catastrophic erosion phenomena, or at least bring about such a depletion of the soil that shifting agriculture becomes necessary.

On the other hand, there are areas with an abnormally low population density, where studies show that soils are sterile (lateric custs) or conversely, quite usable. The latter type of soils are neglected either for purely historical reasons (ethnical borders) or because they are difficult to cultivate with the physical means available to the populatio Such is the case of the vertisols (dark clay), much richer chemically than all the soils normally put to use, but difficult to cultivate without a minimum of mechanization.

Recent mapping activities in West Africa show that the areas which can thus be recovered can be extensive and that a geographical redistribution of human settlement would therefore be sometimes advisable.

B) The soils of tropical areas have certain characteristics which bear important consequences from the point of view of practical utilization.

On the one hand, there are hardened horizons, variously called lateritic, crusted or caked, which cover sometimes extensive areas but in most cases are limited to low depth. On the other hand, most soils are characterized by a very low chemical content and by small reserves of organic matter and humus, these disadvantages being sometimes offset by a considerable depth usable by the roots, and also by quick cycles of utilization of organic and mineral elements. The fact that these soils are for a large part made up of quartz, kaolinitic clay and iron hydroxides limits the possibilities of increasing fertility levels and requires that fertilizers be used in accordance with specific rules.

Thus the sound use of such essentially fragile soils implies, more than elsewhere, a previous knowledge of their physical, chemical and biological characteristics, since any mistake can bring about a deterioration or a rapid and practically irreversible depletion. These dangers, which are less serious in non-tropical areas, point to the need for preliminary soil studies in Africa prior to any agricultural development plan.

C) The geographic context includes some specific aspects of considerable practical importance:

- the presence in equatorial areas of extremely dense forests, the clearing of which poses considerable difficulties, which implies that clearing is performed only on soils known to be usable for a given purpose.

- the existence, in many coastal areas, of estuaries with rias where marine invasions during the Quaternary Period have left behind saline or alkaline soils. Under such circumstances, the sound development of delta areas presents special difficulties which may not be equally important elsewhere and presuppose a solid knowledge of environment and soils.

D) The present state of infrastructure in Africa explains the high cost of long distance transportation and power production. Similarly, under these conditions, dam construction, well drilling, levelling of soils to be irrigated, farm mechanization, fertilizers, irrigation networks are expensive operations.

Therefore, any development project can only become profitable if preliminary studies have been carefully conducted and if their location is selected in accordance with strict criteria, including a thorough knowledge of soils.

II. THE USERS OF SOIL STUDIES

In this field, Africa presents also two rather special aspects:

A) The users are almost always government agencies, and very rarely the farmers themselves.

B) The government agencies require fairly varied documents, which can be classified as follows:

- The agricultural extension services require either simple surveys or large or medium scale maps, sometimes land use maps;
- Agricultural research agencies require soil maps and studies which indicate soil characteristics from the physical, chemical and biological points of view.
- Large-scale development agencies (pilot-estates, irrigation districts) require large-scale maps, accompanied by documents on land vocation and use, with specific determinations of some factors (such as capacity for dry versus irrigated cultivation).
- Planning agencies require small and medium-scale maps in order to set up National Plans (four years or otherwise) based on general information, to plan possible population re-settlements, to select the main areas for intensive implementation of the Plan. The Planning agencies which exist in many countries in Africa need soil studies, although the latter are not yet quite common on this continent.

The development of prospection and soil studies in Africa for more than 20 years is to be understood in the light of both special characteristics of soils in Africa and special users. Schematically, studies were:

- Inventories of soil types, some of them previously unknown;
- Maps on various scales, indicating soil distribution;
- Soil characteristics, so as to better understand their formation, their sounder use and, more rarely, their possible changes under cultivation.

Such studies were conducted mostly by:

- Soil scientists and prospectors from Government agencies (Ministries of Agriculture or Rural Economy, Land-Use Survey Departments), Agricultural Centers or Stations, sometimes from private organizations working under contract;

- Specialists from large research organizations working under bilateral assistance schemes, generally in research centers or on special missions from Europe;

- Experts working under multilateral assistance schemes (UN Special Fund - FAO projects).

The surveys have been conducted according to different methods between two limits:

- in some cases, surveys for land to be used for a single crop (cotton, peanut, oils, etc.)
- in other cases, inventory and systematic description of soils, sometimes even before the establishment of a development plan or prior to a request from users.

The distribution of both trends has also changed with time.

Before 1950, there were almost exclusively large overall surveys, such as those conducted by Kellog in Congo-Kinshasa and Aubert in West Africa.

In 1967, the activities were hardly oriented towards a search for soils suitable for a given plant, but towards complete and definitive maps of soils.

III. STATUS OF PROJECTS

This paper cannot present a complete list of all soil surveys and maps but is intended to show the importance of available documents for the purpose of agricultural development.

A) Soils Surveys and Identification

Such studies have been very numerous; their results are to be found in a large number of reports, some of them published and widely circulated

others available only locally. Attention should be given to these often incomplete works, unknown because unpublished, which exist in all African countries. Sometimes complete lists have been drawn up and it would be useful if all countries could develop, up-date and disseminate them to all national and international users.

It should be noted, however, that many such works have been sent to the S.T.R.C. Office in the OAU (former Inter-African Soil Bureau) which has just been moved from Paris to Bangui (CAR). This agency has a very valuable collection of African documents and its excellent information department has done a very good job of disseminating a large number of studies. We recommend, as a user, that this agency could continue and enlarge its action, since its publications are oriented not only towards soil studies but also towards erosion and all agricultural development projects (publications: Sols Africains and Bulletin Analythique).

B) Large and Medium-Scale Maps

Large-scale maps (1/5 000 to 1/33 000 maps) are quite numerous but extremely dissimilar, very limited in coverage and accompanied with notices or reports with a variable wealth of analytical data. Some countries have drawn up maps for most of their large irrigable plains (Upper Volta, for example); others have drawn maps limited to areas where development projects are being implemented (Morocco, Tunisia).

In some cases, maps are complemented by land-use maps, particularly in English-speaking countries.

There are also many medium scale maps (1/500 000 or 1/350 000 maps); however, they are rather differently distributed depending on the area.

Such maps are few in some countries and numerous and systematically drawn up by area sheet, in others (specially francophone countries). This is true of Chad, Malagasy Republic and Senegal, where more than 50% of cultivable area is covered by 1/200 000 maps.

There are also many sheets in Congo-Kinshasa, Dahomey, Togo, Ivory Coast, as well as in many other countries where population is more thinly or unevenly distributed (Nigeria, Gambia, Central African Republic, Cameroon, and Ghana).

In other countries such as Sudan, Tanzania, Uganda, this type of map appears to be of secondary importance in comparison with land-use maps.

C) Small-Scale Maps

Since 1960, many maps have been drawn up on a 1/500 000 scale or 1/1,000 000 or its equivalent. Such maps are drawn through synthesis or interpolation of larger-scale maps, or through systematic survey, generally upon Government's request.

Among the 1/500,000 maps, mention may be made of the systematic coverage of the agricultural area in Niger, of the Northern area of the Ivory Coast, and of the complete coverage of Upper Volta (in process).

The 1/1,000,000 maps are excellent basic documents, generally in colors, with adequate legends.

Mention may be made of the following (the list is not complete):

- Maps of Congo-Kinshasa, Ruanda, Burundi, in association with vegetation maps on the same scale;
- Complete coverage maps (published or being published) for Senegal, Togo, Cameroon, Malagasy Republic, Ivory Coast (1/2,000,000 published, 1/1,000,000 pending) as well as for Swaziland.
- Various sheets of 1/1,000 000 already published for Angola

Finally the document representing symbolically the numerous contacts existing amongst all the pedologists working in Africa is the 1/5,000 000 map by J. L. D'Hoore of all Africa (published in 1964 by CCTA, Joint-Project No. 11).

This synthesis, the result of ten years' work, after five successive approximations, comprises in addition to the legend seven maps in color with 62 legend elements and 275 cartographic elements. This achievement shows that inter-African coordination efforts have been effective, particularly on the standardization of classification.

Finally it should be noted that this 1/5,000,000 map is completed by F.Fournier's 1/10,000,000 on "The Danger of Erosion in Africa South of the Sahara".

IV CONCLUSIONS

The preceeding account describes soil survey and cartography projects which, though irregularly distributed geographically, represent basic information of use to research and technical personnel involved in agricultural development.

It also indicates that the era of reconnaisance or research on land for a given agricultural objective is over and a period of synthesis has begun, generating moreover new and more detailed research.

If the quantity of available material is reassuring, it is not clear that it is being fully or rationally employed by the different categories of user. Nevertheless these documents exist and it is desirable to keep them up-to-date on a regular basis, in spite of the difficulties, particularly those relating to work in the equatorial forest regions, due to the availability of topographic information or aerial photographs, and finally financial problems.

It would be better still if the users would define their needs more precisely taking into account that soils research, which, in terms of acreage restored, costs only a small percentage of the cost of development project, and which alone can help avoid clearing and planting unsuitable areas, can save as much as the cost of all the studies.

Furthermore, aside from the strictly financial aspects, it is essential to take into account that Africa must not lose any time in progressing out of underdevelopment, and that it is therefore extremely serious to allow agricultural development projects to be jeopardized by a lack of knowledge about soil characteristics.

The consequences of such setbacks to social and political planning can be serious, and this consideration alone justifies the need to develop soil surveys and associate them more with agricultural development projects.

SOIL AND WATER MANAGEMENT FOR CULTIVATION OF OIL PALM

R. Ochs
IRHO

SUMMARY

The need for developing and diversifying the agricultural economy leads to the visualization of oil palm production in regions which often are quite unfavorable in terms of soil or water.

A specialized department has been set up within IRHO in order to do the surveying and conduct improvement studies for plantation blocks.

IRHO is currently involved in conducting geographic, pedological, topographical, and hydrological studies which must be completed prior to the utilization of the zone selected for this purpose; and, developing soil and crop preparation techniques.

A number of soil improvement projects (drainage, terracing) and water control projects show that the right kind of crop techniques will require very thorough prior improvement studies, in terms of the prevailing ecological conditions.

Results recently obtained in the field of irrigation also show that the outlook for this crop cultivation method is excellent in the very near future.

INTRODUCTION

The Institut de Recherches pour les Huiles et Oléagineux (IRHO) has launched a rather large-scale competitive bidding program for international agencies (Fonds d'Aide et de Coopération, Fonds Européen de Développement, World Bank), as well as for governments and private companies in connection with the establishment of agricultural-industrial complexes based on oil palm and coconut palm cultivation.

The scope of these projects (the area under cultivation with oil palm should amount to 150,000 hectares in Ivory Coast in 1975) or the need for diversifying agriculture means that crops are increasingly going to have to be developed in regions which may have unfavorable conditions such as:

Climate - insufficient rainfall in Dahomey;

Soils - gravelly soils at varying depths and on varying surfaces in West Africa;

Physical Composition of the Soils or their Nature - clay vertisols or calcimorphic soils in Dahomey, peat bogs on the east cost of Madagascar;

Topography - in the case of the oil palm, more than in the case of any other perennial crops, the trees must not be planted on terrain that is too heavily broken up because of the large amount of run-off occurring here (15 tons/ha) and to prevent the flow from running off into the ravines.

A specialized department of IRHO (consisting of ten pedologists and agronomists) over the past several years studied the following areas in Africa:

65,000 hectares in the Ivory Coast
11,000 hectares in Dahomey
12,000 hectares in Cameroon
3,000 hectares in Congo (Brazzaville)
1,500 hectares in Madagascar

Tens of thousands of hectares have also been selected in Sierra Leone and in Liberia from among the projects studied for the World Bank and private companies.

How to Plan Agricultural-Industrial Complexes on the Basis of the Morphological and Pedological Characteristics

In general, detailed soil prospecting is preceded by a rapid survey mission (lasting anywhere from several days to several weeks, depending upon the dimension of the projects involved) to develop a general study of the soil and the climate, in order to outline the general area, and in order to determine the general nature of the soils in the zone to be studied by aerial photography (National Geographic Institute, Paris) and then by means of a survey on the ground.

The percentages of cultivatable soils vary from 75% to almost 100% in the sandy zones of the Ivory Coast, Dahomey, and the Cameroon, dropping to about 10-20% in the gravelly zones located on the ancient shelf of the western part of the Ivory Coast.

The density of ground coverage for surveying purposes and the dimension of the zones under study are thus influenced by these figures.

The detailed studies conducted by IRHO involve the following:

Highway connections
Climatology
Vegetation (density and diameters of trees)
Relief, hydrology

Geology
Soils (nature and utilization)
Setting up the project block
- access
- prior existing access network
- layout of various cultivatable sectors
- development (layout of plots and operational roads)
- production estimate
- location of processing plant

The following maps are prepared for each unit:

- a 1:50,000 location plan
- a 1:10,000 morphological map
- a 1:10,000 agricultural soil value map
- a 1:10,000 development plan - giving the plots, the position of the limits and their nature (natural limits or man-made boundaries), the network of farm roads, and finally, all of the special directives and indications that can facilitate the job of setting up the entire project here.

After the detailed prospecting (250 m. grid mesh) has been completed, we then have a precise 1:10,000 map of the topography and of the soils. It is generally necessary to get a surveyor to prepare several basic terrain plans so that we can then prepare a map from which we can eliminate the distance errors and above all any angle errors which the pedologists might have made with their rather inaccurate instruments (compasses, chains).

Next, we take up the development study as such which consists in selecting the boundaries of the future plantation; here we also make some internal eliminations and we design the most economical road network which will of course be adapted to the morphology of the terrain.

Because of its simplicity, the continuous stake layout is preferable (9 m. equilateral triangle) to all of the others.

The East-West collecting trails which are usually 250 m. apart, are obtained by eliminating one palm tree, on every other line. The North-South trails are obtained by eliminating all of the palm trees along a theoretical stake line. In certain cases it is preferable to replace North-South trails with oblique trails following the slope of the land. In the most difficult cases it may be necessary to follow a winding course along the line of a ridge. For example:

The plantation manager is given a 1:10,000 management plan showing:

the layout of the surveyor's traces and the location of all the boundary markers,

the network of traces through the area (for winding paths, indicated by a dotted line, the probable deviations from

the direct route can assist in finding good access),

the boundary and boundary markers,

the rough location and nature of the natural features which may serve as boundary markers without erecting markers,

indication, through conventional signs, of the location and importance of natural obstacles which have been necessarily included in the boundary, their limited area not justifying their inclusion with ground markers: perhaps--a thoroughly marshy stream; the head of a steep valley bottom; a relatively short steep slope; a rocky outcrop, etc.

The manager, warned of the obstacle, will by-pass it when he comes to it or clear the vegetation wholly or partly off it, if he thinks that possible.

Along with the management plan he is given a morphological map to the same scale showing the network of water supply and the limits of soil or topography which have served as a basis for the construction of the management plan. These give the forester or planter the basic information on which, with good grounds, he can modify or improve the basic arrangement in the course of development.

Land Preparation

This is limited here to methods of preparation used in the forest region (the development of the savannah does not pose an important problem, with the exception of the extermination of the imperata grass, which can be carried out at low cost by repeated disc-harrowing).

In forest regions which are suitable for the cultivation of oil palm, a good soil preparation method should allow the plant material, which has been chopped down to decompose on the spot in order to maintain soil fertility while still permitting the mechanical maintenance of the plots and providing easy access to the trees for the harvest, for manuring, and for the various health checks and treatments that are necessary.

The method of "Alternate swathing" makes it possible to combine all of these factors. At cutting time, it consists of completely de-stumping every other lane and in clearing it by swathing the stems on the neighboring lane: each line of palm trees is thus easily accessible from one side.

Ten big tree trunks (per hectare) can be left in place, the trunks of leaning trees or hardwood trees (which are the most difficult to pull out when the diameter of the trees is 1 meter or more). By leaving these trunks, we can save several hours of cutting time per hectare.

The basic principle of alternating swathing, as well as the techniques of cutting, de-stumping, and swathing, using mechanical equipment, have

been worked out by the IRHO first at Sibiti and then at La Mé; this method has now been adopted for all of the large-scale projects in forest regions (the Ivory Coast, Liberia, Colombia, Peru, Brazil, and, very shortly, Cameroon).

This procedure alone makes it possible to carry out large programs each year (an example here would be the accomplishment of the Palm Tree Plan of the Ivory Coast), without having to recruit large numbers of men--something which, of course, would involve major hiring expenditures, management costs, and expenses for the logistic support and other necessities.

On the basis of all the necessary calculations here, we can say that the cost of this method is smaller than that of the manual preparation method. It is something like 70,000-80,000 CFA Francs for the virgin forests along the lower portion of the Ivory Coast and Cameroon. It takes about 8 hours of heavy tractor work (260 hp) and this work can roughly be broken down as follows: one-half for felling and the other half for swathing and for clearing the roads and lanes.

The leguminosae cover crops (Pueraria Javanica) are planted as soon as the swathing has been finished and as soon as the rainy season has begun.

Cultivation Techniques

If the average temperature is 27° C, the water requirements of the oil palm are roughly 150 mm per month.

The cultivation techniques used here thus will depend on the rainfall of the regions to be improved and these techniques will be intended to improve the terrain (the peat bogs of Madagascar), to evacuate the surplus surface water (flat and clayey floodland) during those months when the rainfall volume very heavily exceeds evaporation-transpiration; on the other hand, these techniques might be intended to reduce the competition from the cover crop associated with the palm tree or the vegetation that might happen to be there, during the long dry seasons (Dahomey, Togo).

Briefly described are some of the techniques which have been used or perfected by IRHO:

1. Reclamation

The rainfall and sunshine conditions on the east coast of Madagascar are good. Unfortunately, the surface area of the flood plains is very small and already taken up with other crops.

On the other hand, there are several tens of thousands of hectares of peat bog or semi-peat bog whose soils can be developed rather nicely after drainage.

The IRHO and SOGREAH are cooperating on a project in the region of Tamatave; this project calls for planting 350 ha of peat bog, in the near future after the water table has been lowered 1 m below the ground level. This requires the construction of a network of drain pipes which will be laid out in the first phase, at the rate of one drain for every six lanes of palm trees. The depth of the drains has been reduced to 0.70 m. Two years after planting, plans call for the drains to be deepened down to 1 m and to double the density of the network, if this should prove necessary.

These precautions must be taken in order to prevent the peat from drying out or developing too rapidly and in order to prevent the formation of hydrophobic colloids, which have an irreversible structure, on the surface.

2. Surface Drainage

This operation is necessary in loamy or clayey alluvium soils on the surface, in the young plantations (for about 30 months after planting).

The IRHO did this at a plantation in Colombia, on a scale of 5,000 ha., using mechanical equipment (V-shaped drains, 350 cm deep, at the rate of every other lane).

Before the drainage ditches are dug, a subsoil plow is run over the ground to break up the roots.

3. Terraces

In moist terrain (alluvium in Colombia, vertisols in Brazil), it has been found useful to build up terraces or ridges so that the palm tree can be planted above the level of the soil.

The individual terraces are about 1 m long and 20 cm high.

The ridges or benches are made with equipment such as the Border Disk John Deere No 80 which turns out terraces that are 2.50 m wide at the base and 30 cm high at the top.

This method offers the advantage of producing a certain rainwater runoff down the slopes of the embankment and it further reduces the volume of water that is really absorbed by the earth of the little bank or step.

It also offers the advantage of accumulating--at the spot for the future palm tree--a larger volume of humus-containing earth which is better structured and richer.

Since this means moving the soil, we must--in order to prevent a degradation of the structure--try to do this work at a good time. The benches are lined up at a 60° angle, neither perpendicular nor parallel to the line of the greatest inclination, so as to avoid erosion.

Experience has shown that these techniques do not involve any inconvenience, even after heavy hurricanes.

They prevent yellowing due to asphyxia, which had been observed during the first two years of vegetation.

4. Water Management

In the southern part of Dahomey and Togo, the development of oil palm cultivation is an economic necessity, although the total rainfall volume often does not exceed 1,200 mm per year. The water shortage thus varies between 400 and 700 mm per year, depending upon the particular year involved.

The IRHO has studied techniques that would make it possible to save water during the first years. The best method would consist in maintaining the soil by means of repeated passages of disk-equipped machinery.

SONADER successfully applied this method on a large scale in the MONO plantations.

In the case of new plantations, strips of anti-erosion vegetation are recommended when the slopes become too steep.

Irrigation Outlook

An irrigation test in the Ivory Coast, carried out in a zone characterized by a micro-climate which has in recent years become highly marginal for the oil palm, is only in its initial stages now: the total effect of irrigation on the individualization and sexualization of the clusters and bunches will not emerge until after the middle of 1966.

However, the first results obtained here are quite interesting: in a zone characterized by an annual water deficit of something like 600-700 mm, it is possible--with the help of irrigation--to quadruple the yield and, from the 3rd harvest year onward, to get 25 tons of bunches per ha. as against 5.5 tons for the control plot.

At maturity, the output would probably exceed 5 tons of palm oil per ha since section A of this test area has already produced the equivalent of 25 tons of bunches between 1 May 1966 and 30 April 1967. These results give us an idea of the output potential of the selections currently delivered by the Institute.

A check on the nutrition, by means of foliar analysis shows that--on the basis of the irrigation doses and intensities used here (40 mm over 3 hours on the surface that is actually watered)--there is no leaching of mineral elements, particularly potassium.

If we know the anticipated output growth rate and the surplus-value per ha., we can estimate whether, in each particular case, it is economically worthwhile to provide supplementary irrigation, or whether this is not feasible, considering the investments to be made, the availability of water, and the cost of power under local conditions.

The output on irrigated plots (25 tons per ha) can be compared to the output obtained under the best ecological conditions, for example, in Malaysia or Sumatra.

During the coming years, this irrigation test should supply us with a very large volume of additional supplementary information which will also be most interesting.

This data will cover the following:

the appearance of a second limiting factor which might be the insolation at certain periods, or the nutrition,

the influence of the insolation factor, alone, on the output, considering the variations recorded throughout the year,

the nutritional requirements of the palm trees as a function of the output,

the variations of the bunch components and the oil content in terms of high production levels.

As of this moment, this test shows that it is possible to expand the economic zone of oil palm cultivation and to achieve a considerable improvement in the output of palm tree plantations in marginal zones, if we can get the necessary water in a sufficient volume and at a reasonable price.

An irrigated plantation covering 1,500 ha is now being set up in the northeastern part of Colombia, under the auspices of the Colombian Agrarian Reform Institute. The IRHO is giving technical aid to this agency and to this project.

Conclusion

The growing diversity of soils and climates in the current oil palm cultivation development zones requires thorough studies on the improvement of the soil and the adaptation of cultivation techniques that will be appropriate in terms of the varied ecological conditions.

FERTILIZERS AND FERTILIZERS' POLICY

S.Bouyer, IRAT

SUMMARY

Fertilizers are one of the most efficient methods of increasing agricultural production in Africa. Many formulas of fertilizers with a manure base have been developed but they have seldom become popular because of the high cost of the fertilizer and the low commercial value of certain crops, especially those of food products.

Research structures are often satisfactory; in certain cases the insufficient network of experimental stations has been successfully completed with the establishment of supporting centers of regional experimentation.

A methodology of research into soil fertility and fertilization has gradually developed in Africa and it is satisfactory at present. The research program must contemplate the objectives of the development plans of each state.

Some examples of fertilizers' formulas are cited.

The following research can be considered as having priority for the economic development of Africa:

- Development of fertilizers which are economical at low rate of application in certain cases.
- Use of natural phosphates of local origin.
- Different methods of fertilizers' application.
- Fertilization within the framework of crop rotation.
- Fertilizers for correcting dificiencies in certain cases of intensive farming.
- Organic fertilizers.

INTRODUCTION

It is generally agreed today that fertilizers are one of the most effective means for raising agricultural production in Africa. Depending on the types of crops and the amounts of fertilizer applied, increases in yield ranging from 20 to 80 percent have been noted. In optimum

situations it has been possible to double and triple output. This was true of cereal crops in certain very poor ferruginous tropical soils of West Africa. FAO has calculated an average yield increase of 63 percent in 25,000 fertilizer trials conducted between 1961 and 1966.

The technical problems in connection with the use of mineral fertilizers are relatively easy to solve and virtually everywhere formulations of fertilizers are known which will induce substantial increases in production.

However, the application of these techniques of fertilizer use in practice encounters major difficulties of two kinds:

- a general use of fertilizers must be accomplished by a general adoption of proper crop-raising techniques. This calls for major systems of guidance, which is the task of the various governmental services for rural education, rural promotion, agricultural development, farm modernization, regional development offices established by African governments, as well as of foreign development enterprises operating under cooperation agreements. There has been undeniable progress made in this area, but many of them are of such recent establishment that they have not yet produced spectacular results.

- From the standpoint of the economy, it should be noted that it cannot always be assumed that mixtures mentioned by us will be profitable, because of their high cost and because of the low cash value of some crops; this is particularly true of traditional crops.

As a result the consumption of fertilizers in Africa is still very low. FAO figures show, for instance, that of the 40 million tons of fertilizer elements (nitrogen, phosphorus pentoxide, and potash) consumed globally in 1964-65, only about 40,000 tons, or only one thousandth, was for West Africa.

The emphasis, at this working session on African soil fertility, must be placed on the fact that the priority of any agricultural research which could be inaugurated will to some extent be governed by economic priorities. It is a welcome event that one session has been set aside in this series for approaching economic questions and that undoubtedly the policy of fertilizers will form one of its major discussion subjects.

I - Present State of Research on Fertilizer Use in Tropical Africa

We are not able within the space of this article, to present a complete picture of the work accomplished and the results attained in regard to fertilizer use. We would therefore like to endeavor to discuss matters in general terms. Since it is necessary, however, to cite certain concrete facts, we crave the reader's indulgence if we refer especially to facts with which we are most familiar, namely, those concerning the fertilizers for use on food crops in the French-speaking countries.

Research is currently conducted either by agencies of the countries or by foreign institutions operating under cooperation agreements. Mention should be made also of the substantial contribution of FAO.

1.1 - Organization of the Work

Basic research on soil fertility and on methods of fertilizer use is conducted by experimental stations which are frequently well staffed with expert personnel and possess ample equipment. We might mention as an example the Ivory Coast where research is proceeding either in national stations or in stations operated by specialized French research institutions. There are eleven of the latter:

- one on palm-oil;
- one on coconuts;
- two on bananas and pineapples;
- two on coffee and cocoa;
- one on cotton;
- one on rubber;
- three on food crops.

In addition, basic research on soil fertility is conducted by the ORSTOM Institute at Adiopodoumé.

Not all the countries have as many stations, and it has often been found advisable to set up more modest organizations, which are called regional experimental support centers. These centers are established in regions having a different ecology from that of the stations, and they carry on substantially the same kind of studies as do the stations. For example, the Government of Niger has already established four support centers to eound out the research conducted by its two experimental stations, and others will follow in short order.

The phase of verification testing is generally conducted within a network of testing centers at multiple locations as close as possible to each other. These are simply fields leased from farmers for one year, on which very simple fertilizer mixtures are applied. This is the system of tests at multiple sites adopted specifically by FAO in various West African countries. Some institutions operated successively as stations or support centers and also as part of a network of multiple locations. The entire network corresponds to a well-defined ecological zone and is called UREM (Regional Multiple-Site Experimental Unit).

1.2 - Methods of Work Programs

The basic pattern of the general research process followed in soil fertility in tropical Africa is as follows:

- soil prospecting, essential for marking-off various ecological zones and for defining the soil type in each zone;

- analysis of soils, which may not be sufficiently extensive in order to make specific recommendations as to the fertilizer mixture, although it may furnish such useful information and substantiate certain experimental results;

- analytical study of plant life, substantially advanced in some cases. Leaf analysis in such cases already renders great service to the phase of detecting mineral deficiencies in soils as they affect specific crops. This applies to peanuts, for example; but a plot-by-plot experimentation is always necessary to develop fertilizer formulations;

- experimental studies representing at the moment the sole practical method for arriving at recommended fertilizer mixtures; these are conducted in between different phases of research:

    - identification of factors limiting crop growth in a given soil; depending on the situation, this is accomplished either by tests with potted material or by orientation tests in plots; for some crops, as mentioned, leaf analysis may also be used;

    - correction of deficiencies expressed by these limiting factors, by trials factorial or not as the case may be, using stepped-up levels of each factor which has been recognized as useful;

    - techniques of using fertilizer intended for these growth factors;

    - sustaining fertilizers suitable for various crops involved in rotation and capable of preserving the level of productivity after correction of deficiencies.

The current research programs, which conform more or less--depending on the particular country or research agency--to the methods sketched above, are geared to governmental development programs and the priorities set up by these. Thus for some high-value crops, research might be oriented to developing restorative fertilizers which would bring about a complete correction of soild deficiencies. In this case, a phase of intensive cultivation is attained.

In other cases, however, priority must go to research on fertilizer mixtures which are economical and involve moderate applications; this would be the case in particular with traditional food crops, which do not offer the financial prospects for investing heavily in fertilizers. This is the only possible way which, by the way, accomplishes a first phase on the way extending the use of fertilizer under acceptable economic conditions.

1.3 - Some Examples of Results Obtained in Fertilization of Soils

As already mentioned, the accomplishments are already considerable. In many of the countries, research is substantially ahead of extension. However, we are unable in this brief report to present a complete tabulation thereof, and so we will point out a few individual examples as being representative.

Irrigation rice (paddy)

In Senegal, on 5,000 hectares in the Richard-Toll region, 50 units of nitrogen are supplied per hectare in granular form. The average increased output is around one ton per paddy. The index of response to nitrogen, showing the number of additional kilograms of paddy produced per kilogram of nitrogen, is 20. The ratio of added crop value to cost of fertilizer is close to five, with net income over 15,000 francs CFA per hectare. It is also known that very high yields could be obtained (seven tons on experimental tracts) by correcting the fixative ability of soils with the help of 800 units or less of phosphorus pentoxide.

In Mali, in the Office du Niger area, nitrogen is applied at the rate of 30 kilograms per hectare. As in Senegal, intensive cropping could be pursued by the addition of a high phosphate fertilizer level.

In Madagascar, fertilizer is coming into general use on the high plateaus region with a nitrogen-phosphorus pentoxide-potash mixture in a ratio of 30-62-45. The increased yield obtained experimentally is about 1,500 kilograms in Tananarive province, for example, and the practice has been highly profitable. Here, too, very high yields could be obtained (up to 8 tons on experimental tracts) by addition of a corrective fertilizer consisting of 200 parts of phosphorus pentoxide and 120 parts of potash, mixed with 120 parts of nitrogen.

To get these high level fertilizers into general use poses difficult problems for economic planning.

Rain-fed rice

The numerous experiments conducted have demonstrated the effectiveness and prospects for a profitable use of nitrogenous fertilizer, applied in relatively small amounts (20 to 40 units), in Senegal, Ivory Coast, Ghana, Dahomey, the Central African Republic, etc. In some cases a phosphate admixture would serve a useful purpose. The use of this mixture has not been generally adopted.

Maize

In the Barre lands of lower Dahomey an application of 30 to 40 units of nitrogen was effective and profitable; but this manner of increasing yield has not yet been adopted in practice because in the soils of greatest degradation a potassium and perhaps even phosphate admixture would be required, which would jeopardize profitable operation.

Ghana, Nigeria, the Central African Republic have had similar experiences with productive formulas.

In Madagascar, by the application of corrective fertilizers, very high yields were obtained on degraded soils which are virtually unproductive without fertilizer.

Sorghum and Millet

In Senegal an NPK mixture in the ratio 14-7-7, applied at the rate of 100 to 150 kilograms per hectare, is beginning to be used. Since these cereal crops find a ready market, the practice is a highly profitable one.

In Northern Nigeria an NP mixture of 24 parts nitrogen to 16 parts phosphorus pentoxide gives promise of profitable use.

Yams

In Ghana, FAO has demonstrated that application of 22.5 parts of each of the three chief fertilizing compounds, nitrogen, phosphorus pentoxide, and potash, increases yield by three tons and would be highly profitable.

Peanuts

In Senegal, NPK formulations of great effectiveness and profit have been in general use for a number of years. A 6-20-10 mixture, for example, applied 150 kilograms per hectare, has produced gains of at least 3,000 francs CFA.

In Upper Volta, in Northern Nigeria, in Niger a fertilizer containing only 75 kilograms of ordinary superhposphate, which is very economical, has gained extensive use. In Niger it was recently demonstrated that the net return can amount to at least 5,000 francs CFA per hectare.

Mention should also be made of the sepctacular results obtained with oil palms when using only a potash fertilizer, and with cotton by means of a nitrogen-phosphorus pentoxide mixture which is not actively coming into general use, as well as results on coffee, cocoa, banana trees, pineapple, rubber, etc. We ask the participants in this symposium to pardon us for the fact that this portion of our survey is very incomplete.

II - Future Prospects of Using Fertilizer in Tropical Africa. Research Priorities

We have emphasized two seemingly contradictory facts of the present situation. On one hand, effective fertilizer formulations are known, but they are little used. This latter aspect requires some qualification. While utilization is still slight, it is not a static situation. On the contrary, we are witnessing a vigorous tendency toward a general use of fertilizers in West Africa, for example, in Senegal, Ivory Coast, in Nigeria, in Cameroon. In other countries we have not reached what might be called the "take-off" stage.

The chief bar to present utilization of fertilizer is an economic one. This is true to an extent where we might feel that the first order of priority is grounded in the economic sphere. It is actually a priority, but what is involved is not so much agricultural research but planning at the governmental level.

In actual fact agricultural research still faces a vast sphere of action, consisting of two aspects:

- Efforts could be directed to making fertilizer mixtures still more economical.

- On the other hand, the results obtained to date which cannot be readily adapted to general use might be consolidated, to render them more convincing, which would induce more governments to establish or perfect the economic organizations that are essential for a more intensified agriculture.

We should like to discuss further here some topics of agricultural research which today appear to us to merit priority.

2.1 - Development of Economical Fertilizer Mixtures Used at Low Level of Application

This involves effective formulations which have not yet been completely proven to afford profitable return. In general, these are NPK or NP mixtures with the elements present in medium quantities. Crop responses to these elements follow the law of less-than-proportional yield increases, so that the reduction of ingredients should take place at that portion of the curve where the slope is steepest, or where the index of effectiveness is highest. It is a well-known fact with nitrogenous fertilizers, for instance, and one which has already been put into practice, inasmuch as the levels which have been generally adopted for cereals are usually small: 20 to 40 units, for example. It is known that higher levels would produce a greater yield but the cost of fertilizer would rise more rapidly than the market value of the extra crop.

Such a reduction of levels may, besides, cause changes in the balance of a mixture's ingredients. For example, the proportion of phosphate cannot always be reduced without serious effects. In view of its property as a fixation agent in the soil, this element loses its effectiveness if it is applied in quantities below a certain threshold. In such cases it becomes necessary either to keep this minimum level up to the effective level for interacting with the other element or else omit phosphorus from the mix. Depending on the situation one or the other course will be adopted. In soils very deficient in phosphorus the first alternative will be necessary, since it is known that nitrogen alone will not be effective, not even with cereal crops. This is true for the tropical soils of Upper Volta, for example. On the contrary, in the hydromorphous soils of very high fixative capacity, nitrogen alone may be effective, but on the other hand it may require a strong phosphate mixture in order to bring out its effectiveness.

Finally, it is often noted with the ferruginous tropical soils of the Sudan-sahel zone that potash has little or no effect. Its omission from a mixture, as in the case of phosphorus, thus makes the formula more economical.

These principles have been widely applied in Upper Volta and in Northern Nigeria, for example, where peanut cultivation is fertilized with only small amounts of ordinary superphosphate. Research of this order is in progress currently in Mali, in Niger and in Dahomey; it has already been determined, after two years of experimentation conducted on a multi-site basis in Niger, that addition of superphosphate only to peanuts brings a much greater return than the earlier use of NPK formulation. The increase in yield amounted to 5,000 francs CFA per hectare.

This type of research is admittedly not very orthodox as far as agronomy in a strict sense is concerned. When crop production is increased by use of fertilizer, nutritive elements are taken out of the soil likewise at an increased rate and with accelerated soil impoverishment in regard to elements not present in fertilizer. However, such a course is warranted in a country where economic conditions are heavily strained, provided it is looked upon as provisional and transitional, which would facilitate the start of a widely disseminated use. In the case of Niger, already mentioned, along with development of an economical mixture based on superphosphate for use on peanuts, research is continuing to determine after how many uears a potash ingredient would have to be provided for. In Senegal the stage of an NPK mixture has already been reached.

This is therefore a field in which research must play its part in a very circumspect manner, since it points merely to temporary solutions such as are often dictated by economic conditions.

2.2 - Utilisation of Local Deposits of Natural Phosphates

African soils are often very deficient in phosphorus; this is the element which is the primary factor limiting plant growth, so much so that when a nitrogenous fertilizer alone is applied it may be ineffective even with cereals.

Yet, West Africa has important phosphate deposits. At Thies and Taiba in Senegal there is tricalcium phosphate and also calcium-aluminum phosphate, and there is tricalicum phosphate also in Togo, Mali, and Niger. The deposits in Senegal and Togo are being mined for industrial purposes and are almost entirely exported.

To put a stop to such an incongruous situation in which countries in great need of phosphate fertilizers for their agriculture mine such deposits on their own territory and to have them exported, two things might be done:

- Utilize these natural fertilizers in their tricalcium form. Research conducted for several years in Senegal, and more recently in other countries, has shown such fertilizers to be effective.

However, extension of basic phosphate application, which would make it possible to remedy this serious deficiency of African soils, has been greatly impeded by the fact that there is no assurance of an immediate profitable return. A farmer would have to make an initial investment of 5,000 francs CFA per hectare, for example, and he would not see a return on his financial outlay until two or three years later when the phosphate, which dissolves very slowly, will have begun to take effect. There is an entire field open to research, vital on an economic level, since it obviously makes more sense to correct a phosphorus deficiency in soil with a local product selling at only 10,000 francs per ton, for instance, than with a much more costly imported phosphate. This is one more research priority whose essential mission is to discover to what extent the natural phosphates can be most quickly put to effective use. Studies are in progress and have already yielded substantial results.

- Convert the natural phosphates into soluble phosphates on the spot. This solution is approaching reality inasmuch as one plant is under construction at Dakar and plans are being developed for other projects. Soluble phosphate fertilizers manufactured locally will, by the way, not entirely displace natural phosphates. The latter would be preferable for establishing a phosphate base in regions of moderate rainfall and for soils having a fairly high fixative capacity, in which case the soluble phosphates would play a role as sustaining fertilizers.

2.3 - Techniques of Fertilizer Application

This is a highly important area of research, because it is capable of affording substantial improvement in the profitability of using mineral fertilizer.

This has to do with the form in which fertilizers should be applied, the best time for spreading them out, the size of granulation, their placing and the interrelated aspects of farming techniques and the kind of crops raised.

Numerous studies have been conducted and should be pursued on a priority basis.

It is already a known fact that concentrated fertilizers are almost always equally as effective as traditional fertilizers, unit for unit of fertilizing ingredients. Thus they are more economical, involving lower transportation costs from ports of importation to the localities where they are to be used.

Similarly it has been shown that it is more advantageous to apply nitrogenous fertilizers in finely divided state on cereal crops in regions of heaviest rainfall.

A possible benefit in placing fertilizer as side dressing has not been sufficiently proved. On the other hand, application in depth is absolutely necessary for crops that are declining.

Various cases of the effect of altering crops on response to fertilizer have been demonstrated (rice-peanuts, etc.).

This kind of research involves factors of substantial difficulty which may be greatly influenced by climate and therefore may change from year to year; still, they are highly important.

2.4 - Fertilization in Crop Rotation

This is a controversial subject, and one which has been little studied.

In the case of annual crops, to date we have looked at the optional economic fertilizer for industrial crops in the rotation; but when two industrial crops are grown in succession, the fertilizer applied to the first can affect, through its residual effect, the optional level of the second. The situation is further complicated by the fertilization of food crops figuring in the rotation.

Similarly fertilizer use in continuous cultivation (irrigated rice for example) results in the problem of cummulative effects and can lead to modification of the formulas applied after a number of years.

Finally, fertilization of perennial crops also warrants more investigation.

2.5 - Fertilizer Mixtures for Restoration of Soil Nutrients

Certain demanding crops (sugar cane, tobacco, etc.) cannot be considered for production unless sufficient fertilizer is used to restore nutrients to its greatest possible productive capacity. If one is willing to shoulder heavy investment costs for creating irrigation and drainage systems, for land levelling, to use mechanization, to build ships or factories for processing crops, it is altogether logical to include the item "fertilizer" in the investment budget. Yet, application of highly effective mineral fertilizer presents problems of pedology in a tropical region. Actually, soils may sometimes offer a rather poor return because of their low exchange capacity, their texture and their low content of organic matter. Leaching out of subsoil in regions of high rainfall may lead to a waste of fertilizing elements. The high fixative capacity of certain soils may dictate, if no remedy is undertaken, the application of phosphates in large quantities.

Research is currently taking place, in Senegal and Madagascar, for example, but much remains to be done. This type of research must be given priority for rice growing, a matter of generally recognized economic importance.

2.6 - Organic Manure

It is a well-known fact that many African soils have, as a result of cultivation or lack of sufficient restoration, deteriorated in the way of a decrease of nutrients or of organic matter and of a ruinous structural degradation. Such deficiency of organic matter is a major limiting factor for agricultural production. Numerous experimental tests have demonstrated spectacular effects of organic fertilizers in the form of manure, for example, when used on cereals.

This is a very old problem which has spurred much research. It is constantly being studied, but no practical solution has been found for the savannah zone.

Mention should be made of research on procurement or utilization of manure, of compost mixtures, of plowing under of vegetable cuttings, of fallowing, and of green fertilizers, of straw spreading and mulching, of feed crops as part of rotation. These studies are frequently complex and difficult, but their importance entitles them to a high place on the list of priorities.

2.7 - Conducting Research on a Regional Basis

We would like to mention here in conclusion merely one important aspect of the organization of agricultural research in tropical Africa. There are large ecological regions extending often over several countries where problems display a striking similarity. Use of nitrogenous fertilizer on cereals, phosphate treatment of soils having a strong fixative capacity, restoration of the organic composition of soils of grassland plains, to mention just a few examples. The solutions which might be found to these problems in a certain well-equipped country would certainly be of value for other countries in the same zone. It would seem therefore that it would be advisable to coordinate efforts and organize research on an inter-country basis. This aspect is the subject of close study currently in various countries of tropical Africa.

In conclusion, a survey of these various topics of agricultural research which appear to us as having priority and which are already under study, indicates that there exist today limitations due to economic factors with which compromises must sometimes be made. However, there must be hope that these conditions will improve and that it will be possible to work toward a more intensive agriculture. This is the reason why research prog-programs must henceforth take account of this possibility.

IMPROVING CROP PRODUCTION WITH FERTILIZERS IN EAST AFRICA

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SUMMARY

Agronomic evidence in East Africa shows that the extended use of fertilizers by farmers will provide for the increased economic production of both food and cash crops.

Agronomic work in the past has frequently been inadequately supported by data defining soil type, by a lack of soil and plant analysis data and by information on available soil moisture during critical growth periods. Without this supporting data it has proved to be extremely difficult to extend the results of fertilizer trials to provide a quantitative basis however crude, for advisory/extension work.

Reference is made to some of the agronomic work now going on in East Africa, though it is not claimed that this information is complete. In only some cases is all the necessary soil and plant analysis data being obtained so that the results can be evaluated to provide a basis for advisory work on an extensive scale.

It is recommended that a survey and summary of all fertilizer trial work carried out in East Africa post-1945 could make a very important contribution to present fertilizer use and would serve as a sound basis for future work.

A project proposal for obtaining calibration data on a regional basis was put forward in 1966, one crop at a time, and is described briefly. Although the proposal has been accepted by all three National Governments it has not been possible to implement it effectively to date. It is inferred that an injection of external funds would probably go a long way towards solving the problem.

Finally, other research subjects that have National Government approval as part of the EAAFRO program are referred to briefly. Particular note is taken of soil sulphur and it is pointed out that a study of the factors responsible for reduced yields following the late planting of annual crops is worthy of study in the author's opinion.

INTRODUCTION

There is a large body of evidence from agronomic trials carried out in East Africa over many years to show that the yields of a wide variety of crops can be increased substantially by the user of fertilizers (e.g.

8,1,4,13). Many agricultural crops in East Africa respond to the application of nitrogen and phosphorus, a few respond to the application of potassium and less again to the application of magnesium. There is very little information relating directly to sulphur responses in the field and no general evaluation of the micronutrients status of East African soils has been carried out to date.

Much of the field trial work with fertilizers in the past has been carried through without the essential information of soil type being recorded on a uniform system, and without either soil or crop analyses. Where these analyses have been carried out, many different methods have been used and no central record of the information has been kept. The net result is that data relating to particular crops on which even a crude evaluation of soil fertility and fertilizer use could be based, is largely lacking.

There is an urgent need for soundly based, locally derived, calibration data relating soil analyses and crop (foliar) analyses to basic yield and yield responses to fertilizer(s) for specific crops. Unless and until this type of information is available there can be little effective and general extension of economic fertilizer use to the farmers in East Africa. The Advisory Officer when visiting a farm must know that he can take soil and/or crop samples, submit them to his national laboratory for analysis and obtain valid information on (1) the nutrient(s) that are in short supply and (2) the recommended form and a guide to the rate, of fertilizer application that could be expected to produce an economic return for that crop in an average rainfall season.

The Present Position

There is little published data available in East Africa that has been obtained by work with particular crops in the region relating soil and plant analysis to crop yield and fertilizer responses. In Uganda work has been carried out on Robusta coffee (2) and is currently going on for a number of important annual crops - cotton, maize, groundnuts (4). In the latter case, relationships between crop yield, crop response and fertilizer use are being evaluated in terms of soil analysis and to a less comprehensive degree, in terms of plant analysis. Similar work is also being carried out in Uganda with sorghum and millet.

In Kenya there exist excellent facilities for the chemical analysis of advisory soil samples (7) and large numbers are put through each year. The basis for an interpretation of the results in terms of shortage or deficiency and the recommendations for rates of fertilizer application are largely based on local field experiences and on theoretical considerations of the levels and ratios of nutrients derived from work outside the African continent (5,6). There is a serious lack of calibration data relating soil/plant analysis to yield and fertilizer responses for specific crops which greatly reduces the practical value and application of these soil analyses. Work is currently being carried out in Kenya to relate maize and cotton responses to fertilizers and soil analysis

data, the former in collaboration with the Chemistry Division, E.A.A.F.R.O., but there is much less plant analysis work being carried out.

Recently, extensive field trials have been carried out with maize in Western Tanzania over three seasons, and the results from trials measuring yield and response to fertilizer have been related to soil organic carbon and total nitrogen (14) to a soil nitrogen index (12,13) and to other soil analysis data (22). Soil analyses figures are used quite extensively in the sisal industry in Tanzania for basing advice on fertilizer treatment of this crop (12).

Tea research is undertaken on an East African basis by the Tea Research Institute, Kericho, Kenya. Currently, use is made of soil pH data for the selection of suitable tea soils and research is now being concentrated on the use of leaf analysis as a guide to fertilizer application.

Proposals to extend fertilizer use in the future

The assumptions are that if we in East Africa wish to increase crop production by the more extensive and accurate use of fertilizers by the farmer we need, broadly speaking:-

(a) to gather together and process (by computer) all fertilizer trial data in East Africa obtained after 1945. This information would provide a very useful basis for the calibration project referred to below, as well as being a highly desirable, even necessary, job in its own right. This data would be invaluable to all future investigations with fertilizers as well as strengthening the immediate position in this field.

(b) Calibrate soil/plant analyses with yield and yield response to fertilizers for individual crops on a regional basis. It is recognized that initially the calibration levels could only be crude, say into three to five categories, and that it would cover only the main ecological crop areas and main soil types. Further refinement of the relationships is envisaged for particular crops as a later development at the national level; one which would also include small areas of unusual or special soils or climate outside the main areas.

(c) To pursue the lines of investigation put forward by Dr. Dagg at this Conference (3) since this type of work should go hand in hand with the use of fertilizer for optimum economic return.

If the calibration work could be undertaken on an East African basis, at least for the common annual crops, a greater return to all three countries is possible from a reduced expenditure of money and manpower. Furthermore, by using standard statistical layouts for trials and standardized methods of soil and plant analysis, centralized data processing would be possible through the Statistics Division at E.A.A.F.R.O.

Such a proposal was put forward in 1966 (17) and subsequently working details and field trial layouts were prepared (18) on the basis of a meeting of research workers from all three countries. They discussed the practical details at considerable lengths. The proposal was concerned with NPK or Mg factorial fertilizer trials, with standardized soil analysis, and leaf analysis (20) for the elements N, P, K, Ca, Mg, and S. Rates of fertilizer application were chosen on the basis of available knowledge for an area or on inferred fertilizer rates related to soil and climate. Rates were varied for two general climatic classifications, 'high' and 'low' rainfall, with the maize crop which was given top priority. One other factor was included, that of daily rainfall records on each site. This was done to enable running soil moisture deficits to be calculated for the crop period. In this respect certain physical measurements of site profiles would also be undertaken.

To allow for different methods of soil analysis to be compared, National Government Laboratories were encouraged to carry out analyses by their own methods. It should then be possible to use the technique developed by Dr. Crowther (23) to evaluate the different methods.

Other crops noted in order of priority were groundnuts, wheat and phaseolus beans. A similar approach has been outlined for the coffee crop in Kenya (19) and a pilot scheme along these lines was undertaken in Tanzania over a 4 year period.

The project has now been approved but unfortunately none of the required capital or recurrent finance that was budgeted for has been obtained, except the generous supply of fertilizer requirements from a number of European fertilizer manufacturers/suppliers and an East African firm.

With the project now active within existing resources, progress to date has been disappointing. It has been necessary to abandon the laying down of permanent Bench Mark Trials and concentrate on the simple, seasonal Extensive Trials. To date, 12 of these trials with maize have been started in Southern Tanzania; none will be possible in Kenya and it seems unlikely that any will be laid down in Uganda, during 1968.

The F.A.O. Freedom from Hunger Fertilizer Campaign in tropical Africa is similar in principle though on a much larger scale. The scope and progress of this program has been described (9,10) and results from Ghana, Nigeria and Senegal summarized (11). There is little doubt that provided there are adequate supporting services for soil definition, soil and plant analysis and on-site weather records, this method of extensive simple factorial trials on farmers' land will provide data on which to base an increased national and economic use of fertilizers by the African farmer. It has been our experience in East Africa that even within soil types there is considerable yield variation, often as large as between soil types (21); in our experience also with a reasonable level of field supervision, complete yield and analytical data may reasonably be expected from two thirds to three quarters of the total number of trials laid down (15).

Despite general approval of the project within East Africa it appears unlikely that it will be possible to put it into operation on a co-ordinated regional basis. National governments will continue to carry out local fertilizer trial programs on specific crops and international and national aid donors will continue to finance national projects of a similar nature on particular crops. Judging by past experience this will not be the most effective way of obtaining the necessary calibration data with which to build a sound technical advisory service and so extend substantially the economic use of fertilizers by the farming community on a national basis.

Other Future Research

In conclusion it might be relevant to refer to other research subjects under the heading of Soil Fertility and Plant Nutrition that are accepted by the national governments for investigation by E.A.A.F.R.O. in the future. These include:

(i) an investigation of the micronutrient status of agricultural soils in East Africa.

(ii) a study of the contribution of soil organic phosphorus to crop nutrition.

(iii) an investigation of the sulphur status of agricultural soils in East Africa.

(iv) soil potassium status of agricultural soils in East Africa.

Subjects 1, 3 and 4 could be facets of the calibration project referred to earlier, with considerable advantage to all concerned. The question of sulphur is important because of known deficiency areas and soils in East Africa and the shift towards the use of sulphur-free fertilizers, i.e. calcium ammonium nitrate (shortly to be manufactured in Kenya) in the place of both ammonium sulphate and ammonium sulphate nitrate, and triple superphosphate in the place of single superphosphate.

Another important subject for study, is an investigation of the reasons for poorer crop yields with late planting. This is a general phenomenon, common to many soils in tropical Africa. We do not know why yield falls off; we do know that soil nitrogen is not the whole answer as has sometimes been inferred in the past.

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PROBLEMS TO BE INVESTIGATED FOR THE EFFICIENT USE OF WATER IN IRRIGATION IN EAST AFRICA

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SUMMARY

Although the permanent rivers in East Africa provide adequate water for the present acreage under irrigation, future expansion will not be limited by lack of suitable land, but by shortage of water. Efficient use of water in irrigation does, however, raise a number of problems which require urgent investigation.

a) It is not only necessary to select crops which will give maximum economic yields, this choice must also take into account the staple food of the people concerned. The management of a cash crop and a subsistence crop at the same time is bound to reduce water-use efficiency in irrigation schemes.

b) Proper control of irrigation water requires judicious siting of the residential areas within irrigation schemes and better understanding of the water requirement of different crops in all stages of growth and in different environments. Supplementary irrigation of rain-grown crops by individual farmers should be gauged against the general water needs of the community.

c) There is a great need for soil data which can be used in planning irrigation.

d) The problems of mobility of labour and the design of suitable labour-saving machinery should be given greater attention.

INTRODUCTION

Agriculture is likely to remain the main source of revenue for the East African countries for a long time to come. The majority of the population are also entirely dependent on subsistence farming for their food, and are therefore particularly susceptible to sudden famines whenever the little and markedly seasonal rains fail. With increasing pressure on land in the relatively few high-rainfall areas, attention is rapidly turning to the possibility of opening the large tracts of semi-arid river basins for irrigation settlements. This is not a new idea, since some irrigation schemes have been in operation for at least ten years; what is new and will increase in importance in East Africa is the realization of the large excess of potential evaporation over rainfall and the need for application of scientific research for efficient utilization of water in irrigation. Permanent rivers

flowing from high-rainfall forests have to date proved sufficient for most irrigation concerns, and research in progress is aimed at ensuring that these rivers are not adversely affected by changes in land-use within catchment areas. As the acreage under irrigation increases, however, water will become a limiting factor to expansion and greater water-use efficiency will be required.

Problems Associated with Choice of Crops

The first requirement is knowledge of maximum economic return from the irrigable crops in a given area. In East Africa, even in agriculture under normal rainfall conditions, the indigenous farmer cannot afford to experiment and will insist on assurance of a constantly higher income from any extra effort or expenditure he is advised to make from his limited resources. This requirement becomes even more important when the farmer is asked to surrender individuality and a large measure of freedom and to live in a completely different community under the strict discipline necessary in an irrigation scheme. More study should therefore be devoted to finding out what increases in income can be guaranteed and are likely to influence the farmer to co-operate in making irrigation more efficient by working full-time on the allotted piece of land. Agricultural food production is one of the natural systems in which incoming solar energy is partitioned and the areas where irrigation is practiced in East Africa are characterized by many hours of bright sunshine - one of the main reasons why they are dry. Although a great deal can be done to improve yields, and hence water-use efficiency, by choosing high-yielding varieties and better use of fertilizers, it may also be possible to raise the efficiency of energy fixation in photosynthetic production in agriculture through better choice of crops, plant breeding and changes in agronomic practices. Such simple things as optimum spacing between plants in the hotter climates can be quite different in the cooler climates and should therefore be investigated from the point of view of light interception in the canopy as well as the relative effects of soil moisture characteristics and soil fertility.

Selection of crops to be grown in an irrigation scheme must take into consideration the staple diet of the people concerned, and adequate provision made. This factor alone can mean the difference between success and failure in finding - and retaining - good tenants for an irrigation scheme in East Africa. The maintenance of a large family and dependents in the average East African homestead requires that the family be self-sufficient in at least one basic staple food, e.g., maize in Kenya, and in many cases a few cattle, sheep or goats for milk. The average tenant is therefore so used to subsistence farming under conditions of reasonable rainfall that he finds it difficult to adjust to a cash economy when he moves to the drier climates where these requirements cannot be satisfied easily. Thus at Mwea Irrigation Settlement, Kenya, the average annual income per tenant is about £140 from rice sales. But only a small fraction of this income is available to the family in form of food and there is considerable anxiety and hunger among

the tenants whenever their rain-grown subsistence crop of maize fails, no matter how much rice is harvested in the season. There is, therefore, considerable wastage of maize seed planted each year in desperate attempts to grow two crops a year in an area where even one crop is hardly possible. Attempts to restrict cattle are also bitterly resisted on the grounds that tenants cannot afford to buy milk for their children.

Problems Connected with Water Control

Control in the distribution of water within the irrigation scheme is necessary to reduce loss of water through seepage and evaporation and to save labour costs in the maintenance of canals. Preliminary indications on the 1965 crop at Mwea Irrigation Scheme, for example, show very considerable reduction in water use through better control and indeed it may be possible to irrigate a much larger area from the same water supply without building expensive storage reservoirs. Control of this nature is, however, difficult where tenants depend on the same water supply for domestic use and the problem must be solved when initially siting the residential areas within the scheme.

The method used by Pereira (1957) to estimate water balance in coffee plantation could be used very effectively to control irrigation under conditions of limited water supply. The data collected so far for maize in East Africa suggests, however, that the relationship between open water evaporation and crop transpiration is not only a crop factor, but also depends on the frequency of watering in relation to the macroclimate of the area. This method, however, is very promising and maps of potential evaporation and rainfall reliability will soon be available in East Africa. More intensive study of water-use efficiency of individual crops in all stages of growth and under different climatic conditions is therefore required and since there are relatively few places where this can be done, the problem of applying the results in different environments requires careful investigation. Little is also known about the quantitative relationship between soil moisture and fertilizer application on one side and yield on the other.

Supplementary irrigation of rain-grown cash crops and vegetables by individuals is on the increase. Since this usually means tapping the rivers before they reach the major irrigation schemes, a well organized study is required so that rainfall reliability and the importance of such supplementary irrigation can be viewed against the general water needs of the community. In the absence of this control, enthusiasm of some farmers to irrigate land for vegetable production in the dry season has led, in a few cases, to periodic water shortage for farmers and population downstream.

Problems Connected with the Soil

The present lack of detailed physical and chemical soil survey data in East Africa is a serious handicap in designing irrigation for maximum water-use efficiency and for safeguarding the soil against

salinity and other problems likely to result from bad management. Soil fertility may also present problems where maximum efficient use of water, labour and equipment can only be achieved by almost continuous cropping. Thus, poor yields from the second crop of rice a year has discouraged the extra effort involved at Mwea Irrigation Scheme, and fields have to be left idle for half the year.

Labour Problems

Efficient use of water in irrigation requires timely performance of all farming operations. In East Africa, irrigation settlements are usually isolated many miles from the densely populated areas where labour is in good supply. The members of the family have therefore to work on the land, but since children go to school and farming operations must be synchronized within the scheme, the tenant has at times great difficulty in finding extra labour which he can only afford to keep for limited periods. Mobility of labour and the design of labour saving machinery suitable for the small farmer should therefore be given greater attention.

Conclusion

Efficient use of water in irrigation requires not only the proper choice of crops, tenants and proper planning, but also the education of the farmer to appreciate the need for water conservation and the effect his actions have on increasing food production and the general welfare of the community. A lot of research is therefore needed in finding out how best this can be achieved in different communities, and above all how the information can be conveyed to the farmer in a language he can understand.

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ORIENTATION OF RESEARCH ON WATER MANAGEMENT AND USE IN AFRICA

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SUMMARY

Hydro-agricultural projects are one of the technical means that can be used to develop agricultural production. But the rational concept of the projects and the optimum utilization of these involves determining certain basic data which until now is often badly known.

It is therefore necessary to initiate some research project of which the most important should deal with:

- evaluation of water needs by plants
  - Measurements of evapotranspiration , for reference, in tanks sown with grass
  - Measurements of actual evapotranspiration in cultivated plants, by means of evapo-transpirometer and in open field
  - Seasonal variation of requirements, critical phases
  - Influence of rationing
- study of hydrodynamic characteristics
  - Comparison of results obtained in the field and in the laboratory
  - Relationship between granulometric composition and hydro-dynamic characteristics

This research can be conducted at the level of large regions with rather homogeneous climate by means of networks of stations. Other more specific research will require the setting up of stations that are not part of a coherent whole.

INTRODUCTION

In order to feed a rapidly growing population African must develop its agricultural production.

In many important regions, however, water resources are a limiting factor of that production since they are insufficient in quantity or because their distribution in time is incompatible with a rational

agriculture. Even in these regions having relatively high rainfall there is no protection against the effects of temporary moisture deficiencies. The technical means to overcome these shortages is the development of hydro-agricultural projects, and more and more of these projects can be seen to be developed in this area.

However all too often the necessary data for appropriate orientation of the studies is not available to the experts in charge of designing the projects. Under those conditions it is very difficult for them to obtain rational utilization and optimal evaluation projects.

Part of this data, as we will see, is not the responsibility of the engineer but of other specialists: for example, the ability of the population to utilize the new technical means put at its disposal. In the paragraphs that follow only those fields of research of a technical or techno-economic nature are mentioned. We have voluntarily limited our list to the engineer's field, but he has to realize fully that the success of any of these projects depends on other factors, especially social factors.

I. BASIC DATA TO BE DEFINED

In order to conduct a rational study the project designer must have the following data as applicable on the scale of the area to be transformed.

- water requirements of plants to be cultivated: total needs, distribution in time, possibilities of rationing.
- hydrological, hydrogeological and climatological data, that will enable him to evaluate the water resources and the drainage possibilities.
- soil (growing aptitudes) and hydrodynamic (irrigation and drainage aptitudes) characteristics.
- parameters and cost price of the different irrigation systems. Drainage possibility.

In other areas there can be also particular problems that need special research high salinity soils for example.

We shall examine now the research to be undertaken in order to obtain the above mentioned data.

II. RESEARCH TOPICS

1) Water requirements

1 - Systematic compilation of meteorological reports, attempting to collect the parameters used in the different evapo-transpiration formulas.

2 - Measurement of evapotranspiration, for reference, in grass sown tanks. Selection of reference plant.

3 Validity of classical forumulas: eventual adaptation.

4 - Measurements of actual evapotranspiration in cultivated plants

5 - Distribution in time of water needs - critical phases.

6 - Influence of water rationing on yields.

7 - Drought resistance of cultivated plants.

8 - Study of production systems and growing procedures bringing economy in water-use.

9 - Economic study of increases in production and income obtained through irrigation.

2) Water resources - Drainage

1 - Systematic compilation of hydrological or hydro-geological reports: rivers' flow, level and volume of water-tables, in areas under study.

2 - Comparison between needs and resources: eventual creation of reserves.

3 - Together with the study of the rivers' flow, study of drainage conditions, eventual influence of irrigation on water-table behavior, drainage opportunity.

3) Soil science: hydrodynamic characteristics

1 - Classical soil studies: cultivation characteristics of soils.

2 - Study of hydrodynamic characteristics: rapidity of filtration, coefficients of retention and wilting, available water, useful reserves, easy used reserves. Comparison of results obtained in the field and in the laboratory.

3 - Determining irrigation quantities and time of application.

4 - Determination of the relationship between granulometric composition and hydrodynamic characteristics.

5 - Evolution of soils under irrigation.

6 - Farming procedures that permit the improvement of the physical moisture and hydrodynamic characteristics of the soil.

4) Irrigation systems and their parameters

1 - Comparative study of irrigation systems better adapted to soil and climate conditions, crops to be planted and the technical competence.

2 - Determination by means of the method selected of the parameters conditioning the use of water to the plot (i.e.: length of furrows, water and maintenance flow, amount delivered by sprinklers, etc.)

5) Specific research problems

1 - Water needs of rice paddies

What is needed is:

- to try to establish standards to estimate water needs both for new projects to be developed and for a better utilization of existing ones.

- to study possible water economies by using appropriate farming techniques.

2 - Utilization of halomorphous soils and brackish waters

- study and classification of coastal forests and muddy soil, setting up desalination and utilization techniques.

- reclamation of continental soils containing salt.

- use of brackish waters for irrigation.

III. SITE OF RESEARCH

Some of the above mentioned research can only be conducted in the field (i.e.: 3.1, soils study - 3.2, study of hydrodynamic characteristics).

Others can be regionalized and conducted in specialized stations, at the level of large regions sufficiently homogeneous

both as regards climate and soil

For example, for the sahelian and try tropical regions a network of stations could be established following a West-East axis, going from the Senegal delta to the eastern shore of Lake Chad.

Certain particular problems that go beyond the scale of the isolated perimeter are of interest only for much more limited zones and will require the estabiishment of stations that will not be part of a coherent whole.

IV. ORDER OF PRIORITY OF THE RESEARCH

It would seem logical to try to define the amount of water to be distributed and the reception capacity of the soils for that water, before getting concerned with the way in which such water will be distributed and utilized. It is that spirit that the following order of priority has been established for research of general interest to be conducted at the stations.

1 - Water needs

1.1. Compilation of meterological reports.

1.2 Reference evapotranspiration

1.4. Actual evapotranspiration of cultivated plants.

1.5. Distribution in time of water needs.

1.6. Water rationing.

3 - Soil Science, hydrodynamic characteristics

3.2. Study of hydrodynamic characteristics, comparison of results obtained in the laboratory and in the field.

3.4. Search for a relationship between the granulometric composition and hydrodynamic characteristics.

SUGGESTIONS FOR RESEARCH IN SOME PROBLEMS RELATED TO WATER RESOURCES DEVELOPMENT:

G. Dekker, E.C.A.

SUMMARY

While some research relevant to the development of water resources has been undertaken, there is need for research in certain problems. The paper describes in short the need for research in the following problems: efficiency of irrigation, evapo-transpiration from swamp areas, impact of providing water on human welfare in West Africa, and mechanical and biological control of water hyacinth and bilharziasis.

INTRODUCTION

Examples of research related to water resources development undertaken in the recent past in Africa are the work of E.H.A.F.R O. in East Africa in respect of the effect of land use on river flow, and the work undertaken by O.R.S.T.O.M. in the so-called "experimental basins" in West Africa. Recently research has been initiated in the problems posed by man-made lakes (Kariba, Volta, Nasser and Kainji lakes). In East Africa a research program has been set up to investigate the occurring droughts and their impact on human welfare.

In the following I should like to mention in short a few subjects of research which, in my opinion do not yet receive sufficient attention. Two subjects are specially of importance to the development of international river basins although they are relevant to other river basins. The third subject concerns the effect of rural water supply on human welfare, while the last subject is related to the control of harmful water-related forms of life.

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The African continent contains fifty-four international river basins; that is, river basins in which the main stem or one of its tributaries crosses or constitutes an international border. A number of these river basins are relatively small, but fifteen basins cover more than 100,000 sq. km. each (Senegal, Volta, Niger, Ogoue, Congo, Cunene, Okavango, Oranje, Limpopo, Save, Zambezi, Ruvama, Juba, Shebelle, Nile). Only international cooperation will enable the full development of the resources of these river basins to take place.

The last few years have witnessed much progress in respect of institutional arrangements between states to co-operate in the study of certain river basins and in the development of their resources.

Examples of basins where such co-operation has occurred are the Senegal, Niger, Lake Chad, Gambia, Mono and Nile basins. In these basins hydro-meteorological observations are being co-ordinated, and in some of them a river basin commission set up by the Governments of the countries sharing the basin is charged with the co-ordination or the preparation of plans for the development of the water resources. There are two subjects which are in need of more attention, and further successful research concerning them could help much in practical river basin planning, especially of those rivers which run through semi-arid and arid areas. The first one concerns the efficiency of irrigation. While agriculture in the semi-arid areas of Africa is still usually rainfed, agricultural production in the arid zones is generally dependent on water from rivers which originate in the more humid parts of the continent. Some rivers run through semi-arid areas where water demands for supplementary irrigation or for irrigation for double-cropping may be expected to increase with the extension or intensification of agriculture. It is realistic to expect that in a few years water supply will be insufficient for the demands in several river basins. If more effective ways to use irrigation water can be found more land can be provided with the available water. Research should perhaps be undertaken in several directions. Large losses of water through infiltration in irrigation canals are experienced, and cheap methods should be found and tested for the prevention of seepage. In certain areas this should have also the advantage of lowering the ground water table. More studies should be undertaken into the water needs of appropriate crops during the various stages of growth. Further investigation is required in regard to the yield response to water supply and its implication for potential water saving where the advantages of larger irrigated areas might more than compensate for yield losses from a reduction of water supply. These problems are of course narrowly related to the economics of farming and collaboration between irrigation agronomists and farm economists would be required of course.

A related question is the relative efficiency of rainfall and of irrigation water under different farming practices. Supplementary irrigation is often considered for those semi-arid areas where failures of rain sometimes causes sever crop reductions or even failures. Varieties of crops which are more drought resistent might be a more economic solution than the construction of often very expensive irrigation schemes and it is suggested that there should be more research on drought-resistant varieties.

The second problem concerns evapo-transpiration from swamps and from large surfaces covered with floating water weeds. What will be the effect on the useful water yield from the basin if such a swamp or weed-covered lake is drained or by-passed by a canal, or if the lake is cleared by weed-control measures? There is much contradiction in the existing literature in the evapo-transpiration of such areas. In the sahel-sudan belt and in the mountainous areas in east

and central Africa there are many lake and swamp areas, and several proposals have been made for their drainage and reclamation, in order to increase the area of cultivable land or to increase the quantity of water available for irrigation. A more precise understanding of evaporation and transpiration from areas wholly or partly covered by water needs would be more helpful for the planning of the development of the water resources of several large and small river basins.

In the past decade a large number of water points (wells, boreholes and small barrages) have been constructed in the Sudan-Sahel zone of West Africa. Much money has been spent on providing rural areas with water and the countries and aid-agencies concerned have made provisions for further investments in this field. Although in the countries in this zone ecological and socio-economic conditions are often similar, no common policy is being followed regarding the design of the network of water points, their management, etc. Even within a country the approach to the development of water points often depends more on the views of the provincial administration concerned or that of an enthusiastic technician than on a rationally established policy guided by past experiences and sociological studies.

In respect of water points for cattle, varying principles have been followed regarding their location and spacing. As regards the water supply for domestic use in rural areas, the technique involved (borehole, dug well, small barrage) has depended of course partly upon the local conditions, but even in these cases there is much variety of construction and operation practices. Also, some water points have been conceived only for domestic water supply purposes, while elsewhere other uses have been envisaged, such as cattle watering and small scale irrigation of fruits and vegetables for village needs.

As mentioned above, it can be expected that in the near future much more money will be spent on establishing water points in the rural areas. A sound policy regarding their location, construction and operation is therefore highly desirable. It is time to undertake a study of the socio-economic results obtained with water points established in this zone during, say, the last ten years. Such a study should help greatly to define more sharply the policy to be followed with the design and the management of networks of water points in these rural areas.

As a last subject I should like to plead for more research regarding mechanical and biological control of water weeds and waterborne diseases cuch as bilharziasis. There is no need to dwell on the harm done by water hyacinth and bilharziasis and the necessity for their control. The questions is one of how to control. Chemical methods of control are at present generally practised, but I wonder if it is not time to try to find effective alternative methods. I know of a river basin in an endemic malaria area where irrigated agriculture is practised and where, unfortunately, bilharziasis occurs and where recently water hyacinth was noticed. Cotton is a major irrigation crop.

The Government is undertaking a malaria eradication action in the area. Chemicals are being sprayed or distributed otherwise in the basin for the control of malaria, bilharziasis, water hyacinth and cotton pests. It should be possible to find improved non-chemical means for the control of at least bilharziasis and water hyacinth.

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FARMING SYSTEMS - RATIONAL USE OF WATER

R. Sordoillet, SATEC

SUMMARY

1. Place of hydro-agricultural projects in agricultural development operations

2. Value of hydro-agricultural improvement operations

3. Dependency

4. General problems

5. Specific problems

   5.1 - of agrarian structure: farming methods
   size of farms

   5.2 - land-tenure

   5.3 - water management problems: development projects
   maintenance of projects and equipment
   recuperating costs

   5.4 - agricultural exploitation: mechanization
   second crop

   5.5 - development

6. Future of these operations

   6.1 - their limitations
   6.2 - their priorities in rural development programs
   6.3 - special cases
   6.4 - future prospects

* * *

1. All agricultural development operations have:

   - the same goal: to develop production significantly on a countrywide level, improve the socio-economic conditions of the farmers

   - same basic means:

     - application of selected technical principles

- integrated activity providing the inputs and outputs of technological action
- a structure or operational framework

If they act upon the three factors which make up agricultural activity--the land, man, produce--they are distinguished by the dominant mode of their intervention, which gives them their final characteristics, and at the same time their possibilities and their limitations.

Hydro-agricultural development operations take man into consideration as well as the produce, but they may also affect the land, which means water management.

These operations deal with basic rearrangements and development that differentiate them: they are very localized, not very extensive (a few thousand or tens of thousand hectares) involve basic investments. In addition, they have a basic characteristic of controlling water, more or less completely, which tends to industrialize agriculture by eliminating the main climatic hazard and by restricting the work factor. This is probably why these operations are so desirable; it is also the key to their dependency on other factors.

2. Value of hydro-agricultural projects

In general, the water supply of the African regions is in imbalance regarding the needs of men, their beasts, and their crops. The contribution of water management to agricultural development is beneficial for several reasons:

- it increases the volume of production by increasing yields and eventually the area cultivated when water is the limiting factor. Thus there is increased value added to the profit of the farmer and the country as a whole;

- by doing away with the problem of drought it makes it possible to diversify production;

- it improves rural employment in a region where jobs are always insufficient; it does this on the one hand by intensifying cultivation (plants with longer cycles, application of fertilizers) and on the other by making a second crop possible during the dry season.

- it gives value to the natural land and water resources which would otherwise not be utilized or would be underutilized. This is particularly important when land becomes scarce due to a marked increase in population density.

- finally, outside the economic domain, it greatly contributes to the development of the rural world, by tying agriculture to the soil and requiring intensive methods.

In short, the advantages of the industrial model are:

- matters are not left to chance
- more continuous production process
- control of the work factor
- and, to a certain degree, intermediary between dry agriculture (especially shifting) and the industrial complex, spatial concentration.

3. But in a general way, the hydro-agricultural enterprise has also two types of dependency of its industrial model.

First, it is dependent upon economic and financial profitability: Because it costs a great deal, it must bring a high return on capital invested. Profitability is measured in terms of cost benefit and is a multiple dependency: it eliminates the overly costly sites and projects, it requires intensive farming with best possible use of resources, and it also requires regular, steady commercial outlets.

Besides, one must see that irrigation water is not merely an additional factor which is added to the previous agrarian system; irrigation requires changing the farmer's mentality, by plunging it into a high productivity system. In truth, and in spite of the indispensable organization and training programs, the farmer finds it exceedingly difficult to adapt to an irrigated environment: new crops, supplies, methods, marketing, capital, etc. Experience has often pointed up the following dilemma:

- either the farmer pays his debts but finds that he is working more and earning less;
- or he does not pay his debts, either by default or because he is partically exempt from doing so by governmental subsidy, and he finds himself living on unearned income.

When the system attains its most complex form, you have an agricultural wage-earning class.

Here the difference between "economic growth" and "rural development" must be re-emphasized. When they lead to capitalistic exploitation and a wage-earning system, irrigation systems and operations are instruments of economic growth, just as industrial establishments are. They only contribute to rural development, as we noted above, in the case where they are sufficiently simple so as not to cause the traditional system to collapse entirely, that is, where they allow the farmer room to adapt himself "from within".

4. In like measure as development operations concentrate on man and goods, they become involved in problems similar to those faced by mass extension projects:

- choice of technical themes, mode of application according to the land tenure system - extension;

- integrated and related activities: supply, marketing, and credit;

- training of extension agents;

- technical assistance.

At the most, things are made easier by the geographic concentration of the elements of production. It can also be noted that extension arrangements can take advantage of the compartmentalization of irrigation projects.

5. Specific problems are introduced by the preparation of the site:

- agrarian structure problems
- land-tenure problems
- technical development problems
- agricultural exploitation problems
- management problems

5.1 Agrarian structure problems come first. Two preoccupations:

5.1.1 Type of farming

On the one hand, necessity for intensive farming and restraints on water utilization, and on the other hand, rudimentary technological know-how and the extremely limited capital of the farmers, lead to a variable system of concentration of means and responsibilities in a cooperative, collective or free enterprise framework.

The following systems can be found:

a) individual farm, helped by service cooperatives--problem of development of cost schedule and sticking to it;

b) farmers more or less closely associated with the governmental or quasi-governmental development agency or organization which guarantees certain loans (both credit for purchases and against harvests). Under this mixed system, it is difficult to determine which tasks should be done by the agency and which tasks should be left to the farmer;

c) self-management, complete production cooperative: common sharing of land, work, and means of production. The main problem here is to keep up the interest of the workers;

d) operation managed directly by a State enterprise, paying salaries to the agricultural workers. (The sugar-development projects of certain African countries might well be organized in this way.)

No matter what their particular problems are, all these systems have certain restraints in common (obligatory membership in a cooperative, cost schedules, etc.) which are the necessary evils of the needed intensive farming of controlled and developed land.

5.1.2 Size of farms (for types a and b)

An economic criterion, desired income per family, is generally used to determine the size and type of farms. Nevertheless, in certain economically depressed areas, it may be a matter of setting up the greatest number of families possible to which a minimum standard of living can be guaranteed. The social problem is then the dominant factor.

5.2 The land-tenure problems are different in the two following cases:

- if there is a property transfer: purchase, division into lots, or sale: the main problem, which will not be developed here, is the purchase of land at a price more or less equal to its use-value within the framework of the planned project land allocation;

- or there are customary rights, and this is the case for most African countries. Some African countries (Madagascar, Senegal) have settled the problem, at least on a legislative level, in the following manner: if it is a question of setting up small farmers (family-type farms), abolishing customary rights in favor of the state makes it possible for the state to prepare and divide up the land. During the preliminary selective process, first choice is given to the farmers who have been working the land. The contract does not give ownership of the plot to the peasant, or it gives him only long-term future ownership. On the other hand, he has security of tenure as long as he lives up to the terms of the contract. If it is a matter of setting up an agro-industrial project, the management agency (or office) is a State or semi-public company, to which the State, the owner, lends the developed land under certain conditions.

5.3 Management problems are linked mainly to the site chosen:

- valleys and deltas of rivers with seasonal inundation
- valleys of rivers and streams with permanent water flow in the humid zone
- thalwegs with seasonal flow in the Sudan-sahel zone
- coastal marshes
- underground streams, not too deep

Setting up the projects and the work itself generally do not pose many problems.

5.3.1 It nevertheless seems appropriate to invoke two concrete problems at this point:

- obtaining the participation of the would-be users in the building of the project, in the dual objective of reducing the cost and making the future users interested in the project, and familiarizing them with all its aspects and the complementary means that can be put at their disposal (Maintenance, adapted devices, etc.)

Generally speaking, in this domain an effort should be made to simplify the work, use manual labor, and utilize local materials.

- adapting the projects and their cost to the know-how of the users and the gross value of farming engaged in.

5.3.2 Maintenance:

- by the office, against taxes
- by loans in kind
- or by both

5.3.3 Recuperating the outlay:

- depreciation of the projects
- upkeep costs of the projects
- production costs

Paying back these costs is one of the first points on the cost schedule. Nevertheless, the best way for the office to recouperate these outlays is to collect it in kind, in goods of all types, or to control the sale of the goods.

5.4 Agricultural problems stem from the desire for intensification. Two principles:

5.4.1 Mechanization: along the perimeters of the improved areas, mechanization has privileged zones where it is introduced: concentration of the area under cultivation, appropriate division of the land, presence of a development agency with the necessary funds (or ability to get the necessary funds). But the introduction of mechanization must be carefully weighed so that the farmer, as well as the country as a whole, will gain from its introduction.

Mechanization--just as water, as we have already noted--is not an input like the others. Both of these factors can and do transform the agricultural system. In the case of a peasant system of agriculture, mechanization can be beneficial if it helps do away with a bottleneck (time

available or energy necessary) thus making it possible to better utilize the work capacity of family, on a larger area of cultivation.

It goes without saying that in all cases, the users should pay the real cost of the loans which they receive.

5.4.2 The continuous use of the ojects leads one to try a second crop, when this is possib (appropriate temperature). Here are encountered the Agro-economical problem of choosing the right crop, the social problem of making people work who are accustomed to travelling or resting during the dry season.

5.5 Concentration and intensification of activities pose serious management problems:

- management of the irrigation system
- management of a depot for lending needed machinery
- management of the overseeing agency or organization
- direct management of the land in the case of Algerian self-management.

6. Future of the hydro-agricultural improvement operations:

What place should these operations have in an agricultural development program?

6.1 First one must look at their limitations:

Aside from its own inherent drawbacks, agricultural irrigation development finds unfavorable conditions in most of Western and Central Africa.

a) favorable site conditions, that is irrigatable soil near an economically feasible water supply, are rarely found.

In addition, in all the subsahelian or Sudanese climatic area (500-900 mm rainfall) irrigation is handicapped by absence of a reservoir site, the rapid evaporation of stored water, and the fact that the beginning of the dry season, which is the opportune time for planting irrigated crops, is also the coldest time of the year.

b) With the exception of the Diolas of Casamance, who have created locally a veritable rice civilization, the African rural populations are not very familiar with the agricultural manipulation of water. Besides, if they show great solidarity on the family level, they are still foreign to the concept of carrying out a great effort jointly. to be cared for and used on a common basis.

c) The large technical assistance projects, using inported materials and supplies, cost a great deal of money, sometimes as much as 150,000 to 400,000 CFA* per hectare, occasionally even

*Rate of exchange of CFA francs 248 to the US Dollar: July 1968

more. There are few crops that are aimed at export or internal consumption that are sufficiently rich and profitable to fulfill the profitability criterion mentioned above, that is to say, sufficiently profitable to balance off the high investment cost needed by sufficiently increased profits. Probably only sugar cane, fresh and canned vegetables, and sometimes rice and cotton would qualify.

d) Other factors, less immediately perceptible, can also be added to the list of handicaps to irrigation in this region of Africa:

- Capital, both public and private, is very scarce. Not only the necessary long-term capital for building the perimeters but also the short-term capital needed for preparing the site and for farming of the plot;

- In the present state of traditional agriculture, dry crops still offer great possibilities. This is so true that in certain cases where there is competition between dry and irrigated cultivation for evaluating a day's work--a criterion to which the farmer is very sensitive--the decision is often made to the detriment of the latter, giving it bad press among the farmers. For example, peanuts bring as much per hectare to a farmer in Gambia or Casamance as rice does, with half as much work involved. Also, land is still available. Land scarcity is exceptional and very localized.

- Finally, because they are costly investments with only long-term profitability--often decades--hydro-agricultural schemes do not fit easily into the general economic situation of the African countries which are threatened by a deterioration of the terms of foreign exchange.

5.2 Under these conditions, as increasing the volume of agricultural production and rural development in the sense defined above are priority goals, one can say that within the very wide gamut of the average ecologies (500 to 2500 mm rainfall and above) it is man and his produce--thus mass action--which offer the greatest immediate margin of progress, that is to say, progress which can be obtained quickly and at the lowest cost.

5.3 Nevertheless, this general policy, which seems to meet with wide approval, should be qualified to meet certain exceptions in favor of hydro-agricultural development., such as:

6.3.1 Sites with extreme moisture conditions, either because of lack of water (rainfall less than 400 mm; Northern band of the African savannah zone, Southern Madagascar) or an excess of water (flood plains of African coastal countries) which require physical correction before agriculture can be properly

envisaged. If these agricultural projects are the only ones possible and locally the best (typical example being Mauritania), they are clearly justified, unless the investment could be better utilized elsewhere in the country, and if the recurrent costs can be borne by the economic activity the project will create.

6.3.2 The "mortgage",in human terms, can be immediately raised in the exceptional case where there is large favorable site with a rich potential. Given the legitimacy of a modern salaried class of agricultural workers, without neglecting professional training nor the social considerations, then the conditions for the feasibility of a hydro-agricultural project are present. Under these conditions, one could set up projects for the production of sugar, canned vegetables, in certain cases cotton, rice or palm oil.

6.3.3 Finally, besides these exceptions which generally involve very individualized project, smaller, less ambitious hydraulic projects involving more or less complete water control should be undertaken wherever possible, within the framework of the general policy on rural development operations.

6.4 Beyond the present perspective -- let us say more than 20 years hence -- and after appreciable progress has been made on dry cultivation, it is likely that land and water will appear as the most frequent limiting factors, and correction of this problem will have to be undertaken in a more systematic manner. As the present deficiencies -- human and organizational -- are filled, the economic conditions will then become the most important determinants A few of these (hydro-electric projects supporting certain irrigation projects, new sources of energy, air transportation, price policies, within the framework of international agreements, or regional economic unions, etc.) and a fortiori their implications, are difficult to forecast now. Nevertheless, perhaps the main role of the smaller, less ambitious projects mentioned above is to prepare and train the future generation of technicians and African peasants so that they will become accustomed to a new type of rural civilization, based on controlling and managing the environment in which they live

RICE PRODUCTION IN AFRICA

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SUMMARY

With the increase in populations taking place which will lead to twice the number of people in Africa by the end of the century there is need for much greater stress to be placed in the coming years on the development of food crop production. And in this respect rice takes a high priority. At present no good method of continuous cropping of upland soils in the wet tropics has been found and, with population densities of over 60 per square mile, a figure exceeded already in many parts, there is risk of eventual soil ruination unless new methods of cropping are found. Wetland rice can however be grown continuously on the same soil and gives a much more regular yield with less dependence on fertility and weather conditions. Swamp rice has historically fostered economic stability, dense populations and a high civilization.

An attractive characteristic of rice is its adaptability, not only to agronomic conditions but to social and economic conditions likewise. Rice varieties can be found to grow and yield well under a very great range of agronomic conditions, from upland rices grown as rainfed crops on well-drained soils to floating rices which will withstand considerable water depths. This adaptability means that use can be made of existing waste lands without the need for great expenditure in capital cost which would be needed to reclaim them for other crops. The methods of culture can also be varied to suit the social and economic conditions of each country, from simple low input methods which give low to medium yields to intensive methods with high yields but needing high input and high capital expenditure. It is as important that the method of culture is suited to social and economic conditions as that the variety is suited to agronomic conditions. Rice, in fact, grown in this way by the individual peasant cultivator can be one of the best crops for raising his standard of life from that of a subsistance level to the start of a cash economy.

Rice has in addition certain other advantages over many staple food crops, notably in ease of handling, transport, storage and preparation, and in its nutritional value. It is particularly important however from the nutritional point of view that parboiling should be encouraged and that parboiled rice should be eaten, as in most West African countries. Parboiling has the added advantages of reducing losses in milling and in storage. There appears to be no difficulty in changing food habits from other staples towards rice. A notable phenomenon is the astonishing increase in imports of rice into West Africa—an increase of three times in ten years despite increasing internal production. This is not solely due to the increase in consumption by sophisticated urban dwellers with a rising standard of living but there is evidence to show that rural populations are changing as easily from other staple foods to rice when it is available at a competitive price.

Rice therefore is a crop deserving of high priority in the research and developmental fields. At present research is ahead of its application, and this is due to two weakness in communication, a vertical weakness between the researcher and those who should apply his research and a horizontal weakness in the liaison and organization of extension services. There are however strong needs in both the fundamental and applied research fields, the main ones of which are detailed below. It must not be forgotten however that without effective extension services all research is of little use in increasing production.

General Needs (including rice)

1. One central or several regional bodies for coordination of investigational research, i.e., meteorological and hydrological records; distribution of plants, insects, nematodes, etc.

2. National collection of basic data as above (for rice especially hydrological data).

3. National organizations for social and economic research.

4. Local economic and social studies of farming systems.

Specific Needs for Rice

5. A research station for fundamental rice research in Africa. This should be of an international or at least regional character to avoid financial and other pressures and to attract top-caliber staff.

6. Fundamental studies to include physiological studies such as the effects of light, temperature and water on the growth of the rice plant, and studies of soil behavior under flooded conditions.

7. Strong national organizations for applied research, possibly combining research on rice with that on other crops.

8. Important applied studies needing attention are those of the interactions between factors in agronomy practice, and those of fertilizer placement and timing on different soils.

9. Continued varietal improvement and testing especially for adaptibility, varieties for dry-season cultivation, and upland varieties. This involves close cooperation between the fundamental and applied research stations, the actual hybridization being carried out at the former on information supplied by the latter, and the selection and testing being carried out in the ecological regions by the applied research stations.

10. A coordinating body, such as is provided by the International Rice Commission in the Far East, to provide the information services between the fundamental and applied stations, to ensure that important results obtained in one country are made known to other countries, and to arrange cooperative trials between countries.

INTRODUCTION

Rice is included in those crops associated naturally with the humid tropics, but it should perhaps be pointed out that in Africa rice production is not confined either to humid areas or to the tropics. Rice

cultivation outside the tropics, notably in the United Arab Republic, is so different in its approach and in its problems, being more clearly allied to rice growing in the Mediterranean region of Europe, that it can be excluded from discussion here. On the other hand, rice growing in the tropics extends from the humid areas into savannah lands.

Rice growing as we understand it is historically of comparatively recent occurrence in Africa. Exact dates and modes of introduction are not easy to ascertain, but it is probably not much more than three hundred years ago that the Asian rices were introduced into the wetter parts of West Africa, either by the early Portuguese traders along the coast or by the trade routes across the desert from the north-east. Prior to this time, however, there had been some cultivation of the African rice, Oryza glaberrima, which evolved from the wild Oryza breviligulata in the region of the Middle Niger delta in present-day Mali, though this cultivation was of a primitive type and probably very localized. In this wetter part of West Africa, stretching from Casamance in the north-west to the western Ivory Coast in the south-east, as in some areas in the Republic of the Congo, rice became established as a staple food, but until this century it was scarcely grown outside this immediate area. In Western Nigeria for example, although introduced in the middle of the nineteenth century, it had not become well established until 1900.[1] In Ghana, cultivation only really attained any importance in the 1920's.[2] And in Biafra, although there was previously a little cultivation of upland rice, the present rice industry only dates from the 1940's.[3]

One of the phenomena of recent years has been the sharply increasing consumption of rice (and of wheat products) as a staple food in African countries where it was not noticeably important in the past. This has been reflected in increasing imports. Although there has been a considerable expansion of rice production in all West African countries, for example, since the Second World War, imports of rice into this area in 1961 were three times the imports of 1948-50.[4] This has been generally accounted for by increasing urbanization and the tendency for rice (and wheat products) to replace other starchy foods in the diet of the higher income, more sophisticated townsman. While this is an important factor in the increase in consumption of rice, it is not the only factor. Recent studies in the southern regions of Nigeria and in Biafra, though not yet complete, indicate that there is a considerable shift in dietary habits, from yams and cassava products towards rice in rural areas where rice is freely available. Rice, which only a few years ago was eaten solely at festivals and on other special occasions, is now eaten on up to five days a week by the adult population in many areas, and daily by the children. This preference for rice among the younger section of the population is particularly marked and points to an increasing rate of rise in future consumption. It is apparent that it is not only the eaters of the starchy root crops who are changing to a rice diet. Instances have been reported from Mali and from Northern Nigeria of millet-eating communities who have changed over to rice-eating when rice has become freely available in local markets. All this confirms that changing consumption habits in Africa are following

a similar pattern to those in other parts of the world, where root crops in general have tended to give way to cereals, and where millets and sorghums have not held esteem as human food in areas where they have faced competition from other cereals.[5]

The population of Africa as a whole is expanding at a rate of 21 percent in each ten year period at present, and that of the more densely populated parts is expanding at an even greater rate. Unless population growth is slowed down or halted, this means that soon after the end of the century the population will be double that of the present, and the food required on existing standards will be twice that which is available today. But already today in many parts of Africa there is insufficient food. If the food of the developing countries is to be raised to that of the fully developed, it is estimated that a six-fold increase over present supplies will be needed in this time.[6] It cannot be assumed that imports of food-stuffs will continue to be available even on the present scale, as the expansion of population is even more marked in Asian countries and the world resources of food are going to have to be more carefully husbanded. It is thus seen that much more attention must be given in the immediate future to the food crops, which in research have tended to suffer at the expense of the export cash crops. And it is among these food crops that rice is assuming such an important place.

The vegetation climax in the humid tropics is the rain forest, which maintains a balanced relationship with its environment. There are minimum losses of soil fertility by leaching and erosion, and a surface accumulation of plant nutrients, whose rapid circulation accounts for the lush growth. However, once the forest is destroyed and the soil exposed, the accumulated fertility is rapidly lost and lateritic soils may become hard and pavement-like and destroyed for agriculture. There is rapid oxidation of organic matter due to increased soil temperatures, and the accumulation of soluble plant nutrients at the surface by upward water movement in the dry season will be removed by leaching and erosion in the succeeding wet season.[7] It is under these conditions that the system of the bush fallow has been evolved. This system depends on a long period of regeneration of the soil after a short period of cropping, usually only one or two years. If the fallow period is long enough, and soil and climatic conditions are favorable, the forest vegetation will reestablish. This system of agriculture is perfectly rational and a sound system of utilization of the uplands when population densities are low. The disasters brought on by agricultural methods which have taken no account of the wisdom and experience accumulated in this old tropical system are sufficient proofs of its value.[8] This bush fallow system, however, cannot support a dense population. Under the most favorable conditions only 17 percent of the total area can be tilled every year and under average conditions only eight percent. This latter means that a population density of less than 30 people per square mile is needed for the system to be really viable. If the population increases, either the fallow period must be reduced, involving the eventual ruination of the soil, or new agricultural methods must be adopted which will give greater yields without harming the soil—such as the use of the flooded rice field. Wet rice may in fact be called the agricultural climax vegetation of the wet tropics.[7] It is the only crop which can be grown year after year on the same soil in the tropics for long periods without depletion of soil fertility or obvious decline

fertility or obvious decline yield.[9] The cultivation of swamp rice is the best means of ensuring a steady and abundant supply of cereals in tropical lands; in fact, as long as there is a suitable supply of water some rice can be produced on soils that are too infertile to produce any other grain crop.[10]

Swamp rice fosters economic stability, a dense population and a high civilization.[8] If a climatic map of the world is compared with a population map, it is seen that the wet tropical areas are in general sparsely populated with the exception of those of south and southeast Asia where rice is the staple food and where ancient rice cultivation techniques have been developed many thousand of years ago. It is an inescapable conclusion that these high densities of population have only become possible because the economies have been based on rice culture. Even more is this underlined when the extremely dense population on the deltaic lands of North Viet Nam, based on a swamp rice economy, is compared with the low population of areas within the same country where upland cultivation in forested hills is the mainstay of existence. In West Africa itself there is similar evidence, though this is masked to some extent by a similar correlation between higher densities of population and cassava growing. Nevertheless in Casamance and Portuguese Guinea there are dense populations of rice cultivators in some areas, while in nearby areas of much lighter population are tribes which do not cultivate rice.[5] Whereas at the present time populations in some parts of Africa are probably still well below the Critical Population Density[11] for their method of cropping, in many African countries this is not so, and populations are either well over this density or rapidly approaching it. The impact of over-population is delayed. It is characteristic of our biological environment that we can, for a limited period, exploit it in excess of its real productive capacity. It is only later that it is evident that we have started to use our capital as well as our income and that our future income has thus become permanently reduced.[12] The Mediterranean lands which were once fertile areas and are now semi-desert are an example of the irreversible decline in productivity which can occur after millennia of over-exploitation. It is essential, therefore, that radical changes in the agricultural system are made well before the stage of over-population is reached, and it is in these changes that rice can play such an important part.

Among the agronomic advantages of rice, of which its ability to give reasonable yields on soils of low fertility has already been mentioned, and which also includes its independence of weather conditions when water can be supplied, with the consequence that annual fluctuations in yield are far less than those of other crops, the most important is its adaptability. And it is this adaptability, not only to agronomic conditions but to social and economic conditions, that makes it so extremely attractive as a crop.

Even in the more densely populated African countries there are areas of land which at present are virtually wasteland—mainly the swamps, riverain flood plains and coastal areas—and in the present state of the world, with the rapid development that is taking place, no country can afford to have large parts of its land lying idle. In

Britain, as in most other developed countries, much of the low-lying part of the land was swamp and wasteland in the distant past, and this was reclaimed for agriculture by expensive drainage and reclamation works, often proving to have the most fertile soil in the country. In Africa the capital needed for this type of development is hard to come by, but it is fortunate that these waste lands can often be made use of, without having to drain them or impose large engineering works, by putting them under rice cultivation. And if a country can grow a large part of its food on land which was formerly wasteland, this will release the uplands, which were formerly needed for food crops, to grow the much more valuable cash crops that the nation needs for its increasing prosperity. Rice varieties can be found to grow under most conditions, and in fact are being grown as a rainfed crop on well-draining and oxidized laterite soils and on upland soils with impeded drainage which water-log for part of the year, through normal swamp rices growing in the seasonally flooding depressions and riverain flood plains, the perennial valley swamps and the raphia and mangrove swamps of the coastal area, to the floating rices which will stand considerable depths of water, providing the rise is not too rapid, and which are being successfully used to exploit the deeply flooding riverain grasslands. By use of suitable varieties and appropriate cultural methods, with minor modifications to improve water conditions where necessary, most of these areas can produce good crops of rice.

It is seen that rice can be adapted to suit most types of agronomic conditions. At the same time its culture can be fitted in to most social and economic structures. Rice is grown in some form in countries ranging in the scale of development from the most primitive, such as Papua and New Guinea, to the most advanced, such as France, Italy, and the U.S., and many of the techniques involved can be adapted for use in Africa. It does, however, seem at present extremely unlikely that the extensive methods of cultivation with full mechanization as used successfully in the U.S. and Australia can be possible in much of Africa, especially in the wetter parts. These methods are used in countries with comparatively low population densities and high costs of labor, and involve high capital expenditure. They are also countries where rainfall is light and irrigation is used, thus making it possible to control closely the climate of the rice fields. Under intensive conditions, as are used in countries with high population densities such as Japan, full mechanization has not proved possible, despite the advances that have been made in the development of small scale machines. Rice in Africa would appear to be a crop of the small to medium farmer and not a crop for plantation culture. Within this limitation, however, any degree of intensification of farming can be carried out to fit it into the progress in the economy of the country.

It will generally be found that rice growing in any country is in balance with the general economy of that country. In countries in the Far East where the population density is low, the methods used are much less intense than in those countries where there is a high population density. This is because where there is no pressure on the land it is best to take the maximum production that can be obtained from the land

on a continuing basis with the minimum of effort and capital put into it. On the other hand in countries with high population densities it is essential to get the maximum production from each square foot of land in order that the population shall not starve. In these countries will be found very intensive cultivation with very high yields, but to get these a great deal of labor and capital has to be put in. It is a common mistake for a country developing its rice industry to aim immediately at the high yields that are obtained in Japan and Taiwan, for instance, without realizing the amount that is put in to get these yields, and that this intensive type of cultivation has evolved in balance with the much higher economies of those countries. It is indicative of this to examine the position in countries in the Far East which have very different population densities. In Japan and Taiwan the theoretical densities are over 750 per square mile and the actual densities on the arable land may be twice this or more. Here is found the greatest development of the intensive method of rice growing, where there is accurate control of the water, heavy use of fertilizers and insecticides, meticulous cultivation and continuous cropping, with correspondingly high yields. In Thailand, however, a country with a very much lighter population, approximating to the population density of many West African countries, the cultivation method is very similar to that used in West Africa with resultant lower yields, although rice is the most important crop and Thailand is the most important rice exporting country in the world.

In Africa there are countries with very different population densities and at varying stages of development. Rice, however, is a crop which is not tied to any particular economic level. It can be produced by relatively simple and low input techniques to give low to medium yields in a country with a general low economic level, and it can be produced on an intensive scale to give very high yields in a country with a high economic level of cultivation can be developed to keep in line with the development of the country as a whole, and its culture is unlikely to be restricted due to rising economic levels as may happen with other crops. It is important however, that the method of cultivation in present use is adapted to the economic status of the country and that it is realized that, while the methods used may not give such high yields as are obtained elsewhere, they may be the best and most fitted to the present economy.

The agronomic advantages and adaptability of rice culture have been stressed at some length, as they alone should be sufficient to indicate the outstanding importance this crop is likely to have in the future through large parts of Africa, an importance realized in many West African countries where rice has been given one of the leading places in their development programes.[4] The other advantages that rice has over most of the existing food crops should, however, be briefly mentioned in support. In many places rice can be used as a cash crop for areas which are at present purely subsistence farming and for which a cash crop is badly needed. This was the case in northern Ghana, where the introduction of rice to the numerous small swampy areas on the granite soils was the initial step in raising the economy of what was hitherto a very backward area. A similar raising of the economy, with rice becoming a staple food, is seen among the Somba people in northwestern Dahomey. Traditionally, agriculture here is largely subsistence agriculture with low

yielding millets forming the staple food, although some poor moistland rice is grown and eaten on special occasions. There is no spare land or labor for cash crops. The introduction of swamp rice cultivation to the depressions and valley bottoms, with yields of up to ten times those of the upland cereals, is proving extremely successful. The consumption of rice is increasing as it becomes more available, and it is anticipated that the cultivation of upland cereals will rapidly decrease and the labor and land thus freed be available for the cash crops, cotton and groundnuts. For the first time, these people will then have a cash income after their basic requirements have been met. In fact, the introduction of rice as a crop is one of the best ways of transforming a basic subsistence economy into an internal exchange economy.[13]

In handling and transporting rice shares the advantage of all cereals over the root crops, while in storage it has smaller losses than practically any other tropical food crop. Raw paddy is very resistant to insect attack in storage, and parboiled milled rice is similarly resistant. (Parboiled paddy and raw milled rice, however, are moderately susceptible.) With reasonable care, storage losses can be kept to a very low figure, and with modern techniques of hermetic storage, it is possible to store rice perfectly satisfactorily for several years. Rice storage in this way is thus a very good method for a Government wishing to store reserves of food for release in times of seasonal shortage.

Another advantage of rice is its ease of preparation. Parboiling and cleaning of the grain is not particularly laborious, even when done in small quantities for immediate consumption in the household, while it becomes a simple and relatively cheap process when organized on a commercial scale. This means that rice is one of the most suitable staple foods in an economy with increasing urbanization, as it can be bought in a state that needs the minimum of further preparation for the table. Rice also has a high nutritive value compared to many of the other starchy staples, and this is especially so when it is parboiled. Although a diet based on rice may be deficient in animal protein, this is a failing of all staple roots and cereals and a common failing in all diets in the tropics. Rice has, however, a reasonable protein content (analyses have sometimes given contents of over ten percent—the figure usually taken as the minimum nutritional level) and this protein is of an exceptionally high quality and digestibility for a vegetable protein. It is in fact said that an adult in a sedentary occupation can obtain his total protein requirement from a pure rice diet, though, of course, a manual worker or a growing child would not be able to. Rice also, when parboiled, contains adequate supplies of the two vitamins, thiamine and nicotinic acid. It is import, however, to note that this is only when parboiled. If rice is raw-milled, the supply of these vitamins is completely insufficient.

The following results of analysis of a normal swamp rice variety illustrate this.

	Milled raw	Milled parboiled
Fat percent	0.11	0.40
Protein (N x 6.25) percent	9.30	10.40
Thiamine micrograms per gram	0.32	2.20
Nicotinic acid migrograms per gram	8.00	46.00

This underlines the importance of encouraging the consumption of parboiled rather than raw-milled rice in Africa. It is usually easy to introduce parboiled rice to a population who are acquiring a rice-eating habit, though it is difficult to do so in a population who are accu tomed to earing raw-milled rice. Properly parboiled rice is exceedingly palatable (the fact that a locally produced parboiled rice introduced to the American market under a branded name has become so popular both in the home and export markets and has taken over such a large share of the market illustrates this) but there is a real danger of unsatisfactory methods of parboiling producing an unpalatable product and a preference for raw-milled rice therefore becoming established.[14] There are other advantages in parboiling, notably the sealing of the cracks caused in the field by alternate periods of high and low humidity with the resultant higher milling out-turn of whole grains, and the greatly decreased losses from insect attack when rice is stored in the milled state.

Discussion so far has been an attempt to put rice in perspective in the agricultural economy of developing Africa, and to show that rice is a crop which is deserving of high priority in the research and developmental fields. Agricultural research can be subdivided into fundamental (the acquisition of new knowledge) and applied (the application of existing knowledge to different conditions and in different environments) and these can further be subdivided. We thus have (a) fundamental scientific and agronomic research; (b) fundamental investigational research; (c) Applied agronomic research; and (d) applied economic and social research. In addition, outside research but vitally related to it if its results are going to have any impact on the economy of the country is extension—the putting of the knowledge of tested results to practical use.

Fundamental research must be carried out if there are to be real advances in the future. Although existing knowledge has not been put fully into effect and has not been reflected in increased yields, there will come a time when this has been done, and it is vital that new knowledge is then available to enable further advances to be made. Fundamental research is, however, a long term process and usually involves high expenditure without any immediate signs of results, and for this reason in national organizations there is usually pressure for research to swing over more to the applied approach. Also at times of financial shortage, research is the first thing to suffer. For these reasons, and also to attract international staff of the highest caliber, it is better for fundamental research to be carried out on an international basis, or at least on a regional basis. Unless it is linked to some strong international or regional organization, however, it is liable to disruption, as occurred in the case of the former West African Research Organization. By its very nature, fundamental research lends itself to such international organization as, if the research programme is well planned, the results obtained will be basic to the crop as a whole and will not depend on local conditions. At present time the International Rice Research Institute, set up in the Philippines by the Ford and Rockefeller Foundations, and working closely with the International Rice Commission, is carrying out good work on fundamental research which is generally applicable but is inevitably oriented towards Far Eastern problems. In

West Africa the West African Rice Research Station similarly carried out good work with African problems in the forefront, but it has now become part of a national University and the policy is tending more towards applied research. The International Rice Commission has realized that its main branch in the Far East is rather divorced from African and American problems and has, therefore, already set up a branch of the Commission for the Americas and has proposed one from Africa. In a similar way it would seem that a Central Rice Research Station is needed for such of these continents, not necessarily under the same authority as the International Rice Research Institute, but working in close liaison with it and under some international control. General experience has shown that a research station dealing with all aspects of fundamental research on a single crop has greater chance of producing worthwhile results than a less concentrated organization. Results of these existing organizations can be seen in their annual reports and published papers, but it may be worth while mentioning here, as examples of fundamental research that could have far-reaching importance in increasing rice production, the studies of acid sulphate soils of the West African Rice Research Station[15] which have led to an understanding of the chemical and biological processes in these widespread soils and to methods of making them productive, and the concept of breeding for plant type developed at the International Rice Research Institute[16] which has already been the basis for the breeding of a new extremely high yielding variety.[17]

It would seem, therefore, that certain priority is needed for establishment of an African Rice Research Institute to work in close cooperation with the International Rice Research Institute. This should be of an international nature and should attract international staff of the highest caliber. It is important that the African countries should feel that this Institute is working for them, and thus accessibility and easy communications are major points to consider in siting, so that frequent visits can be made to the Institute by interested persons and from the Institute by its staff. Provision of full amenities should also be considered in the siting, so as to attract and keep the highly qualified research workers necessary. It is extremely difficult to indicate which are the most important subjects for future fundamental scientific and agronomic research. Such research usually follows its own course, important points needing attention arising in the course of existing work. However, without in any way lessening the importance of continuing research in other fields, it is possible that more fundamental research into the physiology of the rice plant will give rewarding results. In the past this aspect has received little attention, and it is only in later years that physiological investigation has been given any prominence. As two examples among many of recent outstanding physiological work may be mentioned the studies of Matsushima and his co-workers in Japan[18] on the greater response from fertilizers by precise timing of application, and the studies of Roberts in Sierra Leone[19] on viability and dormancy which have given new concepts of these factors and led to several new practical techniques. Subjects which would appear to offer good promise of results in Africa are investigations into light and temperature effects on the rice plant, and in particular of their interaction,[20] and

investigations into the detailed water needs and relationships of the rice plant.

Fundamental soil studies such as carried out by Ponnamperuma in the Philippines,[21] and Jeffery in Sierra Leone,[22] would also seem to indicate that future and continuing studies of this kind could be extremely valuable. There is also considerable need for further varietal improvement through breeding and selection. This is a subject which is both fundamental and applied and will be discussed later.

The need for fundamental investigation research is not confined to the rice crop, and in fact such research when carried out is widely applicable to all agriculture. Under this heading is included all collection of information which, while not at the time being necessary for any particular object, will be available for reference for all development in the future. It is in this field that there are some notable lacunae, and also some well investigated areas. While some meteorological records are now wide-spread and reasonably complete, hydrological records are lacking except in a few limited instances. The plants have been well studied and documented, while the insects and nematodes have received much less attention. This type of research is usually best carried out in detail by national authorities but, since the results are applicable over wider areas than fall within national boundaries, there id need for a strong coordinating regional body to exercise overall supervision and compilation of results. As far as rice is concerned, the subjects that need particular attention are, first, the collection of hydrological information. There are many areas of what appears to be potential rice land along the major rivers, for example, but until something is known about the depths and speed of flooding, it is impossible to proceed with any development. Secondly, the study of insect pests and their parasites, and of nematodes, should be carried out. At the present time insects and nematodes are not vitally important in damaging the rice plant in Africa, but undoubtedly in the future, as rice culture is intensified and extended, they will become important and will require control action. This basic information should be collected now, while there is leisure to do so.

Applied agronomic research is best carried out by a national organization of much of this type of research is rather limited in its application to local conditions. It can be carried out by the experimental sections of the Ministries of Agriculture and their experimental farms. In large countries it may be necessary to have one of these farms in each of the main ecological divisions, though some of the work could be centralized and one of the farms would become the main one. In general, centralization of research should be aimed at wherever possible and only when essential would it be dispersed. By centralization it is possible to group together research officers, who work better in this way than when isolated, and to concentrate resources. For applied research in many cases it may even be possible to combine work on rice with work on other crops at one farm. There should be very close cooperation between the applied research organizations and the fundamental research station, results from the latter being passed on to the former for practical testing. In the reverse direction there should be a flow of

information to keep the fundamental station fully aware of local problems. It is in the field of plant breeding that this cooperation can be most clearly seen. The actual technical procedure of hybridization is best made at a fundamental research station, but the program must be based on a knowledge of problems and requirements which have been fed back by the applied research organizations. At a fairly early stage in multiplication of the hybrid seed, however, this must be sent out to the applied organizations so that consequent generations can be grown and selection made in the broad environment for which the new varieties are needed. Applied research very largely consists of field trials either statistical trials of new factors such as varieties of fertilizer applications, or of trials of new mechanical equipment of new practices. It is important that these are carried out thoroughly and repeated from time to time. It has been suggested that cultural practices are closely linked to form a balanced method of cultivation, and that changes in any one practice should be followed by a reappraisal of all the others now that the balance of the method has been upset.[23] Certainly the introduction of new varieteis of short erect plant type and high response to fertilizer has meant in many countries that recommendations as to plant densities and spacing have had to be radically revised.

Priorities in applied research on rice will vary from country to country but in general it can be said that the continuing search for new high-yielding varieties to suit local conditions and their thorough testing is one priority. It is still not at all certain that modifications to natural conditions can economically be made in many African countries, so it may be that for years to come it will be necessary to take full advantage of these natural conditions and to produce rice varieties which will be suitable for them. The bringing into production of the deeply flooding grasslands of Sierra Leone by the development of suitable varieties of floating rices is a successful example of this policy.[24] More recently similar results have been obtained on part of the Niger flood plain in Mid-West Nigeria. Another important line in improvement work is the production of short duration varieties of low sensitivity to day-length. These are not only likely to give higher yields than existing varieties when sown late, as occurs in northern Ghana[14] but should be suitable for culture in the dry season, a matter of great importance when irrigation schemes are being established, as is taking place at present in Biafra. Varietal improvement is also very necessary with upland rice. Great interest is being taken in this at the present time in most West African countries, both for use on well-draining upland soils and for use on the seasonally waterlogging moistlands, and it is likely that it will play a considerable part in the future in agricultural systems. Large scale mechanized schemes are being attempted in Liberia, and in north-eastern Dahomey good results are being obtained on soils with impeded drainage.

In Sierra Leone the general introduction to farmers of a newly available higher yielding variety could result in longer fallows and consequent conservation of soil fertility,[25] and in Northern Nigeria it is estimated that the widespread use of a new upland variety, now in the hands of the Nigerian Federal Rice Research Station, on seasonally water-

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In Sierra Leone the general introduction to farmers of a newly available higher yielding variety could result in longer fallows and consequent conservation of soil fertility,[25] and in Northern Nigeria it is estimated that the widespread use of a new upland variety, now in the hands of the Nigerian Federal Rice Research Station, on seasonally waterlogging but not flooding moistlands, would increase rice production in that country by a large amount.[26] A thorough examination of the effects of placement and timing of fertilizers on different soils may well bring to light responses which have hitherto been unobserved and lead to considerable potential increase in yields. Extremely striking results, of which indications have been obtained earlier in Sierra Leone, are now being found in Liberia from the placement of phosphates in upland rice on well drained soils. Another priority is the rechecking of all present recommendations where new practices have been introduced into the existing systems. It is this interaction of factors which in general has been largely neglected in applied research on rice in Africa at present. In addition the dissemination of information laterally between national applied research organizations is very necessary to avoid duplication and to stimulate complementary and cooperative studies. For this an international or regional organization is essential and the African branch of the International Rice Commission, when established, should fill this gap.

Applied economic and social research on agricultural subjects is an essential though neglected part of agricultural research and there can be much misdirection of effort in the putting over of research findings to farmers by the extension services unless the information that this can provide is available. As has been discussed earlier, it is essential that the method of cultivation is fitted to the economic level of the country. Improved practices, while desirable in themselves, and capable of giving enhanced yields, may in fact not be suited to the present economic levels, an effort by extension services in propagating them may be wasted. A sound investigation of the cultural practices from the social and economic standpoint will evaluate these in their context and will show which of them will warrant effort at improvement. This type of research is best carried out at a national level, and in large countries at even more local levels. It is of course applicable to all agriculture but at the present time, with rice as a developing crop in so many countries, is particularly important for this crop. For example, the mechanization of rice growing in Africa has often been attempted, and even more often been considered by some to be an important advance that should be made as soon as possible. Yet in the developing African countries, capital is a commodity that is scarce and valuable, while labor is still reasonably cheap and plentiful in many areas. A full economic and social evaluation of the position will often show that a capital-intensive system such as a fully mechanized system, even if it gives enhanced yields, is not the best suited to present conditions and that a labor-intensive system should continue to be used. On the other hand,

such an evaluation may often point out one stage of the industry which would repay mechanization, or where there is a bottleneck which can be removed. Mechanization of post-harvest practices, for instance, has often proved worthwhile with the rice crop; and seasonable labor shortages caused by the demands of other crops may be overcome, as for example by the use of chemical weed killers. There is an urgent need to relate experimental work to the critical problems that farmers are facing and to identify and develop improved techniques that are feasible with the managerial skills and resources actually available to farmers.[27]

At the present time, there is a general backlog of research findings with rice which has not been put into practical use in the field. In some respects this is normal—research should always be at least one step ahead of practice. This backlog, however, is greater than it should be in many cases. There are two reasons for this; one is the lack of good information services, particularly between countries, which will allow the results of fundamental research to be taken up fully by the national applied research organizations; and the other is lack of good liaison and organization in the extension services, which should pass the tested results of the applied research organizations on to the farmers. In the Far East this first hinderance, the lack of information services, has been obviated by the Food and Agriculture Organization of the United Nations, who set up the International Rice Commission. This not only gathers experts together for discussion in the meetings of its working parties and publishes a monthly newsletter but maintains a Regional Rice Improvement Specialist who, by visits and discussions, ensures that any new research result is made known in the place where it will be most welcome. The proposal to set up a regional branch of the International Rice Commission in Africa should bring these benefits also to this continent. It is out of place here to go into details of the shortcomings of extension services, except to stress the importance of such services and the great need in most cases for their reorganization on sound modern lines. Research into economic and social factors will be extremely important, not only in choosing the most suitable practices to disseminate, but also in determining the best means of approach to the farmers.

It has been argued above that rice itself is a crop the development of which warrants a high priority in agricultural research in Africa, and a number of important aspects of research on rice have been singled out for particular attention. It may be useful to summarize these. It must not be forgotten, however, that without effective extension services, all research is of little use in increasing production.

General needs (including rice)

1. A coordinating body for investigational research
2. National organizations for social and economic research
3. Collection of basic data, especially hydrological data
4. Economic and social studies of farming systems

Specific needs for rice

5. A research station for fundamental rice research in Africa
6. Strong national organizations for applied research
7. A coordinating body (such as the International Rice Commission)
8. Fundamental physiological studies, including effects of light, temperature and water.
9. Fundamental studies of soil behavior under flooded conditions.
10. Applied studies of interactions between factors in agronomy practice
11. Applied studies of fertilizer placement and timing on different soils
12. Continued varietal improvement and testing, especially for (a) adaptability; (b) varieties for dry season cultivation; (c) upland varieties.

In conclusion it may be of interest to compare briefly two African countries of about the same size and in both of which rice is of considerable importance, but which have very contracting conditions.

In Sierra Leone rice has been the staple food for several hundred of years. The population density is light, being only about 80 persons per square mile, and rice farming is on the individual scale, farms being small and worked almost entirely with family labor. Rice has received considerable attention from the Government and sufficiency in production was attained at an early date. Increasing population, urbanization and per capita consumption were, from the early 1930's, covered by an annual increase in production of just over two percent, and despite a temporary set-back in the 1950's, due to non-agricultural causes, prospects for a continuing self-sufficiency with a rising population appear very good.[28] The application of research findings to rice growing on the scale of the small family holding has achieved the objects of maintaining the production of the staple food crop to keep up with rising consumption and allowing the rural standard of living to rise in time with the rising economy of the country.

In Biafra, on the contrary, rice growing was only introduced about twenty years ago. The population density is high, being on average over 500 to the square mile while, due to areas of light population such as the Niger delta, the density is over 700 to the square mile in a large part of the country. Rice farms tend to be medium in size and are worked with hired labor, often on rented land. It is particularly interesting to see how, in this short space of time, rice has become so firmly established in this country of high population density as a paying crop. how parboiling and milling industries have arisen and trade channels been established, and how rice has, in fact, become a staple food with steadily increasing consumption and retailing at a price which makes it cheaper than most other staples. Fertilizers are becoming quite widely used, irrigation schemes are beginning to make two crops a year possible in some areas, and there is all the evidence of increasing intensification of rice culture to fit it to this high density population and relatively high economic level.

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MAJOR PROBLEMS AFFECTING PRODUCTIVITY OF MAIZE

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SUMMARY

The type of methods and attitude of mind needed for maximum sucess in African agricultural research is discussed with illustrations drawn from the experiences of Kenya's maize improvement program. This program includes a comprehensive breeding scheme in one overall joint plan covering basic and applied research, genetics, breeding and agronomy research, commercial seed production and extension teaching.

The discussion is concentrated on four main points:-

(1) Food crops are the key to agricultural progress
(2) Study of biosystematics and ecology gives a good starting point
(3) Pioneering research needs first class scientifts with wide interests
(4) Team organization is needed to solve major economic problems.

The methods and attitude of mind adopted in the Kenya program of maize improvement are an example of the application of principales that have been discussed elsewhere. The vital problem of increasing yields from staple food crops, to meet the needs of a rapidly expanding world population, has frequently been discussed at meetings of the American Society of Agronomy (1): at the 1966 gathering Dr. Wortman (6) emphasized the need in developing countries for close cooperation between research, development and extension. Dr. McMeekan (5) has covered the same ground in the wider context of agricultural research as a whole, stressing the need to adapt Western thinking and approach towards meeting the different needs of developing countries and proposing teams of specialists directed towards joint attack on major problems decided upon by economic study.

Eberthart et al. (3) have outlined the comprehensive scheme of maize breeding used in Kenya. This adopts methods originating in the research of Western countries but joins them together, taking advantage of Kenya's specific circumstances and needs, to provide an approach that is different and new. Harrison et al. (4) have described the development of the breeding program into one joint plan covering basic and applied research, gentics, breeding and agronomy, with commercial seed production and extension teaching.

The intention of the present paper is to extract from the above experiences the four major points that seem the most relevant to the present conference and have been the key factors in the success of Kenya's maize improvement. There is also an expansion of those aspects that have a bearing on improvement of other crops.

(1) Food crops are the key to agricultural progress

Priority of agricultural services in Kenya was the first given to soil conservation measures, to preserve the legacy of agricultural wealth; and to cash crops to pay for these measures nd raise the living standards of the people. Fortunately, there was sufficient land for this policy so that food crops were neglected. There are, however, agricultural parts of Kenya with population densities up to one-thousand per square mile, there have been national food shortages in recent years requiring expensive imports, and a human population increasing by more than 3% per year can only be fed by increasing yield per acfe. Shifting cultivation has long since tended in some areas towards continuous maize, declining yields, and declining soil fertility threatening the whole basis of agriculture.

The average size of farms in the Central Province is between four and seven acres, while the average yield of maize is five bags per acre and a man requires two or three acres to feed his family at this level of yield. The current provincial agricultural development plan gives priority to grade cattle, grazed on improved pastures, and more planting of cash crops, especially tea. The family's food requirements pould easily be met from only one acre of land if maize were grown properly. This would release land for the other purposes and enable a real rotation to be established, including grazed pastures, thereby raising the fertility of the soil. Comprehensive agricultural planning of this nature is needed to realize maximum benefit from research progress. In this way, improvement of cereal crops can be the key to agricultural progress. For these reasons, the Kenya Government puts a major research effort into maixe improvement.

(2) Study of biosystematics and ecology gives a good starting point.

Maize is a comparatively recent introduction to Kenya, yet it has already almost completely replaced sorghum and the millets which were the African indigenous cereals: the latter are now less important than wheat, another introduction. Sorghum, in its Sudan centre of origin, evolved on dark cracking clay (cotton soil) and is able to withstand drought and foooding, both frequent on this impervious soil. Bullrush millet, by contrast, is typical of the other extreme, that is almost pure sands that in a past geological age were blowing dunes, and has a root system that can draw up moisture from great depths. It is unlikely that maize will ever replace sorghum on clays or bullrush millet on sand but its expansion on good well-drained soils is likely to continue. Field crops of 40 bags an acre of maize (135 bushels an acre or 88 quintals a hectare) have been achieved in Malawi, Zambia and Keyna, and much hightr yields are possible following further breeding and agronomic research. Comparable yields are possible from sorghum which is also valuable for marginal conditions, but the future is probably limited for use Eleusine, Setaria and Panicum indigenous millets which have lower potential.

Wide evaluation of introductions, the first preliminary to plant breeding, has not yet been carried out for all crops in all African countries. Comparatively little effort in time and money can often establish a better starting point than plunging immediately into an

expensive long-term breeding project with whatever local material happens to be at hand. Even in the United States, certain maize breeders are concerned that they only have a fraction of the germ plasm available from the Latin American centre of origin. Our Kenya Flat White maize type comes from the mixing of varieties intorduced from South Africa which in turn came from the Southern United States, whose maize comes from Mexico: that is, we have only a fraction of a fraction of a fraction of the germ plasm available, and it is the wrong fractions at that (having come through conditions dissimilar to our own). We have made introductions from Europe, the United States, South Africa, Australia and India but all with little success until we tried the centre of origin material. Yet the greatest genetic diversity is always in centre of origin material and in our case the centre of origin has similar ecological conditions to our own, on the Equator with the same association of rainfall and temperature to a wide altitude range. This material gave us a "break-through" so good that we found varietal crosses for immediate use and all three of our main breeding programs are now making much more rapid progress than was previously possible.

The Rockefeller Foundation and others have now made available an incrediably wide variation of maize, from many different ecological conditions of the centre of origin, so that the range of maize in Africa could be greatly extended with material suited to conditions different from the first chance African introductions. Latin America is also the centre of origin of groundnuts and food beans so that it is likely a similar "break-through" could be made with these crops in areas of Africa with the same ecological conditions. Intelligent bio-systematic study of ecological conditions, both locally and in the centre of origin, coupled with study of the history of introduction of the crop plant to Africa, may result in introductions mare useful than the products of long-term expensive breeding and provide a better starting point for the latter.

A side observation from this story is that the methods of food preparation for maize in Kenya are the traditional methods used for sorghum and the millets. This does not produce nearly such attractive dishes as the "tortillas", "tomales" and "arapas" which have developed over the centuries in the Latin American home of maize. Introduction of methods of food preparation suitable to the new crop should greatly increase the value of maize in Africa. Incorporation of the opaque 2 and/or floury 2 genes into African maize could produce protein values as good as cereal legumes - most important in countries where maize is the staple food crop of the people (Mertz and Nelson),(2).

(3) Pioneering research needs first class scientists with wide interests

Highly specialized and advanced studies in narrow fields, geared to the needs of sophisticated agricultural countries, are not suitable for the present stage of development of African food crops. We need the general practitioner type of research worker who made the first practical advances in Western countries, who understands the economic types of the crop in general agriculture and appreciates which aspects to tackle to make the most rapid progress. On the other hand, this does not mean that research workers trained in modern techniques are not needed, nor that useful basic research cannot be done in Africa. Our research workers need

to combine the pioneering outlook with the most modern knowledge and techniques.

As an illustration of this, the introduction of the wide range of useful races and varieties of maize from the centre of origin posed us the problem of how to grasp and best utilize this wealth of material. Conventional maize breeding methods of inbreeding and hybridization are not adequate to make maximum use of this potential. We are back at the time in the United States when northern flints were combined with southern dents to give Corn Belt maize; except that we are fortunate to have a far greater number of good maize races to use, far too embarrassing a richness to exploit by orthodox methods. Instead we have combined our own adaptations of old methods with recent theoretical findings of quantitative genetics and developed a new comprehensive scheme. Eberhart et al.(3) We decided to form all the best material into two composites, glorious mixtures of all the good things we had, and use recurrent selection to improve the composites and their crossing value. First generation hybrid crosses between the continously improving composites are now outyielding and replacing conventional hybrids of inbred lines. From our experience we have developed new ideas on how to choose components for the composites and how to form them. A leading American geneticist in basic research, Dr. Eberhart, not a practical plant breeder with preconceived ideas, has worked out, a basis for choosing the best methods of recurrent selection, going back to fundamental principles to do so. As a result, we are achieving up to 10% increase in yield per year and have good reason for thinking this will continue for a number of cycles. This compares with 30% from ten years or so of inbreeding and hybridisation which we can still use when progress from recurrent selection has slowed to under 3% per year. We think that this scheme of breeding could be profitably adapted and used on maize in other countries, on other open-pollinated crops, and (by the use of sterility as a breeding tool) even in predominantly self-pollinated crops. Dr. Eberhart's studies are also designed to determine certain genetic parameters on types of gene action of importance to fundamental research. Moreover, day-length difficulties do not prevent us making any desired cross in maize with irrigation we can have two or three breeding generations a year on the Equator, so that we are now starting to form extremely wide composites for possible use in the corn belt - (Kenya's aid to America!).

The needs of pioneering research in developing countries are not satisfied with second class research workers and there are some opportunities to make advances of value in all countries.

(4) <u>Team organisation is needed to solve major economic problems</u>

All too often in Africa a new variety of a crop or a new cultural practise is developed on a research station and just sits there, never used, and the research might just as well never have been done. In Kenya the national average yield of maize is 6 bags per acre (20 bushel per acre or 13.2 quintals per hectare) but in most parts of the country yields double, triple or four times this level can be obtained by following good husbandry rules, without research to find new methods or breed new varieties. There is a huge difference, often not fully

appreciated in research planning, between crop improvement programs designed for Western countries and those designed for African countries. Reasonably sound agricultural systems and practises have been developed in Western countries, by generations of farmers through a process of trial and error. With a relatively high standard of husbandry, innovations developed by research workers are ususlly adopted comparatively quickly by farmers who derive immediate economic benefit. In African countries local farmers may be persuaded to spend money trying out new recommendations but the results are aften disappointing if appl ed under poor condit ons. In order to improve food crop yields, it is necessary to raise the levels of all factors which influence yields, and the most rapid results are obtained by raising all the levels simultaneously than by raising the level of one factor at a time.

All this means that agricultural research in African countries must be tackled by teams of specialists covering all appects. This is a costly business and can only be done for those crops which previous economic study has shown are top priority and have a key importance in improving agriculture as a whole. It may be necessary to gain acceptance of the idea of buying seed and it is probable that efficient commercial seed production organisations have to be created before new varieties can be distributed on a large scale. Moreover, extension services, using different methods appropriate for reaching millions of peasant farmers (often illiterate), must be planned to work in close conjunction with the research workers. Package deals are needed to get improvements at once in all aspects of crop improvement, and new varieties used as a lever to stimulate better cultural standards.

Kenya is the first country in Africa to achieve large-sclae success with hybrids by African subsistence farmers, overcoming the problems of buying new high-priced seed each year and not growing on second generation seed (there are now some African commercial farmers producing hybrid seed to meet strict high certification standards). If any of the following four main aspects of the program had been missing, this extraordinary success would not have been possible: -

(a) an effective breeding program which produced hybrids with a 30-80% superiority over local varieties.
(b) an agronomic research program which found out how and where to grow these hybrids to realise their maximum potential.
(c) a commercial seed firm which organised the production and distribution of high quality hybrid seed at reasonable cost.
(d) a large and well organized extension service which made a major effort to get the research results to the farmer and adopted by him. This included placing a demonstration plot of properly grown hybrids in each locality within walking distance of most farmers.

Harrison et. al. (4) have described how the average yields of maize are greatly increasing in many areas since hybrids were released in 1964. Two tables, taken from this paper, illustrate some of the considerations already discussed in general principle. Table 1 shows the rapid uptake of hybrids by farmers. The commercial large-scale farmers were quick to relaise the benefits of hybrids and nearly the whole of their acreage is now planted to hybrids. The subsistence small-scale farmers were very slow to begin with but the major effort by the extension service has now made a big impact, showing the difficulties can be overcome. Small scale subsistence farmers now grow as much hybrid as large-scale farmers but this is still only abut 20% of the acreage suited to Kitale hybrids and the target is one million acres by 1970. Apart from the yield, the aims of the breeding program also include resistance to the principal diseases blight (Helminthosporium turcicum), rust (Puccinia sorghi), and ear rots (Fusarium/Giberella spp. and Diplodia zeae), while a short strong stalk resistance to lodging by frequent storms and good sheath tip coverage of the ear against weather damage and weevil entry are also factors taken into account. Table 2 shows the importance, in both research and extension work, of tackling all factors of improvement at the same time. It will be noted that those factors which cost most sometimes give least return: money spent on fertilizer and hybrid seed is wasted unless the basic cultural standards are satisfactory,unless the crop is planted early, a full and even stand obtained, and kept free of weeds in the early stages. All too often, by both agricultural staff and farmers, modern and scientific developments have such an appeal that what should be the obvious and simple factors are overlooked and ignored so that the modern and scientific developments appear not to work in practice. Data from these trials makes excellent ammunition for the extension service who have now started to use "all minus one" demonstrations - all factors right except one missing - to bring home the essential importance of improving all factors at the same time, as the research work has shown.

Even so, one major omission seriously reduces the value of the achievement. No market has yet been organised for the increased production coming forward which has merely depressed prices. A study group of the various ministries involved has now been proposed to investigate the possibilities of livestock feeding, industrial processing, and other uses, with a view to developing a stable market.

Several African graduates, including three with M.Sc. research degrees, are now employed in the program which included three separate research centres for the three major different ecological areas. With the help of Rockefeller/CIMMYT and U.S. AID grants, an in-service training project is being started and this and other services are being offered to other Eastern African countries. The second regional conference was held immediately preceeding this conference. Duplicate breeding and research programs are not needed in each country and much can be gained from mutual exchange of material, results and ideas. In this way, it is intended to spread the benefits from Kenya to other countries.

Table 1.

ACREAGES OF HYBRID SEED PRODUCTION AND COMMERCIAL HYBRID MAIZE GROWN IN KENYA

Year	Acres of Commercial Hybrids		
	Large scale farms	Small scale farms	total
1963	390	10	400
1964	28,200	1,800	30,000
1965	54,700	20,100	74,800
1966	62,900	37,800	100,700
1967	130,300	134,700	265,000

Table 2.

AVERAGE YIELDS FROM 6 MULTIFACTORIAL HUSBANDRY TRIALS 1966
QUINTALS PER HECTARE (1 quintal/hectare = 0.45 bags per acre)

Factor	Treatment	Yields	Differences	Cost Differences between treatment levels (per ha) in U.S. dollars
1. Time of planting	early in rains	52.6	18.5	Nil
	28 days later	34.1		
2. Plants per hectare	36,000	49.3	11.8	$ 2.80
	18,000	37.5		
3. Type of Maize	Hybrid 613A	52.7	18.6	$ 4.18
	Local Maize	34.1		
4. Standard of weeding	Clean weeding	48.2	9.6	$ 6.96
	One late weeding	38.6		
5. P_2O_5 at planting (kg/ha)	56	44.6	2.4	$11.14
	0	42.2		
6. N top-crossing (kg/ha)	79	44.8	2.7	$27.84
	0	42.1		

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PROBLEMS RELATING TO CEREALS

CORN (MAIZE)

IRAT

SUMMARY

This paper deals with the problem of regionalization of research on maize. It states that regional research studies could be done for the most important maize-growing regions:

- humid tropical region
- equatorial wooded and grassy savannah region
- high altitude tropical and equatorial region

Examples of research work already in progress are listed and the main possible themes for the regionalization of research in maize elaborated. These themes are basically:

- setting up collections, properly equipped and including:
  - a central collection in the equatorial zone (Dahomey or Cameroun)
  - three secondary collections, one in the wet tropical zone and two others in high altitude zones (Rwanda, Equatorial high altitude zone and Madagascar, tropical high altitude zone)

- study of genetic and selection problems, including:
  - comparison of selection systems
  - obtaining of morphological modifications
  - male sterility

- the following physiological studies:
  - the influence of photoperiodism and thermoperiodism
  - mineral nutrition
  - carbonaceous nutrition

- protection of maize against disease and parasites

- the technology of maize especially studies of protein content, flour texture, meal texture, and conservation problems.

Suggestions are made on the possible choice of a location for a future regional center for research on maize.

In tropical Africa, maize is cultivated over a very wide area, because of the large number of varieties adapted to very different climatic conditions; it must be remembered that food maize is cultivated from the temperate to the equatorial zones; feed maize is cultivated even much further north.

Regionalization of maize research could be considered for the most important areas, namely:

Humid tropical area, with a total yearly rainfall in excess of 800 mm; maize requiring 5 to 6 months is cultivated in areas with rainfall between 800 and 1200 mm: Casamance, southernmost area in Mali, northern part of Ivory Coast, northern Togo, northern Dahomey, northern Cameroon central part of Central African Republic, extreme north of Congo Kinshasa, lowlands of Madagascar.

Equatorial area with grassy and woody savannah and high rainfall but with two humid seasons separated by dry spells. Under such conditions, it is possible to devote to maize one or two successive cropping cycles. This area covers the central part of Ivory Coast, the central and southern part of the Central African Republic, the south-central part of Congo Brazzaville, the northern part of Congo Kinshasa.

In the equatorial forest area, maize is still cultivated but is not the basic food crop; it is replaced in that capacity by root crops.

High tropical and equatorial area - Among the first is a large part of the high plateaus in Madagascar, where maize is grown; among the latter Kivu and the western slope of the Rwanda range, in Rwanda and Burundi.

Improvement work on local varieties has been conducted and is continuing everywhere; many studies have been devoted to developing new cultivation and pest control methods; however, it is in Dahomey that large-scale and widely applicable work has been conducted on the use of genetics against American rust (Puccinia polysora); research susceptible of wide application have also been conducted on genetic resistance to pests in storage (Dahomey) and on conservation methods (Togo). Finally, in Madagascar, spectacular results have been obtained by correcting deficiencies in ferrallitic soils, with a resulting large increase in productivity.

Some regionalization of maize research can be envisaged; however, studies would have a general, rather than regional, application.

COLLECTION

Consideration can be given to the establishment - in Dahomey or in Cameroon - of a central collection of stocks of regional and foreign varieties with, if need be, secondary collections, including one in the humid tropical zone and two in high areas: Rwanda (high equatorial area) and Madagascar (high tropical area).

The central station should keep, in a cold room, under controlled temperature and humidity, samples of seed of the central and secondary collections.

Such a collection should be a true gene bank.

The collection should be accompanied by detailed variety maps, to be drawn on a country basis under the supervision of the regional maize station.

As for the other grains, the collections will allow for a series of observations and experiments:

- Morphological observations
- Phenological observations; resistance to disease and parasites;
- Inter-variety breeding
- Transfer of useful genes.

GENETIC AND BREEDING PROBLEMS

Research may be conducted along three general lines:

1 - Comparative study of breeding systems

Various breeding systems will be studied, account being taken of the present knowledge of the various types of gene action. Some breeding experiments will be conducted simultaneously from a single material, in order to test their relative efficiency and draw conclusions concerning the genetic modes of action.

Thus, non-improved heterogenous varieties may be bred for the number of ears per row, or according to the mass and recurrent methods.

Other methods to be analyzed include:

- Cumulative breeding
- Gene transfer breeding
- Breeding through inter-variety hybridization (including the use of the collection)
- Genealogic breeding, followed by hybridization among lines and populations, or by the production of synthetic varieties.

2 - Morphological modifications

- action directed at decreasing the plant height in some varieties, and more particularly the level of the ear.

For the purpose of obtaining the latter result, use may be made of mass or cumulative breeding within each population; also, foreign genes may be used, from low varieties (from Formosa, for examples) or from dwarf lines with homozygous brachytic gene.

3 - Male sterility

Determination of the presence of genes of male sterility or fertility restoration in maize from the central collection. Samples will be taken for the creation of African lines offering cytoplasmic male sterility, which could be used in a program of hybrid creation.

PHYSIOLOGICAL RESEARCH

Influence of photoperiodism and thermoperiodism

Photoperiodism and thermoperiodism influence plant growth (total amount of dry matter produced) and development (seed germination - formation of ears).

Several phases will be arranged; an attempt shall be made to establish the genetic determination of each phase.

Study of carbon nutrition

Through use of labeled CO_2, a photo-synthetic balance will be established in relation to the leaf level and the various phases of development.

Through use of labeled CO_2, determination will be made of the methods of transportation and of the sites of localization and accumulation in the plant for the various products of photo-synthesis, particularly in the grain.

Study of mineral nutrition

Through use of labeled elements, study will be made of the methods of transportation, sites of localization and accumulation in the plant of P, S and N metabolites.

An attempt will be made at analyzing the variations in formation and utilization of fats and proteins between the growing and reproductive stages of a given plant.

Similarly, an analysis will be made of the same elements (formation and utilization) in plants which differ in the stem length (short and long stem).

PROTECTION OF MAIZE AGAINST DISEASES AND PESTS

(see also "Regionalization of plant protection problems.")

The problems to be solved are generally biological, entomological and phytopathological.

In dry tropical areas

Study of maize borers

Study of maize smut

In humid tropical areas and in equatorial areas

Study of diseases and pests of maize

The genetic resistance to certain diseases, and particularly to american rust (Puccinia Polysora) will be further studied and developed in the humid tropical zone.

Maize will be included with other grains in research on food conservation in storage.

TECHNOLOGY

A systematic study will be made on the chemical composition and nutritional value of the most common varieties in the main areas under consideration, or of certain varieties used for their genes.

Special importance will be attached to the determination of protein content, to the mealy or hard texture of the main varieties and to the relations which exist between texture and food value.

In humid tropical areas and in the equatorial zone, the problem of maize conservation must be studied in the more general framework of the conservation of food products.

* * *

The regional maize research center should be established in the equatorial zone:

- either in Dahomey (near Cotonou, for example)
- or in the southern part of Cameroon (at N'Kolbisson, for example)
- or in a high Cameroon area (Dschang, for example)

Even more so than for the other grains, this center should have a network of secondary research stations distributed in other zones.

In the field of technology, research must be furthered on conservation, at the same location as for the other foodstuffs.

SOME PROBLEMS OF SORGHUM AND MILLETS PRODUCTION IN AFRICA

B. N. Majisu and H. Doggett
E.A.A.F.R.O.

SUMMARY

Although sorghum and millets play a minor part in the international trade, they are an important group of food crops in the extensive savannah zones of Africa. Despite their importance, these cereals are as a rule grown by crude methods, resulting in overall low yields. Some of the factors affecting production are considered in this paper. It is noted that while all these factors account for inefficient production, their importance, relative to one another varies from one region to another; and each region must identify its own priorities.

Among the pest problems, birds are identified as the most serious, affecting both the quantity and quality of production. Birds damage possibly 10 to 20% of the total sorghum production, and similar losses are undoubtedly encountered in the millets also. The Quelea constitutes a special menace, in many ways similar to the locusts. Although extensive campaigns have been carried out against birds in the savannah zone of Africa during the past decade, an expanded international effort is required. Pest damage is great under the crude storage used for these cereals in the villages. Sorghum is more difficult to store for any length of time than the millets, without application of fumigants. Reduction in losses during storage is a practical proposition provided that simplified fumigation techniques to suit the small scale farmer are available.

There is a need for careful determination of 'cereal zones', such that each grain type can be grown in a given zone with maximum efficiency. Extensive comparative trials assisted by agrometeorological studies must be coordinated in order to rationalize such zoning. Sorghum and millet should be given priority over maize in the drier parts of the savannah, where maize is likely to fail more frequently than once in five years.

Sorghum and millets are grown almost entirely without the benefit of fertilizers. This cannot go on indefinitely on the same land without serious effects on yield. There is need to determine the role which fertilizers can play in the production of these cereals in a given area. It is useful to determine also the interrelations between variety, plant population and the availability of moisture at the same time.

Although an appreciable effort has been made to improve seed, the impact on production has been little, due in part to an absence of organized seed multiplication. Improvement programs need not be large and

expensive undertakings; rather it is important that their aims and objectives be clearly defined, and simple but effective methods utilized. Regional organizations may be the most effective means of employing resources for such improvement programs. Nevertheless, there is a need for inter-regional co-operation, particularly in the exchange of breeding materials. A well organized seed industry is essential for the distribution of improved seed to the farmer. In countries where private enterprise has not been stimulated, the state should take the initiative.

The policy in most African countries is to be self-sufficient in these cereals for subsistence requirements. Proper marketing organization is not encouraged by such a modest policy. There is a need to review the economic position of sorghum and millets if the present trend in production is to change.

There is scope in extending the range and quality of sorghum and millets food products. This would not only enhance their status but would also save much foreign exchange in the importation of better cereals. More studies on sorghum and millets as human food are required, but it will be necessary for the society to adjust its traditional food habits, and to accept innovations.

INTRODUCTION

Sorghum and millets are extensively cultivated and form a most important group of cereals for human consumption in the savannah zone of Africa, despite the minor part they play in international trade. 'Millet' is a general term used for a wide range of small grained cereals, including bulrush millet (Pennisetum typhoides), foxtail millet (Setaria italica), broom corn millet (Panicum miliaceum) and finger millet (Eleusine coracana). As sorghum and millets are grown for local consumption, accurate information on production and yield is difficult to obtain. However, estimates (5) give some impression of the relative significance of sorghum and millets in different parts of Africa. Maize figures are given in parenthesis for comparison where possible. These figures indicate that sorghum and millets yields are poor throughout Africa. Thus, whereas the average yield of sorghum in the U.S.A. is 2,580 kg./hectare, typical yields for Africa are 500 to 700 kg./hectare, and are comparable to those of the Indian sub-continent, which has many similar problems of cereal production.

Because of the minor part sorghum and millets play in the world economy, their importance as food crops for consumption locally throughout Africa must be stressed. Factors affecting production are considered in this paper especially from the point of view of subsistence farming. Obviously the order of importance of the production problems will vary from one region of the savannah zone to another. Each sorghum and millet producing region should identify its own priorities.

PESTS

(a) Damage caused by birds

Flocks of birds numbering hundreds of millions are a common feature in Africa. Red billed finches, Quelea spp. commonly operating in the savannah areas of West Africa, the Sudan, East Africa, Central to Southern Africa, can inflict locust-type of damage on sorghum and the millets. The Quelea, whose main food is grass seed for most of the year, appear to have neither serious diseases nor predators to control their population. The availability of food is possibly the main factor determining their numbers. In addition to the Quelea, sparrows, yellow weaver birds, bishop birds, doves and many others can cause considerable damage to sorghum and millets particularly in wooded areas.

Birds affect both the quantity and quality of grain produced. The Quelea remove the germ out of the immature grain of sorghum while the bulk of the grain is dropped on the ground. It has been estimated that each bird may damage as much as 2 ounces per day (9), while the actual daily consumption may be 20 gm. (11). If we estimate that 20 birds can consume or damage 1 lb. of grain per day, 1 million birds can ruin 20 tons of grain. Assuming that the total Quelea population in Africa is 1,000 million and that these birds feed for 30 days per year on the crops, then the annual loss is at least 600,000 tons. A more realistic estimate of loss could be nearly 1 million tons, when the damage caused by other birds is considered. Thus, possibly between 10 and 20% of the total sorghum production is damaged by birds.

The choice of the quality of grain to be grown is determined by the activity of birds in a given area. In Eastern Uganda where damage is due to species of birds other than the Quelea, only bitter sorghum can be grown in the first half of the year, when bird populations tend to be large. There is usually a marked decline in the size of populations during the second half of the year, making it possible to grow more palatable grain types. It is worthless to attempt to grow bulrush millet in the first half of the year, but this crop can be grown successfully in the latter half. The success of the finger millet crop in Eastern Uganda during the first half of the year probably depends on the bitterness of the immature grains, which are distinctly unpalatable to birds. Despite this, considerable damage is done to the ripe and more palatable grain just before harvest.

Clearly birds, and in particular the Quelea constitute the most serious drawback in the production of sorghum and millets in Africa. The serious nature of crop losses due to birds has made necessary control measures by fire, explosives and aerial sprays. The Kenya and Tanzania bird control unit destroyed about 66½ million birds per year during the period between 1956 and 1960 (9, 10, 12). Similar campaigns made in Western Africa between 1959 and 1961 destroyed over 600 million birds (11). As well as sorghum and millets, rice and wheat are in constant danger of bird damage. In fact, the Quelea campaigns in Kenya were

primarily to protect the valuable wheat crop grown in the temperate highlands. Even with such large numbers killed, it was considered necessary to have additional campaigns to bring the numbers to a level that could be controlled periodically.

The restriction imposed on small grain crop production in Africa by birds is so severe that unless greater consideration is given to continuing and expanding control measures, the quality and quantity of these cereals will be impaired for a long time. Because the Quelea problem would be prohibitively expensive to manage on an individual national basis, international co-operation similar to the locust control would be a more effective approach to the Quelea problem. Elimination rather than just the control of numbers would be preferable since the Quelea do not appear to occupy an important position in the balance of nature. Damage done by other grain feeders locally is particularly noticeable on small plots scattered about the wooded savannah countryside. As farming on a more extensive scale increases, damage due to this category of birds would become negligible in relation to total production. It will be a long time, however, before such changes become effective. The present outlook for sorghum and millets is that types with poor palatability will continue to be grown for as long as birds are a threat.

(b) Damage caused by storage pests

Storage problems of sorghum and millets fall into two categories. Firstly, since most of the grain is grown for seasonal subsistence needs, it is important that efficient methods of storage should be used if the grain is to last up to the time the next harvest is expected. Grains with poor storing ability tend to be used up within a short time, leading to shortages later in the year. The storage techniques used by the subsistence farmers who form by far the greatest proportion of land users in Africa are crude. Insect pests including the rice weevil (Calandra oryzae), the flour beetle (Tribolium castaneum) and the grain moth (Sitotroga cerealella) must account for considerable losses in grain. There is sufficient knowledge about proper methods of storage at present, which if put across to the farmer in Africa would make an important difference. The application of fumigants specially to suit the habits of the peasant farmer could be developed for more efficient storage. Reduction of losses during storage can be achieved by breeding specifically for resistance to a pest as demonstrated in sorghum (1, 2). Some varieties of sorghum are storable for up to 5 years, while most can hardly last longer than a few months. Unfortunately it is the good quality corneous endosperm types, liable to bird damage in the field, that tend to store well.

The second category of problems affects storing at commerical levels. Proper storage facilities are often lacking at trading centers, with the result that the quality of grain is affected before it is marketed. Better methods of storage should be more feasible at small trading centers than in villages, but solution to storage problems are so bound up with marketing and the economics of the produce that a discussion of one leads to the other.

TECHNICAL FACTORS

Place and time of planting

There is often a complete lack of a rational approach to assigning cereals to climatically suitable areas. The savannah zone where sorghum, millets and maize are grown is by no means a uniform area. Great differences in the amount of rainfall and its distribution occur even between areas close to one another. Areas where the maize crop is likely to fail more often than once in five years because of unreliable rain should be occupied by the more drought tolerant sorghum and the millets. Comparative trials assisted by agrometeorological studies are required on an extensive scale to determine which cereal will yield consistently under average conditions of a given area. In East Africa such trials have shown the superiority of sorghum over maize under poorer rainfall. Sorghum out-yielded maize by as much as four times on 9 inches of rain during the growing season in the Machakos district of Kenya (3), but there was a general tendency for maize to be superior at rainfalls above 15 inches. It is significant that this district with marginal rainfall for maize has had frequent crop failures and famines. Although sorghum and bulrush millet were the major cereals for human consumption in this area before 1900, the preference to maize at present is so great that year after year large acreages of this crop are planted with a great risk of failure. Frequently, serious maize failures are followed by marked increases in sorghum and millets acreage during the next season (4). Increased sorghum acreage after years of drought has been noted in Rhodesia also (8). Solution to the bird and palatability problems are necessary if the sorghum and millet potential in the drier savannah areas is to be realized.

(a) Fertility

Africa will never again go through the old days of shifting cultivation: no new virgin lands will be available once cultivation has exhausted the old. The same crops will have to be grown on the same piece of land generation after generation. A start on scientific methods of land management, including the user of fertilizers, farmyard manure, proper rotations should be made in Africa now. Although sufficient studies have made it clear that phosphate and nitrate increase yields on many soils, sorghum and millets are grown entirely without the use of fertilizer. The consumption of phosphate and nitrogenous fertilizers in Africa was respectively 1.6% and 4.5% of the total for Europe and the U.S.A. for 1962 and 1963 (calculated from data in 6). If is is assumed that most of the fertilizer is used on crops of significance in the world trade, practically none is spared for these cereals. There are two points to the problem. Firstly, fertilizers are not available at prices which the small farmer can afford even though government subsidies are paid in some countries. Secondly, improved seed of hybrids and varieties which make a more profitable response to fertilizer than the local varieties, are usually not available. In this respect, the marked increase in the

of fertilizer by the subsistence farmer in Kenya coinciding with the availability of high yielding maize hybrids must, perhaps, be quoted as a case example.

(b) Crop Improvement

A continuous and expanded effort on plant breeding is a basic need if improved seed of sorghum and millets is to be made available. Work on these cereals has been neglected for too long in Africa in favor of pure cash crops. There has, however, been a realization in the past decade that sorghum and millets will continue to provide a considerable source of food in the expansive savannah countries of Africa. The East African Agriculture and Forestry Research Organization supported by Commonwealth Development and welfare funds started a sorghum improvement program in 1958. Further support to this program came from the Rockefeller Foundation in 1963. The U.S. Agency for International Development, co-operating with the Agricultural Research Services have recently made possible the expansion of this program to include finger millet and bulrush millet. Notable developments in the organization and improvement programs have been made in Nigeria and the Sudan.

Varieties are needed that will not only yield well, but also meet the local demands for quality. Pest problems such as the central shoot fly (Atherigona indica) and birds might be solved, at least in part through breeding "resistant" varieties. There is undoubtedly sufficient variation in sorghum and millets which could be utilized for breeding drought-resistant or drought-avoiding varieties. The need for such varieties should become increasingly important as occupation of the drier savannah lands is made compulsory by the expanding population. The great variability in the protein content of sorghum can be exploited by the plant breeder to obtain varieties with greater nutritional values, and this is probably true in the millets also.

The research necessary for the general improvement of sorghum and millets requires financial assistance and patience. Competition for funds has been overwhelmingly in favor of the cash crops, with the traditional food crops coming low on the list of priorities. There is no reason to believe that a sorghum and millet improvement program need be a large and expensive undertaking. A small and relatively inexpensive program can be effective provided that its aims and objectives are clearly defined, and simple methods are utilized. High yielding varieties of sorghum and millets may be of limited use unless they are of the right quality demanded by the local population. There is a real danger of experts, most of whom have no experience with these cereals as human food, to spend valuable time on a subject of no direct relevance to a given region in Africa. A considerable amount of time must be spent on identifying the problems before a program is started.

Perhaps the most effective approach to sorghum and millets improvement work in Africa is at a regional level. Several countries with common interests can benefit from a single central program led by a few

experienced workers. The individual countries would thus be responsible for extension and only modest programs of research. A much looser co-operation between a number of regional programs might be encouraged especially in the exchange of germ plasm and technical information.

A well organized and expensive improvement program may have very little impact on production unless some system for multiplication and distribution of the seed is available. Thus, during the relatively short time the sorghum and millets improvement program has been in operation in East Africa, superior seed has been obtained which might have had a profound effect on production if a serious block to its multiplication and distribution had not existed.

(c) Availability of improved seed

A properly organized seed industry is a basic requirement if the benefit of research on cereal improvement in Africa is to be realized. Seed industry implies the multiplication and processing of high quality seed, and its distribution to the farmer. In this context, the part played by the seed industry in the production of the savannah cereals, particularly sorghum and millets in many African countries is negligible. The farmer relies on whatever is left over from the previous harvest for seed.

The great impact a seed industry can have in the production of cereals even at subsistence level is well demonstrated by the recent success of the maize program in Kenya. It so happened that a private commercial seed company was close to the National Agricultural Research Station at the time when high yielding hybrid seed was available, and played a large part in the practical application of a research finding. India, with many of her cereal production problems similar to those of Africa has recently made big advances in organized seed industry to support her sorghum, millets and maize improvement programs. It is also encouraging that a seed multiplication scheme, with particular emphasis on the food crops is included in the development plan of Uganda, and its impact on sorghum and millets production is awaited with anxiety (a modest estimate of 10% increase in yields is anticipated by simply improving the quality of the seed).

Admittedly the high capital cost involved constitutes a major drawback in establishing a seed industry, particularly in countries with little experience in the commercial production and utilization of cereals. In such cases the government must take the initiative, at least on a modest scale. A well organized extension service to demonstrate the superiority of better seed should be available at the same time as organized seed multiplication and distribution is introduced.

Management Practices

Sorghum and millets are grown under crude management techniques in Africa. Certain operations which are never carried out properly are known

to reduce yields considerably. Thus, evidence from East and West Africa suggests that planting sorghum later than the optimum sowing date halves the yield: a delay of one month can reduce the yield by 75%. Simple crop management practices including timely weeding and proper spacing, if carried out would make a significant impact on the production of sorghum and millets.

The continued application of poor management practices, despite knowledge of better methods is one of the most disappointing features of agriculture in Africa. A proper understanding of this problem lies in an appreciation of two factors. Firstly, good crop management entails the assistance of farm machinery to spped up the work, if the recommended operations are to be completed in time. Owing to the great cost involved, modern machines will for a long time play a negligible part in subsistence farming. Ox-drawn machinery of modest cost is the most practical alternative. Secondly, proper crop management practices are an education problem which must be handled by extension services. There is need for well organized extension departments to disseminate information by using numerous demonstration plots, on the basis of "seeing is believing", since most farmers are illiterate. Education in proper management stands a better chance of succeeding if the superior performance of improved varieties and hybrids is first demonstrated. Often this has a profound psychological effect on the population to accept other advice. In fact proper extension techniques can be effective without the aid of modern machinery in the subsistence cultivation of these crops. Small scale farming, so dominant in Africa cannot afford (and perhaps does not even require) expensive machinery. It can, however, afford to be advised.

ECONOMIC AND SOCIAL FACTORS

(a) Marketing

The absence of organized marketing systems in many parts of Africa is one of the most serious setbacks to the production of sorghum and the millets. Priority is understandably given to organizing the marketing of cash crops like cotton and coffee, while food crops often referred to as "minor crops", are neglected. A basic requirements for the encouragement of sorghum and millets, and indeed other savannah cereals is at least some form of bulk handling and marketing organization. The ideal system might eventually consist of rapid movement of grain to suitably placed central sites, provided with storage and transport facilities, from where it would be moved to supplement supplies in other parts of the country or to the coast for shipment. The need for such a well organized system would depend on the part which these cereals play in the external trade. Thus, as long as the present policy of self-sufficiency persist, the need for an ambitious marketing system will not arise, nor will there be incentive for improved production. This is an involved economics problem which is more relevant to a later session of this Conference. The important significant point to be noted here is that the grain policies are too modest.

(b) Utilization and processing

Practically all of the sorghum and millet produced in Africa is for human consumption, usually in the form of a thin or thick porridge. These cereals also form the basic ingredients for local alcoholic and non-alcoholic beverages--a function that should not be overlooked in the simple village life. Unfortunately, owing to restricted production of high quality grain types, mostly coarse grains are utilized for food. It is for this reason that maize is distinctly preferred to sorghum or millets in parts of East Africa; their consumption being mainly during months of maize shortages. There is thus a need for food technological methods to make sorghum and millets much more palatable and nutritious food crops. Special milling techniques could be used to extract an improved flour from these cereals, and a much wider range of more attractive recipes developed. There is no doubt that local food industries could be stimulated to produce better foodstuffs from sorghum and millets provided the initiative is taken.

With rising standards of living the demand for better quality food will increase. It would be an unsound economic policy to import wheat on a continued large scale in order to meet this demand, when little is done to improve the status of the cereals of the savannah zone. Although the evidence suggests that sorghum can form the basis of better food products (7), a rapid change from the traditional method of utilization will require education and a considerable amount of extension work.

APPENDIX TABLE I

Sorghum and Millet production in Africa ⊕

M = Millets
S = Sorghum
U = Unspecified sorghum and millets
Maize figures in brackets
⊕ From F.A.O.: World Crop Statistics, 1948-1964

Country	Area: 1000 hectares	Production 1000 metric tons	Yield 100 kg/ha.	Year
Bechuanaland	M...	...	4.5	1961
	S 258(1)	81(1)	3.1(4.4)	1961
Cameroon	U 416	377	9.1	1964
Central Africa Rep.	U 85(65)	53(28)	6.2(4.3)	1964
Chad	U 1150(19)	850(12)	7.4(6.3)	1964
Congo Rep.	U 83(358)	50(333)	6.0(9.3)	1959
Dahomey	U 135(419)	65(228)	4.8(5.4)	1964
Ethiopia	U 4768(776)	3015(714)	6.3(9.2)	1964
Gambia	U 40	44	11.0	1963
Ghana	M 103	70	6.8	1964
	S 166(202)	115(173)	6.9(8.6)	1964
Guinea	U 234	108	4.6	1964
Ivory Coast	M 100	43	4.3	1963
	S 50(248)	35(168)	7.0(6.8)	1963
Kenya	U 423(1170)	379(1108)	9.0(9.5)	1960
Mali	U 1240(85)	820(58)	6.6(6.8)	1961
Niger	M 1777(5)	1013(4)	5.7(8.1)	1964
	S 453	315	7.0	1964
Nigeria	U 4565(980)	2984	6.5	1957
Ruanda and Burundi	M 31(126)	23(149)	7.4(11.8)	1960
	S 164	148	9.0	1961
Senegal	U 972(33)	482(27)	5.0(8.2)	1963
Sierra Leone	M 7(19)	12(9)	16.3(5.0)	1964
	S 7	11	15.5	1964
Sudan	M 609(32)	386(25)	6.3(7.8)	1963
	S 1360	1320	9.7	1963
Swaziland	S 30(75)	16(30)	5.3(4.0)	1961
Tanzania	U 1093(273)	610(375)	5.6(13.7)	1951
Togo	U 268(130)	131(66)	4.9(5.1)	1963
Uganda	M 529(160)	....	....	....
	S 319	....	....	....
Upper Volta	M 822(169)	388(127)	4.7(7.5)	1964
	S 1173	878	7.5	1964
Zambia	S 162	122(52)	7.5(13.3)	1950

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PROBLEMS RELATING TO CEREALS: MILLETS AND SORGHUM

IRAT

SUMMARY:

The present paper first describes the ecological regions in which the two crops under consideration are grown the most, and mentions research already done or in progress on these two plants.

Suggestions are then made of themes for regional research activity. In particular these are:

-the establishment of a central collection for each of the crops

-studies of genetic and selection problems, including particularly

-comparison of selection systems
-analysis of certain genetic systems
-stem/grain relationship
-male sterility
-genetic research on mutations obtained chemically or by radio activity

-the following physiological studies:

-influence of photoperiodism and thermoperiodism
-carbon nutrition
-mineral nutrition

-protection against disease and parasites

-the technology of the two crops under consideration, especially:

-reassessment of knowledge in this area
-the establishment of technological norms
-perfecting methods of analysis and the measures for these standards or norms
-chemical and technological analyses
-studies of beer from millet and sorghum.

A. MILLET

In tropical Africa, millet is grown in areas where rainfall is between 250 and 900 mm per year, i.e., in the dry tropical zone.

Millet is practically the only crop in the driest part of the zone (isohets 250-500 mm) covering the northern part of Senegal, the southern part of Mauritania, the central part of Mali, the northern part of Upper Volta and a large part of Niger and Chad.

Millet is grown alongside sorghum in the more humid part of the zone (isohets 500-800 mm) covering the southern part of Senegal, the southern part of Mali, the southern part of Upper Volta, the southern part of Chad, the northern part of Central African Republic and the climatically very special area of Kwongo (Congo Kinshasa).

Important research has been conducted on millet in this zone, but mainly for local application. A few general studies have been conducted, in particular:

- a taxonomic study of the botanical characters of millet (variety and, on occasion, specific characteristics)

- mineral nutrition.

In view of the narrow climatic limits of this crop in Africa, many general studies should be conducted from a regional point of view.

CENTRAL COLLECTION

A central collection of regional and foreign stocks could be maintained in a station, with samples of seeds kept between seasons in cold rooms under controlled temperature and humidity.

The collection would be matched with detailed variety maps to be established in the region on a country basis.

The collection would be used for systematic observations and studies:

- morphological observations
- phenological observations on disease and parasite resistance
- inter-variety breeding for the purpose of testing heterosis effects
- transfer of useful genes.

GENETICS AND BREEDING PROBLEMS

Problems of methodology should be studied concerning breeding; in particular comparative studies should be made of the various breeding systems; mass selection, recurring breeding, in-breeding.

Improved or pure lines bred genealogically can be subjected to simple hybridization, with cultivation of either F1 or further generations, the decrease in yield during further generations could also be studied.

In addition, special studies should be undertaken as follows:

Analysis of certain genetic mechanisms

- Analysis of genetic mechanisms responsible for the switch from feed to food grains

- Study of sporadic return to wild form, very frequently observed in cultivated millet (N'Doul form in Senegal, Chibras in Niger)

Study of stem-grain ratio

It is important to get as low a ratio as possible; either through creation of artificial mutants or through transfer of dwarfing genes.

Study of male sterility

The creation of millet hybrids which can be grown in F1 is done through use of sterile male lines, which can be either American or African, through transfer in stocks or lines of male sterility cytoplasm.

Separate tests can be conducted on:

-male sterility of American origin (Tifton in Georgia, U.S.A.)
-male sterility of Indian origin (Ludhiama in India)

These two systems of male sterility are independent from one another and can be cross-bred.

PHYSIOLOGICAL STUDIES

Influence of photoperiodism and thermoperiodism

Photoperiodism and thermoperiodism influence plant growth (total amount of dry matter) and development (duration sowing—seed setting).

Development will be sub-divided into several phases and an attempt will be made to establish the genetic determinism of each phase.

For such a study, research will be conducted in the millet zone, with central coordination of tests performed in carefully selected sites in as widely different locations as possible.

Study of carbon nutrition

Use of labelled CO_2 will lead to the establishment of a photosynthetic balance in relation to leaf level and in terms of the various phases of development.

Study of mineral nutrition

So far, studies in this field have been conducted using chemical methods. Future studies should use labelled elements, for the purpose of

determining how and where P, S and N metabolites are transferred and accumulated in the plant.

An attempt will be made to analyze the formation and utilization of carbohydrates and proteins between growth and reproductive stages for plant.

Similarly, an analysis will be made of the same elements (formation and utilization) in plants with different length of stem (long or short).

MILLET PROTECTION AGAINST DISEASES AND PARASITES

Problems to be solved are biological and genetic in nature; the latter category may be studied regionally, i.e.:

-study of millet stem borers
-study of greenness in millet.

Both studies are entomological and phytopathological.

-study of resistance to striga
-study of resistance to birds, with possible use of morphological characters (presence of hard beards, resistance to rooting up).

Both studies deal with genetics.

Of course, millet will be included with other foodstuffs in studies on conservation of agricultural products in storage (in particular, problem of trogoderms) which are to be part of regional crop protection research.

MILLET TECHNOLOGY

Very few studies have been devoted to millet technology.

In the first place, stock should be taken of data already accumulated in the area; on a country basis, a map or a card file (or both) should be established for:

-the various uses of millet (as human food and possibly animal feed, as fermented liquors, sugar production, forage, etc.)

-processing (threshing, protection against insects, conservation, milling, meal texture, etc.)

-cooking methods (organoleptic and qualitative preferences)

-economic aspects (family consumption, marketing, prices).

Then consideration could be given to:

-a definition of specific technological standards, in terms of the above-mentioned elements, which should be met by millet in order to satisfy the special requirements of various end-uses.

-development of methods for analyzing and measuring such standards

-chemical and technological analysis of kernels from most commonly used varieties and of varieties used as gene-bearers.

Such analysis should lead in particular to a determination of nitrogen and mineral contents of the kernels.

-research to give some stability to home-made millet beer - 20 to 30% total millet production is used for beer production.

Beer is made by women; it must be drunk within 24 hours because it does not keep; losses due to instability appear to be considerable.

In order to give some stability to beer, research is desirable on economic, nutritional, social and technological aspects; it is therefore necessary:

-to determine the optimum threshold of conservation with miniuum losses due to alteration

-to determine for each group of human population the nutritional value of millet consumed as solid or liquid food. At the same time, to determine the organoleptic qualities and the social and religious value of each type of beer.

-to develop a very simple conservation method, which could be easily and immediately disseminated among home-brewers and would take into account all the available data.

Similar regional studies are to be conducted on sorghum.

It appears that all the regional agronomic studies could be performed in the dry tropical zone, in a truly representative station (such as C.R.A., at Bambey), equipped with the necessary facilities, which would coordinate research conducted in a series of secondary stations and test-centers located both in the dry and in the more humid part of the area.

B. SORGHUM

In tropical Africa, sorghum is grown in areas with rainfall of between 500 and 1200 mm , i.e. in several of the areas under consideration.

Dry tropical area

In the more humid part of this zone (between isohets 500 and 800 mm), covering the southern part of Senegal, the southern part of Mali, the southern part of Upper Volta, the southern part of Chad, the northernmost part of Cameroon, the northern part of Central African Republic, the Kwongo area (Congo Xinshasa) sorghum is grown alongside millet. In the southern part of Madagascar, sorghum is grown under similar climatic conditions.

Humid tropical area

Between isohets 800 and 1200 mm, sorghum grows in the absence of millet, but is often found in association with maize. This area covers Casamance, the southernmost part of Mali, the northern part of Ivory Coast, the northern part of Togo, the northern part of Dahomey, the northern part of Cameroon the southern part of Central African Republic, the northern part of Congo Kinshasa.

High tropical area

Mention may be made of Kwanda, where sorghum is extensively grown.

Of course, such a distribution is largely schematic; sorghum is grown sporadically in equatorial savannah and along rivers (Senegal, Niger, Logone, etc.), on formerly flooded land in the driest part of the dry tropical area.

Important research work has been conducted for a long time on sorghum in these areas, but mainly for local application.

General studies have been conducted, in particular:

- a study on system and botanical characters of sorghum (variety and specific characters in Senegal, Mali, Chad)

- a study on mineral nutrition of sorghum.

Although climatic boundaries of sorghum cultivation in Africa are less narrow than those of millet, many general studies should be performed from a regional point of view. Some studies could deal with all the above-mentioned areas, or alternatively, with one area only (for the purpose of sorghum research the high tropical area may be attached to the humid tropical zone, account being taken of the special characteristics of lower temperatures).

CENTRAL COLLECTION

A central collection of regional and foreign stocks could be maintained in a station, which should be located on the boundary between the dry tropical and the humid tropical zones (for example, in Upper Volta, at Saria). However, it is not certain that a single station would be desirable; quite likely, the main collection should be kept in the dry tropical zone, in one of the diversification centers (in Chad, for example, in the Déli area), while an annex could be established in the humid tropical area; the main station would keep, in cold rooms, under controlled temperature and humidity, samples of seeds from both collections.

The central collection (with the annex) would be a true gene bank.

The collection would be matched by detailed variety maps, drawn up on a country basis.

The collection would be used for systematic observations and studies:

- morphological observations
- phenological observations; resistance to diseases and pests
- inter-specific and inter-variety breeding
- transfer of useful genes.

GENETICS AND BREEDING PROBLEMS

Problems of methodology should be studied, in particular comparative study of various breeding systems:

- in-breeding (sorghum has a predominant autogamy)
- hybridization, with use of cytoplasmic male sterility, to be found in some dwarf sorghums of American origin; in this connection, use shall be made of the collection, to determine the lines which maintain male fertility and lines with capabilities of restoration of male fertility.

Hybridization may lead to the possible use of hybrids or to gene transfers (dwarfing in particular) through back-cross. This method would tend to shorten the stem of giant varieties with a view of improving the stem/grain ratio.

In addition, a special study should be devoted to the natural maintenance of male sterility, or, more specifically, to the natural maintenance of sterile dwarf lines in the African environment; wind fecundation seems often to be deficient for reasons which are not well understood.

On the other hand, under general research to be undertaken on the use of radiations and chemical mutants, sorghum is the material of choice for the genetic study of mutants.

PHYSIOLOGICAL STUDIES

Studies similar to those devoted to millet.

Influence of photoperiodism and thermoperiodism

Work is to be undertaken under the scientific supervision of the central station, not only in locations selected at latitudes as widely different as possible, but also in high altitude zones (under temperature conditions very different from those at the same latitude but at low altitude).

Study of carbon nutrition

Study of mineral nutrition

PROTECTION OF SORGHUM AGAINST DISEASES AND PARASITES

As in the case of millet, problems to be solved are biological and genetical in nature; problems which can be studied on a regional basis are:

- study of stem borers; their biology; variety resistance to borers (research to be conducted on the central collection)

- study of dipterons leaves and flowers (midges in particular); their biology; specific and variety resistance to those insects (research to be conducted on the central collection).

- study on sorghum kernel smut.

- study on striga resistance, possibly from extraction of certain chemical neutralizers.

- study of plant resistance to bird bills, through change in certain morphological, or even chemical, characters of the kernel; the anatomical characteristics of the flower stem are to be taken into consideration.

As in the case of millet, research will be performed on sorghum conservation in storage.

SORGHUM TECHNOLOGY

Technological studies exactly similar to those on millet; they can even be conducted simultaneously in the same stations and laboratories concerning:

- technological standards
- development of methods for the analysis and measurement of such standards
- chemical and technological analysis
- study on stabilization of home-made sorghum beer.

It appears that most regional agronomic studies on sorghum could be conducted in the humid tropical zone, perferably on the boundary with the dry tropical zone.

Secondary test centers should be provided both in dry tropical and in high tropical areas.

PROBLEMS AFFECTING THE HIGH PRODUCTIVITY OF CEREALS IN THE HIGHLANDS OF ETHIOPIA WITH SPECIAL REFERENCE TO WHEAT BARLEY AND TEFF

Dr. Melak H. Mengesha
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SUMMARY

Several prevailing factors are known to affect the high productivity of cereals in the highlands of Ethiopia. By far the majority of the cereals in Ethiopia are presently produced at the higher elevations and because of that no special attempt is made to compare the factors that exist at high and low elevations.

In general the problems are of a complex nature, involving particularly (1) Unutilized germ plasm (2) Plant diseases and pests (3) Improper grain storage (4) Soil and water problems (5) Lack of efficient transportation and marketing facilities (6) The prevalence of traditional agricultural system (7) Shortage of trained man power and (8) Unclassified land ownership and use systems.

It is most encouraging, however, to note that the Ethiopian Government has taken some aggressive steps to cope with the majority of the problems. The most prominent one, as far as productivity is concerned, is the establishment of the Institute of Agricultural Research with the help of the United Nations Special Fund and FAO. Equally important development is the establishment of the Ethiopian Ministry of Land Ownership and Use. Such steps are signs of recognition of the main problems affecting the productivity of cereals.

The wide range of variation of problems in Ethiopia would tend to suggest that if the productivity problems could be solved through an aggressive program of agricultural research, the results might have a broader framework of application in the neighbouring African States.

BACKGROUND

Ethiopia is a country with wide variations of environmental conditions located between 3½° and 18° North latitude and 33° and 48° East longitude in the Eastern portion of the Continent of Africa. She has an area of about 1,221,900 square kilometers inhabited by a population of approximately 24,000,000. Her topography varies from towering mountains with over 15,000 feet above sea level to altitudes well below sea level. Her great expanses of plateau range from 5,000 to 10,000 feet above sea level. Average annual rainfall widely varies from absolute desert in the Danakil depressions to 2,300 mm. at Gore (2,035 meters). The rainfall pattern is of two general types, namely heavy rain from July to

September and light rain in March and April. The extreme diversity of the country is also reflected in the natural vegetation. The diversity of the country might have accounted for Ethiopia's being one of the important centers of origin for vast numbers of cultivated plants ranging from tropical coffee to temperate cereals.

As ancient as Ethiopia is, her long standing system of traditional agriculture has imposed on her a subsistence type of farming. Increase in population, migration of farmers to cities (presently not very significant), foreign exchange balance, and the establishment of small, local agricultural industries are gradually working against this self-sufficient type of farming.

Roughly estimated data on the 1966 national production of wheat, barley and teff are given below.

	Total cultivated hectares	Yield per hectare (tons)	Total Production (tons)
Wheat	431,500	0.73	315,000
Barley	990,000	0.83	821,700
Teff	1,898,400	0.70	1,328,880

Without artificial soil fertilization

The above table gives a general view on the relative importance of the three crops in Ethiopia as well as the very low productivity of all of them. Obviously, the production of teff is much higher than wheat and barley put together. The cultivation of teff in Ethiopia goes as far back as recorded history. Ethiopia is the only country in the world that cultivates teff for human consumption. Latest research findings have confirmed that the teff bread is a highly nutritive food to man.

Problems Affecting Productivity

In such a most diverse country with long standing tradition, one would naturally expect a wide variation of problems. The majority of problems seems to be typical of the problems prevailing in many other African countries. This similarity would seem to suggest that accelerated agricultural research in the various environmental conditions of Ethiopia might find a wider frame of adaptations and reference to the Continent of Africa.

It must be underlined here that the most basic problem in almost all

African countries is underdevelopment itself. Where should we start to develop? If we for a moment stop and think about the developmental history of the presently developed countries of the world, it does not take us long to discover that they all started their process with agriculture. Thus the most sensible approach of development seems to be where major emphasis and priority are given to the basic nutritional requirements of the most important element in development, man himself. Hence, it is difficult to comprehend that more emphasis is given to other areas when what we need the most is a few more grains per hectare to feed millions of underfed or starved population. If this situation is not reversed immediately, the chances for higher production will remain retarded and the whole situation will breed national catastrophe.

The major technical and nontechnical problems affecting the productivity of crops are (1) Unutilized Germ Plasm (2) Plant Diseases and Pests (3) Improper Grain Storage (4) Soil and Water (5) Weeds (6) Lack of Transportation (7) Poor Marketing System (8) Lack of Training and Facilities and (9) Miscellaneous Problems. The nature and importance of each problem is briefly discussed below.

1. Unutilized Germ Plasm: In Ethiopia it is not the lack of the desirable germ plasm that affects high productivity. Since Ethiopia is the center of origin for a number of cultivated crops, the existence of highly diversified crop germ plasm has made Ethiopia an important collection center. But, unfortunately, this invaluable wealth of germ plasm has not been harnessed for the need of the region. The seed stocks that the majority of farmers are using now are either inferior or impure and as such contribute to the poor productivity of cereals.

2. Plant Diseases and Pests: The rusts, smuts, and helminthosporium diseases are as a group the most limiting factors in cereal production. The lack of completely resistant varieties as well as the lack of means and facilities to carry out nationwide or regional seed treatment operations has been a major drawback. The College of Agriculture has repeatedly demonstrated the feasibility of seed treatments in Ethiopia. It is well known that no other agricultural practice produces such vast benefits to farmers for only few cents per acre than the application of protective fungicides and insecticides to seeds. Likewise no other practice is more practical and economical than breeding resistant varieties to diseases.

In the area of pests serious damage is accounted by army worms, grasshoppers (probably Paracinema sp. and/or Paratettix sp.) and black beetles (chrysomelid sp.). Locusts are also a serious but occasional hazard particularly in the Northeastern portion of Ethiopia.

3. Improper Grain Storage: Stored grain insects add to the problems of productivity of cereals. The rice weevil (*Sitophilus oryzae*) has been reported as the most damaging in various parts of Ethiopia. Reliable sources estimate that the losses from improper storage on the farm range from 20 percent in the drier areas to as much as 50 percent in the more

humid areas of the country. After a farmer has escaped most of the hazards of bad weather, diseases, insects, weed competition and many obstacles, it is unfortunate that a great portion of his grain is lost to insects during storage.

4. Soil and Water: The problems in this area are of high magnitude. Annually, millions of tons of top soil are washed away from the highlands where most of the cereals are grown. The heavy rains are also annually damaging a substantial number of hectares of crops. Because of excessive erosion a great many hectares of fertile lands are losing their fertility and thus yielding less and less per hectare annually. No national soil and water conservation projects have been established which makes the problem even more severe.

Another dreadful agricultural practice in the highlands of Ethiopia is the burning of top soil known as "Gie" in Ethiopia. After several years of fallow, the soil is plowed five to eight times and gathered into heaps and burned with cattle dung for about ten to fifteen days. The burned heap of soils is then spread out, plowed once more and planted with mostly barley. Considerable amount of organic matter that has been formed and stored through the several years of fallow are burned and destroyed in one burning season.

The farmer seems to get a good crop during the first growing season following the "Gie". The yield scales down rapidly to the extent of forcing the farmer to fallow the burned land in only two years. By burning the soil, the farmer apparently enhances the availability and absorption of mineralized nitrogen and phosphorus at the expense of his precious organic matter. Preliminary experiments conducted in this area have shown that the use of commercial fertilizer could remedy the problem.

The problem of soil fertility in general could be declared as a major problem affecting the productivity of cereals. It has been demonstrated experimentally that yields of cereals could be almost doubled with the use of fertilizers.

5. Weeds: A major portion of the farmer's grain production is annually lost due to weed competition. In view of the high expense of hand weeding, the unavailability of laborers at the right time and the inefficiency of hand weeding, urgent studies should be made in the areas of chemical weed control suitable for our conditions. Preliminary investigations on the possible application of 2-4D to combat broad-leaved weeds in wheat plots has shown promising results.

6. Lack of Transportation: A number of vast and fertile areas are still inaccessible due to lack of transportation. Also the grain that is produced in certain remote areas cannot be utilized without access. The inavailability of cheap and efficient means of transportation is seriously hampering the potential productivity. It is therefore

essential to improve the transportation facilities if more grain production is desired. The importance of transportation in agriculture cannot be over emphasized.

7. Poor Marketing System: The availability of accessible and reliable markets is an important incentive to higher production. The cost of transportation and marketing are so often high to the extent of blocking the farmer's desire and interest to produce more. Such a condition definitely affects the productivity of any nation and it must be improved as a high priority.

In general the problems associated with marketing are so complex that their solution should not be left to the farmer. The Government must establish an easy, efficient and reliable marketing system. Before such a system is established a thorough investigation should be made in the areas of standards, units of measurements, values of farmers, traditional marketing systems of respective regions and other similar problems.

8. Lack of Training and Facilities: Since the majority of the present farming population is illiterate, new farming methods and techniques cannot very easily reach the farmer. Basic agricultural requirements such as soil fertilizers, seed innoculants, fungicides, insecticides and farm machinery are beyond the financial capacity of the farmer if not non-existent. All these add to the problems of low productivity.

9. Miscellaneous Problems: There are so many other problems that affect the productivity of crops. For instance, the type of subsistence farming system is a major limiting factor. Government developmental policies may not emphasize or encourage the priorities of agricultural development. In some cases there may be the illusion of higher production which might in fact be lower production when compared with the increase in population. The problem of farmers migrating to cities contributes to the lower production of crops.

The problems seem to be infinite. But as long as we understand and recognize the problems as problems, there is hope that they may be solved through agricultural research and application.

RESEARCH ON TROPICAL RICE-GROWING

R. Chabrolin, IRAT

SUMMARY

This paper is a very general account of the types of research carried out into rice-growing with the goal of improving and increasing rice production in tropical countries that are technically under-developed and sparsely populated. This means extensive rice-growing on small, dispersed areas.

The rice-growing stations in francophone Africa followed parallel research pathways, and an overall approach to the problems encountered was arrived at through their past experience which continues to be followed by the IRAT stations.

Soil - Besides pedological research, some studies were also undertaken on fertilization:

- Fertilizer trials comparing different fertilizer formulas or systematically varying the level of the elements.
- Preliminary research on the mineral deficiencies using potted material. Excellent results are obtained by this method. The potential fertility of rice-growing soils was reconstituted by this method, and it is possible to replace each year the elements removed by the crop. The maintenance fertilizer can be validly determined by field fertilizer trials.

Water - Water control is often defective. Studies of irrigation methods and techniques and submersion systems have not as yet been undertaken.

The Plant - Most of the research undertaken so far has been aimed at the plant itself, results in this area being the cheapest to disseminate. Characteristics sought are about the same for all stations (barring adaptation to various ecological conditions): high yield, resistance to various pests and diseases, good response to fertilizer, good technological qualities.

Results obtained have been excellent—particularly enabling red-grained glaberrima to be replaced.

Varieties with high productivity potential and low level of reaction to varying ecological factors should be emphasized. The author gives a table showing schematically a program of varietal improvement aimed at these objectives and stresses the need to organize seed multiplication.

Man and his activities - Research on cultivation techniques, protection and processing has not gone beyond the stations. This type of research is only worthwhile if the extension and rural development organizations are fully capable of making the farmers benefit from the results obtained.

* * *

In a very general way, research on rice consists in defining all the ways of improving production, quantitatively qualitatively and economically, in the tropical environment.

Tropical rice production with which we are here concerned, is generally found in an environment of low-technology and under-population, and the main elements can be outlined as follows:

- low standard of living of the producers, cause and consequence of a passive attitude towards technical and economic problems.
- widespread under-employment (even in agriculture).
- insufficient or unadapted rural organization: the social structures, when they exist, have long been oriented towards the conservative and static, rather than towards the dynamic (there are some exceptions to this rule, and the future will tell whether these will become the general rule or whether they will become reabsorbed); the professional services are either non-existant or exist only in theory; the technical services are rudimentary. Some have suffered from too rapid replacement by insufficiently qualified personnel.
- very low level of capital investment in agriculture: capital generally means the land itself, and often even that is not owned individually. The farms are very small, one to two hectares on the average. Any improvements, if there are any at all, usually belong to the Government, which make them foreign to the farm itself. Another form of capital which is more variable, is farm capital, which can vary from a few hand tools to simple animal-drawn plows or other material. Mechanical traction equipment is extremely rare.
- very low level of agricultural techniques; often resembling the gathering level of agriculture. This is due to the above reasons, especially the low amount of available capital, lack of information (illiteracy) and to the intellectual passivity of the farmers who really are only interested in their immediate subsistence needs.

Thus, paradoxically, we are dealing with extensive rice-growing systems, practiced on small—often disperse—areas by a great number of farmers who are not very concerned with technological progress and not very receptive to the technological progress brought or imposed upon them. Herein lies the originality of tropical rice-growing research; this is what gives it its own peculiarities.

Nevertheless, progress must go on very rapidly: rice consumption is increasing very rapidly and the rice production goals of most national plans are very ambitious. Here are a few examples:

1. SENEGAL - 3,350,000 inhabitants (July 1964)
Present production: 101,000 tons (paddy)
(1962 to 1964 average) on 75,000 hectares

Goals for 1969: 132,500 tons (32% increase over 1962-64) on 87,000 hectares (+16%)

Goals for 1980: 345,000 tons (or +242%) on 152,000 hectares (+103%)

Imports are constantly increasing. At present they are in the neighborhood of 150,000 tons per year. This means that research must find a way to increase yield per hectare.

2. MALI - 4,150,000 inhabitants (July 1964)
Average production 1962-64: 193,000 tons (paddy)
1960 Production:
A) Office du Niger: 63,000 tons (paddy) on 35,000 hectares, or a yield of 1800 kilograms per hectare
B) Rest of the country: 125,000 tons (paddy) on 150,000 hectares, a yield of 830 kilograms per hectare.
1965 Goals:
A) Office du Niger: 87,000 tons (paddy) on 150,000 hectares, or yield of 2500 kilograms per hectare
B) rest of the country: 237,000 tons (paddy) on 175,000 hectares, or a yield of 1350 kilograms per hectare.

These goals were not reached. A major research effort is required to improve yield per hectare.

3. IVORY COAST - 3,750,000 inhabitants (July 1964)
Production 1960: 165,000 tons (paddy) of which
160,000 tons pluvial
5,000 tons irrigated
1962-63 average production: 225,000 tons (paddy) of which: 200,000 tons pluvial, 25,000 tons irrigated on approximately 200,000 hectares.

Goal 1970: 295,000 tons (paddy) of which 217,500 pluvial and 77,500 irrigated with an average annual increase in production of 16.6%
Projected indexes of increase, 1960 to 1970
pluvial rice: 135%
irrigated rice: 1560%

But the goals foresee yields reaching under certain conditions:

5,000 kilograms per hectare in irrigated farming
1,800 kilograms per hectare for pluvial farming

Yet, the Ivory Coast imported, in spite of its 200,000 hectares planted in rice:

1962-63 (average)	:	15,000 tons of rice (index 100)
1964	:	60,000 tons of rice (index 170)
1965	:	77,000 tons of rice (index 228)

These figures mean that a great deal of research effort is required.

4. MADAGASCAR - 6,100,000 inhabitants (July 1964)

A few years ago it exported 55,000 tons per year
Imported in 1963: 100,000 tons of rice

1963 production:	1,293,500 tons	(paddy)
1964 production:	1,300,000 tons	"
1965 production:	1,100,000 tons	"

Goals for 1968:	1,470,000 tons	
1973:	1,790,000 tons	

Increase forecasted:	1960-62 to 1968:	+ 21%
	1960-62 to 1973:	+ 47%

These figures mean that research must make a big effort at the same time as extension programs see that the application of techniques is done properly and that improved varieties are made available. (example: GOPR Operation)

Research on rice is of relatively recent origin, and it often began when and where rice-growing was taken up in a region, where rice-growing was not a traditional occupation. Starting off with very modest means, restricted personnel, the researchers had to determine the problems and discover the production bottlenecks before they could turn to finding solutions for remedying them. The lack of coordination between researchers and producers, plus the lack of preparation of the researchers who were well-trained to solve problems but not so well-prepared to define them nor to ascertain their order of urgency, has brought about a certain lack of balance in the importance accorded to the different parts of the research programs. This tendency was quickly corrected, and everywhere that research programs were undertaken in terms of the real needs of the farmers, the results obtained were excellent and speak for themselves. This is true of the para-administrative projects such as those of: Richard-Toll, CGOT, Office du Niger, as well as for sufficiently structured rice-growing projects such as Lac Alaotra, Marovoay, and the SMPR of Upper Guinea. This points out the important task of the infrastructure which must send information in two directions between research and production:

- from the rice-grower to the researcher to pose the problems and define them
- from the researcher to the rice-grower, to make the solutions known and see that they are applied properly.

It can be observed that although the rice-experimental stations were placed in different contexts, the results obtained and the paths followed were very similar. From past work a common doctrine developed on how to approach a problem. This doctrine, which is still applicable in spite of some modifications and improvements, is used by the experimental stations that IRAT has taken over or established.

Agriculture is a complex whole which involves the interplay of various factors: climate, soil, water, human beings and their actions, other living beings (the cultivated plant and its enemies). If one seeks to improve the last four elements in this complex, it can only be done in terms of the first, and therefore the climate and its effect must be studied and known. This is the role of bioclimatology. We will not go into this here, as it is beyond the scope of our subject matter.

THE SOIL

Study of soils revolves around two main fields, soil survey and soil fertilization: IRAT is involved in both.

Fertilization is specifically connected to rice-growing, whereas pedology, like bioclimatology, is much more universal in application; nevertheless, the soil maps prepared by the pedologists make it possible to foresee the area of applicability of the results obtained in other branches of research, such as fertilization. Pedology also makes it possible to get an a priori idea of appropriate crops for particular soils and what techniques would suit them best—deep plowing, drainage, etc.

However most of the improvements which can be brought to the soil element of the agricultural complex are brought through fertilization. Research in this domain entails determining the nature, levels, methods of application, of mineral or organic fertilizers which could increase rice-growing yield under the best economic conditions.

General use of mineral fertilizers for tropical rice-growing (currently so rare as to be negligible) will have serious economic implications for the countries involved:

- there will be a need for pre-financing the purchase of fertilizers by the farmers, which means setting up credit organizations and seeing that they function properly;
- establishment of a network of facilities for storage and distribution;
- important repercussions on the balance of payments, or creation of national fertilizer industries.

It would therefore appear there is no time to be lost in completing the experimental studies. Two distinct lines of research are currently being conducted:

a) Experiments in the field making it possible to compare either various fertilizer formulas (established beforehand) or, and this is more rational, formulas systematically varying the level of elements (two or more) that it is believed will improve yield. The NPK 3^3 experiments are

typical of this kind of research. This is a sure but long and costly job. It is not easy from the outset to forecast the action of the different mineral elements (so that a great many must be studied) nor to know the levels at which the elements will start benefitting the soil. Indeed, the phenomenon of fixation, expecially of phosphorus, is often important for the soils involved in rice-growing.

b) Under these conditions, it is necessary to try to reduce the problem by first trying to find the soil deficiencies, which is done on a smaller, less tedious scale than agronomical experiments in the field.

The chemical analysis of the soil and the plants (foliar analysis) was first envisaged. At least in rice-growing, there has rarely been observed sufficient correlation between the results of these analyses and the yield that it was possible to obtain from using chemical fertilizers. The reasons for this are not clearly known though very probably it has to do with the analytical techniques themselves and also the sampling techniques.

Professor Chaminade's method for detecting soil deficiencies by using small pots of a plant such as ray-grass shows the same preoccupation with trying to reduce the tedious work of field trials. There is a direct correlation between the deficiencies observed through this method and the responses observed in the field. This method also makes it possible to approximately evaluate the amount of each element needed to correct the deficiencies.

In field trials, the required elements (individually) are introduced in ever-increasing amounts until the presumed optimum is reached, and then it is possible to establish the soil-plant response curves precisely for each one of the elements. Thus correction fertilizer can be defined, and basic fertilizer, capable of raising the fertility of the soil from its present, often low level, to its optimum potential level, which is often very high.

Then it is only a question of maintaining this fertility level, by returning to the soil the elements that the crops remove from it. This is the role of maintenance fertilizer, which is determined by calculating what is removed from the soil and confirmed through field trials.

Excellent results have been obtained for rice-growing in this context, especially by IRAM in the high plateaus of Madagascar. Here, for example, are some of the results obtained from an experiment done at Mahitsy:

1) Diagnosis of deficiencies from potted material

	Average of 4 cuttings
Complete fertilizer	100
Fertilizer without phosphorus	13.5*
Fertilizer without potassium	30.5
Fertilizer without calcium	90.2
Fertilizer without sulphur	42.2
Fertilizer without magnesium	98.3
Fertilizer without trace elements	97.7

*Weight of clipped ray-gras, taken to 100 for the control.

Definite deficiency in phosphorus and potassium, less in sulphur (nitrogen deficiencies are not measured by this method).

2) Effect of fertilizer

Nitrogenous fertilizer	1964-65 Complement: 1000 kg P_2O_5/ha 600 kg K_2O/ha	1965-66 180 kg K_2O/ha
0	4487	4733
30 kg nitrogen/hectare	4997	----
60	5096	5892
90	5437	6027
120	5787	6326
150	----	6546
200	6572	6131
control	2821	2905

3) Response to phosphorus

Phosphated fertilizer applied in 1964	1964-65 Complement: 120 kg N/ha 600 kg K_2O/ha	1965-66 Complement: 120 kg N/ha 180 K_2O/ha
0	5842	5502
100 kg P_2O_5/ha	6173	5728
200	6513	6413
300	6852	6489
400	6681	6714
1000	6854	7088
control	2821	3080

No response was observed to potassium.

All aspects of the application of fertilizer (date, break-down, placement techniques) and the different forms in which it can be applied, have not been studied or have been studied only in a sketchy and fragmentary manner. Nevertheless, these techniques have a great deal to do with the efficacy of the fertilizer and therefore with the yield, which is the primary concern of the users and governments involved.

Finally, in the field of flooded rice-growing, a vast field of study has scarcely been touched upon. This is the whole area of soil toxicity, which is often due to low pH and low redox potential. World experience shows that these problems are found everywhere; scarcely any work has been done in this area in the zones that we are concerned with there.

WATER

In pluvial or submerged rice-growing, it is generally not possible to control the quantities of water at the disposal of the plant, and there is usually either too much or too little. In the case of submersion rice-growing, the water regimes are generally conceived as a function of hydrological, topographical and economic considerations rather than for the precise needs of the plant, which are not generally known. Defective manipulation of water is very often the main reason for low yield.

The extension of old fields and the realization of new preparations at the best price possible, will require more and more rigorous use of available water; the price of water should never be dismissed as negligible if only because of the work involved for its distribution.

The quantity of water necessary for the irrigation of a rice-field varies with the terrain (percolation), the climate and the variety of rice grown (evapotranspiration). These vary themselves over time and depending on the quantity of water available (ground water system, irrigation system). A precise study of the water needs of rice, linked to the metabolism of the plant, cannot be done at our experimental stations. However, a few of our stations are being equipped with the necessary hydrological equipment to do so.

Nevertheless, if secondary structures (dams, irrigation and drainage canals, etc.) were put in, in most cases, this would be a vast improvement over the existing water-utilization. While this type of secondary structure was originally foreseen by the initial plans, but left to the users to put in, they were often left out, because of the lack of follow-through on the one hand, and the lack of motivation on the other. The maintenance of these structures is often a problem as well.

In the case of irrigated rice-fields, it would be important, and this has only been sketched, to define the irrigation norms more strictly, if only for reasons of economy, so that countless wasted liters of water are not thrown into the drainage canals.

The water temperature generally is not a problem in tropical climates, nor is its composition. Some marl water (estuary-water) is salty, but one can protect the crops against this by using dams, catching rainwater, etc., and by using rice varieties that are resistant to salt such as Basse Guinée, Casamance, and Siné Saloum.

The study of submersion systems can be done at experimental stations if certain modifications are made. One station, the Guédé Station in Senegal, is actually equipped to do this at present; another, the Ibétémi station in Mali is currently being modified so that it can engage in this kind of research.

These studies will be of particular interest for establishing the utilization norms for the makeshift hydraulic equipment which has been set up here and there, and which, although they do not make complete

water control possible, nevertheless generally make it possible to reduce flooding and falling as well as to control flooding level for submerged fields (such as Senegal delta operation, 30,000 hectares).

THE PLANT

The plant has been up to now the main subject of research. This is perfectly logical, as it is through varietal selection that the least costly improvements could be made.

The characteristics sought are more or less the same from one experimental station to another. They only vary as to adaptation to the ecological particularities of each rice-growing zone. These are:

- duration of vegetative cycle adapted to the requirements of the environment or the user (multivarietal series, spacing of the crops, etc.)
- high yield
- resistance to disease, lodging, shattering, salt (if applicable) and so on
- good response to fertilizers
- good technological quality: white grains, generally long or of medium length, translucent, and not breaking or cracking when handled.

Up to now, the organoleptic qualities of the product, which are particularly hard to define, have not been taken into consideration for selection.

Variety improvement is done at the stations by distinct processes used individually or concurrently:

- collection of local varieties, shelling, characterization and isolation of best types;
- introduction of foreign selected varieties from other experimental stations;
- hybridization of varieties with other worthwhile characteristics;
- pedigree selection within the above material;
- generalized use of comparative trials in various stages to determine the best variety for the local conditions.

All the stations have obtained excellent results in this manner, and we now have good varieties of white-grained rice to replace the red-grained glaberrima where the latter has been traditionally grown.

This kind of research is in full swing at present, and there are many stations studying hybrid varieties. However, there is a great difference between the environments in which these hybrids will be grown, and the hybrids will naturally have to be adapted to the different environments.

This adaptation usually has to do with the length of the vegetative cycle of the plant, from seeding to fecundation, which means the period

during which the plant needs water. The allowable cycle will be that during which the local ecology, natural or artificial, will be able to fulfill the water needs of the plant. The duration of this cycle is thus the essential characteristic to be taken into consideration; it is a function of the variety, the light, and the temperature.

It is known that the potential yield of a rice plant can only be expressed under optimum environmental conditions. In the case of light and temperature, it is impossible to modify nature, and it is necessary to create or use varieties that adapt to their variations.

The first selection research that was done on tropical rice plants, taking account of the generally low soil fertility, was based on the assumption that the excessively high price of mineral fertilizers was prohibitive, and therefore the experiments were carried on on the soil just as it was. Without fertilizer or with very weak fertilizer, they created rice varieties that were not demanding at all and were relatively productive.

This type of research, which must be considered as having fulfilled all that it set out to do, must now be considered obsolete.

The population explosion that has taken place in the tropical countries means that a rapid increase in the yield of the productive land must take place as soon as possible.

Researchers became aware, especially in the work groups of the International Rice Commission, that setting up a correct fertility level, especially in nitrogen, made great increases in productivity and profit possible, even at current mineral fertilizer prices, provided that varieties adapted to high fertility were used.

The fertility of land can easily be modified, thanks to various mineral fertilizers, and thus it is less important that a plant be able to adapt to a wide fertility gamut. Thus high yields can be obtained more easily by modifying the environment than by trying to change the genetic constitution of the plant. This does not mean that increases in yield will be the same for all varieties put into a fertile environment. Response to fertilizers varies from one variety to another, and improvement research is now trying to determine what this response is, in order to produce varieties best capable of using high fertility levels. As they are very demanding, these new varieties would have very low yields in non-improved environments.

Things are not this simple in reality, and other things often interfere:

- the need for large crops to have harvests spread over a long period of time, thus a gamut of varieties is required with varying vegetative cycles;
- resistance to certain adverse factors (parasites, disease, toxicities, cold, dryness, excess of water, etc.)

In this context, selectors have been working for more than a dozen years with basically similar goals and methods. These researchers, after dealing with a great number of plants (local varieties and foreign varieties, especially hybrids and mutations from the Far East) have been able to develop whole gamuts of very well-adapted varieties that are extremely productive. It can be said that these varieties answer a great many of the problems that were asked of them. It is very interesting to note that this gamut of varieties from different countries have many points in common. Thus the D52/37, which originated in British Guiana, is the best semi-early rice from Casamance to Chad.

Makalioka 823 is cultivated in Richard-Toll and at Lake Alaotra.

Ali Combo (from Marovoay) covers Madagascar from North to South, from the West Coast to the Central Plateau. Research in such varieties (so-called "great adaptability" varieties) has been a constant theme of the International Rice Commission (FAO).

The advantages are evident: besides the fact that they result in the definition of simple commercial standards, these varieties, capable of outclassing the others in a large geographical area in spite of slightly different environments within the area, lead to considerable economy of research labor which is necessary for perfecting optimum vegetal material.

To gear our selection to such varieties would make it possible to have a certain regionalization for variety improvement, and this would save specialists, who unfortunately are too scarce to delve too deeply and finely into a great number of varieties; this type of research for every different variety of ecological situations is still an inaccessible ideal at present. The territorial phase of the work would then simply be limited to comparisons, in multi-local environments, of the improved varieties and the existing local varieties.

In order to carry on this work properly, it would be necessary to study the action on yield and the vegetative cycle that the different ecological factors (capable of having any influence) might have.

The yield factors are: density of plants on the ground (function of planting mode), tilling, number of weedings, etc.

The last three, like the length of the vegetative cycle, can be influenced by ecological factors, of which the most important are the following: temperature (absolute values and size and variation of diurnal-nocturnal variations), lighting (length and intensity), duration of the period during which water is available.

Attention should be placed on lines of rice which show, at the same time, high productivity and low reaction level to these factors, including analogous behavior in different environments.

Undoubtedly, sooner or later, this type of research will lead to the study of hybrid descendencies between sensitive and insensitive varieties. It will be necessary, in order to gain time, to perfect sensitivity tests.

Thus very early seeding combined with tracking down one or two months later following floral initiation (method perfected at Rokupr in Sierra Leone) makes it possible to rapidly eliminate the photosensitive plants, which give no sign of this initiation.

To put things more clearly, a selection program would thus include:

- the setting up of a collection of non-photosensitive varieties, selected from as wide a base as possible;
- a first selection from this group based on the criteria previously defined;
- isolation of retained variety-lines showing definite insensitivity characteristics;
- the cross-breeding of these lines with others with high yield and good technological qualities;
- research among the descendants of individuals, having the good qualities of both parents. The technique of bulk with early seeding and elimination of sensitive plants could be used with F2. Choice of mother plants for yield comparisons was done at F4 or F5, and the classical method was then followed to arrive at the definition of a gamut of varieties, early to late, having all the usually sought-after characteristics, plus one of passivity to ecological factors.

Beyond this there should be an additional criterion to add to the selection criteria, so that it does not have any narrow geographical limitations. This would make it possible to cover a larger rice-growing area, with fewer stations and fewer specialists.

Beyond this, the possession of varieties unsensitive to photo-periodism would make it possible to use early seeding which is indispensable with the classical varieties, whose yield goes down if seeding is delayed. As yet, this delay is often imposed, either by natural causes (water for instance) or by the overloaded cultivation calendars, in the case of polyculture cultivation systems. The worth of such varieties has already been proven in Senegal, Mali, the Ivory Coast, Cameroon and Madagascar. Besides this, if there is sufficient water, these varieties can be planted twice a year.

If research is always seeking to improve yield, nevertheless this alone will not suffice for making very great progress. It is now necessary to gather together and associate all the factors which contribute to high yield: water supply and control, improvement of soil fertility and structure, optimum cultivation practices, control of plant enemies, etc....so that the very best varieties that researchers have to offer can be put at the disposal of the rice-growers.

It is also very important to see that good seeds from selected varieties are distributed to the farmers, and therefore production and distribution of seeds must be organized. Quality seeds are characterized by:

- their belonging to a good, well-defined variety
- their purity

- their good sanitary condition (they might be treated with fungicide)
- their energy and high germinative faculties.

Substantial progress is being made everywhere in this area, but there still remains a great deal to be done. The problems are many:

- high cost of setting up and running administrative production enterprises;
- dispersion and small size of individual farms which makes the cost of seed distribution higher as well as cost of credit;
- affection of the farmers for their traditional methods of cultivation and traditional varieties;
- excessive number of varieties at present, making storing, production and distribution very difficult.

MAN AND HIS ACTIONS

If everything in this chapter could be of interest, rice-growing is only concerned with cultivation practices, the use and industrialization of the product being a question apart.

Here we reach a point where the gap between research and the application is very large. The research themes are relatively simple, and in most cases, the best cultivation practices have long been established (determined). Research dealt with:

- soil preparation (time, method, tools)
- seeding (date, density, treatment of seeds, etc.)
- planting out (age of plants, density, preparation of the rice-field, etc.)
- control of plant pests. The most important of these is weeds, and a great deal of attention is centered on them. The recent creation of chemical herbicides, which are effective but do not harm the rice, is a great step forward.

With the increase in yield which results from selection and fertilization research, defending the plants against their enemies becomes increasingly imperative, and research is needed on this score. Among rice's worst enemies are:

- cryptogamic diseases: helminthosporiosis, piriculariosis
- insects: caterpillars, diopsides, lice
- nematodes, especially Aphelenchoides Besseyi, which seemingly exists in all rice-growing zones.

Unfortunately, very often the results of research in this area have not reached beyond the experimental station where they were done, or they were done locally on a very small scale. Thus they have not been tested on a large scale, which would define the economic aspect, and local testing could be done with appropriate tools. Beyond this, wrong practices are used in the field, such as overly light direct seeding or overly dense seeding, the absence of weeding or weeding done sketchily, irrational water management, etc.

And yet we can but repeat that agriculture is a complex whole, and it serves naught to improve one factor without improving the others.

This global perfecting of agriculture, which can be appreciated and sought by the researcher in his experimental station, is totally disarmed when faced by the peasant environment which is really the only environment which will give the fruit of research its true worth. The transmission of the "know-how" elaborated by the researcher to the peasants is the specific job of the extension agent. How successful they are will determine whether or not the research will be appreciated and more important, how effective it will be.

No one, in view of the huge amount of work that remains to be done, would want to say that we have reached a panacea. Others, because of the small inroads that have been accomplished, seemingly, tend to dismiss the research effort as inefficient.

Is it necessary to say that both the panacea positions and that of total inefficiency are incorrect? Far from being an end in itself (at least in the essentially practical domain that ours is) research is part of a whole; it is a tool, which can be perfected, but which can make immense contributions if it is used wisely and well.

RICE-GROWING IN MADAGASCAR

IRAT-IRAM

SUMMARY

Agricultural research to be effective in developing countries should not be limited to development themes that are immediately applicable.

In a first approach, it is necessary to have a thorough knowledge of agriculture and to find simple and relatively inexpensive methods to introduce to the farmers.

Next it is necessary to study the possibilities for a major intensification of agriculture, which is a goal to which the farmers should strive. This presupposes that these improvements are being introduced.

Finally, general agricultural problems have to be studied since they will arise from the intensification of the agricultural system.

For rice-growing in Madagascar, the possible improvements that are available are reviewed:

- traditional rice-growing.....2 tons to 2.5 tons per hectare (paddy)

- rice-growing in the first phase of development.....3.5 tons to 4 tons per hectare (paddy)

- possibilities of intensive rice-growing.....6 tons to 8 tons per hectare (paddy)

INTRODUCTION

Agricultural research in Madagascar has followed two approaches for improving the crops.

A. IN A FIRST PHASE:

a) Identification of local varieties. Selection among the varieties deemed the best.(Example R. 1285, Mk. 34, etc...)

b) Research on best cultivation techniques.

c) Research to find a cheap and relatively efficient fertilizer.

d) Identification of main diseases and insects.

The idea underlying all this is the following: the very low means available to the peasant make rapid intensification of agriculture through costly new methods unrealistic.

It is hoped that generalizing knowledge on less ambitious but good methods will increase total production more rapidly; this is the easiest and most rapid means to this end.

Nevertheless, it is necessary to note the following:

1. Selection among local varieties rarely leads to better rice varieties than those with which you started. There are nevertheless exceptions to ths general rule: Ali Combo, Makalioka 34.

2. Without extensive modifications of the environment, cultivation techniques used by the better farmers may be ascertained (proper planting dates, density, etc.)

3. Cheap fertilizer usually has the following faults:

a) It is difficult to reach a great many peasants and there is a problem of guaranteeing distribution to all, because the would-be recipients are very scattered and it is often an environment of tiny commercial operations (the refusal to sell in quantities of less than 100 francs proves this)

Even if the fertilizer itself is not too expensive, the outreach and distribution programs are prohibitively costly.

Also, it is difficult to establish credit for a multitude of farmers for very small quantities of fertilizer.

b) It is impossible to change the varieties used rapidly: without a radical modification of the soil fertility, the local varieties prevail. Thus, superior plants cannot be used (example: at the present time, Chianan 8, which is far superior to R. 1285, cannot be widely used).

4. Identifying diseases and insects includes a long list of parasites. One hesitates to fight against the latter, because the profitability of the operations is largely unkown: so damage from parasites is tolerated. Exceptions to this are: one can economically fight against the rice bug (cercospora) and against Fusariosis by treating the seeds.

At any rate, agricultural progress got a slow start in all countries. The plan outlined here is worthwhile in that it

- makes the farmer aware of new techniques.
- makes the farmers aware of a need for organization extension, distribution, credit, etc.

Experience has shown that if this primary development stage is successful, the agriculture of the country does not remain static but rather tends towards ever-increasing intensification.

B. IN A SECOND PHASE:

a) It is necessary to find high-yielding varieties that respond well to fertilizer. This is done mainly by introducing varieties from regions where cultivation is already quite intensive.

b) Cultivation techniques must be perfected in a more rigorous and precise manner. (Example: an R 1285 can take 60 days in the nursery while a 1632 cannot).

c) High levels of fertilization should be tried out. Example: 90 kg/N/ha is the level that should be recommended, one must be certain that level does not have unfortunate repercussions. Therefore, levels of 120 to 150 kg/ha, for example, should be tried over a period of years, until it is clear that the level recommended is without harmful side effects.

It is also necessary to test the response of new varieties to high levels of fertilization.

d) It is necessary to study the evolution of parasitism as a function of intensive cultivation and to study control methods against parasites. Example: if for one rice which yields 3 tons per hectare stem borer makes you lose 10%, the gross loss is 300 kilograms; if the rice yields 6 tons per hectare, and the parasite makes you lose 20%, the total loss is 1200 kilograms.

The parasite must be precisely defined and identified. (Example: different strains of Biricularia) and varieties must be found for each area which are resistant to the parasites most commonly found in the area.)

e) Finally, economic studies become more and more important as costly factors outside production are involved to a greater degree.

A THIRD PHASE

If experimentation in the field is, and will always be, indispensable, nevertheless it cannot be infinitely multiplied.

The variety between individual cases is such that very often we must adapt our recommendations to particular cases.

But this adaptation requires a comprehension of general agricultural phenomenons beyond the knowledge gained from simple experiments in the field. (Example: fertilization of peaty soils must depend upon the nature of the vegetation that has formed the peat, the climate, the level of evolution, etc. The effectiveness of an anti-parasitic treatment will depend on the level of infestation observed, the possibility of contamination from other fields nearby, the rate of multiplication of the parasites, etc.)

Without an understanding of these factors, experimentation in the field can give different and sometimes contradictory results (at least apparently).

Extreme intensification of cultivation modified the environment. Subjects such as the dynamics of mineral elements, the loss of mineral elements introduced, the incidence of antiparasitic treatments on the biological equilibrium, etc., should all be studied. For example, annual yields of 8 tons of paddy per hectare and as much straw immediately point up the dynamics of potassium for rice-growing.

At present, in Madagascar, we are in the Third Phase. Slowly it will absorb more and more of our activity.

THE IMPROVEMENT OF RICE-GROWING IN THE MALAGASY REPUBLIC

IRAM, Tananarive, Madagascar

SUMMARY

The National Development Plan for the Malagasy Republic has set a 1972 national rice production goal of 1,700,000 tons, with an average yield of 20 quintals per hectare, which means a 25% improvement over the present situation.

Results obtained from rice-growing research were gained from studies on fertilization, varietal choice and selection, the improvement of cultivation techniques, and phytosanitary protection.

For the high altitude regions, the methods developed by the Agricultural Research Service of IRAM, and which are already being intensively popularized, make a gain in yield possible of 50% above the existing conditions.

For the western coast, the problems involve fertilization, better care of the rice fields, respecting the agricultural calendar, and double rice crops on the same land.

In other regions, Lac Alaotra, Mangoky, Morondava, Mahavavy, etc., the intensification of cultivation methods will only make it possible to obtain yields of 45 to 50 quintals per hectare.

Research which is currently under way is aiming at determining the potentials of the rice-growing soil in the main rice-producing sections of the Large Island and is aiming at perfecting rice-growing techniques capable of producing yields among the peasant environments of somewhere between 60 to 70 quintals of paddy rice per hectare.

In experimental rice-fields, regenerated with basic fertilizer and fertilized with 150 units of nitrogen, the Japonica No. 1632 variety, or Chianan 8, gave a yield of 103 quintals of paddy per hectare.

I. PRODUCTION GOALS:

In 1967, Madagascar produced around 1,353,000 tons of paddy rice on 850,000 hectares. This represented an average yield of 16 to 17 quintals per hectare.

The National Development Plan forecasts a production of approximately 1,700,000 tons of paddy rice for 1972, which is an average yield of 20 quintals of paddy per hectare.

II. METHODS TO PUT INTO OPERATION:

In order to attain these goals, the rice fields must be extended as much as possible and the yield must be improved in rice fields that are already in existence. In this area, the progress that can be attained is considerable.

Increased yields can be obtained by the simultaneous application of the following practices:

Water control
Fertilization
Varietal choice
Respect of the cultivation calendar
Improved cultivation techniques
Phytosanitary controls

III. RESULTS OF AGRICULTURAL RESEARCH 1961-1966, CURRENTLY BEING DESSEMINATED:

As of 1961, the Institute for Agricultural Research in Madagascar (IRAM) which was charged with improving rice production in the country, set up a series of regional experimental stations in the six provinces of the Large Island; it includes six units and controls 400 experiments.

1. Fertilization:

Diagnosis done from vases of vegetation and fertilization experiments have shown that the rice fields are lacking in phosphoric acid at high altitudes and on the western coast. Potassium is also lacking at times.

Response to nitrogen is about the same everywhere.

Results obtained:

A study was undertaken in Tananarive Province. Under the conditions

of the experiment:

Years / Formulas	1961-62 10 Experiments	1962-63 9 Experiments	1963-64 10 Experiments	Average kg/ha	Average % (Per cent)
NPK	3951 T	4665 T	4638 T	4418 T	155
NP	3552 T	3946 T	4108 T	3868 T	136
NK	3232 T	3778 T	4125 T	3711 T	130
PK	3106 T	3963 T	3867 T	3648 T	128
N	3450 T	3715 T	3899 T	3688 T	129
P	2976 T	3548 T	3612 T	3438 T	120
K	3142 T	3557 T	3617 T	3438 T	120
Control (without fertilizer	2514 T	2781 T	3238 T	2844 T	100

of fertilizing material per hectare:

N = Nitrogen .....:30 kg/ha
P = Phosphoric acid P_2O_5 .....:60 "
K = Potassium K_2O .....:45 "

Under conditions of the experiment:

1 kg of phosphoric acid produces 11.4 kg of supplementary paddy
1 kg of potassium produces 12.2 kg of supplementary paddy
1 kg of nitrogen produces 25.5 kg of supplemetary paddy

Thanks to these experiments, the Production Service of the Department of Agriculture is popularizing a progressive formula in Tananarive and Fianarantsoa which includes:

ammonium sulphate ..... 150 kg/hg, or 30 units N
tricalcium phosphate ..... 250 kg/hg, or 60 units P_2O_5
potassium chloride..... 75 kg/hg, or 45 units K_2O

These elements can be applied by 300 kg to a hectare of complete fertilizer 11-22-16.

This fertilization (30-60-45) which costs in Tananarive from 7000 to 8000FMG, and which is part of good cultivation techniques, can make rice yield reach as high as 2800 to 4400 kg of paddy per hectare. The supplementary harvest obtained is 1600 kg/ha the first year, which is worth 25,600FMG. Beyond this, since fertilizer is subsidized at present, this operation is definitely a "good deal" for the peasant.

The fertilizer formulas to be applied naturally depend upon the nature of the soil and its richness. In organic soil, in drained marshes, it is necessary to emphasize phosphoric acid. In alluvial environments, it is necessary to use nitrogen fertilizers.

The 30-60-45 formula takes care of the phosphorus deficiencies quite efficiently.

For rice fields that have been thus regenerated, the following maintenance fertilizer is suggested, according to the nature of the soil:

40 to 80 units of nitrogen
30 to 50 units of P_2O_5
30 to 50 units of K_2O

For this last element, it seems that the rice fields are capable of producing it in appreciable quantities, for a length of time that is as yet still uncertain.

Certain regions that have been well favored (alluvial plains, delta) such as Lower Sambirano, Northern Mahavavy, Lower Betsiboka, have naturally fertile rice fields that can give yields of 45 to 60 quintals of paddy per hectare without fertilizer:

2. Varietal Improvement:

The multiplicity of local species, which reflects the great diversification of Malagasay rice ecology, is a definite obstacle to the production of seeds and their normalization for export.

Adaptive, hardy and productive varieties must be found that can be grown in a wide range of different climates, so that the number of types of rice can be reduced to approximately 20.

Beyond this, fertilization experiments have shown that most of the local rice varieties respond to fertilizer up to a certain point and then do not react anymore. Selected varieties of the Japonica type, originating in Formosa, react much better to high levels of fertilizer and can attain yields of as much as 7 to 10 tons per hectare.

Selected Varieties that Have Been Popularized through Extension Programs:

Today, about a dozen varieties have been popularized:

Selections	Regions	Observations
Ali Combo	Lower Betsiboka, Lower Mangoky - West versant Plateau	Luxury rice
Makalioka 34	Alaotra, Andilamena, Ankaizinana, Diego-Suarez, South West	Long, thin, translucent Hot season rice only (November-May).
Makalioka 752	Ihosy	Long, thin and translucent. Excellent rice for export.

Selections	Regions	Observations
Rojofotsy 1285	High Plateaus-Alaotra	Medium-length rice
No. 342	High Plateaus, West Versant	Similar to Rojofotsy 1285
No. 1300	Tananarive region (Vary sia)	Japonica for fertile rice fields
No. 1283 Ambalalava	Ambositra (Betsileo) Wet, humid zone	Medium long, chalky rice
No. 1055	West Versant (Manakara) Fenerive-Tamatavo	Medium long, translucent rice

Selected varieties that were recently qualified, superior to local rice:

Numbers	Provinces	Observations
No. 1329 Madinika	Diego-Suarez	
No. 1632 (Chianan 8)	Fianarantsoa	Fertile soil
462 Vary Vato	Tananarivo	
996 Hybrid Alaotra	Tulear	
1345 Ca 435 R.C.A.	Diego-Suarez and Majunga	

The flexibility of the No. 1632 variety should be noted as well as that of Chianan 8, which originated in Formosa. That selection, of the Japonica type, has given yields of 10 tons of paddy per hectare near Tananarive and at Fianarantsoa on experimental rice fields that had been well fertilized; it gave yields of 7 tons per hectare at Tamatave and 8 tons per hectare at Vohipeno. In the West Coast climate, this variety can make three harvests during one year possible.

Local Rice:

About twenty local rice varieties should be retained because of their hardiness and their good yields.

Local Designation	Cultivation Region	Qualities
Vary Lava	Betafo	Long, fat, more or less translucent grains, flexible shape; average productiveness. Resistance to lodging and shattering. Exportable to Common Market if translucent
Maintisomotra	Mahitsy	

Local Designation	Cultivation Region	Qualities
Kalila Tsipala Bengala Morima Sinjany Mamoriaka	Lower Betsiboka West and Southwest Diego-Suarez Mahavy (North)) Bas Sambirano	Fine grains, more or less long; vary from translucent to very translucent. Productive, suckering important. Exported to Reunion, Mauritius
Malady	North-West	Early, hardy rice. Resistant to drought
Rakaraka Mangakely Ambalalava	Ankaizinana Vakinankaratra Ambositra	Medium-long grains, more or less chalky. Very hardy rice adapted to high altitudes.
Latsika	Vakinankaratra	Medium-long grains, chalky. Resistant to cold.
Botohavana Borizina	Tananarive	Medium-long grains. Rice developed for regions menaced by floods. (Vary Aloha of Betsimitatatra.)
Angiky Sandramanitra Beditra Java Maintibotsy Fotsiavarina Maitsebe Kitrana Soabe	Ambalavao Ihosy Maroantsetra " " East Coast " " "	Medium-long, more or less translucent grains. Productive and hardy.

In the near future, these composite forms will yield to confirmed selected varieties.

Advised selections, confirmed by several years of experimentation, are always superior to the best local rice.

3. Cultivation Techniques

During the period 1962-1966, one hundred and sixty multi-local experiments undertaken in 29 regions or rice-growing sectors of Madagascar have made it possible to evaluate the progress that can be obtained by applying improved cultivation techniques.

These improved techniques, which are being popularized in the Central Provinces, include merely respect for the agricultural calendars, planting out in a line, good maintenance of rice fields and a little moderately priced fertilization, within the reach of the peasants.

Total Results: In kg-Paddy-Hectare

Provinces	Rice-growing		Gains	
	Traditional Planting out in lines but without fertilizer	Improved Planting out in lines with fertilizer N P K (30-60-45)	Kg/ha	%
Tananarive	2,413	4,018	1,605	66.5
Fianarantsoa	2,628	3,786	1,158	43.9
Tamatave:				
Season:Dec.-May	2,784	3,934	1,150	41.3
Season:June-Nov.	2,410	3,427	1,017	42.1
Double annual rice	3,194	7,361	2,167	41.7
Diego-Suarez	3,667	4,584	917	25.0

IV. RESEARCH CURRENTLY GOING ON:

The research currently going on is aimed at determining the potential of the rice-growing soils of the main rice-producing regions of the Large Island and at defining very elaborate and profitable techniques.

Research is going on in the following areas:

-Optimum fertilization of soils
-Research on types resistant to disease and responding the best to fertilizer
-Cultivation techniques as a function of the types chosen: cultural calendar, compactness of planting, possibilities for double annual crops on the same land
-Phytosanitary protection against borers, nematodes and brown rust.

The first results obtained are very encouraging.

Experiments: 1966-1967
Region: Tananarive Plains
Variety: Introduction by IRAM of No. 1632, "Tainan No. 8"
Fertilization: The corrective fertilizer basically contained 340 kg of phosphoric acid per hectare and maintenance fertilizer had 150 kg of nitrogen, 60 kg of phorphoric acid and 90 kg of potassium per hectare.
Planting out: beginning of December 1966
Water control assured: Protection against borers
Harvest: May 10, 1967
Yield on 15 ares: 10,360 kg per hectare
Gain as compared to neighboring traditional rice fields: 7,660 kg/ha, 283% gain.

V. CONCLUSIONS

1. Present results that are being recommended in extension programs:

Proven improved cultivation techniques, selected varieties or choice local types, and fertilizers determined for altitude regions in particular, make it possible to attain yields of 3,800 to 4,500 kg of paddy per hectare instead of 25 quintals, which means a gain of 50%.

For the West Coast, fertilization is important, better maintenance of rice fields, respect for the agricultural calendar and double annual rice crops on the same land.

In other regions, Lac Alaotra, Mangoky, Morondava, Mahavavy and Diego-Suarez, yields of 4,500 to 5,000 kg paddy/hectare can be attained by intensifying the cultivation methods.

Based on the facts acquired, productivity operations undertaken by the Ministry of Agriculture already give significant results.

2. Goals of research that is being carried out:

The research that is being carried on at present aims at perfecting rice-growing techniques that would make it possible to produce, in a peasant environment, yields of 60 to 70 quintals per hectare (paddy).

VARIETAL IMPROVEMENT OF FOUR FOOD CROPS IN THE MALAGASY REPUBLIC RICE-CASSAVA-MAIZE-SORGHUM PRESENT SITUATION AND FUTURE OUTLOOK

IRAM

SUMMARY

The rational utilization of improved varieties leads to substantial increases in harvests, when linked with improved cultivation techniques and the rational use of fertilizer. From the first, the Agricultural Research Institute of Madagascar has worked on developing selected varieties within this framework.

Along with increased yield, the goal of this approach is to develop varieties with a maximum of good agricultural and technological qualities and the greatest possible degree of adaptability to varied climates. Research efforts concentrated on rice and cassava for many years and more recently on sorghum and maize. These four plants are part of a much larger group of food crops that are being studied by the Institute.

The present programs deal mainly with:

a) Rice: Improvement of yield and the quality of the product for consumption; also concentration on resistance to parasites, potential from use of fertilizers, and large cultivation areas for a given variety.

b) Cassava: Resistance to disease mosaic and rotting; high yield combined with a vast utilization range for a given plant; direct consumption and starch for industrial purposes; aim at very flexible cultural aptitudes for plants.

c) Maize: Yields and cultural aptitudes with homogenization of the product and wide variety range-synthetic, fixed forms, hybrids.

d) Sorghum: Yields linked to resistance to drought and adapted to consumers' tastes.

The results obtained as to yield along have brought out the following facts: for rice yields of experimental fields have varied according to region between 60 and 108 Qx/ha; for cassava, between 24 and 68 tons/ha; for maize 45 to 98 Qx/ha and for sorghum, 22 to 45 Qx/hectare. In general, these yields are two to six times greater than yields obtained on large farms in the same regions.

Nevertheless, there is still much research to be done. Research must be intensified - it must diversified with relation to certain aspects or on the contrary concentrated on a limited theme. Research on the problems of resistance to parasites, climatological adaptation, response to fertilization, for example, must be carried out in a more detailed and comprehensive manner. More tests of experts including for instance, specialists on vegetation improvement are indispensable if, as is desirable, the present research is to effectively enlarge upon the progress already attained.

INTRODUCTION

These four plants are part of a large group of food crops being studied by the Institute for Research in Tropical Agriculture and Food Crops (IRAT) and its organization in the Malagasy Republic, the IRAM.

Among the various improvement factors which are being studied on the Large Island, the problem of varieties has been studied by IRAM since its creation in numerous programs. If the main effort is still concentrated on rice, because of its primary importance as a good crop, cassava is also extensively studied and the first variety selection work on cassava was begun forty years ago. More recently, maize and sorghum have been integrated into the variety research programs.

The present research clearly indicates that variety improvement should only be used in a comprehensive framework including improved cultivation techniques and fertilization. It is only by judicious and rational combinations of these three factors that agriculture, through improved yields, will make appreciable progress. Yields putting the Malagasy Republic on the same level as key nations have already been reached experimentally. Levels of 10 tons per hectare for rice, 60 tons per hectare for cassava 9 tons per hectare for maize grain and 4 tons per hectare for sorghum grain have been attained repeatedly.

Nevertheless, many problems remain to be solved, because these high yields were reached only in particular cases and under special conditions. It is only through intensification, in space and time, of current research that research can become more effective. This intensification, a definite development factor of the national economy, will require a greater outlay for materials and qualified personnel.

The present document, going from the goals to be attained and an expose of actual programs and results attained, proposes to establish short, medium and long-term perspectives and indicate which path variety improvement research should follow for the best results within the plans of the development of agriculture in the Malagasay Republic.

1. Current Research Programs

The variety of ecological factors--both soil and climate--condition the four crops in the Malagasy Republic, and therefore the programs, if not basically variable, are at least different as to their form according to region.

From a climatic point of view in particular, if the East Coast as a whole enjoys a hot and humid climate all year round, the West Coast and

Northwest are even hotter, and drier, the Southwest and the South are at a disadvantage as to average annual rainfall, the High Plateaus (700 to 1500 meters) have a more temperate climate--all of which explains the diversity of the research programs on the one hand and the difficulties encountered on the other.

1.1 Rice

In all cases, general goals are the same:

-high yield
-best possible technological qualities

a) Research on early varieties with medium grains.

b) Research on varieties with average cycles, resistant to rice blast and helminthosporiosis, lodging and shattering.

c) Research on late varieties resistant to lodging and shattering.

d) Research on early varieties resistant to cold.

e) Research on double-crop and continuous cultivation varieties.

f) Research on varieties cultivatable in particular soils
-peat soils
-salty soils

Means put into operation are:

a) Introductions from abroad
b) Selections from local varieties
c) Hybridization
d) Mutations through chemical mutagenesis

Lac

As of December 31, 1967, the agricultural experimental station of the base for all varietal experimentation had:

A collection of 2008 varieties
81 selections of local types
150 hybrid lines from F_1 and F_{10} being studied
1169 mutations under observation.

which makes it the largest rice research experimental station of all the African nations . On the average, 25 varieties are introduced there annually from abroad.

1.2 Cassava

The general goals are:

-high yield
-resistance to mosaic disease and rotting

) Research on varieties has two goals, starch production and human consumption, for the industry-oriented regions and the High Plateaus.

b) Research on sweet varieties with very rapid growth for the East Coast.

c) Research on sweet varieties and resistant to drought, without lignification, for the South.

Methods put into operation are:

a) introducing varieties from abroad
b) selection among local types
c) hybridization

As of December 13, 1967, the same station has:

A collection of 204 varieties
245 hybrid species in a separate collection
723 hybrids currently being studied

Four collections of local types are studied directly in the field in the cultivation zones which are under experimental observation. Here again Madagascar probably has the largest collection and most advanced studies in this area of all the African countries.

1.3 Maize

General objectives are:

-high yield
-resistance to parasites

Methods put into operation

a) Varieties introduced from abroad
b) Selection among local types
c) Hybridization

Still as of the same date, the same experimental station has:

-a collection of 340 types
-many tests either on recombination or on hybrid value, or on creation of synthetics and composites.

1.4 Sorghum

The general goals are:

- high yield
- resistance to drought
- food organoleptic qualities

a) Research on early varieties
b) Research on hardy and flexible varieties
c) Research on varieties resistant to parasites.

Methods put into operation:

a) introduction of varieties from abroad
b) selection among local types

Again as of December 31, 1967, the same experimentation station

-a collection of 343 varieties
-7 local varieties currently under selection.

1.5 Regional Experimentation

Even though the research programs going on at the Lac Alaotra experimental station include, for the four plants, a collection of 3140 varieties, more than 2000 hybrids and mutations under observation, or a total of more than 5000 forms being studied, without counting the first generation hybrids which total (mostly cassava) some 14,000--nevertheless, the Station is making it possible to test, under the best possible conditions, the results of the work going on at the Station.

To take rice as an example, the methodology for this experimentation is as follows:

a) In each large ecological area which is to be studied, a so-called "heavy" collection of 80-200 varieties is made, in which a first sorting takes place. Each heavy collection is enlarged each year by a variable number of varieties chosen from the basic collection to replace those that are eliminated because of their inferior quality.

b) In each ecological sub-zone, a so-called "light" collection at 2 levels of fertilization is drawn up, grouping 10-20 varieties chosen from the heavy collection and this is used to make a more precise sorting.

c) Finally in each sub-zone many varietal experiments grouping 5 to 7 varieties support and reinforce the conclusions reached through the collections.

The work method thus used has led to many interesting results which are described further on. Let us emphasize again the fact that these results

are not merely a function of variety research but are due above all to a combination (as logically as possible) of the three key factors leading to high yields:

appropriate cultivation techniques
rational fertilization
selected varieties

If agricultural research in the Malagasy Republic has made considerable progress in the last few years, it is above all due to profound studies of the three factors and by putting these into operation as harmoniously as possible.

2. Results Obtained

Without ignoring results obtained for the other three plants, rice will be the main subject of this section and regional experimentation will be brought out.

2.1 Rice

To simplify the discussion, the facts will be given as a multi-annual balance sheet by province and by region. The variety number is that of the Lac Alaotra station collection.

2.1.0 Diego-Suarez Province

a) Diego-Suarez Region
Variety 1329 = 108% of the local control variety on the average; short, translucent grain, resistant to lodging and shattering; remarkable response to fertilization.

b) Ambilobe Region
Variety 1329 = 114% of the local control variety on the average.

c) Ambronja Region
Variety 34 = 119% of the local control variety on the average; long, fine grain, very hardy and resistant to disease.

2.1.1 Fianarantsoa Province

a) Ambohemahasoa Region
Variety 1632 = 162% of the local control variety on the average; short, translucent grain, resistant to lodging and shattering; remarkable response to fertilization.

b) Ihosy Region

Variety 1632 = 168% of the local control variety on the average.

Variety 752 = 126% of the local control variety on the average.

752 - long, translucent grain, (lodging and shattering).

c) Isorana Region

Variety 1318 = 116% of the local control variety on the average; long, translucent grain, resistant to lodging and shattering.

d) Fianarantsoa Region

Variety 1632 = 159% of the local control variety on the average.

Variety 1283 = 149% of the local control variety on the average; grain long and rather thick: local type selected. The average yield of 1632 on two trials in 1967 is 10,710 kg/ha.

2.1.2 Majunga Province

Majunga-Marovoay - Popularization of the Ali Combo variety. Long and translucent rice.

Bealanana - Popularization of varieties 34 and 823. The latter, of the same type as 34 but more resistant to lodging, has been advised for this area for a long time.

2.1.3 Tamatave Province

Lac Alaotra Region - Popularization of varieties 34 and 1055 - the latter is more earlier with a fine and translucent grain.

2.1.4 Tananarive Province

a) Mahitsy Region

Variety 342 = 115% of the local control variety on the average; average grain, average vegetative cycle .

Variety 462 = 113% of the control on the average; average length, translucent grain.

2.1.5 Tulear Province

a) Bezaha Region

Variety 996 = 117% of the local control variety on the average; very long, translucent grain

2.1.6 Global or overall conclusions

Improvement of yield for one variety is 30% on the average for the regions mentioned above; this figure only gives a sketchy, overall idea of the improvement obtained. Let us look rather at what were the key yields obtained, taking account of the fertilization in the same region in 1967.

Diego-Suarez	= 1329	= 46.31 Qx/ha	without fertilizer
Ambilobe	= 1329	= 71.52 Qx/ha	" "
Ambanja	= 34	= 45.27 Qx/ha	" "
Ambohimahasoa	= 1632	= 64.71 Qx/ha	with 100 units N + PK
Ihosy	= 1632	= 60.63 Qx/ha	" " " "
Fianarantsoa	= 1632	=107.8 Qx/ha	" " " "
	1283	= 90.33 Qx/ha	" " " "
Mahitsy	342	= 92.33 Qx/ha	" " " "
	462	= 83.12 Qx/ha	" " " "
Alaotra	= 34	= 75.79 Qx/ha	with 90 units N + 100 units P+K

Thus the yield obtained, for the best varieties, fluctuates between 45 to 107 Qx/ha. On large farms it varies between 30 Qx/ha in the climatically unfavored regions with minimal fertilization, to 80 Qx/ha for the best. Nevertheless, agricultural research has shown that rice production potential in the Malagasy Republic is equal to that of nations with the highest yields in the world.

Nevertheless, there is still a great deal to do.

2.2 Cassava

The results obtained from research on cassava shall be presented as were those for rice.

2.2.0 Diego-Suarez Province

a) Ambanja Province
Hybrids 53, 54 and 56 (8 to 23% better than the local control); yields of 15 to 44 tons per hectare in nine months.

b) Ambilobe Region
Hybrids 43 and 53 (from 12 to 56% better than the local control) yields ranging between 8 to 21 tons per hectare in nine months.

c) Diego-Suarez Region
Hybrids 43 and 54 (from 14 to 37% better than the local control) yields of 13 to 19 tons per hectare in 18 months.

2.2.1 Finanrantsoa Province

Manakara Region
Hybrid 54 (56 to 87% better than the local control) yield of 25 to 35 tons per hectare in 11 months.

2.2.2 Tamatave Region

a) Tamatave Region
Hybrid 58 (from 28 to 54% better than the local control); yields of 23 to 31 tons per hectare in ten months.

b) Brickaville Region
Hybrid 58 (34% better than the local control) yields of 25 tons per hectare in 10 months.

c) Alaotra Region
Hybrids 54, 56, 57, 58 - Yields of 37 to 52 tons per hectare in 22 months.

d) Moramanga Region
Hybrids 35, 49, 56, 57 and 58 - yields of 28 to 45 tons per hectare in twenty-two months.

2.2.3 Tananarive Province

a) Tananarive Region
Hybrids 43 and 54 (25 to 65% better than the local control); yields from 6 to 15 tons per hectare in 23 months.

b) Manhakandriana Region
Hybrids 43 and 54 (22 to 108% better than the local control); yields from 12 to 17 tons per hectare in 23 months.

c) Betafo Region
Hybrids 43 and 53 (from 45 to 280% better than the local control). Yields from 6 to 15 tons per hectare in 23 months

2.2.4 Tulear Province

a) Ankazoabo Region
Hybrids 41, 53 and 54 (8 to 56% better than the local control). Yields of 19 to 28 tons per hectare in 10 months.

b) Tulear Region
Hybrids 41, 53 and 54 (from 25 to 38% better than the local control) yields of 17 to 19 tons per hectare in eleven months.

c) Ambovombe Region
Hybrids 53 and 54 (32 to 90% better than the local control); yields of 22 to 38 tons per hectare in 11 months.

d) Betioky Region

Hybrids 41, 54 and 56 (9 to 22% better than the local control); yields of 17 to 40 tons per hectare in 11 months.

2.2.5 Global considerations

Results obtained with cassava indicate that production of roots varies from 6 tons per hectare under the worst conditions (poor soil, high altitudes) to 50 tons/hectare under the best conditions. These yields can be obtained in 11 months to 2 years if appropriate cultivation techniques and balanced fertilization is used.

2.3 Maize

Because experiments were begun only recently on maize, selection having begun in 1961 and experiments in 1964, it is still premature to advance conclusions for maize as precise as those set forth for rice and cassava.

Nevertheless, two experiences are worth mentioning:

a) Selection-by recurrence-from maize varieties from Fianarantsoa Province made it possible to popularize a fixed type, number 237 which has given in experiments yields of 73 qx/ha as against yields of 54 to 60 qx/ha for the original varieties.

b) Beyond this, the introduction of double hybrids from Rhodesia made it possible to attain yields of 93 qx/ha with SR13 and SR11.

It is thus certain that with types well adapted to local conditions and with high potential yield, created on the spot through local selection and hybrid recombinations, the goal of 100 qx/ha will be reached in the best experiments in the near future.

2.4 Sorghum

As for maize, the improvement program only began in 1961. The results of the experiments have therefore not been confirmed as yet. Nevertheless, it is interesting to note:

a) In the early variety group in 1967 the control Hazera 610 had an average yield of 1525 kg/ha. This control was better than the local sorghum with which it was compared.

On the other hand, 15 varieties were superior to it, the two best giving yields of 4360 kg/ha (TM 11-originating from the Sudan)-or 256% of H610 yield and 4049 kg/ha

(Wad Akr 10-also from the Sudan) or 161% of H610. These results were obtained from two different experiments but at the same place.

b) In the late variety group in 1967 the local Bevolo control has a yield of 1175 kg/ha. 24 varieties are superior, the two best having yields 79% and 200% better respectively, in two different experiments.

Here, too, progress has already been made. It is certain that in the near future several varieties will be picked out and popularized. With these, average yields on the order of of 1500 to 2000 kg/ha can be attained or more than twice as high as the present average yield.

2.5 Conclusions

Thus progress has already been made. And in the near future, many varieties will be popularized--as some have been already.

Nevertheless, this progress is restrained by the research which still remains to be done. This remaining vast research, on varied subjects, is very important to the national economy. The goal has been (and still is) to find, as soon as possible, new more productive varieties, which fulfill the requirements of research programs. All efforts at present tend toward this end, and therefore other research, which could be very useful, may be ignored.

3. Directions for Extending Present Research

It would be desirable, on the one hand in order to better understand the phenomena observed at present and on the other to increase the effectiveness of the research currently being undertaken, to develop certain activity.

Let us take the four plants that we deal with in this paper, in order, and see what research themes are needed for improving the research that is presently going on.

3.1 Rice

-Intensification of systematic introduction tests, after multiplication, in all relevant regions. Two hundred new varieties per year seem to be about the minimum.

-Intensification of the search of local types and deep selection of the types chosen.

-Broadened studies on the physiological types of the main diseases, blast and helminthosporiosis.

-Studies of photoperiodism

-Floral biology of rice according to regions, with determination of the allogamic level

-Physiology of the plant under very peculiar soil conditions or in exceptional climatic conditions.

-Intensification of hybridization.

-Intensification of induced mutations.

-Studies of dormancy and induction of dormancy in certain cases.

-Problems of wild rice.

-Studies of the genes for length and translucence for certain interested regions.

-Studies of the dynamics of certain local rice types.

3.2 Manioc

-Research on heredity and hereditability of resistance to mosaic rotting and starch content.

-Broadening of interspecific hybridizations through recombination with new species after introductions.

-Germination biology in local conditions.

-Intensification of research in local types and more profound studies of the types retained.

-Problems of abnormal seeds of very small size.

-Pollen and intra - and inter-specific hybrids.

3.3 Maize

-Intensification of introductions of pure lines and tests of hybrid combinations after observation.

-Broadening of research on the local types and rational and optimum utilization of these types.

-Intensification of

-recurring selections
-obtaining pure local lines
-obtaining multiple hybrids and synthetics
-"pedigree" selection.

3.4 Sorghum

-Intensification of varietal introductions
-Broadening of investigations on local types
-Work and research on parasites (cryptogams and insects)
-Introduction of sterile males for hybridization.

This enlarged research program (the list above is not intended to be limited) can be the key to more rapid progress. Yet, the present means at our disposal, both as to material, supplies, equipment and to personnel, are insufficient. Thus it would already be indispensable for the present research and for extending the program to have a reinforced and larger team, containing at least four phytogeneticists.

CONCLUSION

The food crops are of vital importance to the Malagasy Republic, notwithstanding the need for industrial crops as well.

While we underline the importance of perfecting cultivation techniques and the marked influence of fertilization on yield (these two factors being the two pillars of any increase in yield), it is certain that varietal improvement has an important part to play in the economy of a country, both for internal consumption and external export.

Thus it would be advisable, taking as a base the yield obtain in experiments, which are high but could be improved, to forge ahead with varietal improvement for the four plants discussed in this paper. Enlarging the programs, with increased research means, will contribute to the rate of progress.

MAJOR PROBLEMS AFFECTING PRODUCTIVITY OF CEREALS

The Pest Problem

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SUMMARY

The productivity of cereal crops such as sorghum, millet, maize and rice which constitute the staple food source for people of tropical Africa, are in some cases severely limited by pest attack. A review of the pests of cereals is given and the major ones are categorized as stemborers (mainly lepidopterous larvae); grain-feeders (mainly midges, lepidopterous larvae, bugs, beetles and birds); store pests (mainly beetles and lepidopterous larvae), and rodents.

Losses in yield are variable but significant enough to warrant consideration of control methods. Available data on the bionomics of the different insect species attacking cereals in the field suggest that an integration of the cultural methods noted by many authors and biological methods based on a study of the insect complex in the agro-ecosystem may prove useful in reducing the general equilibrium position of these pests. It is considered that the establishment of the economic thresholds of the principal pest species as a basis for integrated control is of top priority. An integrated pest control approach is proposed as the most appropriate in the present economic and cereal pest circumstances of most parts of tropical Africa.

Fundamental ecological studies on a regional basis are suggested for the problem of the control of the grain-eating bird, *Quelea quelea*, and effective disinfestation and improved storage facilities are considered essential provisions for a program of increased cereal productivity and production.

INTRODUCTION

In Africa, as in most other parts of the world, cereals constitute an important item of diet for the human and animal population and a major item of international trade. World exports of wheat and coarse grains, including sorghum, maize, oats, barley and rye rose from 54.3 million metric tons in 1959/60 to 101.6 million metric tons in 1965/66, almost doubling, and imports followed the same trend (Anon, 1966). With the acute shortage of vegetable and animal protein in most African countries, the bulk of the calorie requirement (up to 90 percent in some cases) is provided by cereals, root crops or a combination of both. Although most of these are produced locally, large quantities of cereals and cereal products are still imported: for example, more than 4 million metric tons of wheat and wheat flour were imported into Africa in 1965/66.

The pattern of staple food production and consumption in the majority of African countries depends largely on climate and altitude, the forest population of the equatorial regions depending mostly on root and tuber crops, the Savannah and drier area populations on sorghums and millets, and the intermediate or derived savannah dwellers on a combination of cereals and starchy roots. Although it is now fully appreciated that greater emphasis should be placed on and considerable attention given to increasing the production of foods rich in protein and fat, rather than foods which provide mainly carbohydrate, the productivity of major cereals in tropical Africa (millets, sorghums, rice, maize, and to a lesser extent, root crops) will have to improve considerably in the years ahead in order to cope with the demands of a growing population and effectively supplement the other major source of protein.

Wherever and for whatever purpose cereals are grown in Africa, they are subject to attack by a variety of insects, rodents, birds and other pests which severely limit their productivity, both in terms of harvested grains and grains available for consumption after short or long periods of storage. Any attempt to increase production and productivity cannot afford to ignore these problems and other problems that might crop up with the concomitant changes in the pattern of agriculture that a mass drive for increased productivity is bound to bring about. Therefore as well as improvements in the seed, improved cultural practices, use of fertilizers and other requisites, a program of effective and imaginative field and store pest control based on an ecological approach is essential to the ultimate goal of increased productivity.

The major cereals produced in tropical Africa are sorghum (*Sorghum* spp.), millet (*Pennisetum* spp.), lesser millets (*Eleusine* spp.), maize (*Zea mays*), and rice (*Oryza sativa* and *O. glaberrima*). The relative distribution and importance of the species as well as the pattern of production vary from country to country, but the major pests associated with them seem to be found throughout their range and can be broadly divided into the following:

1. The stemborers (mainly Lepidopterous larvae)
2. The grain feeders (mainly Midges, Lepidopterous larvae, Bugs, Beetles and Birds)
3. The store pests (mainly Beetles and Lepidopterous larvae).

Rodent pests, where they are abundant, may also cause considerable damage by attacking cereal crops both in the field and store. Other minor insect pests are also known to occur but on the whole are responsible for negligible damage.

1. The stemborers

Lepidopterous stemborers are widely recognized pests in all cereal-growing areas in Africa. Many species are known to attack sorghum,

millets, maize and rice and a variety of other gramineous crops. The effect of the attack of the main species, Busseola fusca Fuller, Sesamia spp., Coniesta ignefusalis (Hmps.), and to a lesser extent Eldana saccharine Wlk. on sorghum, millet and maize ranges from loss of vigor in individual plants to actual loss of stands, and may be slight or serious depending on the area, the circumstances, and the local economic importance of the crop. Harris (1962) provided a detailed account of the bionomics of the main cereal stem-boring species in Nigeria and recorded attack rates of 5-51% on maize in 1957-60. He reported some preliminary observations on the effect of borer infestation on yield. From these it appears that the main source of losses in yield is stand loss, there being no direct significant relationship between percentage bored stems and yield in the field. Both Harris (1962) and Adeyemi (1967) have emphasized how difficult it is to carry out and interpret investigations on the effects of stemborers on yield, or to demonstrate the economic control of stemborers. Although it appears that under the present system of agriculture in Nigeria, and this applies to most of West Africa, the incidence of natural stemborer infestation is low, Harris (1962) suggested that losses in yield may be high on late millet or the second maize crop in the wetter areas due to a stand loss of over 20 percent. Nevertheless, it can be deduced that in many areas stemborers at the worst can be regarded as occasional pests which only reach the economic threshold periodically.

One significant contribution emanating from the study of the bionomics of some of these species is the indication that effective control may be achieved in the main growing areas by cultural methods involving suitable disposal or destruction of crop residues so as to kill the carry-over population of diapausing stages. This type of method forms one of the key points in the integrated control approach which I am going to advocate for the cereal pests in general, and if enforced can go a long way in reducing the general equilibrium position of these groups of pests.

The situation with regard to the rice borers is not yet clear. A few stem-boring species have been discovered and identified but their economic status has not been determined. The need here is for more fundamental studies aimed at developing a reliable basis for integrated control.

2. The grain feeders

Cereal grains in the field are subject to attack by many species of insects, birds and rodents causing considerable reduction in yield of grain obtained per acre in most parts of tropical Africa. One of the most important of the insects is the sorghum midge, Contarinia sorghicola (Coq.), which is known to occur in all countries where sorghum is cultivated. Harris (1961) showed that 4-10 percent of the sorghum spikelets grown in Nigeria was attacked, and estimated that an overall annual loss of 91,100 tons of grain (equivalent to total annual production in Ghana) occurred on 218,200 acres of native farms.

Bowden (1965) recorded a 20 percent loss in yield on sorghum in Ghana but suggested that this was due to attack not only by midges but by other species of insects, notably the Coreid bugs, Mirperus sp. and Riptortus sp. He recorded an attack rate of 10-15 percent by midges and over 15 percent by 'others' and showed that attack rate could be reduced by the application of 1 percent DDT. He rightly concluded with a strong plea for further work on the determination of the nature and magnitude of other losses and the determination of the economic status of the sorghum midge in the light of the feasible cultural methods suggested in his work and in Harris, (1961).

The other major pest of grain in most parts of tropical Africa is the bird, Quelea quelea. This species (and subspecies) is widely distributed in Africa and may be responsible for up to 40 percent loss of grains in some years. Vigorous efforts are being made by regional and international organizations to solve this problem. Recently, the UNDP has proposed a comprehensive program of investigation for West Africa. A fundamental approach is required to elucidate further the biology, breeding habits, behavior and migration of this species so as to provide a reliable basis for a detailed research program in control methods.

3. The store pests

When productivity is considered in an elastic sense, that is in terms of the quantity and quality of grains available for consumption, the store pests must be taken into full cognizance. This is all the more important when we consider that many of the store pests on cereals initiate their attack in the field and cause some damage to harvested grain. A successful program of increased productivity must therefore be closely integrated with improved facilities for storage, disinfestation and protection of stored grains. Giles (1964 a & b) recorded a mean corrected weight loss of about 8 percent as a result of insect attack under peasant storage conditions in northern Nigeria. He further estimated that 4 percent of the total sorghum and millet is lost to stored product insects, but storage losses of grain are known to be generally higher and to be at least 10 percent in most parts of Africa. A large number of beetles, including Sitophilus oryzae (L.), S. zea mais Motsch., Tribolium castaneum (Hbst.), Rhizopertha dominica (F.), Oryzaephilus mercator (Fauv.), and lepidopterous larvae like Sitotroga cereallela (Ol.) and Cadra cautella (Wlk.) cause this toll. Effective disinfestation and adequate storage facilities will help to minimize this type of loss.

Future Approach

From the review of cereal pests given above, the following two important needs arise and appear to deserve top priority:

1. The need to establish the ecoromic thresholds of the pests recorded on cereals and determine other sources of loss.

2. The need to consider an integrated control approach in solving the pest problems on cereals.

Stern (1965) stated that the establishment and accurate determination of the economic thresholds of pest species is fundamental to integrated control programs. He described the economic threshold as "the density at which control measures should be determined to prevent an increasing pest population from reaching the economic-injury level." There is no doubt that these thresholds have not been established for many of the cereal pests, hence the lack of foundation for any type of control. It is therefore considered that this should be a fundamental priority in solving the pest problems on cereals. A coordinated program for the establishment of economic thresholds of different pests based on mutually agreed methods should go a long way in providing this essential background information.

In no other place than in arable agriculture in tropical Africa is the concept of integrated control more pertinent. So far very few artificial factors have been introduced to modify the environment and there has been little or no use of those pesticides which have given rise to a number of complicated problems and undesirable effects in other parts of the world. It is admitted that with increased productivity the pattern of agriculture will change and this may result in a significant modification of the agro-ecosystem. But progressive studies in an integrated control approach would easily anticipate, determine and direct the effects of these changes in the agro-ecosystem towards a more favorable pest climate.

Integrated control has been defined as "a pest population management system that utilizes all suitable techniques in a compatible manner to reduce pest population and maintain them at levels below those causing economic injury." (Smith & Reynolds, 1965). This implies the recognition and augmentation of the biological, cultural and other controlling agencies, and the use of chemicals only as and when necessary. Indeed it is a system which involves a profound consideration of the whole agro-ecosystem and the manipulation of all the processes and practices which favor the factors reducing the pest population.

In tropical Africa the tentative or deduced general equilibrium positions of most of the cereal pests show that they are generally below the economic threshold. This suggests the potential success of an integrated control approach. Harris (1961) recorded three important parasites Eupelmus sp., Aprostocetus sp. and Tetrastichus sp. on the sorghum midge and suggested that they play an important part in controlling the population, but no further attempt has been made to evaluate their importance critically and augment their action. Pediobius furvus (Gah.) has also been shown to be an important parasite on the stemborer, B. fusca, and thirteen other parasites have been recorded. It is felt that the study of these parasites, the augmentation of their action and the implementation of the cultural control practices suggested by Harris (1961, 1962) and other authors within an integrated control

program could bring about a satisfactory solution of the pest problems on cereal. Fortunately, African farmers can hardly under the present economic situation afford the high cost of the insecticides, some of which are known to cause more problems than they solve; but agricultural science can contribute to the solution of their problem of increasing agricultural productivity by a coordinated, well-informed integrated pest control program.

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PRIORITY RESEARCH IN THE FIELD OF FOOD CROP PROTECTION IN FRANCOPHONE COUNTRIES IN AFRICA SOUTH OF THE SAHARA

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SUMMARY

With the exception of Madagascar, the Francophone countries of Africa lack facilities for applied research in the field of food crop protection, with the result that efforts for agricultural development and crop diversification are likely to be stymied or nullified by the action of pests which remain so far uncontrolled.

The major pest problems in Africa are reviewed.

Biological control, virology, bacteriology, nematology, phytopharmacy are branches of research to be established or developed. It is suggested that new research facilities be integrated within large regional organizations dealing with other branches of agricultural research.

INTRODUCTION

As a rule, the Francophone countries of Africa have a National Plant Protection Service, which is sometimes remarkably well organized. However, such services are not concerned with applied research in the field of plant protection.

In this field, the Institute of Agronomic Research of Madagascar, a subsidiary of IRAT, is a modest organization with a relatively complete structure including laboratories for Plant Pathology, Agricultural Entomology and Biological Control, and Nematology, which provide scientific supervision for a Quarantine Station, in connection with plant material introduced from areas contaminated with dangerous diseases.

In Francophone Continental Africa[1], the several institutions specializing in various export crops have laboratories which conduct research necessary for the maintenance and development of crops. No such arrangement exists for food crops. True, in the past, the agricultural research stations of Bambey (entomological work of Risbec, Mallamaire and Appert), Bingerville and Boukoko as well as the laboratory of O.R.S.T.O.M. at Adiopodoumé have conducted research on food crops, resulting into a fair overall picture of the entomological and nematological fauna of such crops; however, in the field of plant pathology, knowledge is still scanty.

Since food crop cultivation is generally practiced on very poor soils, with old methods, thus producing very low yields, non-specialist agricultural

[1]This paper does not include Congo Kinshasa which does not use French bilateral assistance in this field.

engineers in charge of research have tended to think that, since chemical applications cannot be considered, breeding of resistant varieties is the only means of control. Under the circumstances, specialized research in plant pathology or entomology did not seem to be profitable. This approach is changing. Recent advances in fertilization and cultivation methods show that it is possible to radically change traditional systems and obtain yields comparable to those of intensive agriculture. In Madagascar, for example, where yields exceeding 6 tons of rice per hectare are achieved, it has been observed that pest and disease control in the field is not only profitable, but necessary. It is quite certain that the same will be true in continental Africa, and that various diseases, still unknown or thought to have a negligible effect under traditional cultivation, will be included among the major yield-limiting factors under intensive agriculture. The following lists, which deal with the main current problems, are to be considered, therefore, as quite provisional and subject to many and large additions:

1. Pests harmful to all crops

In this category, in the dry tropical zone, locusts and millet-eating birds raise serious problems. These pests are so important that international control organizations have been set up (O.I.C.M.A., O.C.L.A.L.A.V.). However, these organizations, although undoubtedly efficient in practice, do not have research laboratories.

Yet, a detailed understanding of the origin of locust invasions lies at the very basis of an efficient control. Biological data, in particular on population dynamics and ecology, is still too fragmentary to result in positive pest control measures. True, for some years now, a lull has set in. Governmental authorities have come to forget the danger, investing too large a measure of confidence in the existing organizations; yet these organizations, at least as far as the migratory locust is concerned do recognize that it would be impossible to control a new invasion of a certain magnitude. The time has come, therefore, to probe more deeply the matter of locust biology and to explore new control procedures by organizing inter-continental exchange of entomophagous insects.

As for the millet-eating birds, when mass destruction of quelea succeed in achieving control, new species are appearing, whose scattered nests make control much more difficult.

The black rat is to be added to the list of native rodents. Control of these redoubtable pests has been sporadic. It should be based on very detailed biological studies, in order to avoid, as has been the case with harmful birds, that the destruction of a dominant species be followed by the proliferation of species much more difficult to control. Here, control extends beyond the purely agricultural field, since rodents are carriers of several serious human diseases.

2. Rice pests and diseases

Rice cultivation is still limited in Africa south of the Sahara. Madagascar is the only important producing country. However, in the other countries, consumption is increasing and far exceeds local production. Senegal, for example, spends about one-fourth of its foreign currency earnings from peanuts on rice. Since production potential is large, no one doubts that rice cultivation will develop rather quickly.

Fungus diseases observed in Africa as the same as in other rice-producing countries: Piricularia oryzae (however, we do not know which line, or group of lines), helminthosporium and Cercospora (same remarks), moniliform Fusarium, some diseases of the sheath (including Ophiobolus oryzinus), about which very little is known.

Rice Nematodes are important. Heterodera oryzae has been described in the Ivory Coast and should be investigated further. It is known since 1965 that Aphelenchoides besseyi exists in Africa and since 1967 that Ditylenchus angustus exists in Madagascar. Although O.R.S.T.O.M. has an excellent laboratory of nematology, it is oriented principally towards drawing up an inventory of the fauna, with description of many new species and forms. Agronomic studies of nematodes in food crops remain to be performed, relationships with environment, methods of cultivation, wild and cultivated host plants, etc.

In the field of entomology, the fauna of stem borers, diopsids, hispids, and bugs offers many subject matters for study and will become increasingly important from an economic point of view.

3. Diseases and pests of other grains

A list of possible research on these crops would be long. It should be noted, however, that the problems raised by Sclerospora and various bacterial diseases should be studied in particular. On the other hand, the great number of ordinary fungi, rusts, smuts, diplodia and root fungi should be classified precisely and studied in relation with environment, yield and possible treatment.

On the entomological side, stem borers, noctuidae and Pyralidae are the most constant and important pests. Control is made difficult by the fact that the parasites live in the plant itself. Solutions are to be found in cultivation methods and, more particularly, in biological control. Gall gnats may bring about total failure of sorghum in dry tropical areas. Their study has been started by IRAT in cooperation with I.N.R.A.

Grain crops cover millions of hectares and are the basic food for the population. Their economic and social importance is considerable.

4. Sugar cane

Sugar imports are a considerable burden on trade balances for most African countries, which are obviously trying to alleviate the problem by

developing a domestic sugar production. Few diseases have been observed as yet. Two viral diseases, ratoon stunting and chlorotic streak, have been recognized. In the latter case, it would be advisable to look for hosts in the self-sown flora. A few bacterial or fungus leaf spots diseases could be special to Africa. The role of nematodes (Heterodera oryzae, H. sacchari, various Tylenchidae) should be studied. Borers seem to be present in many varieties. Rodents are active. Experience has shown that this crop can only be maintained, anywhere, with the help of pest and disease control. It must be scientifically supervised if the burgeoning sugar industry in the area is to develop.

5. Food pulses

Food pulses are particularly interesting in view of their high protein content. Unfortunately they are attacked thoughout their growth by a number of insects which often completely annihilate the crops. Study of these problems has been undertaken, particularly for coropeas (Vigna sinensis), by M. Breniere, chief of the Central Entomology Service for IRAT. It must be pursued and extended to the various concerned areas, since control of these insects is required for the proper development of this crop..

6. Vegetables and tobacco

Among bacterial diseases, Pseudomonas solanacearum is particularly important, both from the point of view of the number of crops involved and because of the severity of the attacks, particularly on tomato and potato, whose cultivation can be completely prevented by bacterial wilt. This is one of the major plant protection problems in tropical Africa.

Many leaf diseases, almost all described in Europe, some of them probably new, should be studied and treatments should be developed; in addition to the research for more resistant varieties, research could deal with the impact of several methods on air and soil environment.

Soil fungi responsible for root and collar diseases are very badly understood. Nematodes, Meloidogynae in particular, play an important part.

In the field of entomology, the list is still incomplete. Gourds are severely attacked by flies of Dacus gen. and beans by Melanogromyza phaseoli. Pardalopsis cyanescens attacks tomatoes. A large number of insects in the soil destroy the young plants just after germination. Leaf and fruit insects are quite numerous. For these crops, use is often made of chemicals; however, the use of toxic pesticides in the special conditions of African farming should be closely investigated (problems of residues and their harmful effect on the population).

7. Stock conservation

Problems raised by foodstuff conservation at all levels in marketing channels are beginning to concern Governments in West Africa. Trogoderms raise obviously a very serious problem, native species being brought to

the ports with exported goods and foreign species introduced in the ports with imported goods. However, common species such as Sitophilus oryzae, various Tribolium, etc., play an important economic part and cause damages in grains. Weevils are an obstacle to the consumption of cowpeas but the problem is about to be solved.

Regarding fungi, the recent discovery of aflatoxin in groundnut and groundnut cakes has led to a number of studies. However, many points are still unkown, so that no safe preventive methods have as yet been developed for the production of really clean groundnuts.

There are probably other mycotoxins on other products.

CONCLUSION

This paper has shown the main gaps in research organization as applied to food crop protection in Francophone Africa.

If these gaps are to be filled, we believe that action should preferably involve the following fields:

1. Biological control of insects is a method of choice when the farming population is very poor, quite uneducated and when crops bring a very low financial return.

2. Agricultural Nematology, virology and bacteriology of food crops are not practiced in Francophone Africa.

3. On the other hand, there is no permanent research organization dealing with small vertebrate (rodents, birds) and locust biology.

4. It would be extremely useful to have a plant-pharmacy laboratory, with equipment for assaying residues.

The new research facilities would be more efficient if integrated with existing organizations. They should be established within the large regional station which already includes the other disciplines dealing with agricultural research.

CROP PROTECTION

Max Diaw, OCAM

INTRODUCTION

Crop protection in each nation of Africa is the responsibility of its crop protection services composed of technicians trained in putting into effect the recommendations of the Commission Phytosanitaire Inter-Africaine and in organizing, in line with the advice of research agencies, campaigns to control the main epiphytes.

However, in several member countries of OCAM specialized research services are as yet inadequate. In several countries no applied research at all is being done in the field of crop protection (entomology, plant diseases, nematodes). Under these circumstances, plant protection services are unable to make either laboratory examinations or rapid diagnoses. A further consequence of this lack of specialists is the spread of diseases introduced more or less without anyone becoming aware of it in time to prevent heavy economic losses (white tip of rice, pests of stored grains). Additonal damage usually attributed to climate is caused by pests, there being failure to link cause and effect (as in the case of the Sorghum midge parasitism of millet land sorghum and various virus diseases).

Parasitism is one of the main causes of low yields, although this goes unrecognized. In sorghum it is caused by the sorghum midge Contarinia sorghicola, a pest that by its bite destroys from 10-30 percent of the crop in certain years, equivalent to several millions tons for all of Africa.

In order to cope with this situation, OCAM, jointly with the Institut de Recherche Agronomique Tropicale (IRAT), has framed a guideline project for the organization of research applied to protection of food crops common to member countries of OCAM.

All aspects of crop protection will be studied by this regional agronomic research organization - soils, plant improvement, cultivation techniques, plant physiology, bioclimatology and so forth. Major plant research stations already functioning in OCAM countries capable of supporting such an organization are:

- for the dry tropics, that at Bambey
- for the humid tropics, that at Bouaké, and
- for the Guinean (Equatoriale) zone, either that at Yangambi or at Boukoko.

PREVENTION OF WASTE WITH SPECIAL REFERENCE TO THE ROLE OF AGRICULTURAL ENGINEERING

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SUMMARY

The importance of the prevention of waste is discussed. The role of agricultural engineering is emphasized in relation to prevention of pest damage and minimization of in-field losses and milling losses. Some examples of crop losses recorded in West Africa and in the Philippines are reviewed. These are: (1) losses due to the absence of the appropriate agricultural machinery or to inefficient processing machinery; (2) losses caused by pests; and (3) losses in tuber crops due to unrestricted respiration.

Attention is brought to the utilization of natural air drying in the tropics as a simple and economic procedure. Prevention of waste is suggested as a research priority in Africa.

INTRODUCTION

During the past few years, interest in the possibilities of increased agricultural output by preventing waste has been greatly stimulated and some locations of loss have been identified. These are principally at harvest, during field handling, during storage and transport and in processing.

The losses caused by pests during storage are the most easily observed. They must have been occuring since the beginning of agriculture and have probably become more conspicuous due to gradual crop increases. Losses in the field have also probably existed for a long time and, although they are not so easily recorded as those occuring in rural or central storage, they are probably at least as great. There exists a danger that, in the course of increased production due to advanced agricultural practices, the field losses may be greatly increased if sound harvesting and drying methods are ignored. For example, when rice is harvested during rainy seasons from artifically irrigated areas improved drying methods must be regarded as essential. Even when sun-drying is possible during dry seasons harvests, serious losses can occur due to over-ripening and scattering of grain and to excessive exposure of grain to alternating day and night atmospheric conditions.

It may be expected that if improvements in field handling, storage and processing are not co-ordinate with advancements in agriculture the percentage of loss will increase because of the

over-loading of any existing harvesting and drying facilities and because of storage congestion.

THE NATURE OF LOSSES AND EXAMPLES

Some important known losses in crop yields are as follows:

1. Losses due to badly-timed or inefficient harvesting.-

   This kind of loss may occur in root crops but it is most important in cereal grains. In the case of rice, it is well established that the most suitable grain moisture content at which to harvest is about 20%. At this moisture content, the seeds are attached firmly to the panicle and loss due to shedding is negligible. After harvesting, the grain may be dried by a number of well-established systems.

   In this respect African countries, which are considering rice production, may wish to benefit from the knowledge now being gained in the Philippines. It has been recorded recently by the author that in some of the most important rice-producing areas in the Philippines, dry-season rice crops may be harvested with a moisture content as low as 12%. Losses due to shedding of the grain before harvest, during harvest (almost entirely manual) and field handling range between 6 and 18%. These losses have been recorded by counting in a representative number of meter squares the number of grains remaining on the soil and calculating the loss per hectare. This problem is now being tackled by the introduction of improved bulk storage together with natural forced-air drying or heated-air drying. This makes possible earlier harvesting and reduces field losses.

   In Ghana and Togaland, and probably other countries, heavy losses occur in the maize crop before harvest. The cobs are left to dry on the stand and may therefore remain in the field for six weeks after maturity. During this time pest damage is severe. It has been recorded in Ghana that at the point of harvest maize had already incurred a 4% loss in weight due to attack by the weevil, sitophilus oryzae, and had acquired heavy infestation which continued to cause weight loss of further 16% during four months of storage. Initial work demonstrated that, by means of a simple drier, the green cobs could be harvested, artificially dried and the shelled grain stored without loss in polythene-lined jute sacks. It is clear

that correctly-timed harvesting together with mechanical drying can effectively increase the yield of maize crops by up to 20% in certain places. Where farms are large enough or in co-operative farming, mechanical harvesting would also be of great value in reaping the harvest at the critical period.

2. Inefficient Milling.-

In the case of rice crops the prerequisite of efficient milling is correct drying. Exposure of the grain to fluctuatinglow and high humidities, such as occur between day and night during exposed drying, causes desorption and absorption stress within the grain. The result is extensive cracking of the kernels and poor milling recoveries. Furthermore, excessive heat during artificial drying (over 130°F) produces a similar effect. But even when the grain has a high milling potential, bad adjustment in the milling machinery may cause fragmentation of the rice kernels or inefficient separation of the grain factions, both of which contribute to low recoveries. For example, a number of recent observation in the Philippines showed an outright of loss of 0.5% of rice kernel(broken) due to incomplete separation from the husk. Incomplete separation of the bran and broken kernels was shown in some cases to result in losses in rice recovery of between 3.2 and 6.4%.

Another problem now being investigated there is the deterioration of maize grit due to the inclusion of the germ oil in the fragmented endorsperm. This induces rancidity due to the formation of free fatty acid. The maize grit, which is used for human consumption, deteriorates in about one month. This is an example of loss of quality which can be prevented by improved milling. Separation of the germ, as part of the milling process is to be considered.

3. Uncontrolled Respiration in Tuber Crops.-

In West Africa, the weight loss is incurred by the yam crops during normal storage has in recent years been seriously investigated. In Nigeria, LA. W. Hayward reported losses of more than 10% in yam crops over storage periods of several months. In Ghana, the author and co-workers have recorded losses of up to 35% over five months of storage. This loss, which results from normal starch respiration has gone unnoticed because yam although it looses weight, may increase in money value

during the inter-harvest period. Preliminary work showed that cool storage (60°F) greatly restricted respiration and weight loss. More practical research, to include the possibilities of cool storage, gas storage and irradiation seems now to be necessary.

4. Damage by Insects.-

It has already been stated that insect damage may be prevented by correct harvesting and drying followed by insect-resistant packaging. It may also be necessary in tropical countries, because of the high incidence of insects, to fumigate seed grains after a limited storage period. In such cases, when the produce is intended for internal retailing, it should immediately after fumigation, be packaged in inexpensive insect-resistant containers such as plastic bags. The reason for this is that a re-infestation of unprotected produce is practically a certainty.

In Ghana where weight losses in the bean crop(vigna sinensis)caused by the weevil calasobruchus maculatus is often as much as 30%, simple fumigation and retail packaging has proved to be an effective control and to cost about 1/10 of the expected lost value.

As in the case of tubers, which are sold by the piece, it has been observed that the money value of beans may increase in value during the inter-harvest period even though the weight and quality is reduced. The reason for this is that the beans are presently sold by volume and not by weight: the weevil cavitations do not cause a reduction in over-all volume. It is necessary also to point out that insect attack causes a decrease in quality. A weight loss of 20% in grain or legumes, for example, does mot mean 80% of good grain. It probably means 80% of inedible grain because each seed is at that stage cavitated several times and contains much insect excreta and frass. Here, the need for education as well as further research is indicated.

NATURAL AIR DRYING

It is of course impossible to dispense with heated-air drying methods for grain and these are fairly well understood. It is thought to be appropriate, however, to emphasize the potentialities of drying with natural-forced air in the tropics because of its low cost, simplicity and safety.

In many tropical countries, although the average relative humidity is high, there may be between late morning and afternoon (say 1000 to 1600 hours) relative humidities of around 65% or less with temperature of about 85°F. These conditions are suitable for reducing grain moisture content to the safe level of 12-14% provided fans of the correct capacity and static pressure characteristics are used for forcing air through a bulk container. The high air temperature in the tropics offers the advantage that, for a given relative humidity, grain equilibrium moisture content decreases with temperature increase due to the increased grain vapor pressure. With a little careful management the waste heat of the fan motor may be utilized to increase the air temperature during humid seasons. For example, an 8 h.p. diesel engine, driving a 10,000 CFM fan offer sufficient waste cylinder and exhaust heat to raise the temperature at least 12°F, reducing the relative humidity by about 20%. The salient features of such a system are: - air tight bin about 10 feet high having a flat perforated false floor raised about 12" under which air is introduced from the fan. In a well-constructed bulk container with a properly-engineered fan, it should be possible to reduce grain moisture content by from 20-14% in one to two weeks, operating the fan during relative humidity periods of less than 75%. A very satisfactory air flow is about 3 cubic feet per minute per cubic foot of grain. For a 10' depth of grain a fan capable of delivering the required air volume at 5" static pressure water gauge is suitable, using an 8-10 h.p. engine.

CONCLUSION

Although it is possible to point out a few instances of easily-avoidable crop losses, there are certainly many more which require investigation. It would seem, however, that sufficient knowledge exists to allow the establishment of waste prevention to become a research priority. The prevention of waste is perhaps one of the most simple and inexpensive means of increasing agricultural production - and it does so without the use of further land.

THE IMPACT OF PLANT PROTECTION RESEARCH ON COTTON PRODUCTION IN THE IVORY COAST

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INTRODUCTION

Cotton growing, which has been practiced in the Ivory Coast for many years, was never made the object of fundamental research until the establishment of IRCT in 1945. Cotton, grown in association with food crops, was not properly cultivated or considered as a real crop. Traditional cultivation was based on hardy, low-yielding varieties (Gossypium barbadense) which were at the same time able to resist competition from the food crops. The replacement of these archaic types by hirsutum varieties, selected by IRCT, enabled progress to be made from the fruit gathering stage to the industrial cropping stage.

From their initial introduction in 1958, the potentially high-yielding varieties posed serious agronomic and crop protection problems. In fact hirsutum, in contrast to barbadense, must be grown in monoculture, planted at exactly the right time, and above all grown with drastic plant protection measures.

It is clear that in the Ivory Coast the principal obstacle to cotton production for many years has been the importance of parasites. Their prevalence results from a number of factors:

- in the Ivory Coast there are alternately two wet and two dry seasons; these climatic conditions greatly influence the parasite problem, which is extremely variable according to season.

- cotton-growing, furthermore, practiced for many years, has never been made the object of strict plant protection measures. In particular, the plants have only been partially removed from the ground after harvesting. The dry seasons being neither very long nor severe to stop the growth of the barbadense cotton, the pests could find nutrients and multiply easily on the abandoned fields.

These climatic and cultivation conditions thus supported parasitic infestations remarkable for their variety and severity.

THE PARASITE SITUATION

There are numerous pests whose effects can cause appreciable losses; among the pests of growing crops are:

- Empoasca facialis:

  This homoptera is very common. It is generally found in association with Lygus vosseleri. Swarms of this insert can be extremely large when the rainfall is moderate and spread-out;

strong winds, on the other hand, affect its distribution considerably. New varieties of crop introduced by IRCT into the Ivory Coast are sufficiently hairy to prevent this homoptera from causing extensive danage.

- Lygus vosseleri:

This is undoubtedly the most common pest. It is the most persistent and most thoroughly distributed throughout the cotton zone. In this category it can be considered as the most dangerous of the pests.

- Helopeltis schoutedeni:

The damage caused by this hemiptera is occasionally very serious, but always very localized. Most seriously affected are the fields adjoining the trees growing along river banks or other sources of water.

- Hemitarsonimus latus:

Acariosis is widespread throughout the Ivory Coast, particularly in the northern regions.

Pests which attack the seeds are more dangerous than the preceding ypes, since they are more difficult to detect and less vulnerable to nsecticides. This group includes:

- Argyroploce leucotreta:

The flight of the adults are seen very early during the rainy season. The damage attributable to this pest is important because its larvae penetrate the seeds and introduce fungi and bacteria which causes the total loss of the seed. In the Central region the most severe swarming times for this pest can be avoided by changing the time of seeding. IRCT is also studying the possibility of controlling Argyroploce by biological means.

- Diparopsis watersi:

This nocturnal insect appears very often in the cotton plantations and is found practically throughout the year. The most affected places are on sandy soil. This is the major pest of the Northern region.

- Earias insulana and biplaga:

The appearance of these butterfiles is observed irregularly throughout the cotton cycle.

- Heliothis armigera:

This is the most regular of the fruit pests. Present every year, it appears always towards the middle of October throughout the

region at the two rainy seasons. Only the intensity of the infestation is variable. It is even more severe when there is a long minor dry season.

- Dysdercus sp.:

The observations on the migration of this insect have shown that the maximum period of infestation is always between the 18th and 28th of October. The withering of the bush flora drives these hemiptera into the cotton. If the drying out is rapid it produces a particularly severe infestation. In some years more than 100,000 Dysdercus can be counted per hectare.

- Platyedra gossypiella:

This is the last of the important pests. The flights of the winged stage are particularly abundant in January and February. It is necessary to plant in such a way that fruiting is over and part of the harvest collected before swarming time.

PHYTOSANITARY RESEARCH

Since its establishment in the Ivory Coast, IRCT has undertaken qualitative and quantitative research on these pests. The biological studies and collecting insects has led to the determination of the times of flights and migrations, to ascertain the conditions and location of the breeding sites as well as the ecological conditions which favor swarming, and finally to discover the most vulnerable periods.

Many trials bearing on a wide variety of insecticides has led to an understanding of the times of application, the types of insecticide, and effective and economical doses for each type of pest.

From 1955 to 1965 IRCT tested more than 30 insecticides and estimated their effectiveness against larvae affecting seeds, particularly Heliothis, Diparopsis, Earias, Prodenia, Argyroploce and Platyedra.

As regards an action program, the estimates of effectiveness and strength enabled the extension service to be advised of the best techniques of treatment under local conditions. As a result of these trials and observations, the possibility of controlling the parasites effectively and economically has now been achieved. The differences in the figures of yield per hectare shown below, obtained at the research station, emphasize the degree of infestation and the importance of the results:

- plots treated with insecticide : 2,500 to 2,800 kg./ha
- untreated control : 100 to 200 kg./ha

IMPACT OF THE RESULTS OF CROP PROTECTION RESEARCH IN COTTON PRODUCTION

The results have enabled hirsutum cotton to be introduced, particularly of the Allen variety. The first farmer's hectares were sown during 1959.

The yields obtained were highly satisfactory and the Ivoirien government decided to set a production target of 50,000 tons to be achieved by 1972. This figure, which at the beginning seemed to be very ambitious, will be greatly exceeded. In fact, during the 1965-66 campaign the areas planted totalled 11,777 hectares, with a production of 9,125 tons; in 1967, the figures were 23,820 hectares, producing 22,047 tons--an average yield of 925 kg./ha. This year the acreage covers 38,000 hectares with a production of between 32,000 and 35,000 tons. It seems probable, therefore, that 50,000 tons will be achieved and even exceeded in the course of the next campaign. The Ministry of Agriculture of the Ivory Coast has therefore revised the original target, now reckoning on a production of the order of 100,000 tons by 1970-71.

Before the introduction of the Allen varieties of cotton, which, it should be stressed, could only be introduced as a result of appropriate crop protection methods, the production varied through the years between 4,000 and 8,000 tons of barbadense with an average yield of less than 100 kg./ha.

ORGANIZATION OF CROP PROTECTION IN THE IVORY COAST

The farmer himself treats the area under cotton with a portable Vermorel continuous pressure type machine. This equipment is provided with four jets which enable two rows to be treated at a time. In this way two hectares can be treated a day. The insecticides currently used are:

- Endrin-DDT, mixed, with 450 g. DDT and 120 g. Endrin per liter

  2.5 L. of this mixture are applied per hectare. For convenience the product is available in metal bottles of 250 cc. capacity. One bottle is used per machine and 10 bottles per hectare.

  In some areas an Endosulfan-DDT mixture is used. The application is exactly the same.

Insecticides are not used systematically in the Ivory Coast, but are applied on the advice of the responsible organization--the Crop Protection Service. This form of arrangement is certainly something new for cotton, and the Ivory Coast is undoubtedly the only country with such a service. The Crop Protection Service has established 28 observation posts distributed throughout the cotton zone. Each day counts are made of the number of crop pests or breeding places. When the incidence of parasites reaches what is considered a dangerous level the CFDT sector chiefs are notified to have the area treated. This method has a number of advantages:

- the farmer carries out a minimum number of treatments, and it is clear that in these conditions the treatments are performed with a great deal of care

- this results in an appreciable economy in the use of insecticide

- the reduction in the application of insecticide should clearly reduce the rate at which resistance to it is acquired.

IMPACT OF COTTON PRODUCTION ON THE SAVANNAH POPULATION

The population, some few years ago, was primarily oriented towards food crops produced for their own consumption or for possible sale in always uncertain markets. The price was never fixed, no permanent system of marketing was developed and the sale of yams, maize or peanuts was highly variable. Cotton on the other hand is a crop for which there is a fixed market price. The savannah farmer therefore has today a readily available cash crop.

When the objective of 100,000 tons has been achieved this will earn for the savannah regions about 3.5 billion francs CFA. Cotton, which up to now only comprised a very small part of the income of the farmers, has developed considerably in a short few years. The following figures are for the village of Bokakouamékro in 1966:

PRODUCTS	INCOME (CFA francs)	Percentage of category	Percentage of total income
Yams	48,100.00	61.6	4.5
Rice	1,100.00	1.4	0.1
Peanuts	5,850.00	7.5	0.5
Fruits and pulses	4,545.00	5.8	0.4
Tree crops	2,700.00	3.5	0.3
Palm Wine	14,650.00	18.7	1.4
TOTAL FOOD PRODUCTS	78,145.00	100.0	7.3
Cotton	782,995.00	90.1	73.5
Coffee	3,875.00	0.5	0.4
Cocoa	81,655.00	9.4	7.7
TOTAL INDUSTRIAL PRODUCTS	868,525.00	100.0	81.6
Livestock	23,425.00	-	2.2
Local industry	29,825.00	-	2.8
Collective Rice	65,502.00	-	6.1
TOTAL.....	1,065,422.00	-	100.0

Following the development of cotton production it is evident in the Baoulé region that the tendency towards seasonal migration which amounted to 30% has largely stopped since a focus of interest has been created at the village level, supplementation of income through cotton production.

One other effect of cotton growing is its educative value; in fact, the hirsutum varieties are only cultivated in excellent conditions--choice of land, weeding, insecticide treatment, application of fertilizer. It is clear that the farmers draw valuable information from this type of farming

and that in the future they will have the tendency to apply the same principles to other crops, such as maize, peanuts or rice, when there is a guaranteed market for the crop.

The impact of cotton growing can thus be summarized:

- bringing income to the village
- checking seasonal migration
- education of the farmers in new techniques

ORIENTATION OF PHYTOSANITARY RESEARCH

Classical insecticide experimentation is carried out on new products from the chemical industries. The most effective of these at the experimental level are tested at a number of the observation posts in the Crop Protection service, distributed throughout the cotton growing region.

A major principle in the methodology of the trials is the objective of getting the maximum amount of information out of the experiments. Biological experiments are necessary to distinguish the differences between two very similar products.

It is also essential to develop testing techniques, easy to carry out, which will enable acquired resistance to particular pests to be quickly revealed. Here again the cooperation of the Crop Protection service is invaluable in collecting live material from the different parts of the cotton zone.

A preponderant amount of research carried out at the Bouaké station is devoted to biological control:

- possibilities of transferring to commercial varieties of presently grown characteristics which would give them a certain degree of tolerance towards certain pests

- utilization of diseases of cotton insects discovered or introduced into the Ivory Coast

The following interesting results have been obtained already--the entomologists have brought to light the important role played by the bracts in cottonseed parasitism. The absence of bracts leads to a reduction of about 30% of the damage caused by Argyoploce and Pectinophora. Using the "frego" characteristic, geneticists have obtained identical results to those obtained in plants with the bracts removed. The "frego" character gives reduced bracts which are long and thin and which curve back towards the base as the seed grows. Crossing is being carried out to transfer this character to the varieties grown in the Ivory Coast. The acquisition of this character has a double interest:

- reducing parasitism
- increasing the quality of the fiber; the reduced bracts curved back towards the seed base have less chance of being mixed with the seed when it is harvested.

Other characteristics are being studied; glandless cottons, smooth leaf, and an antibiotic reaction found in the Marie Galante varieties.

The survey of the environment in order to discover diseases of insects has led to the isolation in the last few years of:

- a cytoplasmic virus on Diparopsis watersi
- a cytoplasmic virus on Heliothis armigera
- a granulosis and intestinal virus in Argyroploce leucotreta
- a mycosis of Spicaria rilei in Heliothis armigera
- sporulent bacterial disease common to many pests.

In addition, the complement of pathogenic microorganisms is increased by a nuclear virus of Heliothis armigera introduced from the United States.

The virulence of these pathogenic organisms has been studied or is being studied at the Bouaké laboratories.

With the Ivoirien government financing, very extensive trials are being undertaken on the granulosis of Argyroploce. The object is to manufacture sufficient virus to treat the major areas. In order to achieve this, Argyroploce is being extensively reared artificially. It is likely that production of the virus can begin in the very near future when the optimal date of infection of the larvae has been determined.

Promising results have already been obtained on an experimental basis with this virus affecting Argyroploce. In particular cases, the possibility of integrated control of cotton pests can thus be foreseen.

IRHO CONTRIBUTION TO THE PROBLEM OF OIL PALM CROP PROTECTION

J. DuBois, IRHO

SUMMARY

Blast, a nursery disease, can be effectively brought under control by putting up palm shades during certain critical periods of the year. The size of the plantations sometimes poses a problem of providing enough palm leaves. There are some alternative solutions (interspersed castor oil plants, plastic shelters); a technique must be developed not requiring shade.

Fusariosis, a fungal withering disease of palms, may endanger re-planting operations and sometimes even plantation expansions in certain regions. The selection of resistant parent stock currently seems to be the most reliable way to solve the problem. This unfortunately requires a long-term effort, at least so long as a rapid and early test has not yet been perfected for judging the resistance of a strain. Special cultivation techniques could also offer effective aid controlling the spread of fusariosis.

The symptoms associated with shoot rot should also be studied thoroughly before pathologists are able to use them effectively to determine the chances of plantation success.

Finally control of pests of mature plantations is rendered more difficult by pruning the trees. Here we run into problems of mechanisms of product adhesion and retention under tropical conditions, without overlooking the delicate question of a possible upset of the biological equilibrium about which often very little is known.

There will be a need for "active and foresighted" pathologists in all of the cultivation zones for many years to come.

INTRODUCTION

Crop protection is assuming an increasingly important place in oil palm cultivation, as plantations multiply and as new countries become involved in this industry.

There is no need for reviewing here the reasons which led to the systematic fumigation of seeds and pre-nursery land, nor is there any need to describe the methods of controlling animal or vegetable parasites in the nurseries and young plantations. On the other hand, it

is certainly worth while to focus on some of the most urgent problems here which, though they have been temporarily solved, nevertheless should be the subject of further research in an effort to improve these solutions.

In the nurseries in many countries, we can observe at certain periods throughout the year (heavy sunshine periods at the end of the rainy season) a sudden and rapid wilting of the plants which turn brown and dry out. This disease, which was first reported in Nigeria in 1939, has been given the name "blast".

Losses due to this disease can be very heavy and in some years amount to as much as 85%. It goes without saying that it is then impossible to carry out a plantation program.

The studies undertaken by the IRHO in 1955 have made it possible to recommend -- as of 1957 -- the provision of shade made from palm fronds during certain very specifically defined periods: from 1 October to the end of February under the conditions prevailing in lower Ivory Coast. This procedure is employed each year at all of the IRHO stations and on the plantations to which the Institute acts as advisor; and a mortality rate of more than 5% has never been found during the last 10 years. The scientists at NIFOR (the former WAIFOR) were able to show that blast was due to the association of two fungi; however, in spite of many soil fumigation tests conducted at various periods throughout the year, it has never been possible to reduce the spread of blast by this means.

The expansion of plantations in many countries poses a new problem here. It is indeed sometimes difficult or perhaps even impossible to obtain enough palm branches to cover large areas of nurseries. This is why IRHO has been looking for other solutions offering sufficient shade. In Dahomey, the castor oil plant has proved satisfactory as long as it is treated against its own parasites. Currently, a plastic shelter used in Ivory Coast, provides excellent results -- unfortunately, this material is rather expensive. Ultimately other solutions which do not depend on provision of shade must be found.

The paper on Oil Palm Selection takes up the problem of Fusariosis. This disease seems to advance only at a rate of 2% per year, actually precludes any planting in the fusariosis zone if it becomes established early, since in that case only 82% of the trees would be left after 10 years, 67% after 20 years and 60% after 25 years. This is why IRHO considers it necessary to take this problem very seriously. The previously cited paper describes the orientation of the research on this subject: selection of resistant parent stock, production of seeds from crossings between resistant trees, and multiplication of these trees by self-fertilization. This work is justified by the observations which have been made at Dabou. Crossings which did not tolerate the artificial inoculation tests in the nursery at all well showed 15% of the plants stricken

with Fusariosis at the age of 6 years. One crossing is particularly sensitive to the test reached 25%, whereas the percentage varied between 0 and 5% for other lines planted alongside.

The test used so far in the nursery is performed one month after transplanting and it is necessary to wait at least 6 months for the result. It takes more than 50 plantules per crossing and this number would have to be increased in order to get greater precision. Finally, the agreement between the behavior vis-a-vis the test and the behavior in the plantation is, on the whole, sufficient to demonstrate the possibility offered by this research approach; nevertheless, it is not rigorous enough to enable us to arrive at a rapid classification of parent stocks as a function of their resistance. Numerous controls and new tests will be necessary. It is also highly desirable to develop a test — as soon as possible — which would rapidly produce reliable results. This requires perhaps extensive and certainly meticulous research as to the characteristics associated with resistance, charcteristics which moreover must be easily measurable.

As regards other possibilities, quite apart from the basic research on the transformations which cause the Fusarium in the unplanted savannah soil to make the transition from saprophyte to pathogen when the palm tree is introduced there, it is hoped to reduce the virulence of Fusarium through particular methods of land preparation and through the choice of cover crop.

Pathologists, however, are also preoccupied with other problems These problems consist, above all, of a complex of symptoms of leaf anomalies, sometimes associated with or leading to shoot rot — which of course kills the tree. Very often no primary organism can be detected; a minimum food deficiency (in terms of boron for example) may be responsible for these symptoms; but the explanation is never as simple as all that and the diagnosis then requires as complete a knowledge as possible of the climatic and edaphic conditions, as well as the observation of tree growth under these conditions.

Although it is relatively easy to take the proper action in the nurseries and in the young plantations against insect or fungus attacks, the situation is entirely different at maturity. The pruning of the trees, the volume of the leaf system in themselves create tremendous problems in connection with the proper application of the products. Crop protection and control equipment manufacturers are not aware of these difficulties; they undoubtedly think that there would not be enough of a market for this kind of equipment to make it worth while to design and develop the required models.

Taking the case of Coelaenomenodera, a parasite whose larvae sap the folioles and whose adults live primarily along the underside of the leaves, if we want to destroy the larvae, we must use penetrating products and, since the top side has a thick and waxy cuticle, we must

apply the substance from the ground. Here is where we find that the existing equipment is inadequate. If we want to kill the adults -- which are a priori much easier to reach since they live on the leaf- we nevertheless run into problems of powder or liquid adhesiveness, problems of retention and above all, once again, the problem of the equipment to be used. Crop-dusting from aircraft constitutes an apparently satisfactory solution in terms of large areas to be covered; but here the use of aircraft would not enable us to treat the foliage sufficiently thoroughly to be able to deposit these substances on the underside of the folioles.

Assuming that all of these problems have been solved, we would still run into others. The intensive control against a parasite - without knowing the laws which govern its rapid multiplication and without regard as to the species which would provide for the limitation of this rapid multiplication - involves the risk of bringing about a disastrous rupture in the balance of nature.

In conclusion, we would like to quote from the report by Prof. Wardlaw to the May 1965 conference in London:

"There is no doubt that progress has been made over the past several years in research on oil palm diseases and pests, but much remains to be done. With the expansion of plantations into new regions, we must always keep in mind the need for using improved genetic lines, we must be aware of the ageing of the plantations, and new health problems keep coming up all the time. We are therefore entirely justified in emphasising the need for having available active and shrewd pathologists in all of the most important cultivation zones for many years to come."

IRHO CONTRIBUTION TO THE PROBLEMS OF COCONUT PALM CROP PROTECTION

D. Mariau, IRHO

SUMMARY

There are two problems which remain major preoccupations in coconut palm plantations in Africa.

Oryctes, which is rather widespread, jeopardizes the success of young plantations. An international research program, financed by the UN and carried out through the South Pacific Commission under the control of FAO, has been underway since 1964. IRHO is making its contribution here through the work in progress at Port-Bouet and the work done in France (La Minière INRA Laboratory) at IRHO's request on the possibility of applying the method of male sterilization to the control of oryctes.

The Kaincope disease is still a threat to African coconut palm plantations. Only the introduction of dwarf varieties from Malaysia can be recommended for the time being.

The pathology of the coconut tree has essentially for many years been characterized by the existence of a number of major problems. These problems have so far not been satisfactorily resolved and they still are the object of much concern; they have also been the subject of international research programs or, at least, of meetings of scientists from various countries.

With its many species, Oryctes, is certainly the most widespread pest of the coconut palm in the world. The United Nations'Special Fund through the South Pacific Commission and under the control of FAO, supports a research project on the eradication of Oryctes rhinoceros and similar insects. This project was launched in November 1964. Studies here involve the biology and ecology of Oryctes, research on parasite predators and diseases in various parts of the world, as well as the use of attracting substances which will also inhibit reproduction. IRHO, in turn, has asked the Institut National de la Recherche Agronomique in France, (Biological and Biocoenotic Control Laboratory at La Minière-Versailles) to undertake in 1964 studies on the possibility of using autocidal control methods through male sterilization for Oryctes monoceros and Strategus aloeus. When informed of this project, the board of directors of the United Nations project decided to ask that this also be applied to Oryctes rhinoceros. The breeding methods worked out at La Minière at the end of 1965 could easily be adapted to the Asian species.

In this way Oryctes rhinoceros was bred under artifical conditions for the first time. On the basis of this breeding program, it was possible to determine the cobalt bomb radiation doses necessary to bring about sterility in males, without harming their sexual behavior. These studies are now almost complete and they should make it possible to come up with precise answers to the questions asked.

In 1947, the project manager asked IRHO to undertake numerous dissections of African species, in Africa, in connection with the search for parasites capable of being transmitted to Oryctes rhinoceros. In this connection, nematodes were very frequently observed in the copulatory pouch of female Oryctes monoceros.

Laboratory-bred virgin Oryctes rhinoceros have made it possible to demonstrate that these nematodes could be transmitted to female Oryctes rhinoceros by male Oryctes monoceros. The South Pacific Commission is now trying to continue this research. It should be noted that the multiplication of the virus Rhabdionvirus oryctes is being continued successfully at the headquarters of the project.

With regard more particularly to Oryctes in Africa IRHO has worked out a method of chemical control applicable to young plantations, without a risk of toxicity (micronized Lindane) to the trees. IRHO, in effect, demonstrated that the application of insecticides to the crowns of the young coconut palms, over large areas, at the moment is the only effective means of control. The insecticide is incorporated into sawdust. The mixture is placed in the axilla of two or three of the youngest trees. 30 g of 90% active micronized Lindane are required to treat 100 trees. During periods of heavy attack, the mixture is replaced every two weeks. Lindane offers an advantage over the other insecticides: it does not cause burns on the tender tissues at the base of the young leaves. Even with repeated application, it does not lead to a stoppage of root growth which could cause the tree to fall over; this is quite in contrast to HCH.

However, Lindane treatments remain limited to young plantations. We cannot treat adult plantations covering large areas in this way. At any rate, these treatments should only be as a last resort; in the final analysis, cleaning the plantations and the care devoted to the preparation of the land prior to the establishment of the plantation constitute the most efficient way to control Oryctes.

The so-called Kaincope disease in Togo -- which is called the Cape St-Paul Wilt in Ghana -- remains a major preoccupation for African palm plantations. It also seems to exist in Mozambique and recent studies have reported outbreaks in Cameroon. It is almost certain that this is the same disease which was so severe in Jamaica since 1872; this disease there was called "unknown disease" in the past and it is now called "deadly yellowing".

In spite of extensive research and exchange of information between research workers it has so far not been possible to arrive at any reliable conclusions as to the nature of this disease.

In all of the regions mentioned, it was simply observed that certain varieties of dwarf coconut trees (originating particularly in Malaysia), which had been planted in a zone that had earlier been devastated by the disease, did very well. This fact was used in trying the symptoms, which vary slightly according to the country involved, to the same general syndrome.

IRHO introduced the principal varieties of dwarf coconut palm into Togo, along with dwarf large hybrids whose behavior with respect to the disease will be interesting to observe. This newly introduced plantation covered 105 hectares at the end of 1966 and it was possible -- for the first time, in 1967 -- to plant plants from the nuts of dwarf coconut palms gathered in Togo.

The two examples given above certainly are not the only ones to pose problems for officials who are responsible for the health of the coconut plantations. We might also mention the parasitic insects in the foliage, parasites in gashes in the tree trunks, bugs or acarid parasites in the fruits, rats, etc. All of these are problems for which there are temporary solutions; but it would be highly desirable to improve these temporary solutions.

Nevertheless, the examples given here show the necessity of combined efforts in order to develop new directions of research and how necessary it is for everybody to be absolutely up-to-date on the progress of the work being done in each of these diseases so that the preliminary results may be used effectively.

AGRICULTURAL RESEARCH ON GRAIN LEGUMES

P. Silvestre

IRAT

SUMMARY

Various species of legumes are grown in Africa. Although their production is not yet known in detail, it is admittedly grossly insufficient to provide a satisfactory dietary protein level in view of the low availability of animal foods at present.

Among these leguminous plants, Vigna unguiculata is of particular interest because of the importance of its production and its nutritional qualities.

This species has been the subject of a coordinated study program is developed by IRAT, with Senegal, Upper Volta, Niger, Togo, and Cameroon.

Basic studies on the genetic and physiological development of mineral nutrition are being undertaken in Senegal. Experiments on varieties, farming techniques, fertilization and protection of crops are being made in Senegal and in other countries concerned.

A program of experiments on the preservation of stored crops is being carried on in Senegal, Niger, Togo, and Cameroon.

Research on this species must be continued in different areas, keeping in mind that only a comprehensive improvement of the agricultural system will bring about an increase in the acreage devoted to leguminous plants and make the phytosanitary treatments required by Vigna unguiculata worthwhile.

1. The Grain Legume Situation in Africa

Traditional agriculture in African countries is most often of a primitive, itinerant type. Yields per acre or other unit, and productivity from human effort are low. Basic food products, represented essentially by cereals and root crops are not very diversified. It is difficult to determine the position of edible legumes among food crops because of the inaccuracy of the available statistics. It is generally admitted that their production is insufficient to provide a satisfactory protein intake for the populations, when the low availability of animal foods is taken into consideration.

Increased production of grain legumes depends largely on the improvement of other annual crops and the improvement of agricultural systems in general. The increase in yields by the use of fertilizers, improved genetic material, control of parasites, and increased productivity through mechanization will indeed make more land and time available, which will make crop diversification possible; and legumes, which are also beneficial in crop rotation, have great possibilities in this respect.

Leguminous food-grain plants that are grown at present in Africa are in order of importance:

Vigna unguiculata--It seems that the production of this species is limited to West Africa, including Nigeria, with a total of a little over 1,000,000 tons. It is traded from the dry tropical zone, where it is produced in great quantity, to the coastal humid zone. In general, it is grown mixed with the millets and sorghum.

Phaseolus vulgaris--is an edible legume grown in the high tropical regions of East Africa and Madagascar.

Phaseolus lunatus--well adapted to humid climates or to irrigated farming, is grown here and there in Africa as a backyard crop; in the South West of Madagascar this species, cultivated with irrigation, or with subsiding flood water, is produced in sufficient quantities to export.

There are other less important species; especially Phaseolus mungo, aureus, radiatus, cultivated sporadically, mainly in humid zones; Voandzeia subterranea, traditionally produced in small amounts in various countries: Northern Ivory Coast, Upper Volta, Niger, Northern Dahomey..., Madagascar; Phaseolus acutifolius, little cultivated now but of interest for the sub-arid zones, because of its short cycle and its resistance to drought.

Obstacles to the development of the Leguminosae are both their low yield and the low productivity of primitive agricultural systems which leaves little time to the farmer to develop crops that do not fulfill his most immediate food or monetary needs.

2. Research Priorities

The choice of priorities in legume research affects the species to be selected, according to the ecological zones, and the subjects to be studied.

At the request of the interested governments, IRAT has initiated some studies, especially on Vigna unguiculata.

As we have seen, this species is one of the most important, economically speaking; it is well-adapted to hot and relatively dry climates of the tropical plains zone, but it extends, also, although on a more limited scale, to certain humid tropical zones.

Finally, according to several authors, it is one of the most promising leguminous plants, from the point of view of nutritional value, even more promising in certain respects than the grains obtained from Phaseolus vulgaris.

3. Studies Performed by IRAT on Vigna unguiculata

The studies made by IRAT on this species affect mainly Senegal, Niger, Upper Volta, Dahomey, Togo and Cameroon. Whenever possible these studies are made on a regional basis.

Thus, the Centre de Recherche Agronomique at Bambey works on the genetic improvement of the species, with selected varieties being experimented on not only in Senegal but also in Upper Volta, Niger and Dahomey; the physiology of the plant development and mineral nutrition are also studied.

In other cases the studies made are part of coordinated programs affecting several countries, as are those conducted in Togo, Senegal, Niger and Cameroon on the protection of the stored crop.

Finally, experiments on fertilization, farming techniques and phytosanitary protection, which are closely related to local ecological conditions, are conducted at the place of application itself.

Through these studies it has been possible to obtain a better knowledge of the species, to get improved varieties and better farming and storage techniques.

3.1 Knowledge of the plant

The collection at the Centre de Recherche Agronomique at Bambey include more than two hundred different varieties of different origins.

These varieties are classified in different groups, according to their mode of growth, indeterminate or determinate, and their degree of sensitivity to photoperiodism.

Research on development and photosynthetic activity seem to point to the fact that yield is more closely linked to this last criterion than to vegetative growth.

The work done on varietal improvement has made it possible to pinpoint the genetic determinism of certain factors such as: sensitivity to photoperiodism, and the relationship between certain characteristics such as length of the cycle and large seeds, and the rate of natural cross-fertilization which, under conditions prevailing in Senegal, is between 0.22% and 2.06%.

The studies relating to mineral nutrition have given some preliminary indications of the rate of absorption, and eventual excretion, of fertilizing elements during the cycle for different types, as well as indications of total mineral use. They show in particular that this species needs a great deal of potassium.

3.2 Genetic Selection and Improvement

In this field the objectives are: yield improvement, adaptation of

the length of the cycle to different farming conditions, and quality of the grains, which at least in the dry tropical zone countries should preferably be rather large and white.

At present about ten selected varieties are available belonging to different varieties, which are used for experiments under various ecological situations.

3.3 Fertilization

Experiments carried out in Senegal aimed at establishing a graph of yield in relation to increasing levels of primary minerals have shown the uselessness of nitrogen supplements, which indicates a satisfactory bacterial symbiosis and a maximum production of about 1,500 kg. per hectare with approximately 60 kg. per hectare of P_2O_5 and 80 kg. per hectare of K_2O.

These experiments should be continued on different types of soil with the purpose of trying to [illegible] in the most profitable results from the fertilizer.

3.4 Cultivation Techniques

In a very general way, early varieties that are not particularly sensitive to photoperiodism require early sowings, immediately after the first rains in dry tropical Africa; the late varieties, better adapted to regions with longer rainy seasons, accept or require later sowings. The optimum density for sowing is in general about 40 to 50,000 kernels per hectare. Sowing can be done with a slightly modified peanut-seeder.

3.5 Parasitism

Parasitic insects are one of the most important factors limiting production.

In Senegal, the plant is attacked at the outset of vegetation by Amsacta meleneyi caterpillars; after flowering it is attacked by different caterpillars, of which the most important is the Prodenia litura; at fructification by the Piezetrachelusvarium and finally at the end of the cycle by the Jassides, Bemisia, and the Callosobruchus sinensis that lays its eggs on the fields and gets into the crops in storage.

In Senegal, experience has shown that good protection can be obtained through treatment with dieldrin, made after the first manifestation of parasites. In Niger it is necessary to have more treatments, which is unprofitable.

The study made in Togo of local techniques for conservation of grains made it possible to propose improvements. On the other hand,

research of new techniques made simultaneously in several countries led to the conclusion that it is a good idea to preserve the grains in opaque plastic bags with carbon tetrachloride used as a fumigant.

4. Research to be initiated or continued

As it has been indicated above, one cannot expect to obtain a proper development of leguminous grain-plants unless it is within the framework of an intensified agricultural production system, and unless there is improvement in the level of fertility of the soils. These conditions are even more imperative with the Vigna unguiculata since it is only in the case of very high yields that insecticide treatments appear to be profitable and that other research would be justified.

Accordingly the research subjects to be initiated or developed are the following:

4.1 Physiology

- Continuation of the studies already initiated on the development of the photosynthetic activity of the different varieties.
- Study of the plant's resistance to drought and determination of early tests to judge this resistance.

This work is designed to orient the studies of variety improvement.

4.2 Genetics and variety improvement

- Prospection to establish a gene bank in the West Africa region which is considered a secondary diversification center for the species.
- Research on the selection or hybridization of a range of varieties adapted to the various ecological situations of of Tropical Africa.

4.3 Fertilization

- Development of mineral fertilizers to be used for each ecological situation.

4.4 Cultivation Techniques

Adaptation of cultivation techniques to varieties used, according to ecological conditions and farming systems.

4.5 Crop Protection

- Inventory of parasitic insects in the main ecological environments.
- Continuation of trials on means of control.

- Study of toxic residues in the crops according to the different methods of control used.
- Study of the economic importance of viruses and possibility of genetic control.

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AGRICULTURAL PROBLEMS OF PEANUT PRODUCTION IN THE SAVANNAH ZONE: RESULTS OBTAINED, RESEARCH IN PROGRESS, OBJECTIVES

J. C. Mauboussin, IRAT

SUMMARY

After pointing out the importance of the peanut in the savannah zone where economic needs and agronomical realities combine to make it the logical choice for the area, the author distinguishes between the three ecological zones within the larger zone, where peanuts are grown.

Next the author goes into results achieved (based primarily on research undertaken in Niger, Nigeria, Senegal and Sudan), research projects that are currently underway and projects that should be undertaken in order to:

- study the plant and its improvement (physiology and genetics)
- study and improvement of the environment (soil climate and mineral fertilization): light corrective fertilization for basic deficiences and strong rectification and maintenance fertilization
- study and improvement of cultivation techniques (specific techniques, mechanization, cultivation systems which include the peanut)

Finally the author goes into the protection of the plant against its vegetal and animal enemies. There is a schematic map showing the determination of the frontiers of the zone and a brief bibliography.

INTRODUCTION

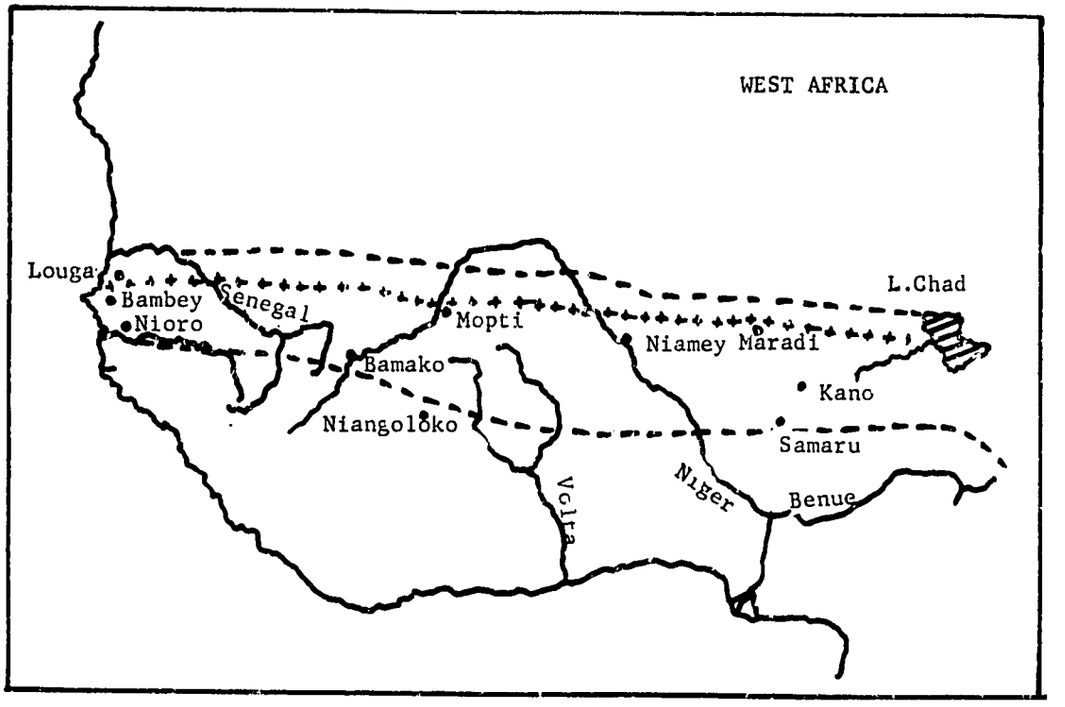
The Peanut situation in Africa

Out of 5,330,000 tons of peanuts produced in Africa (USDA 1965), 80 percent come from the savannah zone to the South of the Sahara and 5 percent come from an analogous zone in the Southern Hemisphere.

The four largest producers are in this zone (Nigeria, Senegal, Niger and the Sudan); they are also the main exporters. Contrary to what occurs in the African forest zone, peanut production is industrial and geared to exports (whole or as oil) and peanuts are a large portion of national income and help account for a large portion of the foreign currency reserves.

We are dealing here with the oil peanut, as the edible peanut represents only a very small portion of the area under cultivation and has few *sui generis* agronomical problems.

AREA FOR PEANUT CULTIVATION IN THE SAVANNAH ZONE OF AFRICA



+ + + + Northermost limit of peanut zone

– – – – Limits of FAO semiarid zone

The savannah zone where peanuts are grown extends from the Northern limit of the peanut zone to the Southern limit of the semiarid zone.

The economic considerations mentioned above would be sufficient in themselves to justify the work already accomplished and that which remains to be done for improving the production of this plant.

However, these are not the only considerations, because an examination of our knowledge on the subject in the savannah zone leads us quickly to the conclusion that this plant is also important for technical reasons in crop rotation, which is another reason for not reducing suddenly the area planted in this crop.

The only harm lies in bad utilization of this plant (continuous cultivation).

The ecology and general conditions of its cultivation area

The savannah zone approximately covers the so-called Semi-arid zone defined by FAO: "a wet season of more than 55 days with a rainfall of more than 250mm to the North, to less than 200 days with less than 1200mm without a short dry season..."

The topography and the soils are not very varied and certain soils cover immense surfaces of land (tropical ferruginous, for example).

This great soil and climatic homogeneity and the great adaptability of the species Arachis hypogea plus its uniform utilization (production of oil and cattle cakes, fodder by-products) excluding any interventions relating to flavor means that many problems can be dealt with on a sub-regional level with local adaptations for soil variations and socio-economic considerations: population density, rate of return, land tenure.

Thus there is more similarity between the peanut problems of Northern Senegal and Northern Chad than there is between those of Northern Senegal and Casamance.

The zone can be divided into three sub-zones:

- the Northern sub-zone dominant dryness (low or irregular rainfall or low and irregular rainfall). Examples: Louga (Senegal), Zinder (Niger).
- the Southern sub-zone where there is sufficient rainfall both as to quantity and distribution; here most of the problems are sanitary or fertility problems. Examples: Samaru (Nigeria), Nioro du Rip (Senegal), Darou (Senegal).
- an intermediate sub-zone where both types of problems co-exist. Examples: Kano (Nigeria), Tarana (Niger), Bambey (Senegal).

Agronomical problems stemming from cultivation of this plant

These can be discussed according to sub-zones.

- In the Northern sub-zone, rainfall is generally the bottleneck, as one really dry year can annul the effect of agronomical techniques developed.

- Thus varietal problems were put first: resistance to drought (with a short cycle if possible), and then fertilization problems and problems of technical cultivation.
- In the Southern sub-zone, the one with the greatest potential, research on productivity within more intensive cultivation systems put problems of fertilization, cultivation techniques (mechanization), and varietal problems all on the same level.
- In the central sub-zone the problems to be resolved are defined locally according to the limiting factor, and the hierarchy is often very hard to establish.

To facilitate matters, we have chosen the traditional breakdown of plant, environment, techniques, but it is evident that the three types of research are connected and the priority given to one or the other can be changed in time and space depending on the dissemination of the techniques to the farmers.

THE PLANT AND ITS IMPROVEMENT

Physiology

Under this category we put knowledge about the plant except for its genetic structure.

Results obtained-

The problems have always been tackled as a function of the needs of other research projects and for this reason our information lacks unity.

Mineral nutrition was studied in connection with foliar diagnosis (which has since been perfected).

The water metabolism was studied as a function of resistance to dryness and the tests were perfected.

The chemical composition is known and foreign studies on this subject can be used without modification.

Growth and development have been studied but mainly for the period flowering-fruiting and generally outside Africa.

Research to be pursued or developed

Progress in other branches depends greatly on a more refined study and knowledge of the plant and its reactions *vis-a-vis* the environment and applied physiological studies should be developed:

> chemical constitution from the selection angle, particularly nature and quantity of fatty and amino acids, aflatoxin formation, seed dormancy, resistance to drought, growth and development in the various ecological situations, mineral nutrition under high fertility conditions.

Selection

Selection research was the first to be undertaken. It is generally admitted that the most economic way of increasing yield is to use good seeds of well-adapted varieties. Nevertheless, experience has shown that if the efficiency of the selections was not put up for debate, utilization of selected varieties was not a short-term means for increasing production. The distribution of selected seeds to the traditional sector, even for a crop such as peanuts, causes many problems in underdeveloped countries. It is necessary to create a heavy infrastructure and to work in depth; such efforts are far from completion even in Senegal, where a great deal of progress has been made. Every year, production in the zone (taking into consideration yields of 800 to 1000 kilograms per hectare) requires on the order of 450,000 tons of seeds (unshelled).

Results obtained-

At the present time, the agronomical research centers of Samaru in Nigeria, Bambey in Senegal, and Tozi in the Sudan put at the disposal of farmers in the entire zone varieties adapted to the different climatic and soil conditions. For the extreme Southern zone, there are also varieties adapted for resistance to the rosette virus that were selected by Samaru, Bambey and Niangoloko (Upper Volta).

For edible peanuts, Sudan and Senegal cultivate Jumbo type varieties selected locally (Sudan) or introduced (Ga 119-20 in Senegal); these are very demanding on cultivation conditions so that they have been restricted to areas that are very favorable as to environment (ecological and human).

Research in progress-

In the Northern sub-zone: Improvement of resistance to drought (Senegal).

In the Southern sub-zone: improvement of yield and the technological characteristics of the oil-peanut and edible varieties with higher yield (favorable zones) or more hardy (extension of this cultivation). In the wettest part, research on varieties with resistance to disease, especially rosette (Nigeria, Senegal, Upper Volta).

In the Central sub-zone: Research on oil-varieties with an intermediary cycle between early and late (Senegal, Sudan).

Research to be pursued or developed-

- genetic studies: heredity of good characteristics, possibility of crossing Spanish x Virginia, selection methods;
- selection for response to strong fertilization, resistance to disease, technological characteristics, forage production.

Sub-Zone	Limiting Factor	Proposed Varieties	Average yield in the zone kg/ha (shells)	Current possibilities (simple techniques)	Maximum (experiments)
North	Rain (Quantity, Duration)	Long Cycle: Bambey 47-16 Short Cycle: Bambey 55-437 28-204 48-115	600 to 800	1500	2000
Intermediate	Rain or Soil	Long Cycle: Kano 50, 47-16 48-115 28-206 Samaru 38 But the ideal would be an average cycle	800 to 1,000	1800	2500-3000
South	Soil and Techniques	Bambey 28-206 Samaru 38 Samaru 61 G 153	1000 to 1300	2000	3500-4000
Exteme South	Soil and Rosette virus	Bambey 48-37 Niangoloko 1040	Very low during year when rosette strikes	1500	2500-3000

THE ENVIRONMENT AND ITS IMPROVEMENT

The climate

Results obtained-

The peanut is very sensitive to temperature and rain conditions; it does not seem particularly sensitive to photoperiodic variations.

Temperature is mainly involved in unseasonal cultivation (irrigation) and probably for flowering, but synthesis studies in tropical environments have not as yet compiled all the facts gathered on this subject.

As far as rainfall is concerned, distribution is more important than quantity, dates of first and last useful rainfall are important as is the position of the dry seasons vis-a-vis the growth of the plant.

The means of intervention are through irrigation which is not economical except under specific local conditions (Sudan) and the use of

windbreakers which is not very common. Thus varieties were sought that were adapted to the climates of the sub-zones.

Research to be pursued or developed

Study of the influence of the different climate factors on the growth and development; also physiology and selection.

The Soils

The soils devoted to peanuts in the zone (more than 4 million hectares) are of variable fertility, but it is never high and they are poor in clay and organic matter, sandy brown and red-brown in isohumic soils, tropical slightly leached ferruginous soils on quaternary sand, tropical leached ferruginous soils on terminal continental.

These characteristics explain the relative success (poor yield without fertilizer) of the peanut, which is a very undemanding plant which likes light soil. Only the cowpea vigna unguiculta does as well.

Some of these soils are exhausted (often because of continous peanut cultivation) and sometimes degraded to such a degree that it is difficult to plan on any improvement (Cayor, Thienaba zone in Senegal, Filingue region of Niger).

Results obtained.-

The problems posed by mineral fertilization of the peanut in these soils have been studied under two very different lights; they have often been opposed one to the other, which is an error, as they pertain to two different stages of agriculuure.

1. It was necessary to immediately increase yield without further degrading the soil, in the most economic way possible, as the yields from the peanut made it the only plant suitable in the traditional cultivation pateern which would maintain the living standardat its low but sufficient level. This was to be done to allow the country to "take off" econimically and create possibilities for new investment. This guided the research of the CRA in Bambey (Senegal) until 1955, the IRHO of Senegal since 1951, and that of Northern Nigeria, Niger, Mali and Chad to this day.

2. Next the methods (often different and always more complicated and costly) for developing the cultivation of peanuts within a system aimed at increasing fertility instead of merely avoiding further soil degredation were studied.

The results would be primarily translated into improved cereal yield and real possibilities for diversification, as most plants capable of replacing the peanut are more demanding of the quality of the soil.

The first orientation brings results and mere adaptation is required here and there to make up for a deficiency; an extended structurization and dissemination effort is needed. These are the themes proposed in Nigeria

and Senegal: elementary rotation, alternating a cereal with a fallow field if possible (this will be taken up again in chapter four).

Use of a low level of mineral fertilizer correcting the main deficiencies pointed up by fertilization attempts (yield and foliar diagnosis) of major elements:

Almost everywhere serious deficiencies of phosphorus and sulphur were apparent (sulphur is an important element for peanut). More rarely, potassium deficiencies were found (Niger). Areas with short rainy seasons can lack nitrogen; this can also occur at the beginning of the cycle. Generally the peanut has good functional root nodules which takes care of supplying the plant with nitrogen.

These deficiencies are corrected by applying weak doses of complete fertilizer (Senegal) or fertilizer with one or two elements only (Nigeria, Niger). The quantities applied do not exceed 150 kilograms of fertilizer per hectare. An average of about 30 percent of fields without fertilizer can attain a yield of 800 kilograms of peantus in the shell.

	Level	Content
Senegal	- Louga Zone, Mekhe: 150kg 12-10-10 - Tivaouane Zone, Forbote: 150kg 10-14-8 - Thienava Zone: 150kg 6-10-20 - North Sine Saloum: 150kg 6-20-10 (bicalcium) - Rest of the country: 150kg 6-20-10 1/2 bicalcium, 1/2 phosphal For Louga, Mekhe, Tivaouane, Forbote, mixture for disinfecting seed with molybdenum	S+N: ammonium sulphate P_2O_5: Bicalcium Phospha K_2O: potassium chloride
Nigeria	60 to 120 kg of simple superphosphate per hectare	
Niger	For the time being, Senegal-type formulas are being replaced by formulas with two elements, P, S, (simple superphosphate, for economic reasons	

This system balances soil depletion with difficulty, particularly of those elements for which there is no response in the first years of the cultivation sequence. Also in Senegal a quantity of potassium is added covering the removal corresponding to a harvest of around a ton per hectare of unshelled nuts. Potassium deficiencies are evident after the second or third year of continuous cultivation.

Apart from agronomic considerations, the economics of moderate fertilization have been studied. Thus if the soils of the zone are homogeneous the distance the fertilizer must be transported can vary the price from 1 (Senegal) to 2 1/2 and more (Niger, Chad). Local conditions must be studied particularly to determine the appropriate forms of fertilizer to use.

There is no net response to calcium and magnesium. The contribution particularly of calcium on the quality of the harvest (USA, Israel) does not seem economic in Senegal.

Trace elements: only molybdenum has been found to be deficient in North Senegal, easily supplied by the inclusion of a small amount of the element in the fumigant used to disinfect the seeds.

The problems of varietal response to limited fertilization has been little studied; in fact the utilization of low levels of fertilizer and subsequent selection in varietal trials assures the needed response in appropriate varieties. The corresponding density of spacing is valid either without fertilization or at moderate fertilization.

The only effect of fertilization on technological characteristics is a shift in the ratio of pods/stem which is reduced with fertilization and can be altered markedly with an unbalanced fertilizer.

In the long-term approach the raising of the level of soil fertility has been faced through very large amounts of fertilizer applied throughout the rotation, necessary for cereal production. Consequently the effect of the increased fertility on the peanuts in the rotation had to be investigated.

The first results obtained show that the peanut can utilize the supplementary fertilizer in conditions of adequate rainfall. Levels of differences of varietal response were observed which encourage further work on this approach. It is likely that trying different varieties and spacing will show economic responses in certain areas, but the research has only just begun.

Research - pursue or initiate

- completion of the map of low-level fertilization for all the countries of the area
- detection of new deficiencies resulting from prolonged use of low levels of fertilizer (accrued deficiencies)
- response of peanuts to high levels of fertilization, in the framework of a rotation and fertilizer giving high yields of cereals
- relationship between spacing, varieties and fertilizer
- studies of the problems of nitrogen uptake (rhizobia, molybdenum)
- effect of the fertilizers used on the quality and characteristics of the soils.

TECHNIQUES AND CULTIVATION SYSTEMS FOR THE PEANUT

Specific techniques

Peanuts are generally grown after a field has been allowed to lie fallow, or after a cereal crop.

According to the different countries, peanuts are grown flat or in ridges; this latter technique is often used in zones with average rainfall (700 to 800 mm).

Results obtained-

The ridges are either done by hand or with an animal-drawn ridger. They are used in Nigeria, Gambia, Senegal and Upper Volta.

Everywhere else, peanuts are grown flat on the ground. Studies have shown that except for plowing, which has a definite effect on yield, but requires increased power in the dry regions, the other methods of preparing the soil have little effect, and the traditional method, of superficial weeding and cleaning, which is by far the least costly, is often preferable.

Seeding -

Seeding is done by hand or with a seeder. The most favorable densities are from 90,000 to 140,000 for the late seeds and from 140,000 to 180,000 feet for the early ones. The highest densities are to be found in the rainy zones where there is also evidence of the rosette virus.

These figures can be considered as valid without fertilizer or with light fertilizer, as the results of studies done on the interaction of density x fertility have not always been clear.

Maintenance -

All experiments have shown the importance of careful clearing and weeding. The quality of the first two seedings condition the harvest, especially if fertilizer is present.

Studies as to the effect of deep hoeing have not been conducted as yet.

Maintenance along a row is manual up to now.

Weeding techniques or weeding with chemicals are currently being studied to alleviate this tedious job.

Harvest -

The date of harvest is vitally important, as some varieties have very little tolerance in this regard. It cannot be determined ahead of time and should be controlled in each ecological environment by the farmer according to the varieties grown and the conditions that year; only the briefest limit has been determined for each variety.

Only animal-drawn harvesters will get round all the plots in time, even in hard soil (all peanut soils become compact as soon as the rain stops). One can also plant varieties with different cycles in order to spread out the work.

Drying -

This is a crucial step for the quality of the product, both peanuts in shell and straw (which makes excellent fodder if dried well). A great portion of the agronomical studies on the control of aflatoxin (toxin produced by Aspergillus flavus which makes the cattle-cakes toxic) deal with methods of drying. According to the results obtained, it seems that the traditional methods, such as in loose stacks, are the best, though a good drying session in the field previous to stacking assures the preservation of the crop.

Threshing -

It is done by hand everywhere; spreading it out over time is favorable to storage parasites, so mechanization should be looked into.

Studies to be pursued or developed

- techniques for deep soil preparation
- interaction of density x fertilizer
- early hoeing-weeding (or their suppression)
- drying and conservation of harvests
- preparation, preservation, and conditioning of seeds

Mechanization

The machine will constitute, and constitutes already, an essential element in the technical progress of agriculture, because of the efficiency it brings to human labor both quantitatively and qualitatively.

Research should be carried on on the following:

- mechanization of traditional operations (done manually up to now) such as seeding, hoeing, weeding or new techniques such as preparing the soil and pest control.
- adaptation of existing machines or creation of new ones.
- human training, animal traction or mechanical traction (moto-cultivation)

Results obtained-

Results have already been obtained on:

- the adaptation or creation of machine to be operated by humans or drawn by animals, to take over traditional tasks: shelling-machines, seeding-machines, hoes, ridgers, plows, threshers, wheelbarrows
- defining certain machines for use with new techniques: plows, pulverizers, polyvalent tools (poly-multi-omni-)

Research to be pursued or developed

- creation of animal-drawn machines for specific jobs (weeding machines)
- creation of mechanized machinery for specific jobs: weeding machines, chemical-weeding machines, pickers, shelling machines

Cultivation systems

The synthesis of the foregoing research and their confrontation with socio-politico-economic facts lead us to define cultivation systems for the main categories of the situation.

Results obtained-

This type of research is very delicate and has been embryonic up to now. Only studies of crop rotation have been successful up to the present time.

Nevertheless, the following have been touched upon:

- agricultural needs—necessity for rotations to have the maximum "load" be most nearly equal to the possibilities and initial condition of the soil.

In terms of this, rotations were suggested with the following pattern over a three year period: peanuts-cereal-peanuts-fallow for Nothern Senegal and over a two-year period at the Center, with light annual fertilizers on the crops.

- socio-economic restraints—demographic density, need for more concentrated, shorter crop rotation cycles, and therefore, need for research in more rapid regeneration methods (green fertilizer, manure)
- need for diversification of crops requiring increased fertility and a revamping of cultivation sequences. More intensive and new rotations have already been proposed. For a large section of the zone under consideration, rotations of the following types have been proposed: fallow fields, industrial cultivation (peanuts, cotton), cereals (millet, sorghum, maize), industrial or food crops (peanuts, cowpeas, maize), in rotation with: phosphate fertilizer for correction or rotation, basic specific annual complements.

Research to be pursued or developed

Besides research on rotations adapted to the various ecological climates and the elimination of fallow fields (possible at 900 millimeters of rain or more) the whole problem of defining preferable production systems and optimal farming organization remains unsolved.

This type of agro-economic research is unfortunately shunned in Africa, and therefore, nothing has been done in this area.

PROTECTION OF THE CROP

The peanut is not particularly sensitive to parasites. Its main diseases are:

- mortality when seeds sprout (insects and fungi)
- mortality during vegetation (wilting)
- rosette
- cercosporiosis
- clump or stunting
- storage parasites (harvest, seeds)

One can also cite aflatoxin at this point, which has a fungal origin, but this problem goes beyond the scope of agronomy.

Results obtained-

Sprouting - If seeds are sprayed with a fungicide-insecticide, they usually sprout quite well. The following can be used successfully: captane or thirame (fungicide) and dieldrin, heptachloride (insecticide) at doses of 500 to 1000 milligrams per kilogram of seed. The effectiveness of the treatment can be spectacular (30 percent increase in yield) or low, depending on the condition of the seeds and the soil, but its low cost makes it always profitable and worth the attempt.

Mortality in vegetation - The agents vary according to the region: Aspergillus niger, Macrophomina phaseoli, Pythium sp and Fusarium sp, and Bacterium solanacearium are the main ones. Fungicide treatment of seeds guarantees an efficient but not total protection against Aspergillus niger.

Rosette - It is endemic everywhere and causes serious problems in the Southern part of the zone where the virus vector (5 identified in Africa) Aphis craccivora find favorable conditions.

Control is possible: utilization of resistant varieties in the zones where the rosette virus is a limiting factor.

- good seeding techniques guaranteeing dense cultivation, doing away with staggered seeding in the zones that are not greatly contaminated
- preventive treatments with a systematic use of insecticides, which is very costly, usable only in research.

Cercosporiosis - Its incidence is very variable and difficult to tabulate, even through experimentation. It can be very high: 50 percent reduction in yield (Southern Nigeria 1965, early varieties) or low (Senegal, Northern Nigeria, late varieties).

Treatment must be very frequent, and therefore they are economic. Only resistant varieties would resolve the problem. Research is going on in this matter.

Clump - Virus, with an unknown vector agent, related to the soil, a big problem in Upper Volta.

Storage parasites - Treatments with powder on the shells are effective, but must be very carefully done. It is a more delicate operation on seeds.

Aflatoxin - Protection against this toxin involves biological knowledge of *Aspergillus flavus*, and research is going on in this matter.

Research to pursue or develop

The incidence of disease, which is not very perceptible under traditional cultivation methods, is very marked as yield increases. Studies should be made especially on cercosporiosis and mortality during vegetation.

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PROBLEMS OF PEANUT PRODUCTION

IRAT

SUMMARY

The paper deals with the area and regions where peanuts are grown as well as with the research that has already been done on this crop.

Next a few themes are suggested for regionalized research in this field:

- setting up a central collection

- studies of genetic and selection problems, including:
  - the cytogenetic structure of different varieties, especially for setting up dormancy-early flowering associations and resistance to rosette-early flowering associations
  - genetic determinism of drought resistance
  - perfecting oil-varieties equally adapted to climatic zones
  - perfecting of edible varieties equally adapted to these zones
  - resistance to cercospora and toxic cryptogams
  - reaction to high fertility levels

- the following physiological studies:
  - drought resistance
  - development and photosynethetic activity
  - nitrogen nutrition and bacterial symbiosis

- studies of phytosanitary protection of peanuts

Suggestions are made as to the possible location for two experimental research stations for peanuts.

INTRODUCTION

The peanut is the legume that is most commonly found in Africa at the present time; it is found in all ecological situation from sub-arid zones to equatorial regions to high altitude climates.

Industrial production of peanuts is mostly carried on in the tropical zone (dry and humid both), in sandy soils (less than 7% clay) with a nearly neutral pH; this zone is mostly along the 12° latitude North, which seems to be a secondary center for peanut diversification.

In the other regions, the peanut should rather be considered as a substantial food crop.

For the last several decades, the peanut has been the subject of many research projects in Africa, dealing with what varieties are best to use in what localities, the best cultivation techniques, methods for control of parasites and diseases that attack the young plant, fertilization, and implements and materials.

Certain projects that were carried out by IRAT and IRHO have already been applied in the Francophone countries of Africa:

- varieties created in Senegal were found to be superior to the local varieties of Senegal and Chad (naturally, under similar ecological conditions).

- varieties resistant to rosette developed by the CRA at Bambey (Senegal) which were useful for Upper Volta, Northern Dahomey, Southern Niger; more recently, similar virus-resistant varieties were developed in Upper Volta which may be useful in Madagascar.

A few studies which were done more recently, especially certain physiological research projects, are of more general interest:

- studies of mineral nutrition making it possible to perfect foliar analysis

- studies of varietal resistance to drought and perfection of a specific test of this.

Although research projects that have purely local application as goals must be undertaken, it is undeniable that research with regional applicability, even general applicability, must be carried on with redoubled effort and new research projects started.

COLLECTION

The CRA of Bambey in Senegal already has a collection of some 2000 numbers corresponding to plants brought in from abroad and some that have been tried out in certain zones of West Africa.

In order to satisfactorily complete the genetic improvement project discussed below, it is necessary to enrich the plants with new types; the 12° North latitude zone being extremely rich in different types of peanuts, their collection seems extremely useful to all the African countries that are interested in growing peanuts. There is need for speed in this project because some of the types that are present in this zone may soon disappear as they are replaced by the varieties that are being selected today.

Thus the genetic stock can be improved, the basis of varietal research, and the enriched collection constitutes a veritable gene bank.

Various projects and observations should be undertaken after the collecting work has been done:

-conservation of root stock

-supplying of root stock to other experimental stations

-study of the seedlings and research on useful characteristics: productivity, response to fertilization, oil content, large nuts, resistant to drought, to rosette, to cercospora, Aspergillus flavus.

GENETIC STUDIES AND SELECTION

General studies should be made or followed through on the following:

-cytogenetic studies - genetic structure of different varieties for making dormancy-early flowering associations and resistance to rosette-early flowering associations.

-genetic determinism - resistance to drought (important for the tropical zone where peanuts are grown).

Parallel to this, research could be undertaken for each one of the large agroclimatic zones where peanuts are grown, and for two types of production: peanuts for oil and edible varieties.

A. In dry or slightly humid tropical zones:

.peanut oil-yielding varieties with drought resistance.

This research, which has already been undertaken at the CRA in Bambey concerns the zones of West Africa and South-West Madagascar which are characterized by irregular rainfall at the beginning of the cultural cycle: Spanish-type variety with a short vegetative cycle (90 days) for zones with very short rainy seasons, or the Virginia type (120 days) for zones with slightly longer rainy seasons.

.peanut oil-yielding varieties adapted to the rainy season of the dry tropical zone and the dryest part of the humid tropical zone.

If varieties of the Spanish group are adequate for 90 day cycles, and the Virginia group varieties are suitable for 120 to 140 day cycles, creating hybridization intermediate varieties suitable for 90 to 110 day cycles, poses a problem: there is an anomaly making it difficult to associate the dormancy of characteristic Virginia seeds with a short cycle.

For the humid sector of this zone where viruses are rampant, the characteristics of resistance to virus must also be investigated.

.research on edible varieties.

In areas which have adequate rainfall, the Virginia-type can be be grown, which has good edible peanuts with large nuts, greatly in demand. Research in this domain consists in locally experimenting with selected varieties, or trying out new ones through hybridization, if special resistance to rosette is necessary.

B. In very humid tropical zones and the equatorial zone:

.research on oil-producing late varieties that are resistant to rosette.

In the African tropical humid zones: Southern Upper Volta, Northern Dahomey, Northern Ivory Coast, South Senegal, etc., research is being carried on to find varieties with lengthy cycles (125 to 140 days) of the Virginia type, varieties which will benefit from the long rainy season, and particularly which are resistant to rosette.

Work will be carried on through hybridization with the goal of combining high productivity with resistance to the virus which is found in certain varieties of Virginia-type peanuts.

.research on early productive oil-producing varieties, with dormant grains, and resistance to rosette.

In the equatorial zone with a very long rainy season, broken up or not by a brief dry season, the best adapted varieties and those best-suited to the ecological and cultivation conditions (two crops per year) are early Spanish or Valencia types.

The peanut can be grown at the end of the rainy season, which is favorable for harvesting, which is then done at the beginning of the dry season. Nevertheless, yields gained from crops planted at the beginning of the rainy season are generally higher, but harvest conditions in the wet climate are difficult due to difficulties in drying the peanuts out and the absence of dormance among the seeds of many varieties, which means that germination occurs among many shortly after they are picked.

These zones, moreover, frequently suffer from rosette attacks.

The problem lies in creating varieties of the Spanish or Valencia type that have seeds with a certain dormancy and which are resistant to rosette. Transferring these two characteristics, which are only known in the Virginia group, presents serious genetic problems. Nevertheless, these problems should be possible to overcome. Spanish types with dormant seeds and resistance to rosette are currently being developed by the IRAT in Senegal and the IRHO in Upper Volta. This problem should nevertheless be studied in a systematic fashion (see below, cytogenetic research).

.research on edible varieties.

If typical edible varieties of peanuts are in the Virginia group and are rather well-adapted to moderately humid regions of the tropical zone, this is not true of the equatorial zone nor the cold high altitude regions. For these last two regions it is better to use Valencia varieties, improved through hybridization by combining them with large-nut Virginia varieties. This research should be carried on now.

C. In all regions

According to the local ecological conditions and the degree of the agricultural development, varietal research should take the following into consideration:

-resistance to cercospora
-resistance to toxic cryptogams (Aspergillus flavus)
-reactions to high levels of fertilizer

PHYSIOLOGICAL RESEARCH

Physiological studies would be useful for orienting genetic research:

.physiology of resistance to drought (tropical dry zone)

.physiology of the development and activity of photosynthesis in different varieties and groups: under conditions in dry Africa (where such research has already begun), and humid Africa: early types (Spanish and Valencia) and late (Virginia).

.study of nitrogen nutrition and bacterial symbiosis.

In general, the nodulation of the roots gives sufficient nitrogen nutrition except in some very isolated and localized regions; one of these is Northern Senegal, where research is currently going on on the action of molybdenum on the symbiotic activity. This kind of research should be looked into more carefully.

PHYTOSANITARY PROTECTION OF THE PEANUT

(See also regionalization of crop protection).

The most important problems are the following:

-peanut rosette which must be looked into genetically (see general and regional research above)

-aflatoxin. The investigation of this problem, which has already been looked into in depth in Senegal, should be more widely pursued.

.general biological research must be carried on into Aspergillus flavus and the conditions under which it develops (such research should be undertaken in the dry tropical zone);

.research and development of harvest and drying techniques so that aflatoxin can be held in check; research should be undertaken in dry tropical zones and extend into the humid tropical zone and the equatorial zone;

.systematic research of resistant varieties should be undertaken.

-arachis clump which is seen in some parts of Senegal and which appears to be due to some type of virus.

In short, in the equatorial zone, it would be desirable if bacterial research (Pseudomonas solanacearum) were to include the peanut.

The general and regional research as a whole could be carried on by:

-the CRA in Bambey for the dry tropical zone, as it has been specializing in peanut research for forty years;

-for the humid tropical zone and the equatorial zone, another research center should be chosen, for example in Southern Dahomey, in Cameroon or in the Central African Republic.

ECONOMIC FEASIBILITY OF MINERAL FERTILIZATION OF PEANUTS IN SENEGAL

A. Bockelee-Morvan, IRHO, Senegal

SUMMARY

Mineral fertilizer is capable of improving peanut yield profitably in Senegal; the author proposes to summarize the results obtained by IRHO in the field of mineral fertilizer used with peanuts.

The conditions are described under which the experimentation project was carried out; factorial tests controlled by means of leaf analysis and performed in great detail, particularly as regards seed density.

The author gives an example for the analysis and interpretation of one of these tests, followed by an interpretation of all of the 185 experiments conducted on this topic, leading to the development of a fertilizer formula for each region.

The experimental results obtained are confirmed in practice through in-depth trials; these are confirmation tests through which we can study the evolution of the needs in terms of mineral elements and the importance of supplementary levels of fertilizer.

So far, low levels of mineral fertilizer (100-150 kg/ha) have always turned out to be sufficient and profitable and no change was therefore necessary in the original fertilizer formula.

INTRODUCTION

The studies which IRHO has been conducting for the past 15 years in Senegal have shown that small doses of fertilizer were capable of improving the yield in a rather profitable fashion, provided the composition of the fertilizer applied was well adapted to the areas in which the crops were grown.

Research on the effectiveness and optimum profitability of each element (the major elements N, S, P, K) and the trace elements (molybdenum) made it possible to outline the zones of application of the formulas that have been worked out (fertilizer map) with precision. The use of leaf analysis in the research and control phase makes it possible to determine--at any moment--the state of nutrition of the plants and to verify the value of the fertilizer used.

At present, the agronomic results and the leaf analyses enable us to conclude that the recommended levels of fertilizer in current use are indeed sufficient.

In order to place the problem of fertilizer use in its proper perspective, we will take up the various study and control phases, which have been completed so far, and provide a synthesis of the results obtained in this field.

I. RIGOROUS CONDITIONS OF IRHO EXPERIMENTATION PROGRAM

Research on peanut fertilization has been conducted since 1952 by six expatriate agriculturists. All of their efforts were concentrated on an extremely accurate experimentation program.

In all of Senegal, 185 multilocal factorial tests were thus performed (and to these we must add several dozen permanent trials and long-term trials, as well as several hundred confirmation and demonstration tests).

The number of chemical determinations (leaf analysis) made in Senegal exceed 100,000 by far (determination of critical levels, control of the absorption of fertilizer, cartography, development of fertility).

The very great precision necessary in agronomic experimentation must certainly be emphasized here: in the southern part of Senegal, the effect of fertilizer is 620 kg/ha, with an optimum density of 110,000 plants; on the other hand, the effect of the same fertilizer is no more than 400 kg/ha in the case of low-density cultures (50,000 stands/ha) Figure 1).

IRHO considers that it is essential:

- to operate under constant and obtimum density conditions (planting two seeds, followed by one thinning), in order to determine the fertilizer composition and the effect of the elements;

- to subsequently obtain confirmation for the formulas developed under large-scale cultivation conditions (confirmation tests).

These considerations on the importance of the densities to a great extent explain the differences in the effects of fertilizers observed at the level of experimental plots and large-scale cultivation, or the sometimes different conclusions arrived at by the various research organizations.

II. STUDY OF REQUIREMENTS FOR VARIOUS ELEMENTS

We will analyze the results obtained by means of a factorial test, taking as an example an experiment performed at Koungheul in 1964, involving 32 combinations of four levels of N, four levels of P, two levels of K; these were studied on 32 plots.

DENSITY-YIELD RATIO

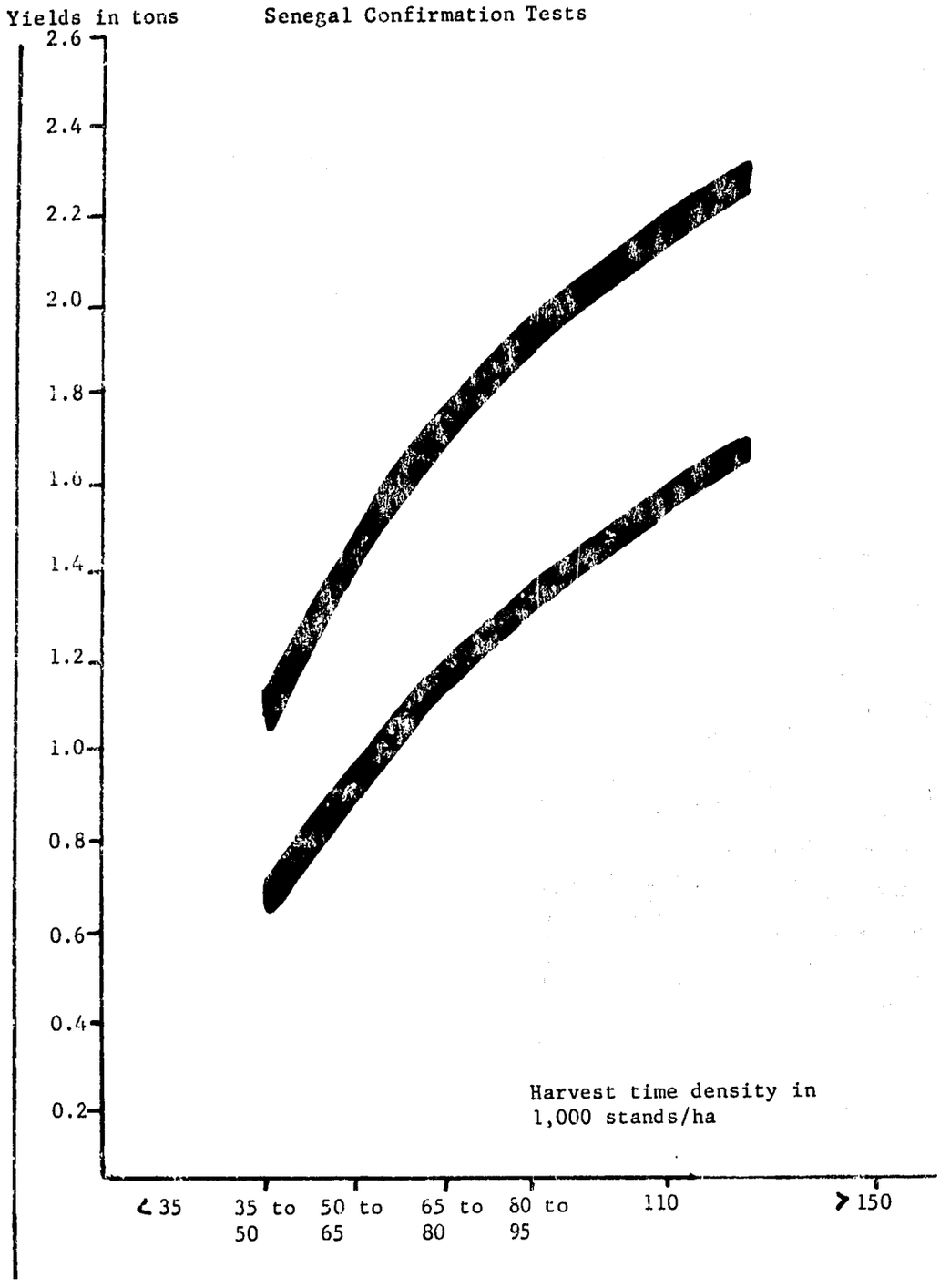


Figure 2 summarizes the principal effects of fertilizer on the levels of the elements and the yields.

Ammonium sulfate has no effect on the output.

Dicalcium phosphate simultaneously increases the level of P and the yield.

The effect of the first dose of 25 kg is 580 kg/shells/ha.
The effect of the second dose of 25 kg is 150 kg/shells/ha.
The effect of the third dose of 25 kg is 50 kg/shells/ha.

The critical level of P in the leaf is 0.200, and we can now see that the P2 level (50 kg of dicalcium phosphate), the nutrition, and the yields are very close to the optimum (for the yields, the adjustment to a Mitsherlich curve gives us a maximum yield of 2,113 kg).

The standard formula used for the region (60 kg of dicalcium phosphate) appears to be perfectly satisfactory (yield of 760 kg).

The application of a double quantity here gives us a yield of something like 2,110 kg (in other words, an additional 30 kg of peanuts) and this would therefore not appear to be "profitable."

The critical level of potassium on the average is about 1%, and we can thus perfectly well explain the absence of any significant response to the application of 40 kg of potassium chloride, even though it is absorbed.

The same methods of statistical analysis have been applied to the 185 multilocal factorial tests made in Senegal.

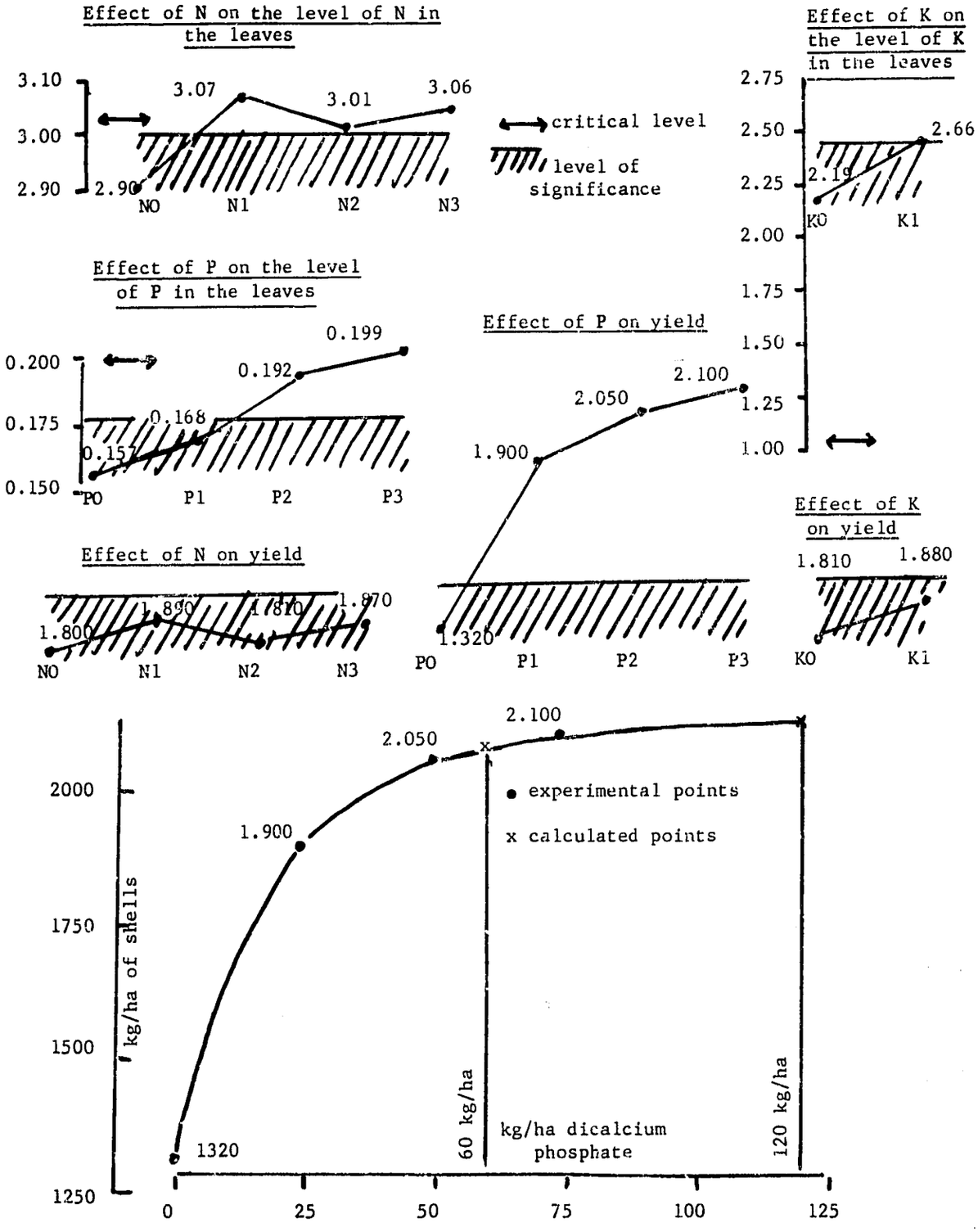
In Table I, below, are summarized the average figures obtained in the southern (Sine Saloum) and center (Bambey) zones.

TABLE I. RESPONSE TO THE ELEMENTS N, P, K

	Number of Trials	Ammonium Sulfate			Dicalcium Phosphate				Potassium Chloride		
		0	25	50	0	25	37.5	75	0	20	40
Center	51	1.435	1.640	1.635	1.395		1.675	1.645	1.465	1.590	1.535
South	72	1.980	2.225	2.185	1.845	2.010	2.230	2.290	2.055	2.165	2.190

1. The dose of 25 kg/ha of ammonium sulfate (involving the application of 5 kg of nitrogen and 6 kg of sulfur) gives maximum efficiency.

Figure 2
KOUNGHEUL TRIAL - 1954



The role of the sulfur contained in the ammunium sulfate is much greater than that of the nitrogen in the southern region. In the central region, the two effects are rather close together (see Figure 3).

The dose of 40 kg, which has been recommended in the extension program would appear therefore to be quite sufficient here.

2. A level of P_2O_5, equal to or slightly greater than 20 kg/ha (50 kg/ha dicalcium phosphate) gives us an optimum yield. The outline of the response curves shows that no economic increase can be obtained by increasing the doses beyond 60 kg of dicalcium (24 kg of P_2O_5 ha), in other words, the dose currently recommended.

3. A dose of K_2O of 12 kg/ha (20 kg of KCl is sufficient.

The response curves obtained for each element (Figure 4), along with the list of trials in which these results were obtained, clearly demonstrate that it is useless to exceed the doses indicated if we want to remain within the limits of maximum profitability of fertilizer use.

The formula recommended by the IRHO for the southern and central zones, composed of:

40 kg of ammonium sulfate
60 kg of dicalcium phosphate
20 kg of potassium chloride

would thus appear to be mostly based on calculation.

In order to take into account the existence of soluble phosphate resources available in Senegal, a formula consisting of the following:

40 kg of ammonium sulfate
45 kg of dicalcium phosphate
45 kg of phosphal
20 kg of potassium chloride

has been worked out for recommendation in the southern zone.

In view of the shape of the response curves to the major elements (N, P, S, K), it is clear that doubling the quantities of N and P or K, as has been sometimes suggested, would not produce any improvement:

80 kg of ammonium sulfate have no more effect than	40
150 kg of dicalcium phosphate have no more effect than	60
40 kg of potassium chloride have no more effect than	20
270 kg of fertilizer have no more effect than	120

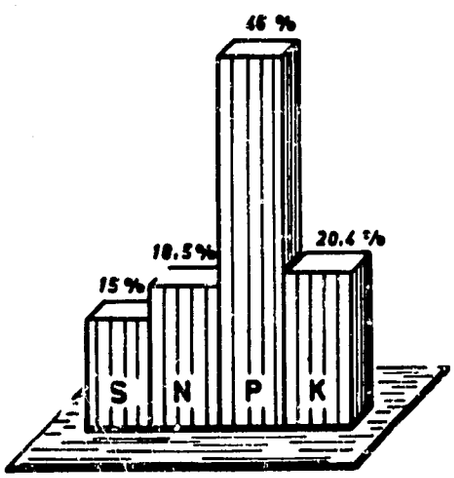
The results of the six tests in which the doses varied from 0 to 400 kg/ha of fertilizer (average balance 6-20-8) (see Annex 1), thus

Fig. 3

SENEGAL

Effects of elements N.P.K.S. in the increases obtained with fertilizer

CENTRAL ZONE



SOUTHERN ZONE

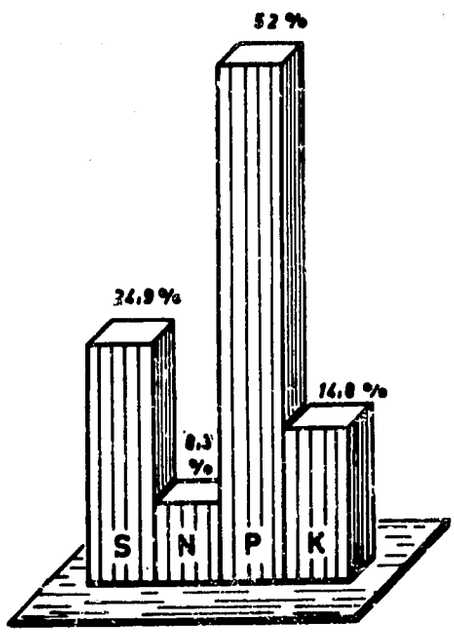
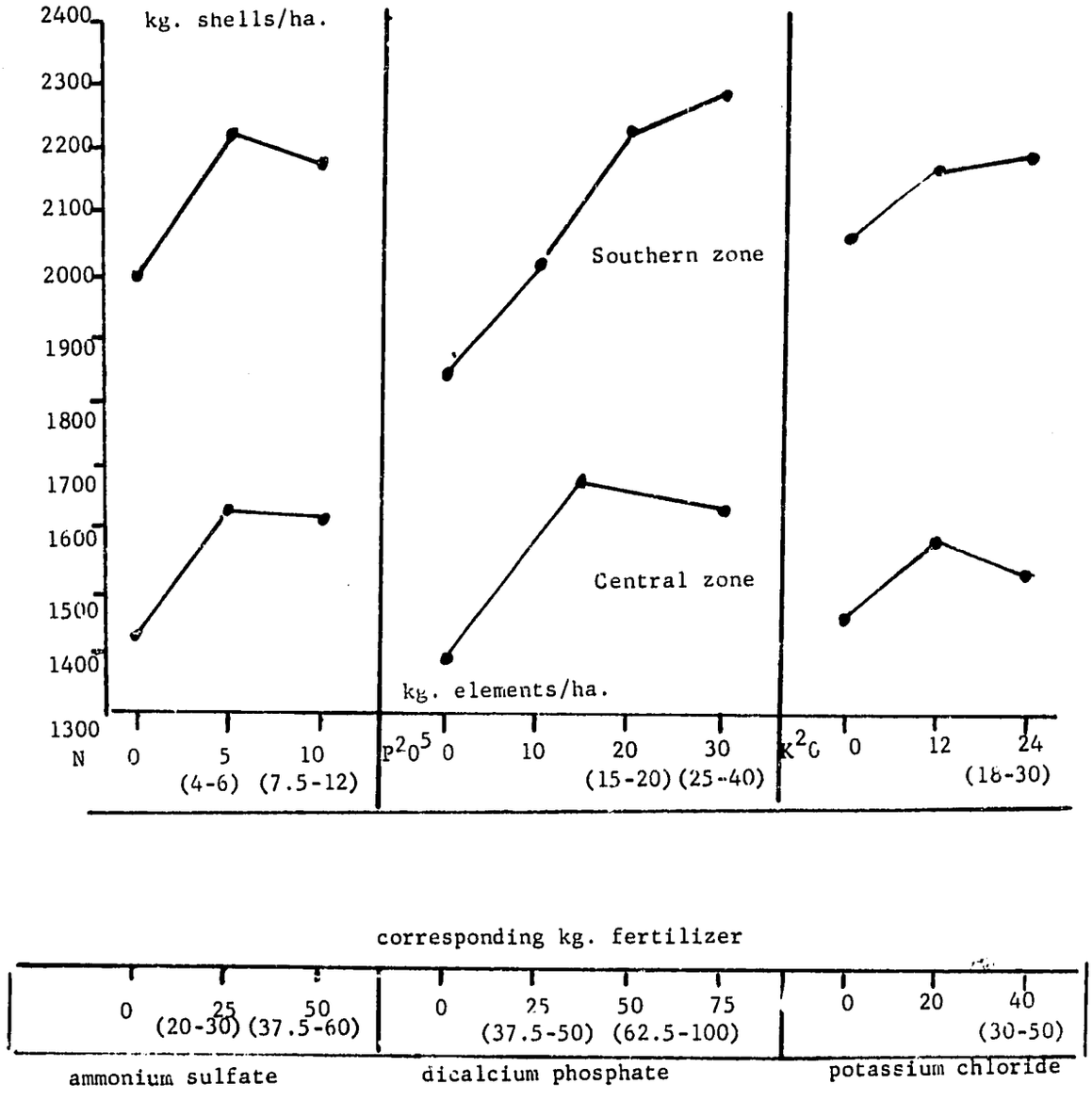


Figure 4

Response curves of the different elements



confirmed that the best dose is around 150 kg/ha and that it would often be possible to drop below that figure in order to get good fertilizer profitability (for instance, the well-known case in Upper Volta, where 75 kg/ha of simple superphosphate are considered the optimum for peanuts; the same goes for Ghana and Nigeria, where these levels are widely used). The fertilizer trials conducted in Niger resulted in the same findings.

III. CONFIRMATION OF RESULTS

In the course of the past 15 years of experimentation, it was possible to demonstrate that the effect of the compound formulas (N, S, P, K) on average were equal to the sum total of the individual effects of the elements. An average, established on the basis of the same agronomic tests in experimental plots, brings out the average effect of the formula 6-20-10 of 850 kg/ha for the southern zone (theoretical effect 795) and 500 kg/ha for the central zone (theoretical effect 615).

Confirmation tests made by the growers themselves--under normal cultivation conditions and on large plots--made it possible to obtain very high average results over large areas, as we can see in Table II, below.

TABLE II. AVERAGE RESULTS OF CONFIRMATION TESTS, 1955-1965

	Southern Zone	Central Zone
Number of trials	257	49
Area under peanuts (in hectares)	514	98
Average yield without fertilizer	1,335	1,070
Average yield with fertilizer	1,855	1,380
Average effect of fertilizer	+ 520	+ 310

The yields of plots with fertilizer (involving several hundred hectares over a period of 10 years) were only influenced during any specific year by the weather conditions (we cannot observe any tendency toward a drop in the yield when fertilizer is used and there is no decrease in the action of the manure).

In order to determine whether the initial fertilizer formula might gradually become more sufficient, after several years of cultivation, a permanent experimental program is being carried out in connection with these same confirmation tests, in order to detect, in time, any increase in the fertilizer requirements. For this purpose, factorial tests have been made since 1961 on the plots which are getting the standard manure in order to measure the effect of the complementary doses of fertilizer which might possibly become necessary. In Table III, below, we will find the average results of the tests and in Annex 2 we will find details on these experiments.

TABLE III. EFFECT OF MINERAL SUPPLEMENTS ON CONVENTIONAL MANURE

Yield of controls without fertilizer	Nitrogen Supplement		Phosphate Supplement		Potassium Supplement	
	40-60-20	60-60-20	40-60-20	40-90-20	40-60-20	40-60-40
1,845	2.620	2.610	2.610	2.620	2.610	2.620
	Effect of Supplement : - 10		Effect of Supplement : + 10		Effect of Supplement : + 10	

The supplementary application of 20 kg/ha of ammonium sulfate, of 30 kg/ha dicalcium phosphate, or of 20 kg KCl produces only an insignificant and meaningless variation of 10 kg per hectare.

We can thus see that, for the moment, any supplementary application of fertilizer is strictly worthless.

These various research efforts give us results that absolutely agree with each other because all of the work was controlled by means of leaf analysis and the optimum levels were calculated with the help of this technique. We know, in effect, that it is impossible to obtain significant increases in the yield once the optimum nutrition has been achieved.

CONCLUSION

The application of a fertilizer formula well adapted to the particular region, at the level of 120 kg/ha, is capable--on an experimental basis--of producing supplementary yields on the order of 850 kg peanuts per hectare in the southern zone (and this has been demonstrated in a very clear fashion over 15 years of experimentation); this is true because this fertilizer is applied on well-planted and well cared-for crops, and because the fertilizer is spread regularly and in the right places.

As we go on to the large-scale cultivation stage (514 hectares of confirmation tests), the effect of the fertilizer is somewhat less, in other words, 520 kg/ha, but it is still very satisfactory.

The effect of fertilizer becomes less and less as we go into the area of those farmers who are not a part of this program.

It thus appears to be essential to improve the cultivation techniques, in particular to encourage the use on a wide scale of fertilizer spreaders which have made it possible to obtain the above-mentioned results in the confirmatory trials.

ANNEX 1

(1) SEPA : 1951.

Fertilizer levels	0	50	100	150	200	250	300	400	
	1,705		1,935		1,895		2,095	1,905	SE ± 52
	100		113		111		123	112	

(2) BAMBEY : 1951.

Fertilizer levels	0	50	100	150	200	250	300	400	
	2,180		2,460		2,440		2,375	2,495	SE ± 50
	100		113		112		109	115	

(3) BAMBEY : 1952.

Fertilizer levels	0	50	100	150	
	2,260	2,575	2,620	2,670	PPDS255
	100	114	116	118	

(4) BAMBEY : 1956.

Fertilizer levels	0	60	120	
	1,450	1,990	2,200	PPDS 384
	100	137	152	

(5) PATAR : 1964.

Fertilizer levels	0	150	290	
	1,000	1,240	1,320	PPDS 166
	100	124	132	

(6) DAROU : 1964.

Fertilizer levels	0	120	240	
	1,690	2,405	2,390	PPDS 242
	100	142	141	

Mixtures used:

(1)	3.7 - 29.7 - 37	(4)	6 - 20 - 10
(2)	7 - 17 - 7	(5)	4 - 10 - 38
(3)	3.3 - 26.5 8	(6)	6 - 20 - 10

ANNEX 2

		Yield of Controls Without Fertilizer	Nitrogen Supplementation		Phosphate Supplementation		Potassium Supplementation	
			40 - 60 20	60 - 60 20	40 - 60 2[illegible]	4[illegible]-90 20	40 - 60 20	40 - 60 4[illegible]
TAIBA MAMATE	1961	1,630	2,690	2,610	2,660	2,640	2,680	2,620
KOILAL	1961	2,235	2,890	2,780	2,840	2,830	2,800	2,870
DAROU	1962	1,780	2,490	2,490	2,450	2,530	2,480	2,500
MATAR SAKHO	1962	1,710	2,420	2,450	2,420	2,450	2,440	2,430
MATAR SAKHO	1963	1,530	2,190	2,220	2,230	2,180	2,180	2,230
KER ALY BASSINE	1963	1,400	2,160	2,160	2,240	2,080	2,130	2,190
DAROU	1965	1,835	2,975	2,940	2,895	3,020	2,965	2,950
DRAME	1965	2,305	2,980	3,020	2,995	3,005	3,010	2,990
KOILAL	1965	2,17[illegible]	2,605	2,80[illegible]	2,77[illegible]	2,835	2,829	2,785
AVERAGE		1,845	2,620	2,610	2,610	2,620	2,610	2,620

I.R.H.O. RESEARCH AND DEVELOPMENT RESULTS ON PEANUTS IN UPPER VOLTA

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IRHO, Senegal

SUMMARY

Studies are described on the most important research results which have made it possible to develop peanut cultivation in the southwestern part of Upper Volta, a description and overall review of the extension program conducted on the basis of these results.

(1) Varietal improvement particularly for plants resistant to the rosette virus disease.

Determination of optimum seed density in strip cultivation

Selection of mineral fertilizer suitable for peanuts.

Crop rotation studies.

(2) Demonstration and preliminary extension program launched in 1959, to be expanded progressively to two sectors consisting of more than 5,000 growers.

Methods employed, topics proposed, and practical accomplishments.

Results obtained and overall review of entire operation: per hectare yield tripled.

* * *

IRHO research in Upper Volta is primarily oriented toward a rapid improvement in the peanut cultivation conditions.

The experimentation, in the field, is essentially oriented toward practical objectives, immediately profitable to the growers; through this experimentation and through its extension dissemination and briefing activities, IRHO tries to make an effective contribution to the development of agricultural output in Upper Volta and of the country's economy.

All of the regions of Upper Volta have peanut crops ; the country's current output, according to official statistics, varies between 100,000 and 130,000 tons of unshelled peanuts. However, there are regions which have a very pronounced emphasis on peanut cultivation: this is true of the southwestern part of the country, the zone of the high basins, where the peanut is practically the only cash crop the farmers have.

During the 1950's there was a rather considerable letup or even abandonment in the peanut cultivation effort as a result of the rather heavy losses caused in the southwestern part--on the average of one out of every three years--by a virus disease called rosette, which is transmitted to the plant by an aphid (Aphis leguminosae). This disease can cause losses in yield which vary according to the date of the appearance and scope of these attacks; one can frequently see entire fields that have been thus attacked and the yield can then sometimes drop to several tons of kilograms of shells per ha.

With the local peanut varieties in these regions, the farmers usually get a yield of about 300-400 kg of shells per ha during years without rosette, although the output can drop to practically nothing during years with heavy attacks.

The research done on peanuts by the experimental station at Niangoloko between 1956 and 1967 made it possible to develop measures for the improved cultivation of this plant in Upper Volta.

* * *

I. PRINCIPAL EXPERIMENTAL RESULTS (RESEARCH)

(1) Varietal Improvement

From 1956 onward, the Niangoloko station was trying to find varieties resistant to rosette and adapted to the particular region, varieties which would consequently be highly productive.

Studies of introduced varieties and comparative trials made it possible to focus the first choice on a peanut imported from Senegal: this was the variety 48-37 (C.R.A.. Bambey).

Healthy stands, coming from fields with rosette, were selected through local prospecting and the descendants were compared: this gave rise to the variety 1.040 which was widely disseminated after 1966.

Hydridization finally made it possible, after crossing the introduced, rosette-resistant varieties with sensitive local plants--to obtain a certain number of hybrid lines, one of which, H-32 is superior to the others after 4 years and which is more productive than the already widely grown varieties. Multi-local experimentation should make it possible to confirm its qualities over the entire zone involved.

The average increase in the yield obtained through the use of the selected varieties which resist rosette, instead of the local variety, is about 35%, when organic-mineral fertilizer is used and it is 20% without fertilizer.

It must be added that these results were obtained when the rosette attacks were very weak.

In presence of the disease, the superiority of the resistant varieties selected, over the sensitive varieties, increases in relation to the size or scope of the attacks.

The resistant varieties, moreover, have an aptitude for utilizing various types of fertilizers that is much better than the local varieties.

(2) Study of Cultivation Methods

In the southern and western regions of Upper Volta, the crops are almost exclusively grown on ridges and studies at the Niangoloko station have taken this custom into account.

a. Density: All of the tests that were performed demonstrated the superiority of heavy densities, as regards the yield per hectare.

Effect of three Densities on Yields
(test on ridge)

Intervals (in cm)	Density (number of stands/ha)	Yield (kg shells/ha)
60 x 10	166,600	2,080
80 x 15	83,300	1,630
100 x 20	50,000	1,300

b. Seed disinfection: the favorable effect of disinfection of the seeds on the seedlings and the vigor of the young plants--and consequently on the yields--has been observed from the very first tests on that point.

A recent test confirmed this effect: the results demonstrate the importance of the effect of the currently widely advertised insecticide-fungicide (particularly the latter) on seeds whose tegument has been damaged, for instance, by pricks or gashes.

Percentage of Seeds Germinated 10 Days
After Planting

	Selected Grains (Per cent)	Damaged Seeds (Per cent)
Controls	66.3	7.3
Disinfected seeds	74.5	56.5

(3) Fertilizer Studies

(Only the most outstanding results are indicated here, results that were confirmed each year and directly applicable at the level of the farmers.)

Permanent tests of the factorial type, involving a study of the elements on two levels, made it possible to determine the principal deficiencies that must be corrected on a priority basis.

i) Role of nitrogen: All of the experimentation on this subject demonstrated the usefulness of supplying mineral nitrogen, at least in terms of the current production levels.

ii) Role of phosphate: Tests demonstrated the importance of phosphate fertilizer. It was then necessary to determine the optimum forms and levels of phosphate application.

The different results obtained here demonstrate the superiority of simple superphosphate over the other forms of phosphate fertilizer, particularly triple superphosphate--and this, moreover, in phosphoric acid equivalents; this superiority applies almost to all of Upper Volta and it is valid regardless of the year involved.

This superiority might be explained by the action of the sulfur contained in the simple superphosphate, which the other forms of phosphate fertilizer do not include.

However, when the doses are doubled or tripled, the yields only increase less and less, so that the cost of the additional fertilizer is not reliably compensated by an increase in yield.

Increasing Levels of Simple Superphosphate
(In the absence of organic fertilizer)

Levels of Simple Superphosphate kg/ha	Bunch Yield kg/ha	Effect kg/ha	Harvest sales price (Fr CFA/ha) peanuts, 17.5 Fr CFA/kg	Price of fertilizer (Fr CFA/ha) simple superphosphate 24.5 Fr CFA/kg	Profit (Fr CFA/kg)
0	1,190	-	20,825	-	20,825
75	1,590	+ 400	27,825	1,837	25,987
150	1,680	+ 490	29,400	3,675	25,725

iii) Role of potassium: All of the tests conducted so far demonstrated the uselessness of adding potassium (at least under current cultivation conditions and at the yield levels observed).

iv) Role of sulfur: The important effect of sulfur in increasing peanut yields has already been suggested as an explanation for the differences in the action observed in response to equal phosphoric acid equivalents, between simple superphosphate containing sulfur and triple superphosphate not containing any sulfur.

Various tests have shown the effectiveness of any addition of sulfur. In all situations here, the need for sulfur certainly makes itself

felt and the action of one of the elements P_2O_5 or S (the principal deficiencies) is much less important in absence of the other elements (interaction).

v) Other mineral elements: As things stand now, none of the other elements which have been tested (calcium, magnesium, manganese, miscellaneous trace elements) produced any worthwhile results.

vi) Organic manure: The results of many tests emphasize the sometimes very important action of an addition of manure (20-40%)over the control).

But the application of manure alone (without mineral fertilizer) very often involves a decrease in the yields at shelling time, that is to say, the filling or content of the shells is not as good.

(4) Crop Rotation Studies

Crop rotation studies, with or without fallowing have been conducted in some cases every since 1956 -- in order to determine the possibility of intensive cultivation, providing, of course, that suitable organic or mineral fertilizers were used.

It turned out that, when these fertilizers are used, the economic advantage of 2-year fallow over 1-year or 4-year fallow is definitely confirmed and that improved natural fallow (Stylosanthes, Brachiaria, Pennisetum) or turned-under natural fallow is in no way superior to burning fallow prior to cultivation, which is the traditional practice.

Among the crop rotation sequences studied, the most varied still are the most interesting and worthwhile, along with the fertilizer used, both from the economic viewpoint for a crop cycle and from the fertility maintenance viewpoint.

The peanut-maize-millet rotation sequence (without fallowing, but with fertilizer) would be the most worthwhile here.

As for the place where the mineral fertilizer and the organic fertilizer are to be applied in a crop rotation sequence of peanuts-millet-peanuts-millet-fallow-fallow, the results obtained after 3 years seem to indicate a superiority both for peanuts and millet, of an annual application of 100 kg/ha of simple superphosphate on peanuts alone and 5 t/h of stable manure on millet alone.

II. EXTENSION PROGRAM IN THE SOUTHWEST (DEVELOPMENT)

All the the results obtained on the basis of the selection program and the numerous agricultural tests that were conducted, both at the Niangoloko station and in many places throughout the territory, demonstrated that it was possible, through the application of simple techniques, to achieve a considerable increase in the peanut yield in Upper Volta.

These are techniques which are being used by a certain number of farmers who work in the extension sectors set up by the IRHO.

A demonstration and preliminary extension effort was launched in connection with a number of farmers in the village of Labola, east of Banfora, in 1959; the success of this operation, which was launched by the Niangoloko station with its own resources, in 1960--upon the request of the government and with financial aid from FAC (French Aid and Cooperation Fund)--triggered an extension program which has been growing all the time.

IRHO set up two sectors which it manages: the Banfora sector, which operated between 1960 and 1967, where we have had an increase from 200 to 2,500 farmers who are a part of this program, and the Dedougou sector which, at the end of 1963, was transferred to the CFDT within the framework of a regional reorganization policy for the rural development programs.

In 1964 a new sector was created centered on Bobo Dioulasso and Orodara with almost 500 farmers; by 1967, this number had gone up to 2,500.

The two sectors of Bobo and Banfara are currently operating, in each case, under a European sector chief who supervises 10 African instructors and, for each sector, 50 village agents who are not salaried but who, at the end of the harvest, get a bonus in proportion to the volume of peanuts sold by the village of which they are in charge (400 Fr CFA per ton); this bonus is taken from the peanut prices and this gets the farmers more intimately involved in the whole process.

The instructors are young men who have a primary agricultural education; they are responsible for a certain number of villages and they have the following functions:

- make a census of farmers who want to work with the IRHO methods;
- survey their fields;
- distribute seeds and fertilizer and keep records of these activities;
- make sure that the farmers strictly observe the various crop assignments for which they make practical demonstrations;
- on the basis of sampling, calculate the yield obtained by the farmers;
- keep an eye on the sales organization in order to check on production and in order to collect the amounts due in connection with the credit for seeds, fertilizer, or insecticides, etc.

The instructors are assisted by specially appointed village agents; these are the most receptive farmers there, if possible they are literate, and they have real influence over the other growers in the village.

Until 1963, the marketing of the harvest was handled by IRHO; the harvest was shipped to the CITEC oil refinery at Bobo Dioulasso. Since 1964 the marketing service has been handling this operation and a portion of the output is used to supply the oil refinery at Bobo, the rest being divided up for export either shelled or unshelled.

A. METHODS PROPOSED

(1) Various topics of Improved Peanut Cultivation

In its recruiting effort, IRHO always particularly emphasizes the fact that the farmers must apply all of the main points of efficient crop management.

Preparation of the land: It is recommended that the intended peanut field be very carefully prepared; this includes correct clearing, hoeing ("daba"), ridging on 80 cm centers. The average area to be sown is about 0.50 ha.

Use of organic manure: Whenever he can, the farmer will--prior to tilling his field--spread some farmyard manure (the fine powder collected from the cattle kralls), between 2-5 tons per ha; the grower in Upper Volta currently does not produce any farm manure.

Use of high-quality seeds: The farmer must use varieties that will resist rosette, varieties with a vegetation cycle of 150 days; IRHO supplies seeds for these varieties at the rate of 80 kg per ha.

These seeds are sold either on credit, which is collected at harvest time (25 francs per kg) or for cash (23 francs per kg).

Fumigation of seeds: Along with the seeds, IRHO supplies a sufficient quantity of a fungicide-insecticide product. The treatment is applied right after shelling, by mixing powder and seed (200 grams of Aldigranox for every 100 kg of seeds) in a calabash or some other container.

Planting: There are two points which must be particularly emphasized here: Planting as early as possible (second half of May, after a rainfall of about 20mm and good density).

The resistant varieties, which are now widely used, are rather late varieties and they take 5 months to complete their vegetative cycle.

In the zones of Banfora and Orodara, all of the crops are customarily grown on ridges 1 m apart. Optimum densities here are obtained by reducing this interval to 80 cm and by planting on the ridges, every 15 cm, in other words, a theoretical figure of 83,300 stands per hectare.

In the flatland crop areas (northern zone and vicinity of Bobo) the recommended density is 111,100 stands per ha and this can be done by planting in lines 60 cm apart, and every 15 cm along the line.

Application of mineral fertilizer: As things are now, the most directly profitable manure for the farmer consists of a relatively low level of phosphoric acid and sulfur. This is done by spreading 75 kg per ha of simple granulated 18% superphosphate (12.5 kg P_2O_5 and 8 kg S/ha).

The result of such a dose is maximum, provided it is spread correctly; no more than 10-15 days after planting and in the right place, near the peanut line, slightly plowed under, or by making a ridge and putting the fertilizer in the middle of it.

The fertilizer distributed was sold in 1967 for 24 francs/kg,cash, and 26 francs per kg on credit.

Careful maintenance of crops: The application of manure and mineral fertilizer promotes the development of poor plants and it is imperative to carry out frequent weeding (2 or 3 times during each cycle) so as to prevent this from spreading. Hoeing at flowering time promotes the formation of the shells.

Harvest at maturity: Theoretically 150 days after planting, the peanut is ripe (the inside of the shells is brownish-black); if they are harvested too soon, there will be a drop in the yield because the shells will not be sufficiently filled.

(2) Practical Accomplishments and Modifications

If a grower follows all of this advice, he will be able to plant under conditions similar to those achieved at the experimental station at Niangoloko and he should, basically, be guaranteed an output that can exceed 2,500 kg shells per ha. In practice, if the average yield is somewhere between 1,200 and 1,500 kg per ha, the analysis of the results obtained shows that it is well within the capability of the best growers to obtain yields of around 2,000 kg per hectare.

The farmers in the southwest of Upper Volta are accustomed to peanut cultivation--something which they have more or less always been doing. Thus, the application of the IRHO method did not run into any major obstacles; however, although certain points have been properly observed without too much trouble, others are still difficult to get across to the farmer. Making ridges, a traditional practice, already represents good soil management, although an effort might be made to get the farmers to reduce the intervals which very seldom are too great.

Organic manure is used when the farmer has it. The use of mineral fertilizer finally did away with the reputation some of these areas had for coming up with empty shells.

The farmers very quickly realized the importance of using peanut varieties that "do not get sick." Even in areas that do not benefit from IRHO organization and training, it is difficult right now to find sensitive local varieties.

Similarly, the treatment of the seeds--which is efficient and not at all expensive--has been readily accepted here and the use of fumigants is quite widespread among the other crops as well.

The traditional planting is generally done with about 30 or 40 cm between stalks, on ridges that are 1 m apart; "marker wheels" have been distributed (at the rate of 1 for every 5 farmers, on the average, about 1,000 of these wheels in 1967) in order to help them maintain the 15 cm intervals on the line.

This wheel is easy to roll along the crest of the ridge and leaves very nicely spaced seed-planting holes behind it; in each one of these, all the farmer has to do is deposit just one seed and he then turns the earth under either with the foot or with the small daba.

Spreading mineral fertilizer requires the correct and regular distribution of 75 kg of granulated fertilizer per ha; this idea was not understood from the very first moment on and it was necessary to resort to all kinds of "tricks" to get to that point. Empty cans (tin cans) were distributed with small strings attached to them, corresponding to the distance over which the content of the box full of fertilizer had to be spread. A thin line is drawn with a stick 6 or 7 cm from the line, the fertilizer is then put down, and it is then plowed under.

In the course of the operation, certain modifications could be made in this method as more experience was acquired. From the very first years onward, the fertilizer was so placed that it was plowed under in two small grooves traced on either side of the peanut line ; then someone figured out that the application of this on just one side of the line (for one and the same dose per ha) would produce almost identical result while cutting the spreading job in half, at a time when the farmer is particularly busy. The same is true for placing the fertilizer while the ridge is made, in other words, a short time prior to planting, at a time when the farmer has a little more time available.

For the variety that is widely promoted here, the studies conducted by the station have always made it possible to use the late resistant peanuts in achieving production gains while demonstrating the superiority, first of all, of an introduced variety (48-37), then of a product of prospecting and selection (1.040) and finally, of a hybrid developed at Niangoloko, which should be widely disseminated within 2 or 3 years. It thus seems that, at least for the time being, we have developed the best variety suited to the southwest zone.

The seed distribution system itself has also developed. With the development of these sectors here, it was no longer possible to distribute all of the seeds required by the registered farmers here, each year; as a matter of fact, the volume distributed in 1964 and 1965 multiplied tremendously from 32 all the way to 168 tons of seeds. The purchasing, shipping, storage, and redistribution system had become too awkward and cumbersome IRHO therefore decided to give out only a small quantity of pure seeds each year (5 kg); the farmer is now responsible for seeing to the multiplication for the following year, in other words, he will still get another 5 kg the following year and thereafter. The operation was launched in 1966 and seems

to have produced the anticipated success. The financial burden on the farmer decreases year after year; and he produces the seeds for his field by himself.

In 1966, 83 tons of seeds were distributed and a new distribution could not be made everywhere; in 1967, the figure dropped to 60 tons; here it is of course understood that a safety margin is necessary in order to supply the newly registered farmers and to be prepared for any accident in individual multiplication.

To facilitate seed storage and distribution operations, IRHO has set up small metal silos in the bush country with a capacity of about 8 tons: it has about 12 of these right now, distributed over the two sectors and set up near the big market towns.

In the same spirit, a program has been worked out for the construction of small bush warehouses, inexpensively built (150,000 francs each), which should further support the supply setup (bags, fumigant, fertilizer, etc.)

As we have seen, the marketing--initially handled by the IRHO--was later on entrusted to the sales office in view of the large volume collected (about 2,500 tons in 1966).

B. RESULTS--OPERATION REVIEW

The three sectors of Bobo, Orodara, and Banfora in 1966, according to official statistics, had 35,000 rural enterprise chiefs: one-seventh of the rural population therefore is directly involved in the extension program in these two sectors.

An expatriate sector chief directs and supervises 10 instructors and 50 village agents, making a total of about 2,500 registered farmers who are involved in this program.

In other words, in one sector we would have: 2,500 farmers per sector chief; 250 farmers per instructor; 50 farmers per village agent.

In 1966 (the final results for 1967 are not yet ready). 88 tons of seeds were distributed, along with 172 tons of fertilizer; this volume was distributed to 4,812 farmers who had planted and cultivated 2,293 ha (in other words, less than 0.50 ha each); on the basis of sampling, the average yields obtained were 1,170 kg/ha as against 300-500 kg per ha in the traditional cultivation system; this means that a gain of 670-870 kg/ha was achieved as a result of the employment of the methods that had been recommended.

The estimated output of these farmers was 2,700 tons and the sales volume, supplied by the registered farmers came to almost 2,500 tons. The difference was either consumed, sold on the market, or kept for seed.

Peanuts were purchased at 16.50 fr CFA per kg; the net income per ha thus is 17,270 fr (after deducting 2,035 fr for fertilizer and seeds).

In other words, a farmer who cultivates 0.50 ha would make 8,635 fr CFA.

The annual budget of 17,500,000 fr CFA gives an average organization expenditure of 3,635 francs per grower, which leaves 5,000 francs for a registered farmer who gets the direct benefit and profit from this operation; for the entire region, we have a net profit of about 25 million fr CFA.

The growing number of farmers who want to use the improved peanut cultivation method is due to the tangible results derived from the operation but it is also due to the human factor, in other words, the contact between the organizers and the farmers.

With 250 farmers for every instructor, the sectors in 1966 reached the limit of their potential; this is why the authorities in Upper Volta decided to relieve the IRHO with an ORD (Regional Development Organization) which, provided with a larger setup, will be able to continue the peanut cultivation development operation and at the same time launch other agricultural resources in the region. Starting in 1968, the Banfora sector will be picked by the Banfora ORD and the relief of the Bobo sector should take place in 1969 or 1970.

The IRHO extension effort represents an initial operation which was quite justified, in technical terms, through direct contact with the farmer. It made it possible to reach a large number of farmers with rather limited resources; in 225 villages throughout the zone, these farmers will act as the prime movers in the coming extension drive.

The success of this small nucleus was in part due to the value of the methods that were perfected by the Niangoloko station--methods whose acceptance did not run into any major obstacles; on the other hand, the success was due to human contact that was maintained between the organizers and the organized farmers.

This is one of the points which has constantly claimed the attention of IRHO personnel.

Like any other farmer, the African farmer is rather distrustful and particularly reticent towards innovation; this distrust can be quickly dispelled if the results are visible and if the promises made in the initial contracts are kept.

In each village, we therefore tried to find receptive and influential men: here, the village chiefs can offer valuable aid and it is often they who take the first step.

Relations between instructors and farmers are complicated due to the multiplicity of ethnic groups and tribes; these relationships sometimes required personnel assignments or replacements. Eight races live together in these two sectors; each has its own beliefs, its own habits, and each more or less easily accepts the new methods.

Moreover, the cultivation practices differ from one race to the next; the Gouins and the Toussians cultivate on ridges; the Bobos cultivate on the level, and the Senoufos on mounds. This explains the use of different tools, since these practices cannot be standardized and since the tools especially cannot be standardized here, the methods recommended here were adapted--without loss of efficiency--to the working conditions of each ethnic group.

The fact that peanut crop yields were tripled in a traditional environment is essentially tied in with the value of the techniques that were perfected in minute detail and that were confirmed by the Niangoloko station; it is also due to the specialization of the extension personnel; these men concentrated on just one crop which they knew perfectly and they maintained permanent contact with the farmer in the field.

THE DEVELOPMENT OF PEANUT AND SORGHUM YIELDS THROUGH FALLOW OR GREEN MANURE

A. Bockelee-Morvan, IRHO

SUMMARY

The intensification of cultivation implies the reduction of the length of fallow and replacement of it with a regeneration crop grown for green manure.

The study compares two types of rotation - one comprising two years of fallow, the other, one year of green manure, the crop sequence being peanuts - cereal - peanuts.

The yield of peanuts and cereal in this system is better in the series with fallow.

Two other experiments provide an explanation of the less favorable effect of green manure, one showing that the plowing-in of growing quantities of green material increases neither the yields nor the absorption of tri-calcium phosphate plowed-in at the beginning of the rotation, the other showing that green manure, which at certain stages necessitates exposure of the soil, has a deleterious effect on soil fertility due to leaching of potassium.

INTRODUCTION

In a traditional cultivation system, the land is abandoned after a series of crops over several years and it is allowed to lie fallow; the crops are then replanted on the same place only after a very long period of time. The first experiments conducted on crop rotation showed that it was possible to keep up the production level in the southern part of Senegal, provided a light mineral manure application was made on the industrial crop, with short rotation sequecces of 3 years (peanuts-sorghum-peanuts), followed by 2 years of fallowing.

However, in certain regions, the land shortage forced the growers to fall back on a more intensive rotation sequence, sometimes even skipping the rest. It was thus important to find out whether the use of green manure might not help reduce the duration of the regeneration field phase and facilitate the switch to intensive cultivation.

In this case, the green manure would consist of a sorghum or millet cereal, planted at 60-cm interval and turned over with the plow prior to heading.

A number of experiments were conducted on the spot,in order to compare the effect of fallowing and green manure. In this report, we will see that many foreign authors have already demonstrated-for other tropical regions-that the practice of using green manure is absolutely not advisable under the conditions prevailing in the southern part of Senegal.

EXPERIMENTAL RESULTS

(a) Test No. 1

In 1954, the IRHO set up a test area for two series of crop rotations.

The first involved two years of fallowing after three years of cultivation (peanuts-sorghum-peanuts). The second involved one year of green manure, likewise after three years of cultivation.

The nine phases of these two crop rotation experiments were repeated four times.

The plots were subdividied, with and without fertilizer.

In 1967, a complete statistical analysis was made of the results over the past 10 years of experimentation (see Table I, below)

TABLE I

	Peanuts first crop (1959-1966)		Sorghum (1959-1966)		Peanuts second crop (1960-1966)	
	mineral manure	(-)	mineral manure	(-)	mineral manure	(-)
Green manure	2,478	1,964	443	337	2,204	1,561
Fallowing	2,702*	2,260	846**	566	2,426	1,693**
PPDS 5%	165*	349*	163*	292*	260*	64
PPDS 1%			299**			117**

With or without mineral manure and over the average of the past 7 years, the peanut and sorghum yields from this crop rotation sequence, involving 2 years of fallowing, are all superior to the yields of the crop rotation sequence involving one year

We can see that three out of six of these results are significant; the superiority of fallowing over green manure is thus difficult to challenge.

Leaf diagnosis shows a very heavy drop in potassium nutrition in crop sequences with green manure (content of 0.89 K as against 1.37 after fallowing).

The quantities of substances plowed under in 1965 are something like 13 t/ha; this indicates that the green manure was normally cultivated and came out successfully.

(b) Test No. 2

In order to determine whether the results of fertilization could be improved by plowing under larger quantities of organic substances, a test was conducted at the same station, starting in 1964; this test was intended to study the administration of growing doses of green substances (5 tons --- 10 tons --- 20 tons and 30 tons per hectare). The experiment was carried out within the framework of several crop rotations and a basic manure fertilizer (500 kg/ha of tricalcium phosphate from Taiba) was compared to annual manuring (60 kg of dicalcium phosphate).

Although green matter was plowed under in 1966, as during the preceding years, the 500 kg of tricalcium phosphate are much more poorly assimilated than the 60kg of dicalcium phosphate in the annual formula. The presence of a larger quantity of green substances at plow-under time does not improve the assimilation of the phosphorus, whose rate remains low in the leaves; besides, the peanut yields during the first and third years certainly would speak in favor of annual manuring.

The sorghum yields likewise are in no way increased by a growing tonnage of green substances that are plowed under and on the average they are much higher in the case of annual manuring than in the case of one basic manure application (Table III).

(c) Test No. 3

A third test was conducted at the same station after 1958 and it probably supplied an explanation for the poor results derived from green manure.

In this experiment, the scientists studied the elementary effects of green manure: the soil coverage effect, the effect of the plowed-under green substance, the effect of working the soil, and the effect of the root system.

The potassium content of four principal treatments in the experiment is as follows:

Peanuts after fallowing	1.21
Peanuts after green manure	0.95
Peanuts on land left bare during the year prior to cultivation	0.50
Peanuts on land artificially covered during the year prior to cultivation	1.86

The potassium content of the peanut leaves (in other words, very probably, the assimilable potassium content of the soil) is highly influenced by the state of soil coverage.

One of the major disadvantages of the green manure technique resides in the fact that the soil is left bare and exposed to sun radiation at the beginning of the rainy season, if the planting of the plant to be plowed under did not come off successfully and this also applied as of the beginning of September, during the long dry season (9 months).

It thus seems that the unfavorable effects of green manure at Darou might be tied in with the evolution of the potassium in the soil.

TABLE II

1966 RESULTS

PLOW-UNDER TESTS WITH GROWING DOSES OF GREEN MATTER

	Annual Manuring	Basic Manuring	
Burn-Fallowing	2,355	2,010	
Plow-under Fallowing	2,250	2,185	First Year
F + 5 t	2,260	2,255	Peanuts
F + 10 t	2,455	2,205	
F + 20 t	2,245	2,170	
F + 30 t	2,295	2,100	
F - S, continuous	1,945	1,740	
Average	2,260	1,945	
Burn-Fallowing	725	515	
Plow-under Fallowing	735	780	
F + 5 t	860	720	
F + 10 t	680	535	Sorghum
F + 20 t	710	515	
F + 30 t	685	545	
P - S, continuous	590	565	
Average	745	595	
Burn-Fallowing	1,950	1,850	
Plow-under Fallowing	1,805	1,770	
F + 5 t	1,750	1,800	Third Year
F + 10 t	1,905	1,740	
F + 20 t	1,745	1,805	Peanuts
F + 30 t	1,965	1,830	
Average	1,850	1,800	

No difference between fallow treatments.

1st-year peanuts, average	:	2,232**	PPDS	5 % : 138
3rd-year peanuts, average	:	1,826		1 % : 185
Average annual manuring	:	2,082**	PPDS	5 % : 63
Average basic manuring	:	1,976		1 % : 84

ANNEX I

SORGHUM AND GREEN MANURE

Old Test, Millet and Green Manure
(1954)

PURPOSE

Compare the effect of fallowing improved by the introduction of leguminosae to that of natural fallowing and to that of green manure with and without cowpeas.

In 1955, millet was replaced with sorghum.

In 1964, the "improved fallowing" treatment could no longer be administered and the cowpeas were heavily penetrated parasites; the T and V crop rotation experiments thus had to be abandoned.

The test thus boiled down to a comparison, with four repetitions, between 5-year rotation P - S - P - F - F - and a 4-year rotation sequence P - S - P - AM.

TREATMENTS

Two Series of Crop Rotations:

S			
1. Peanuts	(P)	1. Peanuts	(P)
2. Sorghum	(S)	2. Sorghum	(S)
3. Peanuts	(P)	3. Peanuts	(P)
4. Fallowing	(F)	4. Green Manure	(AM)
5. Fallowing	(F)		

PROJECT IMPLEMENTATION

Four repetitions of nine initial plots subdivided into two subplots (with or without fertilizer).

Plot dimensions: 30 x 3 m (initial plots), five lines planted - threee useful lines of peanuts or sorghum.

For testing purposes, the green sorghum fertilizer, in 1966, will be replaced with Sanio millet.

Interval between lines: 60 cm for peanuts or sorghum.

Spacing on the line: 15 cm for peanuts -- 1 m for sorghum grain.

D.F. on S1 - U1 - S3 and U3 - 32 D.F.

Fertilization

	Ammonium Sulfate	Bicalcium Phosphate	Potassium Chloride
1st-year Peanuts and 3rd-year Peanuts	40 Kg/ha	60 Kg/ha	20 Kg/ha
2nd-year Sorghum	70 Kg/ha	18 Kg/ha	12 Kg/ha
Green Manure	100 Kg/ha	-	-

RESULTS SINCE START OF TEST
Peanuts and Sorghum (kg/ha)

	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	Average	Fertilizer Effect
F A1	2,630		2,715	2,785	3,405	2,285	2,685	2,385	2,760	2,590	2,695	+ 445
Fallow (-)	2,180		2,325	2,380	2,775	1,975	1,965	1,985	2,465	2,215	2,250	
F A1	2,250		2,985	2,705	2,990	1,870	2,285	2,605	2,470	1,955	2,455	+ 500
Green Manure (-)	1,875		1,859	2,215	2,265	1,515	1,625	2,230	2,020	1,990	1,955	
F A3	1,695	2,325	2,540	2,775	2,750	1,820	2,740	2,530	2,285	2,205	2,365	
Fallow (-)	1,300	1,595	1,965	1,795	1,795	1,430	1,845	1,790	1,535	1,660	1,670	+ 695
F A3	2,175		2,465	2,755	2,765	1,750	2,320	1,760	2,095	1,990	2,230	+ 635
Green Manure (-)	1,695		1,735	1,965	1,735	1,320	1,565	1,615	1,330	1,395	1,595	
F S	1,920	795	645	750	930	1,335	1,055	860	930	510	970	
Fallow (-)	1,190	565	445	420	815	685	755	465	545	385	625	+ 345
F S	1,220	475	135	230	345	715	430	305	660	255	475	+ 70
Green Manure (-)	960	350	160	260	555	675	350	240	390	130	405	

OVERALL ANALYSIS

Treatment Effect

Table I, below, shows us the peanut and sorghum crop yields, with and without manuring. We considered those plots valid for which the interruption in the crop sequence (fallowing or green manure) was preceded by at least 2 years of cultivation.

TABLE I

	1st-crop peanuts (1959-1966)		2nd-crop peanuts (1960-1966)		Sorghum (1959-1966)	
	F	(-)	F	(-)	F	(-)
U	2,463	1,981	2,361	1,566	466	299
V	2,493	1,947	2,198	1,557	419	374
S	2,619	2,185	2,367	1,611	864*	554
T	2,785	2,337	2,485	1,775**	828*	577
Test F	NS	NS	NS	**	**	NS
PPDS 5 %				90	230	
PPDS 1 %					299	
AM	2,478	1,964	2,204	1,561	443	337
F	2,702*	2,260	2,426	1,693**	846**	566
PPDS 5 %	165	349	260	64	163	292
PPDS 1 %				117	299	

If we group treatments U and V and T and S, which are actually similar to each other, together, we note a very favorable influence by fallowing upon the peanut or sorghym output, regardless of whether these crops were or were not manured.

Influence of Cultivation Duration

Table II, below, gives us the manured and nonmanured peanut output figures for the various years and compares the first crops (A1) to the second crops (A3). We did not consider here the year 1964 with respect to the manured plots, because a repetition of the "V" treatment could not be harvested.

The drop in the yield between A1 and A3 is quite considerable for the nonmanured plots (20-25%). It seems that green manure attenuates the output drop.

TABLE II

Manured Peanuts, kg/ha

		1960	1961	1962	1963	1965	1966	Average
AM	A1	2,708	2,985	1,822	2,288	2,471	1,957	2,372 (100)
	A3	2,758	2,765	1,749	2,323	2,095	1,990	2,280 (96)
F	A1	2,790	3,408	2,286	2,686	2,759	2,590	2,753 (100)
	A3	2,780	2,735	1,819	2,741	2,257	2,207	2,426 (88)

Nonmanured Peanuts

		1960	1961	1962	1963	1964	1965	1966	Average
AM	A1	2,215	2,260	1,515	1,627	2,230	2,017	1,992	1,979 (100
	A3	1,968	1,740	1,321	1,565	1,616	1,327	1,394	1,562 (79
F	A1	2,393	2,770	1,977	1,967	1,984	2,462	2,215	2,251 (100
	A3	1,798	1,798	1,432	1,844	1,788	1,535	1,659	1,693 (75

Relationship Between Leaf Diagnosis and Output

Table III, below, gives us the average contents of N, P, and K, depend upon whether the antecedent crop sequence phase was AM or F for the first peanut crop. For further emphasis, we repeated the 1959-1966 production effort. Only K appears to be connected with the yield figures here in any way.

TABLE III

Leaf Diagnosis, 1961-1966 (on A_1)

	F		(-)	
	AM	F	AM	F
N	3. 54	3. 43	3. 58	3. 53
P	0. 217	0. 194	0. 192	0. 186
K	0. 892	1. 373	0. 864	1. 430
Production (1959-1966)	2. 478	2. 702	1. 964	2. 260

The samples were taken on the basis of the various years involved from different rows and at different times, after planting.

We can only compare the results of 1963, as well as 1964 and 1965. On the basis of these figures, we calculated the correlations between the yields and the P and K contents. Here are these correlations:

P		K	
Manured	Nonmanured	Manured	Nonmanured
0.00	0.53	0.37	0.48
0.32	0.21	-0.43	-0.29

It is interesting to note that the correlations are positive after AM and negative after fallowing.

For the reason pointed out earlier, it is impossible to calculate the core.

ANNEX 2

DAROU 1967

MULCHING -- FALLOWING -- GREEN MANURE TEST (1958)

GENERAL REMARKS

1. The long-lasting tests emphasized the importance of fallowing at a cultivation series. The results indicated that 2 years of fallowing are sufficient to obtain good soil fertility reconstitution.

2. Furthermore, green manure should facilitate faster improvement than fallowing but the results obtained so far are not conclusive because millet generally sprouts rather poorly. In this case, one might ask oneself whether plowed-under fallowing is not equivalent to millet.

3. The action of green manure millet may be broken down into several factors:

Mechanical action of the millet roots,
Action of the green substance in the plowed-under aerial portion,
Action of tillage as such.

4. Finally, there is one capital problem which overshadows the questions of fallowing and green manure and that is the problem of coverage (mulching).

PURPOSE

The purpose of this test is to measure the share of or part contributed by each of the factors considered earlier in the phenomen of soil fertility reconstitution.

ORGANIZATION

Land which had been subjected to an exhaustive P.M.P.P. crop cycle was then treated nine times.

To facilitate good distribution, treatments were necessary over a period of 2 years and the calendar of operations was set up as follows:

No. of Treatments	Treatment in 1958 & 1959 & 1963 & 1967	Treatment in 1960 & 1964	1961 & 1962 1965
A	Fallowing	Fallowing	Peanuts
B	Fallowing	Plow-under fallowing at the end of September	Peanuts
C	Fallowing	Burn-fallowing in June, green manure millet	Peanuts
D	Fallowing	Burn-fallowing in June, millet whose aerial portion is removed from the plot, soil then returned in September	Peanuts
E	Fallowing	Burn-fallowing in June, land switched to (hilum), lightly covered artificially, tillage at the end of September, with plow-under of aerial portions of millet from treatment D	Peanuts
F	Fallowing	Burn-fallowing in June, then cultivation of burned millet stalks at planting time	Peanuts
G	Land systematically stripped	Land systematically stripped	Peanuts
H	Land systematically stripped and covered arti-vicially	Land systematically stripped and covered artificially	Peanuts
I	Fallowing	Land prepared as for A.M. millet and then kept bare until September, followed by tillage, then left as is.	

In 1966: Sorghum

IRHO RESEARCH AND DEVELOPMENT RESULTS ON PEANUTS IN SENEGAL

A. Bochelee-Morvan, IRHO

SUMMARY

Peanut production in Senegal has increased from 420,000 to 750,000 tons in the course of the two decades following the second world war; this increase is due in part to improvement in the conditions of cultivation in the course of development.

The author intends to show how IRHO arrived at the results to establish the technical methods before using them in extension programs:

1) Long-term experimentation at research stations for studying the evolution of crops in more or less complex systems.

2) Experiments of short and average length at the research station level, with immediate practical results (fumigation of seeds, density of seeding, etc).

3) Short-term experimentation in the field followed by general use, in studies on mineral nutrition, conducted in part to find profitable fertilizer formulae and in part to determine by leaf analysis applicable areas for these fertilizers.

4) Determination of levels and types of fertilizer to recommend.

5) Confirmation in depth of the experimental results.

6) Control of possible development of plant requirements under mass cultivation by correcting if necessary the recommended methods.

Finally, the author looks at the future situation and outlines the main directions of research which should be undertaken.

* * *

INTRODUCTION

Harvested peanuts marketed in Senegal during the decade following the second world war amounted to approximately 420,000 tons.

Efforts of research together with an increase in cultivated area made an average production of 750,000 tons possible in the following decade, but this was still far from the planned target and only important measures in the organization of extension permitted higher levels to be reached.

The adoption in 1964 by the Government of Senegal of a program in which the principal recommendations were made jointly by IRHO and IRAT, has greatly favored the yield increase; production in 1967 has exceeded 1,000,000 tons at the same time that consumption of fertilizer increased from 23,000 tons to about 50,000 tons.

We will see how progress made by IRHO gave results which enabled research methods to be established and supported by the Government of Senegal which are envisaged as future steps in the normal research and development framework.

RESULTS

The stages of research by IRHO which yielded these results have been the following:

I. Long-term experimentation at the station.
II. Short- and medium-term experimentation at the station (basically on leaf analysis)
III. Short-term experimentation in the field (focussing on leaf analysis)
IV. Application and generalization of leaf analysis with a view toward mapping fertilizer needs.
V. Precise determination of types and levels of fertilizer to recommend.
VI. Confirmatory trials prior to recommendations at the farmers' level.
VII. Control of the fertilizer requirements for large-scale cultivation.

I. Long-term Experimentation at the Station

Since the creation of research centers at Louga, Tivouane and Darou, a certain number of fundamental problems have been posed which are soluble only through long-term, rigorously planned experiments. This explains why a whole series of permanent trials were established on mineral fertilizers, continuous rotation of crops and the treatment of fallow land. These experiments are designed to follow the development of crops under various conditions and constitute the basis of our studies, representing a fourth of the activity of IRHO in Senegal. They have since been complemented by other lengthy studies on new topics for which the growth of our knowledge has led to interesting evidence.

II. Experiments of Short and Average Length at the Station

Other less complex and more readily soluble problems were also tackled at the station in 1952, then re-evaluated in light of the appearance of new requirements.

Experiments then established rapidly yielded results in precise areas:

Fumigation of seeds:	selection of products (T.M.T.D.) and levels of application (2%).
Density of seeding:	determination of the relationship of density to yield, determination of the optimum density at 110,000 stands per hectare for the 28-206 variety.
Leaf analysis:	basic study on the method and time of sampling the leaf. New evaluation criteria.

This final method applied for the first time to the peanut requires minute analysis, in order to relate the percentages of leaf mineral elements to production.

III. Short-term Experimentation in the Field

The preliminary results obtained at the stations regarding mineral nutrition have served to lay the foundation of foliary diagnosis. It was necessary to ascertain whether the critical levels (amounts of the elements below which there would be a deficiency) thus determined enabled extrapolation over a homogenous zone, and also whether for each element, the comparison of the fertilizer response curve and the critical levels would allow substitution of leaf analysis in agronomic research for determination of fertilizer requirements for all the productive regions. A complete series of studies on mineral fertilizers was carried out in the field at each station and nearly into Eastern Senegal. Then, from 1952 to 1962, IRHO established 185 factorial trials (representing more than 5,000 experimental plots and 30,000 chemical determinations in order to cover, by as comprehensive a checkerboard as possible, all the peanut zone of Senegal. These studies have already established the main lines of mineral nutrition in each region.

IV. Application and Generalization of Leaf Analysis with a View to Mapping Fertilizer Needs

Once the first results of the preceding studies were obtained, it was possible from 1955 to propose economic and profitable fertilizer formulas for the three principal zones of Senegal.

The broad mineral requirements of the peanut being known and a simple, rapid method of investigation established, there remained tracing the exact limits of the zones before introducing a given mineral fertilizer. With the use of this valuable technique of foliary diagnosis, very precise maps were drawn from 1956 to 1961, working directly from the samples and analysis of leaves taken from the farmers' land. More than 100,000 chemical determinations were made for this whole study which resulted in one very detailed mapping of the different zones and delineation of those with adequate phosphate levels, work that would have been practically impossible to do well with only the information available from agronomic experimentation. Senegal was thus provided with an instrument to determine the fertilizer formulae appropriate for each region.

V. Precise Determination of Types and Levels of Fertilizer to Recommend

Concurrent with research on fertilizer requirements of peanuts, carried out either at the station or in the field, regarding the general area of mineral nutrition, experiments at the station determined that the levels of fertilizer to be used could and should remain modest (100 to 150 kg/hectare).

The types of fertilizer of the formulas proposed in 1955 were as follows:

- Formula composed of ammonium sulfate 70 kg/hectare and dicalcium phosphate 30 kg/hectare for the North with an addition of molybdenum provided with the seed fumigant.
- Formula composed of ammonium sulfate 40 kg/hectare, dicalcium phosphate 60 kg/hectare and potassium chloride 20 kg/hectare in the Center and the South.
- Formula composed of ammonium sulfate 50 kg/hectare and potassium chloride 50 kg/hectare in the Region of Thiès.

These break-downs were obtained after the incorporation of one part of P_2O_5 in the formula for the Southern zone in the form of phosphal, replacing the tricalcium phosphate in the annual fertilization. It was consequently possible to safely recommend fertilizer formulas with assured returns.

VI. Confirmation and PreExtension Trials at the Farm Level

In order to demonstrate that these formulas were correct and to determine their profitability to African farmers, IRHO undertook in 1956 to set up in-depth confirmation studies which used, in addition to all the better-established techniques of the Institute, the recommended fertilizer formula. These studies were permanent and were conducted in the framework of a family unit. They were comprised of 5 plots of one hectare each following the peanut - millet - peanut - two years of fallow rotation. Each year, the two plots of peanuts were subdivided into three strips, one control encircled by two fertilized strips.

The demostration dealt with the following points:

- crop rotation
- careful preparation of the land
- seed fumigation
- seed density (110,000 seeds/hectare)
- mechanized spreading of low-level fertilizer
- good hoeing maintenace

Established in 1955, these studies have been in existence more than 10 years and cover nearly 700 hectares of cultivation. They confirm indisputably that the application of simple techniques and use of an appropriate fertilizer formula enables peanut yields to be doubled.

Thus, in the region of Kaolack, where 257 trials have been carried out at this time representing 514 hectares of cultivation, the average harvest with fertilizer (all other improved cultivation techniques having also been applied) is from 1,855 kg/hectare. This figure (average of 10 years) is practically double that reached with traditional cultivation in a region which has not exceeded 1,000 kg/hectare.

VII. Control of the Development of Fertilizer Needs in Large-Scale Cultivation

Nevertheless, the application of the techniques recommended by IRHO in these confirmation studies (techniques resumed in full by SATEC in 1965) was concerned at length with depletion of the soil or structural changes incompatible with maintenance of fertility. In addition IRHO wanted to use these confirmation studies as evidence of development of Senegalese agriculture, so each trial was now made the object of a series of measures giving at any moment knowledge of the mineral reserves of the soil and the future needs of the plants for fertilizer. Established 10 years before the generalization of these techniques by SATEC, these studi thus constitute "safety flashers," since with this considerable progress, it would be possible each year, if the fertilizer formula should prove insufficient, to immediately propose the necessary modifications. In 1967, twelve years after their establishment, these studies still give as good re. lts as at the beginning; all supplementary contribution on fertilizer or formula modification thus proves for the moment to be witho benefit, as has been confirmed elsewhere with complementary agricultural experiments on the types and necessary levels of fertilizer.

Under these conditions, it would be premature, having only just reached the level of 150,000 tons of fertilizer consumed in fertilization of all peanut cultivation, to attempt extension of other techniques. The latter basic phosphate plowed-in green manure, high levels of fertilizer spread out over the rotation), have not been proven by sufficient experimentation on its productivity to yield positive results, capable of comparison with annual low level application of fertilizer to the peanut.

The fertilization of all peanuts, reckoning on the basis of annual growth of cultivated area, necessitates many years' study, in the course of which it will be necessary to mobilize all available financial and human resources to achieve this eminently profitable "investment."

The Government of Senegal has already taken a fundamental step in this direction by creating a fertilizer industry to produce the necessary tonnages for carrying out this program.

FUTURE STAGES

If IRHO insisted in 1964 that the simple measures proposed to the Government of Senegal be expanded "to the exclusion of all else," it is essentially because it would have been extremely undesirable to waste energy on insufficiently proved complex techniques.

But we believe that it is essential that the research be pursued, in order to improve still further techniques already used on a mass scale and to discover new methods of increasing yields, the latter only recommended after conclusive experimentation confirming their suitability for African farming conditions.

Hence, the value of short fallow periods for maintenance of soil fertility, which was demonstrated experimentally and at the farm level, should be recommended generally, to give time necessary for developing other methods.

The purpose of IRHO in Senegal is to follow-up the work already carried out, in order that once the generalization of techniques proposed to the Government of Senegal has been obtained, more elaborate solutions can be adopted in order to pass into a new stage of research. The number of permanent experiments established on trial projects over the last years is a decisive contribution to the solution of future problems.

- Continuous Cultivation

Certain regions of Senegal, as a result of the population increase, will be no longer able in a few years to continue using a system of production with fallow and intensification of the farming will become an absolute necessity. It is thus important to consider change to this new type of agriculture.

- Progressive Integration of Crop and Animal Production

Use of organic fertilizer and draft animals necessary for the development of mixed farming implies an integration of crop and livestock production.

The fallow land will serve in the first instance as grazing, then in a subsequent development can perhaps be transformed into rotational forage in the framework of an intensive farming system.

- Intrinsic Growth of Productivity

Research on new varieties to give increased yield for the investments (cultivation practices, mineral fertilizer) should be followed-up. Already as a result of studies on drought resistance, undertaken by IRHO at Bambey, better varieties than those currently grown have been selected and multiplied; this work must be continued.

- Edible Peanut

If diversification of cultivation is desirable, it is not possible at the present time in the peanut zone; consequently the peanut is still called upon to play a primary role in the economy of Senegal for some time to come. This is why research on the edible peanut, in which IRHO has taken the initiative, should be pursued actively with the aim of developing production complementary to that of the oil peanut.

The future programs of IRHO are centered around the pursuit of research in the area of growth of productivity of the peanut. They have already made possible reaching yields of two tons per hectare in practice as well as in experiments; the next stage is to raise this to three tons per hectare.

CONCLUSION

Fifteen years have passed since IRHO started three study projects in Senegal at Darou, Louga and Tivaouane.

After undertaking serious agricultural experimentation both at the station and in the field, establishing leaf analysis of the peanut and multiple trials for confirmation prior to extension among the farmers, recommends that the following measures be implemented immediately:

- fumigation of seeds
- greater seed density
- a low level of fertilizer of a formula adapted to each region.

These measures, whose implementation into widespread use will evidently require much time and patience, are capable of doubling per hectare yield.

Since 1964, the first stage has already enabled the objective, set by President Senghor in his address of December 17, 1963 before the National Assembly, to be attained:

"An increase of 25% yield per hectare."

Commercial production of less than 800,000 tons in 1963 has increased to a million tons in 1967.

During the last campaign, 50,000 tons of fertilizer were distributed, enough to cover more than 400,000 hectares.

The continuation of extension and application of the fertilizer to all peanut cultivation (which would represent a consumption of 150,000 tons) should enable an additional increase of 50% production.

Incidentally, the research projects which have already made possible the increase from one ton to two tons of peanuts per hectare should be followed-up in order to establish techniques before assuring a yield of three tons per hectare.

ANNEX

HISTORICAL ACCOUNT OF THE ACTIVITIES OF IRHO ON PEANUTS IN SENEGAL

IRHO began studying peanuts in 1949.

At that time the level of production in Senegal was of the order of 450,000 tons and research on the peanut was conducted by the Centre de Recherche Agronomique of Bambey (CRA), established in 1922, which was principally concerned with selection.

The CRA had in fact concluded that it was less important to place emphasis on cultivation techniques (density and fumigation of seeds), and mineral nutrition.

IRHO then asked Professor Prevot, a physiologist from the University of Liége, to carry out a preliminary study on the causes of low yields of peanuts in Senegal, with the view of successively examining each one of these. This was the beginning of an investigation, the stages and most remarkable results of which are summarized very briefly as follows:

1949: The comparison of yields obtained in France (more than 4 tons/ha in very favorable conditions, good soil and irrigation) and Senegal outlined the areas to which the subsequent research programs were oriented: reduction in losses in germination by fumigation of the seeds, improvement in cultivation techniques (particularly density of seeding) and soil fertility (rational rotations, mineral fertilizer applied at levels accurately determined by leaf analysis).

1950: Two very different results, the effect of potassium in the region of Thiès, and the effect of dicalcium phosphate on the areas of CGOT and Séfa, showed the need to study the fertilizer formulas adapted to the principal soil types and the danger of applying a master formula of predominantly dicalcium phosphate and potassium.

1951: One section of IRHO was established at the CRA at Bambey and research concentrated on the application of leaf analysis to peanut cultivation.

1952: IRHO established at Louga (annual rainfall 350mm/year), Tivaouane (550mm/year) and at Darou (850mm/year) three field stations responsible for studying the problem in the very different conditions of the major peanut-growing areas of Senegal.

At the same time permanent trials were set up to study the development of soil fertility and its reconstitution through natural fallow. This long-term program, never attempted previously in Africa, is of the greatest importance for guiding Senegalese farmers without other practical means of regenerating their soil.

1953: An important series of mineral fertilizer trials was established which, in five years, covered the whole country (120 trials carried

out) and enabled maps of peanut mineral nutrition and fertilizer requirements to be [illegible].

To this end more than 20,000 chemical analyses were carried out by the IRHO laboratories in Paris.

Simultaneously, conclusive results were obtained regarding the fumigation of seeds. At minimal expense of a few hundred francs per hectare a profit of many thousands of francs could be made.

1954: A phosphate-rich area in the Thiès [illegible]ion was discovered and surveyed.

1955: The first synthesis of results obtained since 1951 enabled the most economical types and levels of fertilizer to be determined for each region. These amounted to less than 120kg/ha in the South and 100kg/ha in the North. Requests from the Senegal Government for bids specified from that time on that the type of fertilizer used should contain 18kg/ha of P_2O_5 in a soluble form (dicalcium or phosphal).

1956: in order to obtain higher seeding densities IRHO developed the seeding disc with 24 teeth in use today throughout the whole country.

To capitalize on the results obtained the previous years IRHO undertook at the request of the French Overseas Government a large scale demonstration in the East Laghem canton.

1957: This canton comprised 18,000 hectares of peanuts, and 130 villages were successively affected by the demonstration.

1958: In 28 villages, a permanent area of 5 hectares (confirmation trial) was cultivated by the Africans themselves, in a demonstration of the following improvements: rotation, seed fumigation, high density, seeding using a seeder, spreading a low level of fertilizer (120kg/ha), good maintenance.

In these conditions, yields reached 2,000kg as opposed to the 1,000kg average for the region.

In the other villages regular demonstrations of mineral fertilizer were held. The consumption of fertilizer by the canton went from 78 tons in 1955 to 320 tons in 1958 (an increase of 400%) while the use of fertilizer in the other cantons only doubled.

1959: After three years work on cultivation methods and mineral fertilizers (agronomic experimentation, focussing on leaf analysis and critical levels) IRHO was able to confirm the validity of the formulae adapted to the different regions of the country.

Knowing the difficulty of applying low levels of fertilizer by hand, IRHO studied the possibility of adapting a small fertilizer spreader from the peanut seeder. After two years of trials, IRHO recommended and got

2,000 fertilizer spreaders made and distributed by the Agricultural Service of Senegal.

1960: Further studies on mineral fertilizer identified the role of sulfur in nutrition and led IRHO to advise the supply of less than 10kg/ha of that element, which henceforth was included in the tenders for fertilizer.

1961: Very detailed surveys led to the discovery of a new high-phosphate area in the Diarhel region, near Pater.

1962: After 10 years of experimentation, the permanent trials on the use of fallow for the maintenance of soil fertility demonstrated the superiority of fallow over green manure and established the length of cultivation cycles and the types of crop rotation.

1963: The effect of a mixture of trace elements, nutramine, was demonstrated in the North and Center of Senegal.

1964: New research on trace elements showed that the effect of nutramine was due to molybdenum and that very small levels of ammonium molybdate (27g/ha) facilitated nitrogen uptake and increased yields by 175kg/ha

1965: First trials with edible peanuts carried out at Darou gave promising results, and the Senegal Government asked IRHO to multiply 150 hectares of seeds.

The average yield in the multiplication reached 1970kg., providing ample seed for the following year. In 1967 this production was expanded on a large scale (3,500ha).

1966: The mixture of ammonium molybdate with the seed fumigant tested at Louga, was recommended by extension services throughout all northern Senegal.

The necessary amount of ammonium molybdate was then included in the fumigant tenders.

1967: Drought-resistant varieties isolated in the course of physiological tests by IRHO at Bambey and multiplied at Louga were extended for the first time in a pilot village. IRHO signed a contract to multiply 350 tons.

DROUGHT RESISTANCE OF PEANUTS

J. Gautreau, P. Prevot, M. Ollagnier & P. Gillier
IRHO, Senegal

SUMMARY

A study of the influence of moisture on growth, development and production of the peanut under controlled conditions with potted plants receiving 400, 800 and 1,200 mm of water enable the authors to classify the degrees of sensitivity of the plant to drought.

This research was then completed by field trials carried out on temporarily covered plots in order to confirm the previous theoretical results. This then allowed the authors to elicit the factors which could increase drought resistance.

A number of tests have been developed and used to select plants particularly resistant:

- germination at increased osmotic pressure
- relative growth rate
- resistance to heat

Selections performed through these tests were compared in the field in drought trials in temporarily covered plots.

All the favorable varieties selected after the tests showed in field trials a high resistance to lack of moisture, and as of now three varieties, both drought resistant and high-yielding, can be grown by the farmer.

INTRODUCTION

Drought resistance may be the result of a combination of various physical or anatomical factors.

According to Levitt, we might distinguish between "constitutional resistance," which is a plant's ability to maintain a relatively low water deficit under drought conditions and a "protoplasmic resistance," which is the ability to maintain normal metabolism when the internal water deficit rises and, at a more advanced stage, to maintain the structure of the protoplasm intact.

Stocker emphasizes this form of resistance: according to him, the properties of protoplasm are essential in resistance to dryness because "all of the effects of dryness result from changes in the structure of

the plasm." Ghenkel likewise emphasizes the importance of the protoplasmic characteristics. He distinguishes resistance to heat and resistance to dehydration and he believes that both of them are tied in with different characteristics.

These various manifestations or determinations of drought resistance are not mutually exclusive; but neither are they necessarily tied together since resistance can come from just one factor or from several factors. Hence the complexity of the search for the causes of resistances and these causes will have to be looked for on all levels of the plant: transpiration, stomatic regulation, ratio between the aerial portion and the root system, and cell metabolism.

In the first portion, we will show first of all that the peanut is sensitive to drought throughout its entire lifetime and the most critical stage is the stage of full bloom. Then we will study the intrinsic factors of this sensitivity and we will try to work out some criteria which might help increase the peanut's resistance to drought. Finally, we will examine the practical results to which this type of study can lead.

1. INFLUENCE OF WATER UPON GROWTH, DEVELOPMENT, AND PRODUCTION

Writing in Oleagineux in 1947, Delorme discussed the relationship between the rainfall volume and peanut yields in Sénegal. On the basis of statistics from 1931 to 1940, he demonstrated the existence of a direct ratio between the yields and the average annual rainfall level. Roughly speaking, the yield increases by 80 kg of shells for every 100 mm increase in the rainfall. But this does not take into account the differences in the soil fertility which varies from one region to the next.

According to Porteres, who made a study in 1952, a decrease in the useful rainfall in the Bambey area (rainfall between planting and harvest) from 700 down to 400 mm reduces the yields by about half; working at the experimental farm at Louga, this author found a rather high ratio between useful rainfall and yield: $r = 0.797$; over 22 years of observation, half of these years give us figures below the average rainfall volume of 411 mm. This indicates -- for this particular region -- the importance of the yield losses due to a rainfall volume shortage.

Let us first of all examine the influence of the water factor under conditions that will be as controlled as possible. We will then verify the results obtained by means of field tests.

A. Research Under Controlled Conditions

(1) The test was conducted with three repetitions in boxes with dimensions of 40x40x50 cm, sheltered during periods of rainfall

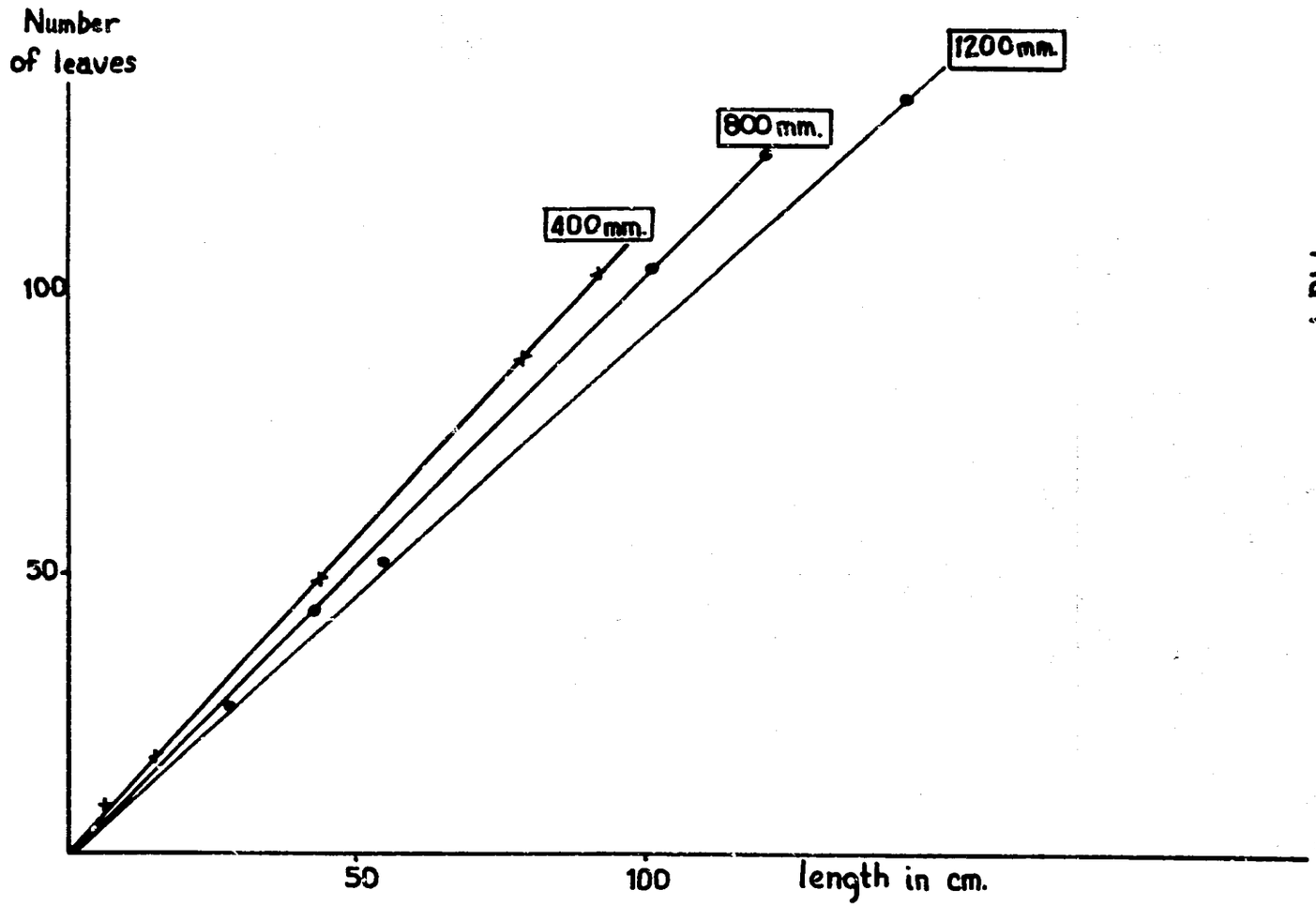

Number
of leaves
100
50
50
100
length in cm.
400mm.
800mm.
1200mm.

FIG 1

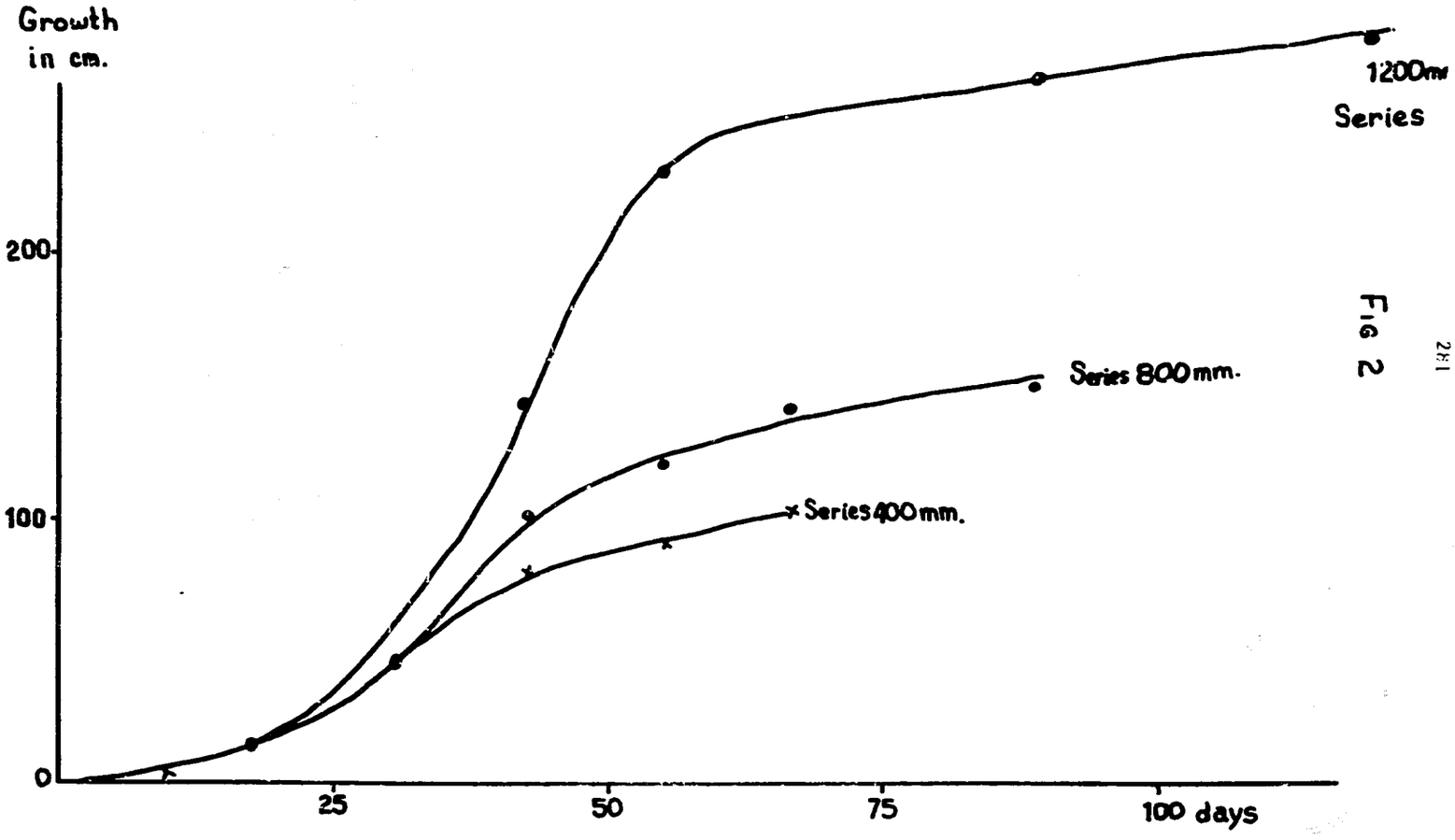

Growth
in cm.
200
100
0
25
50
75
100 days
1200mm
Series
Series 800mm.
Series 400mm.

Fig 2

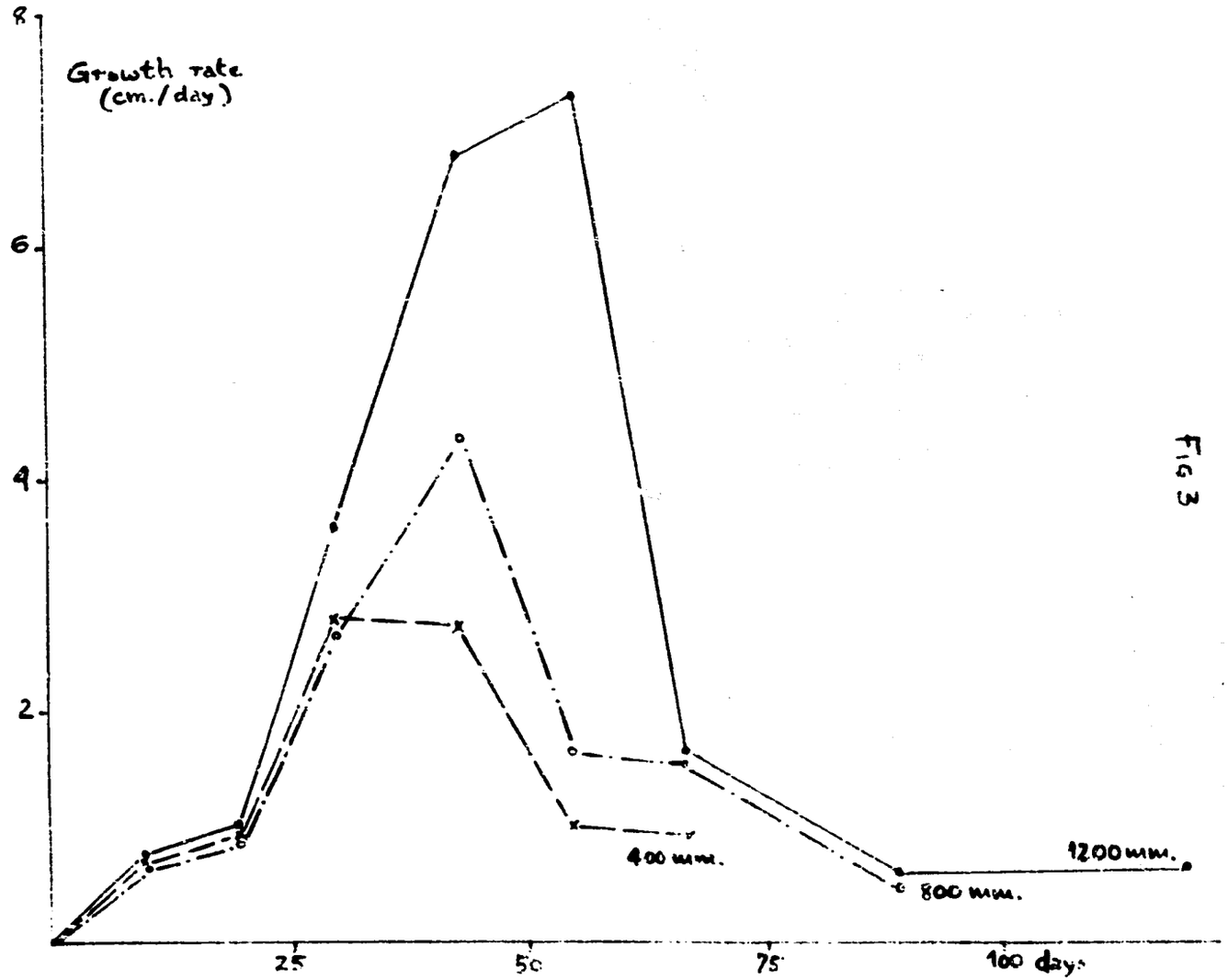


FIG 3

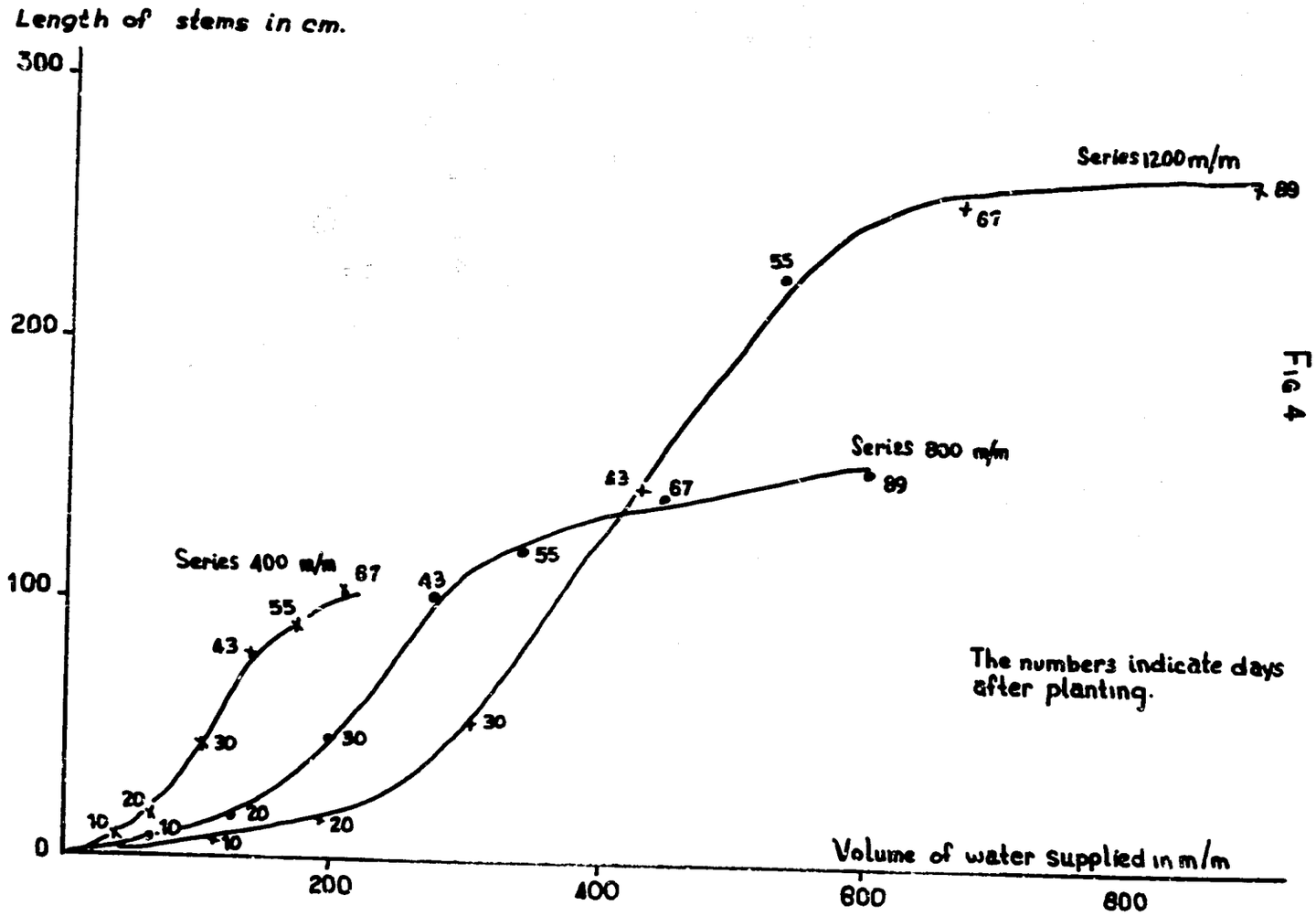

Length of stems in cm.
300
200
100
0
Series 1200 m/m
Series 800 m/m
Series 400 m/m
The numbers indicate days after planting.
Volume of water supplied in m/m
200
400
600
800

FIG 4

in a mobile hangar or shed. The peanuts thus received only sprinkling water. The quantities administered were 400 mm, 800 mm, and 1,200 mm. Variety 28-206.

The sprinkling was distributed over 120 days and began at planting time and then took place every other day.

At 400 mm of water, the plants die after 70 days and at 800 mm they die after 90 days.

The growth, expressed in the length of the branches and the number of leaves present, was measured on various occasions: 10, 20, 30, 43, 55, 67, 89, and 120 days after planting (4 August).

The allometric curves (Figure 1) between the length and the number of leaves show that these two values are proportional (at least up to the moment at which a major drop in the leaves might occur at the end of vegetation, thus modifying this ratio). The length measurements can thus be used to express the growth. Moreover, the slope of the curves indicates a shortening of the internodes when the water supply is reduced.

Figure 2 shows us the evolution of the lengths in time; Figure 3 shows us the evolution of the growth rate in time; and Figure 4 shows us the evolution of growth with the volume of water supplied.

The overall growth is greatly increased by the administration of larger quantities of water (Figure 2). We can also see (Figure 3) that the growth rate is almost identical in the 3 series up to 25 days. On the 30th day, it is clearly differentiated from the 1,200 mm series. This coincides with the beginning of flowering.

It is thus at the beginning of flowering and during the full bloom period that the growth phenomena are most intensive and that they are also most heavily modified by water supply.

The growth rate increases up to the 50th day for 1,200 mm series, it increases up to the 40th day for 800 mm series, and it increases up to the 35th day for 400 mm series. (These numbers of days are obtained by extrapolation of the curves.)

The volume of water thus simultaneously affects the growth rate and the duration during which this growth rate increases.

If we relate the growth to the volume of water supplies (Figure 4), we can see that the points at which the slope changes are located, for the first point, at 20 days and for the 2nd point, at 55 days, for all of the three series here. This shows that the growth rate has not been modified by the water supply. In other words, it was the intensity of the growth phenomena which was affected here. We can thus

arrive at the same conclusions as we can find in ths studies made in 1949, where we have a comparison of peanut growth in France and Senegal (Prevot, 1950).

2. THE FOLLOWING 5 TREATMENTS WERE ADMINISTERED

(A) Consumption of 25% of the water volume available, followed by sprinkling up to the field capacity, etc. If we set the field capacity at 100% and the wilting point at 0%, then this treatment may be schematically expressed as follows:

100%	75%/100%	75% etc

Similarly:

B - 100%	50%/100%	50% etc
C - 100%	25%/100%	25% etc
D - 100%	0%/100%	0% etc
T - 100%	100%	

This last treatment T is the control in which the soil was kept at field capacity for the entire duration of the experiment.

Three tests were performed; the following treatments were applied:

-- in test 1, from the 12th day after germination all the way to flowering (end of test);
-- in test 2, from flowering to the beginning of maturation (80th day);
-- in test 3, from the beginning of maturation to harvest time.
Variety used: 31-33, creeping variety.

These tests, on the whole, confirmed the great influence of drought upon growth (Ochs and Wormer, 1951):

"The period of major activity from flowering to the 50th day is very sensitive to dryness whereas the period of low activity on the contrary is much less sensitive."

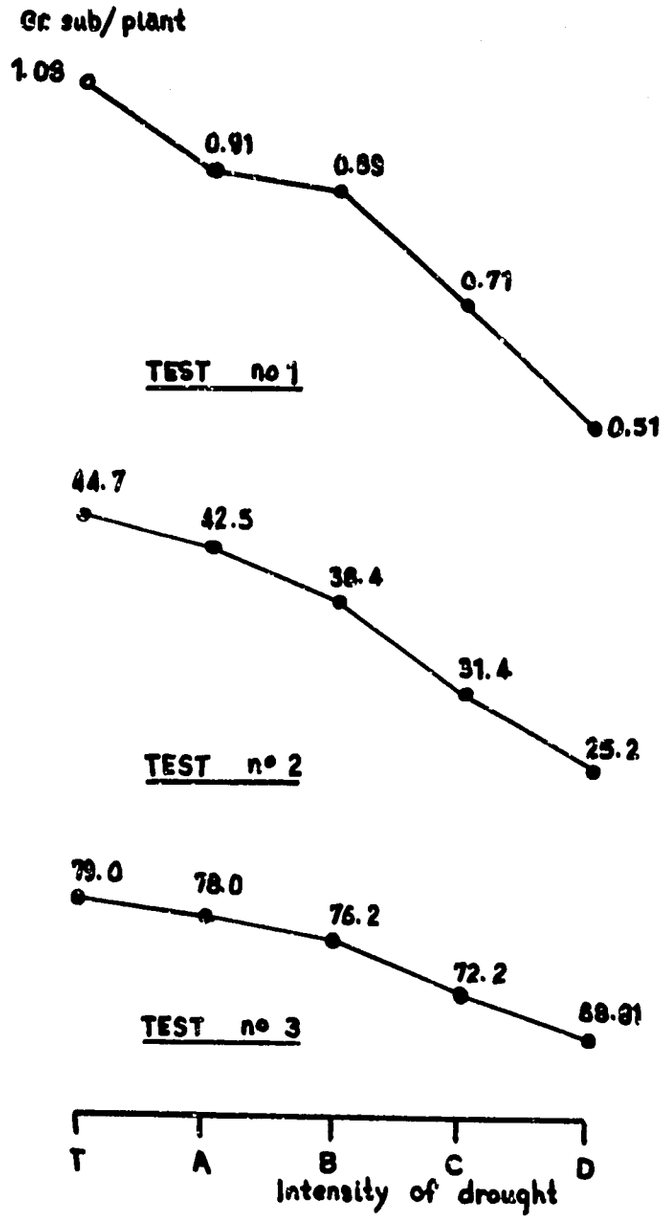
All of the test plots reveal a dry matter output that is statistically smaller than that of the control plot (Figure 5).

3. EXPERIMENTAL PROCEDURE

(a) Periods of Application of Drought

The four treatments involved in the experiment corresponded to various stages of growth and development; dryness was applied in only one of these stages, the plant being otherwise well supplied with water.

FIG. 5



It is thus certain that a soil which has not been kept in the immediate vicinity of the field capacity (pF-2.2) will not guarantee the plant a maximum output in terms of dry substance.

The periods selected are shown in Table 1, with respect to the various treatments.

Table 1. Definition of Treatments

Treatment	Periods of Drought	Stages of Development
T	0 (control)	Removed at first flowering.
A	10th to 30th day (1)	
B	30th to 50th day	Start of flowering.
C	50th to 80th day	Layer of heavy flowering up to the end of the blossom period which is normally referred to as the "useful" blossom period, 40 days prior to harvest, start of fructification.
D	80th to 120th day	Fructification and maturation.

(1) Number of days after planting.

(b) Drought Treatment

The treatments which were well supplied with water had been kept at field capacity by means of 2 or 3 daily waterings. As soon as one of the treatments entered its dry period, the sprinkling was suspended; the plant then used the reserves of ground or soil water up to the permanent wilting point (pF 4.2). The soil was then returned to field capacity and a new drying cycle followed the first and so on.

Going from one treatment to the next the dry periods can thus correspond to a number of different cycles but they nevertheless remain comparable for one and the same duration, since the sum total of the capillary tensions which the plant undergoes is the same in all cases. The climatic variations -- which elsewhere are not at all important -- tend to modify the speed of exhaustion of the available water quite essentially and, for the same reason, do not in any way change the comparison between the different periods (Billaz and Ochs, 1961).

The test enables the stages of sensitivity to be classified in increasing order as follows:

-- period D, periods of filling and maturation of shells (80-120 days);

-- period A, active growth, (10-30 days) and period B, start of

flowering (30-50 days);

--period C, intensive blooming and formation of numerous gynophores (50-80 days);

Drought here acts by reducing the vegetative growth, flowering and the formation of gynophores.

The growth of leaves, for example, is shown in Table 2

Table 2. Average Number of Leaves in each Treatment at Various Observation Dates

	PERIODS								
	A			B		C		D	
Days after Planting	10	20	30	40	50	60	70	80	120
Treatments									
T	4	13.6	40.8	94.4	186.8	289.1	422.8	488.2	547.8
A	4	12.4	26.3	57.2	134.3	246.7	351.4	442.8	548.1
B	4	13.4	41.3	66.2	118.8	227.2	318.8	402.0	506.0
C	4	13.7	42.6	97.1	196.5	261.8	343.2	406.1	698.5
D	4	13.3	40.1	97.5	190.5	287.8	382.3	450.7	417.2

This shows:

for treatment A, a growth delay of about 35%, progressively made up during the following periods;

for treatment B, growth delay of the same order of magnitude, which the plant partially compensates for afterwards (delay at harvest time 8%);

for treatment C, a minimum delay (15%) which the plant compensates for rapidly;

for treatment D, a long delay (25%) corresponding not only to a complete stoppage of vegetative growth but also to a drop of leaves.

As regards yield, treatments, A, B, C, and D can be classified as follows:

Table 3. Yield of Peanuts

Treatments	Yields
Control	78.5 (100%)
B	64.6 (82.2%)
A	61.6 (78.4%)
D	57.5 (73.2%)
C	42.1 (53.6%)

From the statistical viewpoint, the comparison of averages per couple (the final number of plants per test object varies greatly) leads to the following results:

A, B, C, and D are significantly smaller than T.
A, B, and D are statistically equivalent.
C is significantly smaller than A, B, and D.

This leads to the following conclusions:

-- all of the periods of the vegetative cycle thus are sensitive to dryness which seriously reduces the yields (at least 20%).

-- the most damaging drought occurs between the 50th and 80th days, that is, during heavy blossoming. In this case, it leads to a drop in the yield amounting to about 50%.

B. Field Research

This research was conducted by the method of "temporarily covered" plots, that is to say, they are conducted in the field, but a portion of the normal rainfall is diverted from these plots according to the dry treatment imposed upon them.

1. In an experiment at Louga, in 1956, the following were particularly studied:

-- normal rainfall or stoppage of rainfall at flowering (normal rainfall: 260 mm, which is extremely low; the shelters eliminated 65 mm of this rainfall);
-- ammonium sulfate (75 kg/ha) or none.

The variety used was 31-33.

Figure 6 shows the evolution of flowering in 5-day increments (sum total of blossoms counted over 5 days). We can see that the stoppage of the rainfall immediately reduced the blossoming. Later on, starting on 25 September, the parcels which had been covered produced more flowers than the parcels which had not been covered; because of this the final difference (Table 4) is not very great.

Table 4. Total Number of Blossoms (5 Plants)

	Stoppage	Normal	Difference
Plus nitrogen	369	409	-40
Without nitrogen	273	310	-37
Difference	96	99	

A test consisting of the evaluation of the strength of the plants in the various plots, based on random sampling, was then conducted. The length of the cotyledonary branches had been measured on 5 plants per plot. The ratio between strength and output is very good (Figure 7). Similarly, the correlation between the output and the length of the cotyledonary branches is highly significant and rather high.

The yields, summarized in Table 5, below, are very small.

Table 5. Yields of Peanuts

	Stoppage	Normal	Difference
Plus Nitrogen	314	414	-100
Without Nitrogen	195	288	- 93
Difference	119	126	

FIG 6

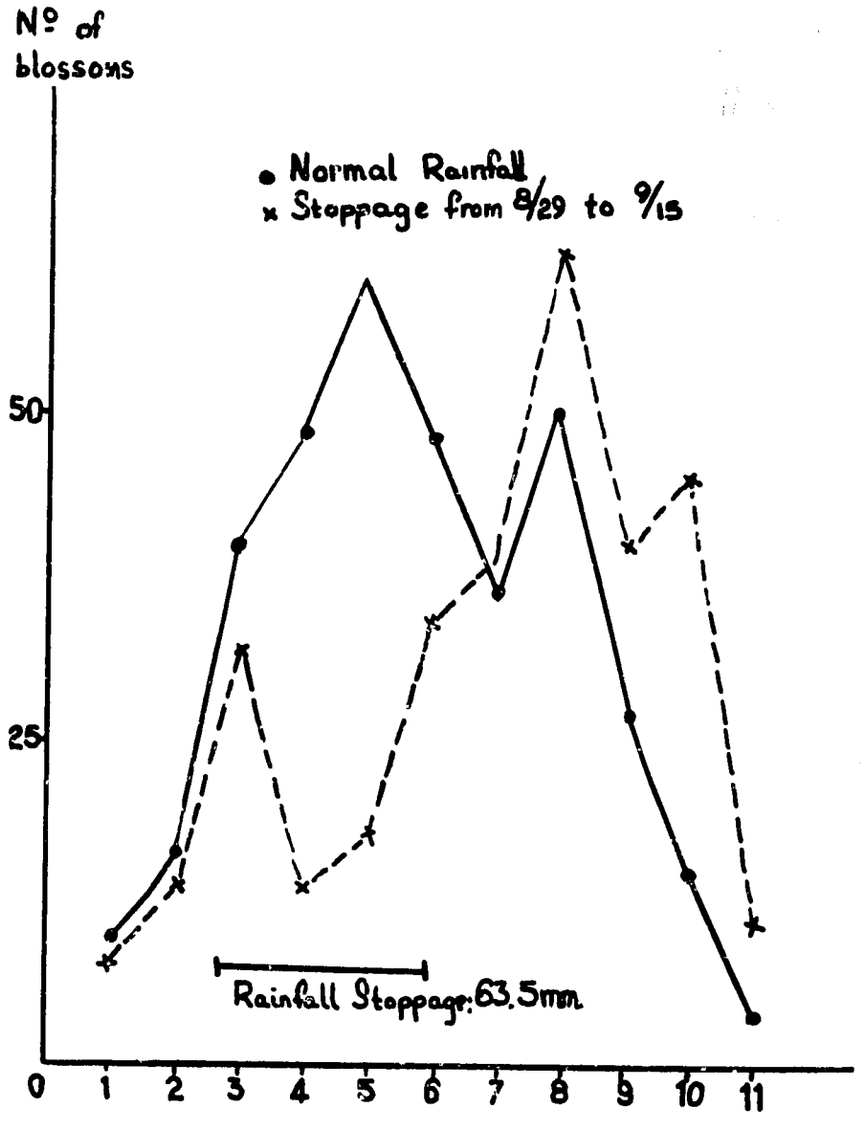
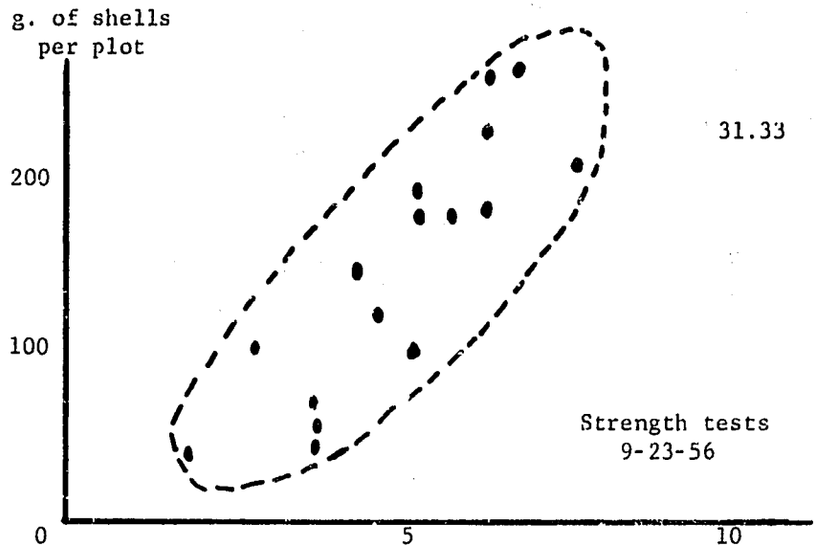

Nº of blossoms
• Normal Rainfall
× Stoppage from 8/29 to 9/15
50
25
Rainfall Stoppage: 63.5mm
0
1
2
3
4
5
6
7
8
9
10
11

FIG 7



The stoppage of rainfall, which considerably slows the blossoming process down, caused a drop in yield of about 100 kg of shells. It should be noted however that this rainfall stoppage was relatively minor since it only eliminated 65 mm of water.

This bears out the importance of a stoppage of rainfall during the period of early flowering.

2. This is a 4 x 2 factorial trial with 8 replicates (64 plots).

Object: 4 different rainfall volumes, with and without fertilizer (Fourrier and Prevot, 1958).

Fertilizer: 75 kg of ammonium sulfate and 40 kg of dicalcium phosphate per ha.

The experiment was conducted at Louga (Sénégal), in a region characterized by a low rainfall volume (450 mm average rainfall).

The experiment involves 3 periods of rainfall stoppage, as indicated in Table 6, on the following page.

Table 6. Rate of Rainfall in Various Treatments (Louga)

	No stoppage A0	Stoppage 35th-60th days A1	Stoppage 60th-85th days A2	Stoppage 85th-110th days A3
Rainfall Deficiency	nil	165.5	95	65.5
Total rainfall received	407.5	242	312.5	340
Percentage received	100	58	76	83

Only the first period of rainfall stoppage was really damaging to plant growth. The shortage of rainfall between the 60th and 85th days also reduced the number of leaves (Table 7).

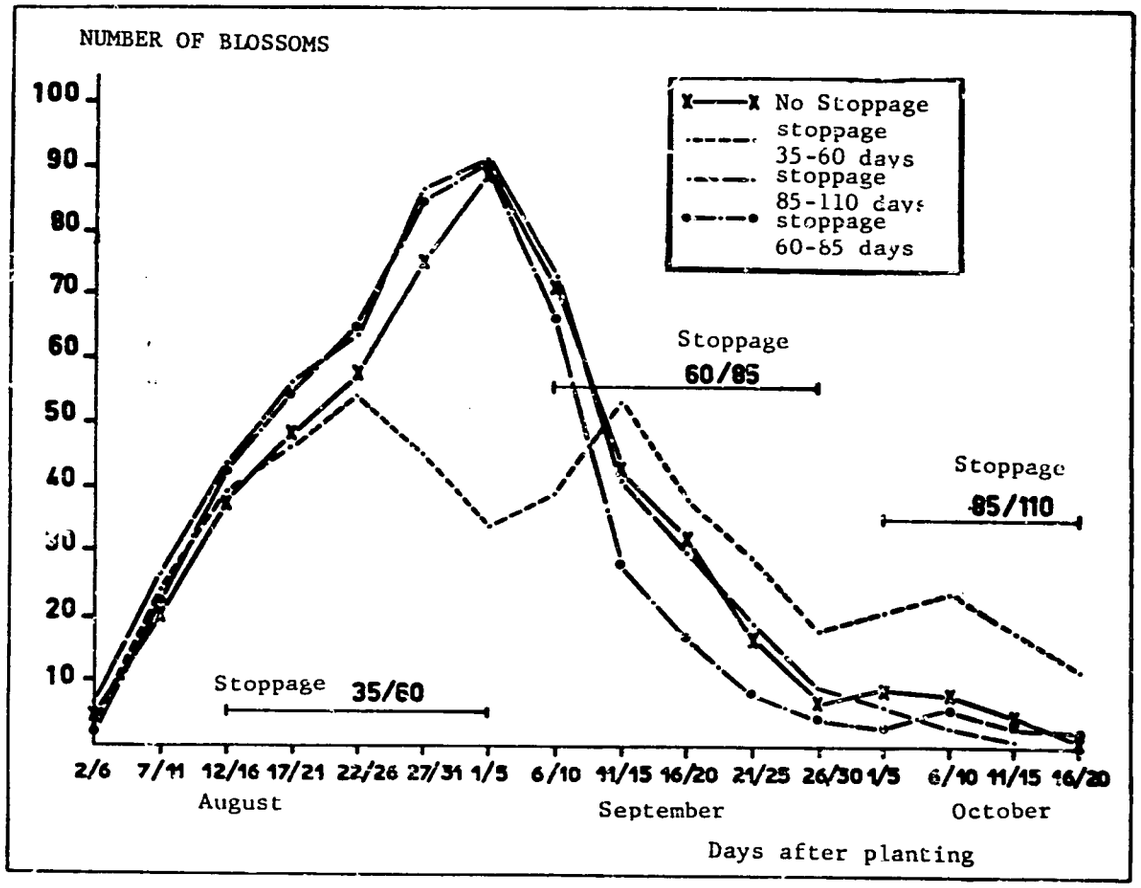
Table 7. Principal Effects of Treatments on Growth in Terms of Number of Leaves on Cotyledon Branches.

Principal Effects	No stoppage A0	Stoppage 35/60 A1	Stoppage 60/85 A2	Stoppage 85/110 A3	Averages
(-)	(a) 23.2 (100)	21.8 (94)	22.4 (97)	24.8 (107)	(c) 23.0 (100)
N, P	25.8 (111)	23.2 (100)	24.6 (108)	25.7 (111)	24.8** (108)
Averages	(b) 24.5 (100)	22.5** (92)	23.5* (96)	25.3 (103)	

P.P.D.S.	Number of Leaves 5%	1%
(a)	1.46	1.96
(b)	1.04	1.38
(c)	0.732	0.979

NP fertilization has a very definite effect on the growth.

FIG 8


NUMBER OF BLOSSOMS
100
90
80
70
60
50
40
30
20
10
No Stoppage
stoppage 35-60 days
stoppage 85-110 days
stoppage 60-85 days
Stoppage 60/85
Stoppage 85/110
Stoppage 35/60
2/6
7/11
12/16
17/21
22/26
27/31
1/5
6/10
11/15
16/20
21/25
26/30
1/5
6/10
11/15
16/20
August
September
October
Days after planting

Examination of the flowering curve shows that the total number of blossoms formed does not provide an exact picture of the development of flowering. It turns out, in effect (Figure 8), that the first period of rainfall stoppage very definitely reduced the flowering but that afterwards flowering was maintained at a higher level than in the control plots.

As far as the average values are concerned, all of the reductions in rainfall significantly reduced the yield (Table 8).

Table 8. Harvest (in kg of shells/hectare).

Treatments	No Stoppage A0	Stoppage 35/60 A1	Stoppage 60/85 A2	Stoppage 85/110 A3	Average
(-)	(a) 708 (100)	549 (78)	579 (82)	791 (112)	(c) 657 (100)
N, P	1140 (161)	763 (108)	749 (106)	763 (108)	854** (130)
Average	(b) 924 (100)	656** (71)	664** (72)	774* (84)	

P.P.D.S.	5%	1%
(a)	181.9	243.1
(b)	128.6	171.9
(c)	90.9	121.5

The following interpretation can thus be made:

- during the period A1 (35/60 days) the rainfall stoppage decreases the growth and consequently the output of blossoms (flowering). This effect has very definite repercussions on the yields.

- in period A2, the rainfall stoppage involves another phenomenon since the growth determined on the 80th day and the weight of folliage are approximately equal to those on the A0 treatment.

It is likely that the stoppage of rainfall at that moment reduces the growth of the gynophores and (or) the maturation of the shells. It thus seems that if the stoppage of rainfall reduces the yields during the three periods studied, it acts on different phenomena.

3. Finally at Bambey our choice rested with varieties adapted to the different climatic conditions in Senégal:

- the 24-5 and 47-16 varieties for the northern region, where rainfall is low (450 mm);

- the 31-33 variety for the middle zone of Thies-Tivaouane;

- the 28-206 variety for the southern region where the rainfall is greatest (700 - 800 mm).

The comparison thus involved two different intensities of drought, which we call S_1 and S_2.

Quite by chance the drought was very severe during that year (400 mm) rainfall. The S_2 series thus did not feature any watering. The drought in the S_1 sub-plots was corrected by supplementary watering.

Figure 9 gives the growth curves in terms of number of leaves, up to the 90th day. It is evident that although growth is essentially the same for the four varieties up to the 35th day, the 47-16 and 31-33 varieties demonstrate a very definite superiority as soon as the drought becomes severe. In particular the four varieties - at the end of the dry spell produced on the 66th day - had the following number of leaves (counted on 6 plants located in sub-plots in a particular block) Table 9.

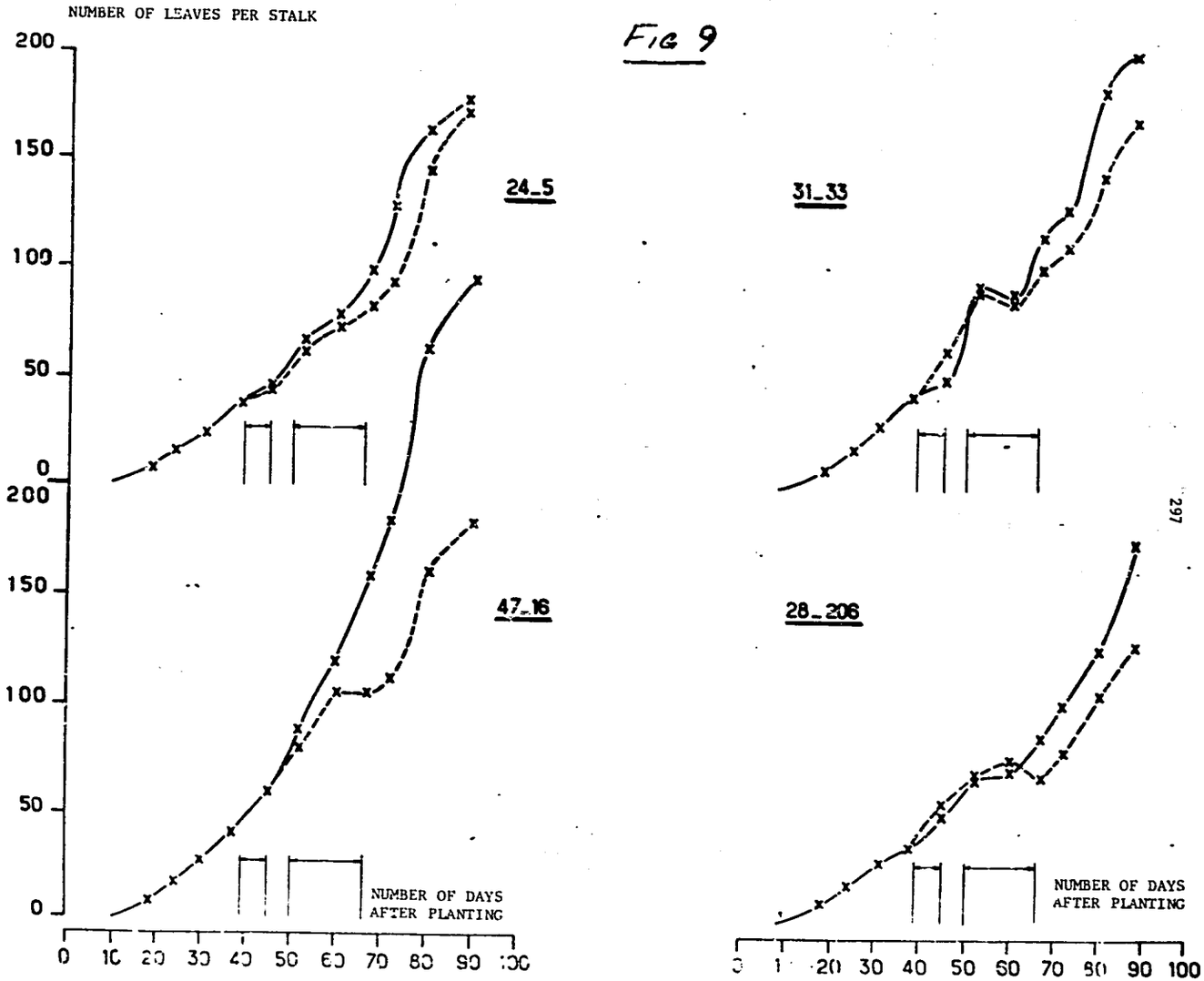
Table 9. Number of Leaves on Different Varieties (66th Day)

	Varieties			
	24-5	47-16	31-33	28-206
S_1	98,3	159,1	122,1	85,8
S_2	84,0	106,1	102,8	68,5
Average	91,1	132,5	112,4	77,1

The corresponding curves are shown in Figure 10. It is evident that the growth in terms of weight of shells and gynophores in the varieties 31-33 and 47-16 was right away much faster than that of the two other varieties and kept up at a much more active rate up to the 80th and 100th days.

Without going into any detail on the per-hectare or per-stand yield (Billaz, 1962), the weight of the healthy seeds per stalk, after shelling, is shown in Table 10.

Fig 9


NUMBER OF LEAVES PER STALK
200
150
100
50
0
24_5
31_33
47_16
28_206
NUMBER OF DAYS AFTER PLANTING
0 10 20 30 40 50 60 70 80 90 100

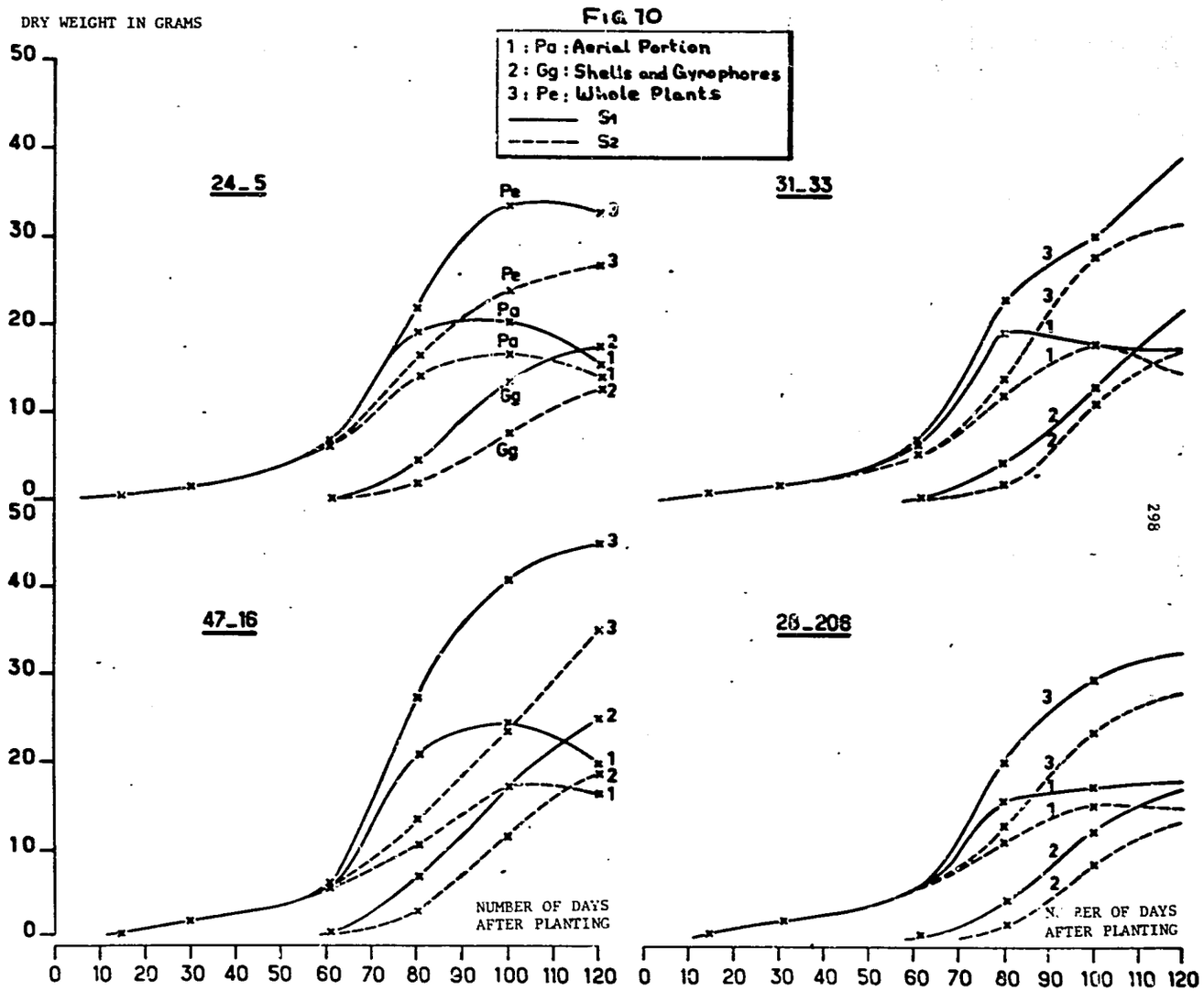


FIG 10
1 : Pa : Aerial Portion
2 : Gg : Shells and Gyrophores
3 : Pe : Whole Plants
S1
S2
DRY WEIGHT IN GRAMS
24_5
31_33
47_16
28_208
Pe
Pa
Gg
NUMBER OF DAYS AFTER PLANTING
0
10
20
30
40
50
60
70
80
90
100
110
120

Table 10. Weight of Healthy Seeds per Stalk, after Shelling. (g)

	Varieties			
	24-5	47-16	31-33	28-206
S_1	8,5	12,6	10,8	6,8
S_2	4,9	8,3	8,3	4,2
Average (g)	6,7	10,4	9,5	5,5
% 28-206	122	189	73	100

From the viewpoint of yield, the two groups of varieties are definitely quite distinct from each other as brought out by these results: drought sensitivity for the varieties 28-206 and 24-5 and drought resistance for the varieties 47-16 and 31-33. Although it had been widely promoted and used in northern Senégal in the old days, the 24-5 variety is not a resistant variety. On the other hand, the 47-16 variety, selected by the C.R.A. at Bambey after the way, appears to be particularly interesting from this viewpoint.

From the physiological viewpoint, the resistance of 47-16 and 31-33 was indeed brought out in the following manner compared to the sensitive varieties: during the stages of active growth and flowering, leaf growth is most intensive and flowering is less retarded under conditions of dryness; fructification is earlier: in particular, the number of gynophores formed by the 47-16 and 31-33 varieties, on the 61st day, are, respectively 10.5 and 14.0 as against 6.3 and 4.8 for the 24-5 and 28-206 varieties.

* * *

Consequently, field tests confirm the conclusions obtained by experimentation under controlled conditions. This of course enabled us to single out factors liable to increase drought resistance. This will be the subject of our next communication.

* * *

II. SELECTION OF DROUGHT-RESISTANT VARIETIES

How to determine the drought-resistance varieties.

The resistance of a plant to drought depends on very numerous factors which may be schematized as follows:

Morphological Factors	Physiological Factors	Effect of Factors
Root system well developed, in comparison to the aerial portion	High osmotic pressure of roots	Increase in water absorption
Small leaves with thick cuticle, narrow stomata	Rapid closing of stomata under conditions of desiccation	Decrease in transpiration
Thick leaves, tissues specialized in accumulation of water	High suction force of cells, high content of bound water	Increase in water reserve of tissues
Growth reduced relatively little under drought conditions	Viscosity and elasticity of protoplasm, resistance to heat and dehydration	Increase in protoplasm resistance capacities
	Synthetic processes active over hydrolytic processes	

Physiological measurements are bound to provide signs of the early manifestations of drought resistance, information which is necessary to enable selection tests to be developed as quickly as possible for resistant lines or stands.

The few tests showing up drought resistance, but which are not generally used, will be reviewed briefly, then the three tests widely employed - increased osmotic pressure, relative growth rate, and heat resistance.

A. Preliminary Tests

1. Stomata test.

A rapid practical test has been perfected for measuring the opening of stomata. This is an adaptation of Molish's infiltration method.

If a range of solutions of increasing surface tension (water and iso-propyl alcohol) is applied to the surface of the leaf only the lower ones will penetrate below the surface, the strength of the last to penetrate providing a measure of the degree the stomata are open.

The strength of the least concentrated alcohol mixture which penetrates into the leaf is a measure of the degree of opening

of the stomata. Since pure alcohol does not penetrate the degree of opening in this system by convention is defined as being zero.

This method has been applied to the study of a variety of problems (Wormer & Ochs, 1959). For example the closing of the stomata in relation to soil humidity has been followed.

At humidities greater than 11% the stomata are opened to their maximum; the progressive closing of the stomata with dryness appears very clearly. On the other hand closing is very often not complete in the immediate neighborhood of the wilting point; complete closing is only produced when drying-out is very marked.

It would be interesting to compare different varieties from this point of view. Nevertheless we believe that this method does not have immediate practical application because of the difficulty of showing intervariable differences in this area.

2. Moisture deficiency

The physiological interest in this notion is great, since the hydration of the tissues to saturation can normally vary from one variety to another.

The method described by Weatherley(1950) for cotton has been adopted for peanuts. Small round disks are removed from one or more suitably selected leaves by means of a punch. These are weighed fresh then placed on water where they are allowed to float until saturation, weighed again, dried, and then weighed once more. This gives: the fresh weight, the saturation weight, the dry weight, and by calculation, the degree of saturation.

In the course of tests with potted plants, it was observed that the degree of saturation is about 96% in the morning and 90% in the afternoon, regardless of the soil moisture up to the vicinity of the wilting point. From that instant onward, the plants enter a period of wilting while the deficit increases. In contrast to the oil palm, high deficits of something like 40% are normal, in the sense that the plant rapidly resumes its turgescence after watering, even if the state of wilting is prolonged for 24 hours; under the same conditions, the palm tree is definitely doomed. Ilyina (1958) found "water conducting cells" in the leaf tissues of the peanut and considered them to be "means of adaptation enabling the plasm to keep ut its moisture content and facilitating the vital activity of the plant under drought conditions."

The deficit thus develops at the expense of these tissues whose desiccation does not have any affect on the vital processes of the plant.

3. Desiccation Resistance

Rather considerable differences are formed if entire plantlets, with their roots, are allowed to wilt and the rapid recovery observed after replanting in moist soil. The comparison involved only the experiment with the variety 47-16 and variety 28-206. After 24 hours of wilting, the 47-16 variety revealed a definitely poorer recovery in terms of altered leaves and dead plants, than the 28-206 variety.

Variety	% of Stands Perished	% of Altered Leaves
47-16	5	5
28-206	27	60

(average of 3 replicates)

These preliminary results indicate that this test might be worthwhile.

4. Protoplasmic Viscosity

Viscosity can be measured by the time necessary for the establishment of plasmolysis in a solution that is 0.1 M above the isotonic solution. Under these conditions, we obtained rather convergent results for several series of measurements and can thus perhaps classify the varieties in the following order (viscosity increasing):

24-5 28-206 31-33 47-16

These studies however are still too fragmentary to arrive at any definite conclusions: on the basis of the very first observations however, it seems that the 47-16 variety has a higher protoplasmic viscosity than the other varieties, particularly the sensitive varieties.

The preliminary tests described above can constitute a basis for the selection of the most resistant varieties. But we have now arrived at relatively simple and precise methods which will now be described.

B. Tests Used

Three tests are used. First of all, there must be a fast and simple test permitting selection among numerous varieties those which revealed the greatest drought resistance. The high osmotic pressure germination test (T.O.G.) meets these requirements (Gautreau, 1966). Two other tests, which are of longer duration, confirm or spell out precisely the results furnished by the TOG: the relative growth rate test (T.C.R.) and the heat resistance test (T.R.C.).

1. High Osmotic Pressure Germination Test

It might be supposed that the germination rate at increased osmotic pressure is proportioned to the degree of resistance to drought. Indeed, selection experiments were conducted according to this principle by various authors (Asthon, 1958; Ghenkle, 1956; Lewitt, 1957; Stocker, 1958).

Two varieties were available, one highly drought-resistant (47-16), the other very sensitive (28-206). Various osmotic pressures were experimented with (range 2-20 atm). A pressure of 14 atm was selected (sucrose) which corresponded to a germination rate normally between 60 and 80% for the 47-16 variety. Under these conditions, the germination rate of the sensitive variety 28-206 was approximately 20%.

The typical way of conducting one of these tests is: the peanut seeds are sorted out, treated with fungicide and then regularly distributed in 14 cm diameter Petri dishes (100 seeds per dish), on a layer of sterile sand (180 g); they are then covered by an identical layer. An automatic device keeps the seeds at constant temperature and humidity (29^{0} and 98%).

Any seed whose radicle definitely pierces the cuticle is considered to be germinated. To test a variety, 600 seeds are generally used: 300 are sprinkled with deionized water, the other 300 are sprinkled with the sugar solution (14 atm). A test lasts 38 hours.

Between 1962 and 1965, 32 tests, involving 265 varieties, were performed.

A very great variation in the germination rate of 47-16 was found, depending upon the season and the climatic conditions during the particular year.

The germination percentages reach their maximum during the months with the heaviest rainfall (July - October). On the other hand, during the dry season they are very low and sometimes they reach zero.

Table 11 summarizes the average results.

The 8 types given in the table are represented in various ways: thus, the varieties of the Saloum type furnish 40% of all of the varieties tested; on the other hand, the Valencia type is represented by only 6 varieties.

For the late varieties, the Baol type varieties present the heaviest germination percentage, followed by those of the Saloum type. The Virginia varieties germinate poorly. Among the early ones, the Spanish type varieties offer the highest average coefficient of

germination. The Java varieties germinate very poorly (at high osmotic pressure).

Table 11. Results of Germination Tests with Different Varieties

Types	No. of varieties	No. of varieties as % of total	% germination (at 14 atm)	Dry Wt. of 100 seeds	No. of varieties germinating at more than 40%	% in type
Late:						
Baol	27	10.2	33.0	43.2	13	48.1
Saloum	107	40.4	23.0	51.6	27	25.2
Virginia	25	9.4	7.9	72.0	2	8.0
Early:						
Spanish	10	3.8	29.4	38.4	3	30.0
Natal	10	3.8	20.3	43.0	1	10.0
Volete	11	4.1	7.3	46.1	0	0
Valencia	6	2.3	8.8	44.5	0	0
Java	37	14.0	4.4	52.3	1	2.7

The reference variety was always 47-16; we therefore considered those varieties whose germination rate was at least equal to half of that of the 47-16 variety as being varieties that were a priori interesting. The threshold does not constitute an absolute limit: it was fixed on the basis of the local supplementary experimentation possibilities (subsequent tests: T.C.R. and T.R.C.). The extreme variability of the germination rate at high osmotic pressure should be mentioned; by itself, this cannot constitute sufficient criterion for the evaluation of the drought resistance. This test however made it possible to eliminate 200 varieties out of the 265 tested.

2. Relative Growth Rate Test (T.C.R.)

In 1962 and 1963 it was possible to determine that the relative drop in the growth rate, during the drought period, depended on the degree of drought-resistance of these varieties: the higher this resistance, the smaller the drop in growth rate. The method thus consists in comparing the relative growth rate of the unknown varieties to that of a control variety, the 47-16 variety.

The text is carries out in the following manner: the seeds are planted in plastic pots containing 1,550 grams of earth. The test lasts 25 days and involves two watering phases: during the first the plants are watered normally, during the second, they are subjected to very intensive drought. The dry weight of the aerial portion of the plants is determined. The growth rate is derived under normal conditions (QN) and during the drought period (QS): the ratio of these two magnitudes characterizes the drought resistance of the variety under test conditions.

Between 1962 and 1966, 22 variety tests were carried out. The humidity, temperature and sunshine conditions varied from one test to the next; the results obtained thus enable us to work out only a general classification of varieties (same problem as for the T.O.G.) This is why a 4-level evaluation scale was adopted for the T.C.R. (relative growth rate): excellent, good, average, and poor, corresponding to the classes I, II, III, and IV. Table 12 below, shows the average results obtained per class.

Table 12

Classes of TCR	Number of varieties	% varieties	% germination TOG	$\frac{QS}{QN} \cdot 100$
I excellent	16	30	56,4	59,3
II good	19	35	56,5	36,0
III average	7	13	46,7	20,1
IV poor	7	13	53,6	5,8
unclassified	5	9	----	----

The majority of the varieties revealed a good T.C.R., even when the water supply was reduced (all of the varieties studied revealed a germination rate, at 14 atm, which was at least equal to half of the rate of the 47-16 variety). Classes I and II represent 65% of all of the plants, whereas classes III and IV account for only 26%. The advance selection by means of the T.O.G. thus offers the advantage of cutting the dispersion down.

3. Heat Resistance Tests (T.R.C.)

According to Ghenkel, drought resistance is a property linked to the ability to tolerate an excess of heat and dehydration. These two aspects are linked to the viscosity and the elasticity of the protoplasm and are thus at least partially antagonistic. Plants which

combine dehydration resistance with the ability to tolerate an excess of heat are rare. The heat resistance test enables us to identify them. The test lasts one hour during which the plants are subjected to a temperature of 61° C so selected that no plant will be irreversibly damaged. The tests are performed in a saturated atmosphere on plants between the ages of 15 and 20 days.

The losses caused by heat vary with the tests and the varieties. We can evaluate the resistance to heat by counting the number of variously attacked leaves and by calculating the ratios characterizing both the "instantaneous" resistance and the aptitude of the plants for regeneration after the test.

Between 1962 and 1965, 12 tests were performed. A classification system similar to that used for the T.C.R. was adopted. The varieties are distributed in four classes. The results are shown, by class, in Table 13.

Table 13. Results of Heat-Resistance Tests

Classes of Heat Resistance	Number of Varieties	% Varieties	% Germination T.O.G.
I Excellent	7	15	56,7
II Good	6	13	67,8
III Average	18	39	56,4
IV Poor	11	24	53,1
Unclassified	4	9	----

The varieties in classes I and II only come to 13, in other words, 28% of the total. Those in classes III and IV are much more numerous, 29, or 68%. These percentages are the inverse of those found in the course of the T.C.R. This fact conforms to Shenkel's hypotheses.

The main difficulty in these tests is in the evaluation of heat resistance: in effect, for one and the same variety, this resistance varies according to the time of year because it depends on temperature conditions under which the plants tested had to exist.

Overall, 46 varieties which had been pre-selected by the T.O.G. were tested from the twin viewpoint of growth rate and heat resistance. We can now proceed to a final classification, combining the

aptitudes of the varieties in adjusting to the two types of tests. The field tests were intended to give the last selection which would give varieties combining good drought resistance and high potential yield.

C. Field Experimentation

Two methods were adopted for classifying the varieties: the first consists of placing the plants under artificial drought conditions, diverting the rain water by means of movable covers. This method has been regularly used at Bambey for the past 4 years. It requires a rather complex organization. The second method compares the varieties to be tested by placing them in poor or irregular natural rainfall zones (tests at Louga and Tivaouane).

1. "Drought Tests" at Bambey

Table 14 below, gives the results of the 1962-1965 tests.

Table 14. Results of Bambey Drought Trials

Years	Varieties	Wt of Shells/Stand (g)		Ratio of Yields S/N %
		Reduced Rainfall S	Natural Rainfall N	
1963	47-16	13,5	22,7	59,3
	48-115	14,4	21,4	67,2
	28-204 (1)	5,0	10,4	48,5
	55-437 (1)	7,0	9,3	75,3
1964	47-16	11,2	17,6	63,6
	59-118	13,0	19,0	68,4
	59-365	11,7	18,7	62,6
	24-11	13,4	20,5	65,4
1965	47-16	15,9	18,2	87,4
	59-127	19,9	22,3	89,2
	48-111	13,8	15,5	89,0

(1) Early Varieties

All of the tests were conducted in a Fisher block with 7 replicates. 2 or 3 varieties were compared with a drought control variety (47-16)

The S stands were collected on plots with reduced rainfall, the N stands from plots with normal rainfall.

The ratio shown in the last column gives an indication of the intensity of drought and the reaction of the varieties.

The varieties tested very generally demonstrated drought resistance on the same order as that of the control. The 28-204 variety revealed a resistance that was definitely lower than that of the others and did not produce any good results in the T.O.G. One of the varieties, 59-127, was significantly superior to the control 47-16, regardle s of whether the conditions were "N" or "S".

2. Tests at Louga and Tovaouane

The tests were arranged in Fisher blocks, involving 7 or 8 replicates. The yields are shown in Table 15.

Most of the varieties tested produced a rather good yield. However, some of those which were not adapted to the region, such as 48-115, 48-21, and 56-382, have a productivity that is poorer than that of 47-16.

In particular, the good performance of two early varieties 55-437 and 61-24 and one late variety, 59-127, should be noted; the 55-437 variety is currently in process of wide dissemination throughout the Louga region.

CONCLUSION

The results obtained involve only 3 or 4 years of testing. Some interesting conclusions -- though provisional -- can nevertheless be drawn now. All of the varieties producing good results in the drought tests exhibited drought resistance during the field test which was of the same order as that of the control used, the 47-16 variety, and this resistance was sometimes even greater.

According to our studies there are three varieties which should be particularly emphasized: two early ones (55-437 and 6124) and one late one (59-127). The early ones are above all interesting in the Louga region, where their short cycle is better adapted to the local rainfall conditions than in the case of the late varieties. The 55-437 variety is as of now being widely disseminated and promoted in the northern zone of Sénegal. The later 55-127 variety proved to be quite worthwhile in the southern part of the above mentioned zone, where there is a port; here the situation is thus favorable in terms of mechanical crop maintenance which should allow the replacement of the variety currently promoted there.

In this report we have shown that, on the basis of the influence of the water on the growth, the development, and production of the peanut, we were able to perfect methods which enable us to select the most

TABLE 15

YIELDS OF DIFFERENT VARIETIES OF PEANUTS IN kg/ha AND AS PERCENTAGE OF 47-16 VARIETY

VARIETIES	LOUGA				TIVAOUANE		
	1962	1963	1964	1965	1963	1964	1965
Late:							
47-16	470 (100)	1,615 (100)	1,230 (100)	1,435 (100)	1,875 (100)	2,090 (100)	2,095 (100)
48-21	-	-	-	-	1,375** (73)	-	-
48-115	320** (68)	980** (61)	890** (72)	1,060** (74)	1,160** (62)	1,845* (88)	1,745** (83)
51-20	430 (91)	-	-	-	-	-	-
56-382	-	-	-	-	-	-	1,450** (69)
58-198	-	-	1,235 (100)	-	-	2,120 (101)	-
59-127	-	-	-	1,470 (102)	-	2,390* (114)	2,250 (107)
59-163	-	-	-	1,395 (97)	-	-	-
Early:							
28-204	560* (119)	1,600 (99)	1,510** (123)	-	1,610 (86)	-	-
55-437	700** (149)	1,650 (102)	1,620** (132)	1,8[illegible]5** (129)	1,890 (101)	1,985 (95)	2,715** (129)
61-24	-	-	1,995** (162)	2,[illegible]0** (139)	-	2,110 (101)	2,670** (127)
Tiefora	500 106	-	-	-	-	-	-
PPDS 5%	72	153	120	147	231	236	160
1%	97	208	161	197	313	318	215

drought-resistant varieties as a result of a series of successive approximations - high osmotic pressure tests, relative growth rate test, and the heat resistance test. We also were able to establish that this aptitude is not incompatible with high yield. We can now supply agriculture with three varieties -- 2 early and 1 late -- which meet these requirements.

* * *

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THE INTENSIFICATION OF COTTON-GROWING IN AFRICA AND ITS IMPACT ON THE DEVELOPMENT OF AFRICAN AGRICULTURE

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SUMMARY

The variety of methods of growing cotton and its possibilities for giving profits proportional to the effort expended, no matter how minimal they might be, make this crop an essential factor in the development of many African economies.

Cotton production is developing in three large zones of Africa: the Sudano-sahelian, Sudanian, and pre-Guinean. The role of cotton has been revealed as indispensable to break the isolation pattern which has made agricultural progress impossible.

The Cotton and Textile Research Institute is studying the best conditions for cotton production at all its experimental stations and in all its experimental zones; this is not done by isolating cotton-growing but rather by studying it within various agricultural systems in the above zones. These studies are undertaken in collaboration with pedologists, climatologists, and food-crop specialists.

The impact of the intensification of cotton production on the agricultural system as a whole is apparent in various areas, such as mineral fertilization, crop rotation, and animal traction.

It is difficult to envisage the development of African agriculture without the use of mineral fertilizer, yet in a subsistence economy, financing such an operation is almost impossible at the farmer's level. On the other hand, fertilization of cotton, a profitable crop, is feasible, and its residual effect on the food crops is an immediate, if only partial, solution to the food problem.

The impact of cotton production on the system as a whole makes it possible to define the general orientation of crop rotations which are adaptable to local requirements.

The succession, cotton-sorghum for the Sudano-sahel Zone, yams-cotton-sorghum in certain Sudanian regions, and maize-cotton rotations for the pre-Guinean Zone are currently being studied and even recommended in extension programs.

The widespread use of animal traction and mechanization, in the absence of a profitable crop, comes up against the same problems encountered in the use of fertilizer: lack of money; it is thus not surprising to find simultaneous development of intensive cotton production and the use of animal traction.

The adaptation possibilities of cotton production to very different environments and its progressive improvement make cotton one of the most dynamic crops for the development of African agriculture. Its effect on the agricultural system as a whole is due both to the revenue it brings and also to the new techniques acquired by the farmer.

1. Adaptation and Development Possibilities of Cotton Production

Cotton is characterized throughout the world by the great variety of environments in which it is grown; the same species Gossypsum hirsutum can be found in Central Asia, California, the Mediterranean Basin, the Middle East, and in the tropical regions of America, Africa, and Asia. From the Equator to the 40th parallel, the same species is often grown quite intensively. Except for corn, there is probably no other crop in agriculture that is so diversified.

Modes of production adapt to natural and human possibilities--cotton is produced either by irrigation, partial or total, or with rain-water or the subsiding water after flooding, and cultivation can be manual, mechanized or motorized. Production costs are proportionate to the intensification of exploitation--nominal or nonexistent where there is only human labor involved, they can go as high as 400 dollars per hectare in the most intensive conditions.

This diversity of production techniques--and especially the possibility of giving a rate of return (profit) proportionate to the effort expended--no matter how minimal it might be--and its capabilities for helping general progress, make cotton an essential developing factor for many African economies.

2. Main Production Environments in Africa

Cotton is grown in economic, ecological, and agricultural environments out of which we can distinguish three large rather homogenous zones:

-Sudano-sahelian Zone

This zone has one rainy season, with an average annual rainfall of 1000 mm or less. Food crops are mainly cereals, and livestock is abundant. In the drier regions, irrigation can be envisaged. The soil is generally lacking in phosphorus.

-Sudanian Zone

This zone has only one rainy season, with an average annual rainfall over 1000 mm. Food crops are more diversified than in the previous zone: sorghum, rice, maize, cassava, yams, and peanuts--but livestock is more scarce. In West Africa cultivation on hills is prevalent.

-Pre-Guinean Zone

Two very distinct rainy seasons lead to two annual crops on the same land. The second season usually has only irregular and insufficient rainfall. Maize, peanuts, rice, and yams are the main food crops. The eroded ferrallitic soils of this zone rapidly show potassium deficiencies.

3. Possibilities for Development of the Traditional Environment

Before contact was established with other economies, the agriculture of these environments was characterized by the very limited exchange and barter it involved. Autoconsumption was the general rule. It is certain that there was equilibrium between the fertility of the soil, the exploitation conditions and the needs of the population, but this equilibrium was at a very low level.

The opening up of these areas to the outside world, needs born of new contacts and the appearance of national economies overflowing the traditional framework, upset the local equilibrium. Increasing the volume of production and improving the farmer's standard of living are necessities now, but this transformation must not be made at the expense of the future nor result in the depletion of the soil. This is where experience gained in the last few years in development operations showed the basic role to be played by cash crops, such as cotton, which created a "treasury," nonexistent up to that point, making it possible to affect production as a whole and go from a subsistence economy to an exchange economy.

4. Goals and Organization of Agricultural Research on Cotton

The IRCT (Institute for Research on Cotton and Textiles) hopes to define the best conditions for cotton production, not in isolation but rather within the various agricultural systems of the three zones defined above : Sudan-sahel, Sudanian, and pre-Guinean. Studying these systems naturally requires the close collaboration of the agronomists of the IRCT with climatologists, pedologists and food crop specialists.

The programs currently developed and their operation have been established in terms of the general characteristics of the environment and its possibilities.

-Sudano-sahel Zone

Operation:	Chad.....	Bebedjia Station
	Cameroun.....	Maroua Station
	Mali.....	M'Pesova and Kogoni Stations
	Upper Volta.....	Bobo-Dioulasso and Ouagadougou experimental sectors
	Dahomey.....	Experimental sector of the North
	Togo.....	Experimental sector of the North

Program: Mineral fertilization with particular study of phosphate fertilizers
Possibilities of cotton-sorghum cycle in crop rotation
Possibilities of using organic manure
Evolution of soils in continuous cultivation
Irrigation--water management of crops

-Sudanese Zone

Operation: Central African Republic...Bambari Station
Togo.....Anié-Mono Station
Ivory Coast.....Experimental Sector of the North

Program: Development of soil and mineral fertilization
Study of cultural associations: cotton possibilities
Role of temporary grassland and fallow
Possibilities for yam-cotton-sorghum-rice cycles grown on hills

-Pre-Guinean Zone

Operation: Ivory Coast.....Bouaké Station
Dahomey.....Experimental Sector of the South
Togo.....Experimental Sector of the South

Programs: Development of soil and mineral fertilization
Intensification of maize-cotton cycle during two rainy seasons
Water management of second rainy cycle crops
Study of absorbant complex of ferrallitic soils and cationic K. Ca. Mg. fertilization

Research and experimentation are not equally important throughout the IRCT operations in Africa. At the main stations, the research is mainly general in nature, dealing mainly with the incidence which it can have on the local environment where it is being undertaken; at other places such as at the secondary centers and the experimental stations, the activity of the IRCT consists primarily in adapting and proving the results obtained at the main stations.

5. Incidence of the Intensification of Cotton Production on Agricultural Production as a Whole

5.1 Mineral Fertilization

It is difficult to envisage the development of African agriculture without the increased use of mineral fertilizers; natural deficiencies in mineral elements of the soil are sufficiently pronounced to shortly become limiting factors as soon as cultural and phytosanitary limiting factors have been eliminated. Nevertheless, no matter what progress is made on mineral fertilizers, their widespread use is made difficult in Africa because of their high cost and the limited revenue available from crops. A few crops are in a

favored or privileged position: crops that have a sufficiently high monetary return to make the use of fertilization possible at least in doses that can assure a good annual return.

This rather narrow limitation on the use of fertilizer, that is when money is available, is not very favorable as far as the use of mineral fertilizers on food crops is concerned, in spite of the fact that these crops are still the main concern of the farmer.

Happily, experience has shown that the effects of fertilizer--even when used in small doses--are both primary and secondary, that is they may have substantial direct effects on one crop and then residual effects on a second crop, for example, planted in the same field, in rotation. We will give below some significant results obtained from experimentation with the effect of mineral fertilization on cotton, on the food crops which were subsequently planted in the same field. It would appear from the statistics that the residual effect on food crops of the fertilizer used on the cotton is practically the same. Let us note that this is even more impressive when one notes that the experiments were done on soil lacking phosphorus at the outset.

MINERAL FERTILIZER: DIRECT EFFECT ON COTTON, SECONDARY EFFECT ON SORGHUM

	First Year: Cotton kg/ha		Second Year: Sorghum kg/ha	
	Miner. Fertil.	Control	Residual Effect	Control
Mali: M'Pesoba				
1966	2,803	1,738	1,415	532
1967	2,101	1,221	1,410	598
Upper Volta:				
Faroko	910	435	1,565	436
Hounde	3,085	1,330	1,190	745
Dedougou	2,992	1,653	1,108	562
Togo: Kande	808	293	937	603
Dahomey:				
North Zone Average	1,294	959	1,432	1,070
General Average	1,999	1,090	1,294	649

This is very important because it brings an immediately accessible solution to the farmer for improving his food-crop

production without external aid, which is always artificial and temporary at best. In 1968, the cotton producers of the Ivory Coast will buy 9,000 tons of fertilizer at the market price with no subsidization, and in 1969 the food crops which will follow cotton will also enjoy the benefits of this fertilization.

5.2 Crop rotation

Crop rotation in Africa is not very well defined. For agronomy, it is difficult to study because of the multiplicity of factors which intervene in the crop cycles and their relative importance. Nevertheless, certain basic observations can be made, which can later be adapted to local conditions.

In the Sudano-sahel region, where a phosphate deficiency can be corrected by the use of one annual fertilizer which can affect several crops, it is certain that the cotton-sorghum cycle is indicated, and our research has led us to believe that it would be possible to envisage a continuous cotton-sorghum cycle without needing a fallow period, but we do not want to say this definitely at this moment.

In regions where yams are grown extensively, we are at present thinking of partially levelling the mounds and planting cotton with a mineral fertilizer after the tubers are harvested; the cotton benefits from the soil action of the tuber and the secondary action of the fertilizer used on the cotton increases yield of the food-crops planted subsequently. The yam cotton-sorghum or maize cycle has currently been giving very promising experimental results in Togo and Dahomey.

In the pre-Guinean zone, where there are two rain cycles, the first is regular and abundant and is generally used for growing maize; during the second cycle, which is usually rather unfavorable, the farmer usually attempts another crop which gives yields that are often mediocre. Cotton would seem a good bet, but because of the riskiness involved one cannot envision costly intervention factors. It is nevertheless imperative to think of fertilizing the soil of this highly populated zone, where fields are practically never allowed to lie fallow. The IRCT is planning at present to fertilize maize first cycle, cotton second cycle, by putting the basic fertilizer on maize and by reducing the cotton fertilization to a nitrogen supplement at the time of flowering. All of the fertilization costs will have to be borne by cotton as it is the only cash-crop of the rotation cycle.

5.3 Animal traction and mechanization

Widespread use of animal traction and mechanization comes up against the same problems, namely lack of a profitable money-producing crop, as did the widespread use of fertilizer. It is

thus not very surprising to observe the simultaneous development of intensive cotton production and the use of animal traction. Development organizations have perfected various financing systems in order to make it possible for cotton growers to acquire draft animals and implements on credit, which they reimburse on time, in installments spread over a period of from three to five years. Thanks to this policy, the number of plows in Chad went from 1100 to 14,600 in five years and in Mali--in Fana alone--the progress was from 1000 to 1696 in two years. We give these figures as an example, they merely illustrate a general trend in the Sudano-sahel zone where livestock is abundant.

6. Essential Role of Cotton Production

The adaptation possibilities of cotton to various environments and its progressive improvement make it one of the most dynamic crops of the development of Africa. Its action on agricultural production as a whole is due not only to the revenue which it engenders but also to the new techniques which the farmer acquires. Regular development of production and increased yields can only be conceived under the agronomical angle that we have described; the geneticists, entomologists and the technologists of the IRCT assure the selection of the vegetal material and the techniques, without which no agricultural progress would be possible.

THE ACTIVITIES OF CFDT IN THE FRANCOPHONE COUNTRIES OF BLACK AFRICA

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SUMMARY

After a brief definition of the nature and objectives of the COMPAGNIE FRANCHAISE POUR LE DEVELOPPEMENT DES FIBRES TEXTILES (French Company for the Development of Textiles Fibres), the author describes the organizational methods and the techniques that have enabled substantial cotton yields to be achieved in those regions where the company operates on behalf of the governments, and also those that result in a guaranteed purchasing price for the farmer and the best possible evaluation of this product for its marketing.

* * *

The Act of April 30, 1946, creating the Investment and Economic and Social Development Fund (FIDES) determined that the execution of plans affecting overseas countries could be assigned, in specialized fields, to state-owned companies or to joint state-private ventures. It was within this framework that on the 8th of February, 1949, the Compagnie Francaise pour le Développement des Fibres Textiles (CFDT) was established by executive order as a joint venture corporation in which the French Government owned the majority of the stock.

The objective of the Company is to give, under the sponsorship of the French Technical Cooperation, its assistance, to those governments who desire it, to promote the development of their textile production.

Although the CFDT took part in different actions in favor of sisal or jute substitutes, and is still interested in them, it concentrated its efforts mainly on the cotton production since the imports of foreign cottons represent a heavy load on the balance of payments of the Franc zone. Also because of the fact that this industrial crop can represent a factor in the economic and social progress of the African countries.

The field of action of CFDT includes the following States in the Franc zone: Cameroon, Togo, the Malagasy Republic, Mali, Upper Volta, Niger, Dahomey and the Ivory Coast, and more recently Sénégal, the Central African Republic, the part of Chad and Mauritania.

Only as a reference, since this paper is especially devoted to cotton production in Black Africa and the Malagasy Republic, we shall mention the fact that upon request of the interested governments, CFDT gives its technical cooperation to Morocco, Argentina, Cambodia, Iran, Thailand, Laos, Afghanistan and Lebanon.

It is in the above-mentioned countries of the Franc zone that the main activities of CFDT take place.

A. Methods

Since the objective was to give the Francophone countries of Africa and the Malagasy Republic new resources through a brand-new production or one that could be intensified, it was advisable to collect all the factors comprising the agricultural production and marketing of the product.

I. Agricultural Production

The launching and intensification of this production required, to be on a sound basis, to establish a system that could group the growers, enabling them to adopt, either progressively in those countries where cotton production was being introduced, the whole set of techniques needed to obtain high yields, these techniques having been developed by the Stations of the Cotton and Textiles Research Institute (IRCT) with which we work in close and fruitful collaboration.

a. Intensive grouping

This kind of grouping which is being progressively substituted for the one called "extensive," whose role was limited to disseminate simple techniques, that did not include phytosanitary protection, of mineral or organic fertilizing and encouragement to use animal power, appeals to a large and competent number of people whose action will enjoy the complete support of the political and administrative authorities of the countries concerned under whose control it produces a surplus.

The sector chiefs, who report to a local Direction headed by a specialized agronomist, are the elements responsible for the grouping activities in their zone of jurisdiction, and, as we will see later, for the harvesting of the production.

The sector chiefs are agricultural technicians, either graduated from French Agricultural "Lycées" where they received a cotton training, or "nationals" at the level of rural works engineers, trained by working at least two years as a twin-team with a graduated foreign agricultural technician.

Each sector chief has under him a certain number of group organizers, ten to fifteen depending on the regions. These organizers, recruited locally, often graduate from a School of Practical Agriculture, are those who are in direct contact with the farmers. Each one of them has the responsibility, by the end of the production development program, of 150 hectares of cotton fields that correspond on the average to 150 growers.

b. We have already stated how the nationals, sector chiefs are trained. Let us add that during the time they work as a twin-team with a foreign technician they follow an on-the job training at one of the IRCT's experimental stations.

As for the organizers, several formulas are used. In Cameroon for example, an agricultural training center has been established at Guetale, which received twelve pupils in 1966 and 24 in 1967.

In those countries where intensive production is progressing rapidly, e.g., the Ivory Coast and Sénégal, a supplementary number of organizer-trainees is recruited based on the acreage planned for the following year, and these trainees are assigned to work for a season with established organizers.

Another formula, as it happens in Mali and Upper Volta, is that of having the newly recruited organizers follow and on-the-job training for several months at one of the IRCT's experimental stations.

This training represents a real investment. And this idea is even more logical when one considers that for the first year of launching the intensive production in a given country (Sénégal, Ivory Coast) the ratio is that of 1 organizer per 10 hectares, or a sector chief per 100 hectares, and that it is only after five years at least that an organizer will control 150 hectares and a sector chief 1500 to 2000 hectares, depending on the situation.

Therefore this investment in training should have special subsidies since the grower cannot pay the cost of the grouping activities until the production has reached a certain volume and the grouping has reached its final stage.

c. <u>The techniques of intensive farming</u>

To obtain yields of 1000 kg/ha of raw cotton grown without irrigation, intensive farming requires the following technical means:

- animal power
- mineral fertilizer with organic complement
- phytosanitary protection.

Needless to say that these last two technical means cannot work properly unless it is on well run plantations that have an acceptable production potential. This represents for the growers to follow an agricultural calendar which is the main subject of the grouping activity:

- respect for the sowing date, density of planting and thinning;
- maintenance practices conducted at the proper time.

Failure to follow the agricultural calendar, or lack of efforts in the maintenance practices, can make the negligent farmer lose the advantages of the mineral fertilizer and that of the phytosanitary protection.

It can therefore be said that the increase in productivity of the African farmer, that has been noted for several years in cotton production, is due to a continuous action that is carried out simultaneously at different levels:

1) - Dissemination of selected varieties by IRCT, which, while improving even more a fibre quality known and appreciated for the last fifteen years in the European market, has increased in fifteen years the yield at the cotton-gin from 28.5 to 37.5% (40% in Ivory Coast).

2) - Improvement in the time distribution of carrying-out procedures

Especially in those regions where the rainy season lasts barely long enough to permit the growing of the cotton plant, it is essential that the sowing operation is carried out without delay as otherwise the cotton will be deprived of water before the ripening of the capsules. A whole series of farming procedures—thining, successive weedings, and after the harvest, pulling up the cotton plants to reduce the risk of propagation of parasitary insects—must also be carried out at the proper time. Growers are counseled throughout the growing season by our agents and sub-agents who visit the fields and try, by persuasion, to obtain, in their interest, the maximum speed on the part of the farmers.

3) - Progressive substitution of animal traction for manual tools

The use of the animal-drawn plow in particular, enabling the farmer to carry out under better conditions and more rapidly the preparation of the land, both for his food crops and for the cotton, permits him to increase the planted acreage and the yield. The sowing operation is made much easier by the time gained in plowing. And the land preparation, better made than with a hoe, insures a better take-off of the vegetation and a better retention of rainwater.

This last factor becomes extremely important throughout the years, unfortunately frequent, in which the rainfall is either insufficient in its total amount, or badly distributed during the season. In this way "resowing" operations can be avoided, which apart from the supplementary work they represent risk to be made too late to permit the plant to give a normal yield.

The use of animal power, valuable as it is for the farming practices is also of extreme value for transportation. Thus we introduce gradually not only the plow but also the cart in order to reduce the transport of crops on human heads and to permit the manure preparation and distribution.

4) - Application of mineral fertilizer

On the basis of experimental results obtained at the IRCT stations, we have tried to recommend fertilizer levels that keep in mind the limited financial resources of the African farmer, and correspond to the minimum application that can, however appreciably increase the yield. The levels

presently recommended by CFDT are about 10 kg. of nitrogen and 25 kg. of phosphoric acid per hectare. Since potash has not, or very rarely, until now, brought a positive response in cotton experimentation, this element is not used for the time being, although it can be used in cereal or peanut production which make better use of it.

We believe, however, that it will be possible when the African agricultural economy has reached a first step, to use higher fertilizer levels that will produce a greater yield.

5) - Phytosanitary protection

The selection of insecticide formulae is ruled by the same concern for return.

The objective is to protect the maximum of flowers and capsules with the minimum of treatments and consequently at the minimum cost. The first treatment is given when the first flowers appear, and the others in a systematic way at intervals of 12 to 15 days depending on the regions and the intensity of parasitism, ending by the end of the humid season. Thus, the first part of the production, the most important part which occurs when the plant benefits from sufficient water, is protected; once this main production is assured the parasitism that will prevail in November can be neglected since generally the harvesting begins in December.

In the Ivory Coast the Crop Protection Service has instituted a warning system that gives a certain economy of treatments.

Thus four to six treatments are given, depending on the regions concerned. With the assistance of the above-mentioned technicians, and following the agricultural timetable recommended by CFDT, average yields of one ton per hectare can be obtained in the areas included between the 700 and 1200 isohyets.

In support of this statement in 1966/67, 22,000 tons of raw cotton were harvest in the Ivory Coast on 22,500 hectares of intensive farming while in Sénégal, where the development program has just started, 1,150 tons were obtained from 1,008 hectares.

d. Transition formula: improved traditional farming

Cotton farming, as promoted by CFDT and with the full support of the authorities of that country, has rapidly developed in North Cameroon where from 1,400 hectares in 1951, on which 525 tons were harvested, the cotton acreage reached in 1966/67, 98,000 hectares with a production of 55,810 tons of raw cotton.

The experimentation with mineral fertilizers and the control of parasites, contrary to what happened in other countries only gradually provided possible fertilizer formulas and valid phytosanitary treatment methods. This is due in part to the particular nature of the moderate parasitism prevailing in North Cameroon.

Consequently it can be said that starting with average yields, more satisfactory than those known in extensive farming in the other cotton countries of Africa, the improvement of traditional techniques should lead to an increase of production without use of mineral fertilizers and phytosanitary protection.

The extension programs were then:

- early sowing with a good density
- thinning at a good time, and right maintenance procedures
- popularization of animal plowing through a system of loan of equipment created by CFDT.

In this case the grouping is lighter than in intensive farming since an organizer control on the average 400 hectares and a sector chief from 5,000 to 6,000 hectares.

The results obtained are remarkable since, as it can be seen in the enclosed graph, the average yield went from 353 kg. per hectare in the three year-period 1951-54 to 605 kg. per hectare in 1963-66.

The interest in intensive farming, however, is not lost in Cameroon. With these techniques presently better known, 1,100 hectares were fertilized and treated in 1966-67 giving yields of 1,300 to 1,400 kg/ha.

II. Marketing

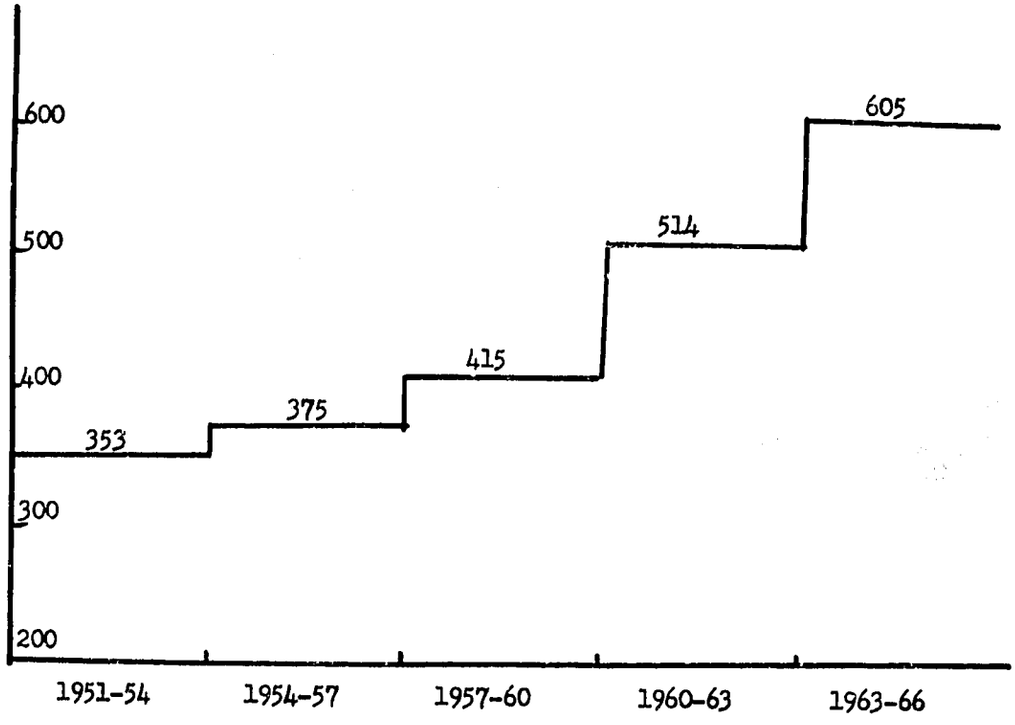
It is not our intention to develop here the characteristics of the cotton world market. Let us say only that the present trends of the market make more indispensable than ever the existance of the mechanism of stabilization of the purchasing prices to the growers established in 1955. In the cotton-producing countries of the Franc zone this mechanism involves funds for the stabilization of cotton prices.

These funds were at first fed, when needed, from subsidies of the French Fund for Support of Overseas Textiles, created in 1956, and which was in existence for some 10 years before the European Development Fund took over, although in much different conditions as everybody knows.

The need for developing countries to obtain guarantees of stability in the prices of their products has been emphasized too often to make it necessary to discuss it here.

It is important to reserve for the grower as important a share as possible from the f.o.b. price of fibre cotton, as guaranteed by the government, through the action of the price support funds. From the purchasing price to the grower to the f.o.b. sale price of the fibre, certain items are independent of the responsible organization (fiscal charges, railway rates, etc.) but conversely others are the result of its efficiency. This is, for instance, the cost of harvesting, ginning, rood transport, if this transport is the responsibility of the marketing organization.

DEVELOPMENT OF PER-HECTARE YIELDS
(Kg. raw cotton by triennial period)



Tons of raw cotton produced (total) during the triennial period

12,124	50,189	64,094	95,770	147,089

Areas Sown with Cotton under the Direction of

CFDT in Africa - 1966-67 Program

Country	Total Area	Fertilized and Treated Areas
Senegal	1,038	1,038
Mali	44,790	13,333
Upper Volta	52,355	5,205
Ivory Coast	23,832	23,832
Niger	16,500	296
Dahomey	11,800	8,636
Cameroon	97,819	1,100
Chad	153,447	16,607
Central African Republic	28,187	4,510
Madagascar (1966)	4,581	4,581
	434,349	79,138

Thus the contribution of CFDT has been on:

1) Ginning, where the concentration of plants, although it increases the costs of transportation, enables a reduction of overhead and the appreciation of the by-products: for example, a gin plant of 20,000 tons can profitably be complemented by an oil plant.

In those areas where the humidity permits it, a substantial economy has been obtained in packing by substituting wire for the classic hoop-iron.

Also, the adoption of high density presses have led to a reduction in the cost of shipping to the embarkation points of the fibre.

2) Transportation, by creating CFDT motor-car pools for transportation over non-paved tracks and without return freight.

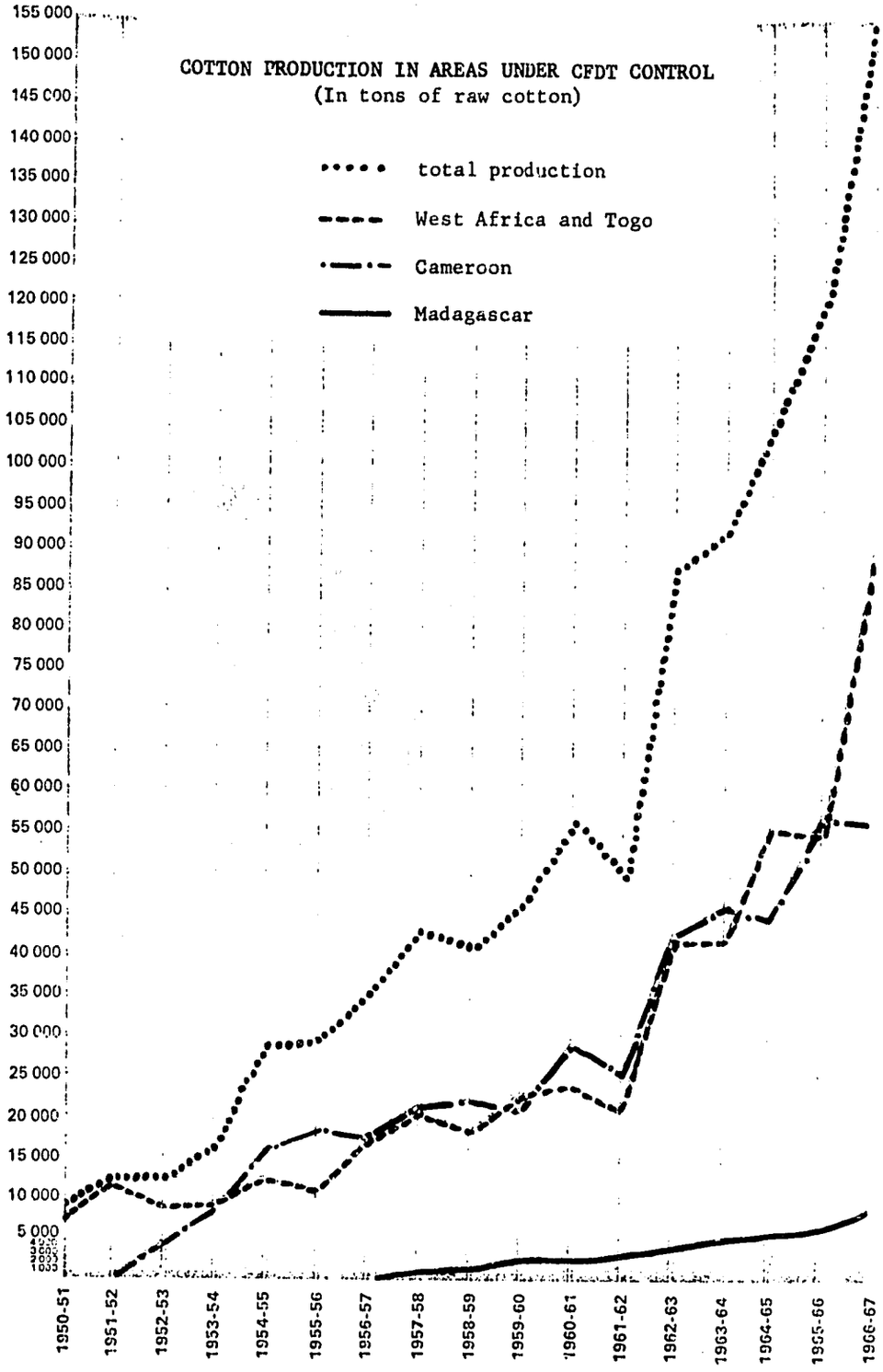
3) Harvesting: the use of the organizers, after the farming season, for the operations of purchase of crops, permits charging to marketing the personnel only for the relatively short period of the harvest and at the same time insures the full employment of our agents.

The quality of the product, by demanding a careful sorting on the part of the growers who, when their cotton is well presented, receive immediate payment at the market place.

To conclude let us say that in the cost price of the fibre, embarkation point, for exported cottons, the share of the grower reaches two-thirds for countries far away from the coasts, such as Cameroon, Mali, Upper Volta, Niger and North Dahomey, which can be considered as highly satisfactory. Moreover, almost the whole of the other third remains in the country in the form of salaries, transportation costs and taxes.

* * *

N.B. - In order to limit this paper we have not touched upon the intervention of CFDT in the case of irrigated farming, which has less consistent aspects from one point to another. Nor have we touched either on our different interventions of Technical Cooperation outside Francophone Africa.


COTTON PRODUCTION IN AREAS UNDER CFDT CONTROL
(In tons of raw cotton)
total production
West Africa and Togo
Cameroon
Madagascar
155 000
150 000
145 000
140 000
135 000
130 000
125 000
120 000
115 000
110 000
105 000
100 000
95 000
90 000
85 000
80 000
75 000
70 000
65 000
60 000
55 000
50 000
45 000
40 000
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1965-66
1966-67

IMPROVING CASSAVA IN AFRICA

Gilbert Cours-Darne, La Romieu, Gers,France

SUMMARY

In order to increase cassava yield, one of the first steps lies in selection and the improvement of types and varieties, because the plants that are actually grown at present have many defects causing low yields. Improvement should concentrate on the following points:

1. Utilization index (U.I.) - This has to do with the ratio of $\frac{\text{Root weight}}{\text{Plant weight}}$;this should vary between 0.90 and 1.10.

Approximately two-thirds of the cassava plants in Africa have an unfavorable utilization index, lower than 0.90, which means that the plant is using most of its nourishment for making leaves and wood instead of using it to produce starch.

Improved varieties would make it possible to obtain optimum yield with each different soil type.

2. Starch content - Among the plants found in Africa having a good utilization index, it has been observed that many have overly aqueous roots. They give a very low yield in starchy matter and cannot be used for the production of starch. In the selection process, varieties with a density of less than 1.15 should be eliminated (that is less than 30 percent of total starch).

3. Low resistance to humidity - It is not unknown for plants introduced into the environment to be very sensitive to humidity. Thus the Sao Pedro, the Criolina, and the Bogor, which were introduced into Madagascar, had to be discontinued because of their low resistance to humidity. It is indispensable that plants be carefully tested for long-range resistance to humidity before they are distributed to the farmers.

4. Sensitivity to the mosaic virus - The mosaic virus reduces the leafy surface of the plant which slows down starch production, and under severe conditions, the plant's roots cease to grow. The degree of contamination depends on two factors:

a) varietal resistance: this is ascertained by conducting experiments with test plants in infested environments, and the varieties range between very high (but never absolute) resistance and the destruction of the plant within a few months.

b) the ecological environment: the hotter and more humid the region, the more virulent the disease. Coastal regions with high rainfall are therefore the most seriously affected.

5. Low resistance to accidents to the root - This means low resistance to various changes occuring inside the root itself such as necrosis, darkening, liquefaction of the starch, etc.

6. Growth characteristics - Ease of regrowth after transplant or grafting, ground cover, etc.

Conclusion: In order to get appreciable and rapid results, it is necessary to put under observation several hundred thousand hybrids each year. An African Center, chosen among the existing ones, should be equipped and subsidized to carry on work to this effect. The results obtained should then be tested in the various ecological regions.

INTRODUCTION

In Africa, yields of cassava (Manihot utilissima) normally reach only ten tons per hectare and fifteen tons per hectare is exceptional.

Improvement of the plant itself is the best economic solution to the problem. Of course, improving the soil and using better means of production would also contribute to increasing the yield, but that is a very slow process, especially in a country where the use of fertilizer is not always possible. Utilization of properly adapted varieties can on the other hand be done quickly, and can give results such as those seen in Madagascar where yield per hectare has doubled in the last decade.

The improvement of varieties has been studied in various parts of Africa (Grimari in the Central African Republic, Yangambi in the Congo, Bouaké in the Ivory Coast, etc.) but only at the Station Agronomique de l'Alaotra has this research been carried out on a large scale.

I. Improvement of cassava in Madagascar

Faced with the general concern over the disappearance, due to the mosaic disease, of the local variety of cassava known as "manioc du pays" the Government decided to do everything possible to avoid a national disaster. Not only was cassava used to feed a large portion of the population, but also the Island exported thousands of tons of tapioca, dry manioc and starch annually.

Put in charge of finding a solution to the problem, the Alaotra Station did the following:

a) collected for observation all the local varieties of cassava and the main varieties planted throughout the world;

b) studied these varieties in order to ascertain their qualities and their faults;

c) multiplication of those then showing sufficient resistance to mosaic in addition to other appropriate cultivation characteristics.

d) numerous hybrids were bred to correct the faults of the plants under observation;

3) development of cuttings.

Very quickly, results were obtained. According to the regions and the soil, varieties that were introduced such as Bouquet de la Réunion, the Java 12/23, the Criolina and first selections such as the 7A and the IB, stopped the ravages of mosaic and many plantations quickly regained some of the yield that they had lost. Nevertheless, the varieties that were introduced were not perfect, each had some or many faults and it was difficult to attain the former yield of twelve tons per hectare then considered a minimum for profitable output.

Improvement of Cassava at the Station Agronomique de l'Alaotra

As Manihot utilissima is heterozygotic, the seeds produced very varied individual plants and some were very interesting (such as 3A, 7A, 10A, IB, 5B), but the Center decided to use a great number of choices of genetic combinations and to undertake numerous hybridations, as varied as possible.

To do this, on a plot of land remote from all other cassava (at least 500 meters), they placed on the periphery several rows of male generators and in the interior of the square one or more rows of the female varieties to be fertilized. Their inflorescences were removed as soon as they appeared, by specialists who visited the plot every day. The work was simplified when a clone of flowering, sterile male plants was used as a female generator.

The seed was gathered as soon as the capsules darkened, spread out in layers and planted three months later. Hybrids coming from this seed after two years growth in an environment infested with mosaic were put through a first selection, and only those which appeared satisfactory and immune were multiplied.

The first series of cuttings were done as follows: as they were pulled after two years, only the perfectly healthy plants were kept for the second cutting, those without a trace of mosaic, any kind of rotting or any harm at all to the root, with a high utilization index, good yield, and a density higher than 1.150. This extremely severe process of elimination meant that sometimes 99 percent of the slips were discarded. The second cutting was done on 100 square meter plots, where the plants stayed another two years. If their qualities were confirmed, they were grown in various localities on a trial basis, to be finally distributed.

The 30,000 to 50,000 hybrid seeds produced each year gave about 15,000 to 20,000 individual plants. Five thousand of these went through the first multiplication process and only some twenty went through the second cutting phase. Only two or three survived after the comparative trials, but they were particularly worthy.

Thanks to them:

- the mosaic was held in check
- planting in inferior soils was made possible
- yield went from 12 to 30 tons per hectare
- yield of starch for the factories went from 21 percent to 15 percent.

Below, going from one to ten, is a detailed schema on the agricultural and industrial qualities of the main hybrids obtained.

Number of the Hybrid	Yield Aptitude	Yield of Starch	Resistance to Rotting	Resistance to Mosaic	Striking Aptitude	Level of HCN
H32	7	7	4	4	2	6
H34	5	5	5	6	6	8
H35	6	6	6	4	6	3
H41	5	6	5	8	5	3
H43	7	6	6	6	4	2
H44	8	6	4	4	6	5
H45	6	5	5	4	4	1
H46	6	6	7	8	4	7
H47	5	5	6	4	5	2
H48	5	6	6	6	3	3
H49	7	6	4	6	8	6
H50	6	5	5	6	5	6
H51	7	7	7	8	6	6
H52	6	6	6	7	6	1
H53	6	6	6	2	5	2
H54	7	5	6	6	6	3
H55	6	5	8	8	6	7

Hybrids number 54 and 55 have Manihot glaziowii among their ancestry. It should be noted in this context that it was only after three repeated crosings of M. glaziowii and M. utilissima that the percentage starch in the roots was approximately normal. Nevertheless, the introduction of this species did not bring the vigor and resistance to mosaic that was expected from it. The pringlei x utilissima hybrids have sterile female flowers and the plants obtained were rather poor.

The figures of the above table are applicable for Madagascar and especially for the Lake Alaotra region which has the following climate:

- average annual temperature: 20°75 (C) with 7° minimum in winter and 30° maximum during the hot season;
- annual rainfall of 1200 mm, spread over a period of about five months;
- a dry and cold season that goes from May to October.

When the Madagascan plants were experimented with in Gabon, the results were different. The numbers H34, H45, H48, H49 and H51 made the best showings.

II. Cassava — agricultural and starch characteristics

A study of the life of cassava is necessary to understand more fully what should be its agricultural and industrial qualities. The observations below apply to Madagascar.

Cassava grows in several phases, each lasting as follows:

Striking phase	0.5 months
Installation phase	2.5 months
Leaf development phase	3 months
Tuberization phase	5 months
First dormant phase	1 month
Second activity phase	5 months
Second tuberization phase	5 months

A. Striking and installation phases — striking aptitude

The ease with which a cutting can take root and grow properly is an important agricultural aptitude. Everyone knows that there are clones that grow easily even if it is dry, while others fail rapidly.

If one examines the cassava cutting which one has just put in the ground, one can see from the fifth day on, at the second or third eye covered with earth, ten or so roots that grow at a rate of about two centimeters per day.

On the tenth day, whereas the exterior eyes show tiny folded leaves, on the base of the cutting scar callus appears, from which the basal roots develop. These will become the true roots of the plant. They will take care of the nutrition of the plant and will tuberize. In three months they will have taken possession of the land which has been allotted to them.

The lateral roots which appeared first will disappear, but their part will have been a determining one during the cutting phase. Without these lateral roots, the callus and the basal roots will not appear, or they appear very late, which dooms the cutting to dehydration. Thus the quick production of lateral roots is something to look for in selection.

B. Leaf development phase

After the plant settles itself, there is a phase when the plant gets its leaf system. The leafy surface may exceed five square meters for an average plant.

Photosynthesis lays down reserves which migrate at night into the tissues. At night the leaves contain six to seven percent of starch while they only contain two to three percent in the morning. But this normal activity is affected by the mosaic virus which reduces the foliage system.

Mosaic

Besides the vector Bemisia Manihotis Frappa which transmits the virus from one plant to another, only grafting will infect new plants.

Varietal resistance

All Manihot utilissima and Manihot glaziowii clones are affected by this virus, but in varying degrees. Some varieties die before their roots can grow; for others, the virus only produces mild blemishes which do not affect the plant, which grows apparently normally.

Manihot pringlei, on the other hand, is practically absolutely resistant; it can get the disease only through grafting and even then, gets rid of the virus after two years.

On very resistant varieties, the virus seems to be pushed down to the stump of the plant, and it is therefore possible, starting from infected stock, to obtain after many cuttings from the extremities, plants without mosaic streaks or blemishes.

In mild cases, the virus is not harmful to the plant, but as soon as the leaves begin to wither, that is as their surface becomes smaller, there is a loss of weight and density of the roots and all parts of the plant show an increase in total nitrogenous matter.

Effect of the environment

The disease is especially virulent in hot and humid regions. This virulence is manifested by a higher degree of contamination and more severe results.

Virulence diminishes with altitude. At Tananarive, for example, at an altitude of 1300 meters, it is possible to grow plants that have been abandoned on the coast because of their low resistance. The same phenomenon occurs in regions with a long dry season. In both cases, the elimination, as soon as cutting has been accomplished, of roots bearing blemishes, is enough to assure a healthy plant.

C. Tuberization phase and dormant stage-utilization index

At the beginning of this phase, in the seventh month of growing, the production of dry matter may attain fifteen grams per day for an average plant. The products are used as follows:

50 percent to form stem
15 percent to form leaves;
35 percent for reserves.

Next, the leafy part of the plant becomes progressively reduced and practically disappears by the ninth month. At that moment the plant uses its products equally to form wood and to store up reserves.

During the dormant stage which is during the eleventh month after planting, activity is reduced, because the leafy surface is reduced to about one square meter. From that point on, three-quarters of the products are used for reserves, and at the end of that period, about one year of growing, that the roots are richest in starch. At that moment one must measure the utilization index.

Utilization index:

It is given as follows:

$$\frac{\text{weight of roots}}{\text{weight of stem}}$$

It should vary between 0.90 and 1.10 and shows the aptitude of the varieties for producing starch. Each clone has its own and it remains the same for a given environment; it decreases as the fertility of the soil is increased. If a variety accustomed to poor soil is planted in fertile soil, the plant is confused and produces a great deal of wood to the detriment of the roots. Thus, as the soil improves in richness, it is necessary to plant cuttings with a higher and higher utilization index. On the other hand, it is useless to plant a cutting with a very high utilization index in poor soil. It will not develop sufficiently.

Increasing the number of plants per unit area is a practice employed to improve yield, but which lowers the utilization index, because under the effect of competition, the stems increase. This is especially true the older the plantation. Close planting is not advantageous unless there is early harvesting.

Most of the plants in Africa have a poor utilization index, which means that too much of the products of photosynthesis go towards producing useless stems at the expense of starch.

The only remedy is to develop clones for each soil type with a satisfactory utilization index.

D. Second year of activity and second tuberization — starch

During the second year of growing, the various phases of activity are well-defined. At the beginning, during the thirteenth and the fourteenth month, all the products of photosynthesis are used for a new leaf system. During the fifteenth and sixteenth months, the stem absorbs 75 percent of the plant's energy. The accumulation of starch begins in the seventeenth month and increases through the twenty-second month. Harvests after two years of growing yield particularly rich roots.

Starch in the roots

The formation of starch granules in the roots is continuous. The amyloplasts begin their activity from the first month and after sixty days one can find full-sized granules. At all times, therefore, there are granules of varying sizes in the root, of from two to thirty microns, but as the plant gets older, the proportion of large granules increases and reaches a maximum during rest periods.

At Alaotra, the following average diameters were found expressed in microns, in the clove Bouquet de la Réunion:

Size of Starch Granules in Bouquet de la Réunion Cassava — Alaotra

Age at:	Average Diameter (microns)
6 days	2.80
1 month	5.56
3 months	11.14
6 months	14.33
9 months	15.43
12 months	13.74
18 months	15.56
24 months	15.06

The average diameter is just about constant for plants examined during the rest period, but appreciable differences exist among the different varieties: Bogor: 13.33; Sao Pedro: 14.00; Criolina: 14.50; Bouquet de la Réunion: 15.40.

During extraction, large granules have been observed, on the order of 10 percent, at the time when the plant resumes its activity. Cutting the stems also causes a reduction in their dimension. It is probable that in each case, the reserve of the stem is insufficient, so that the granules lose their substance to feed the growing tissue.

Density of the tuber

It can go from 1.00 to 1.20, but can be less than 1.00 if the roots have suffered or if the plant is developing in soil lacking in potassium. Low during early growth, the density increases continuously until the dormant period at which time it reaches its maximum.

The amount of starch is characteristic of the varieties, each clove having its own.

As a result of the vigorous selection, the cloves distributed throughout Madagascar have a density of more than 1.150. Those in Africa, on the other hand, have a low density, often less than 1.100. It can be said that a plant has impaired starch depsition when its density is less than 1.130, which corresponds to a total starch content of about twenty-five percent, or twenty percent in yield of industrial starch.

Resistance of the roots to humidity

This means resistance to asphyxia, a phenomenon to which cassava is highly subject due to the underground accumulation of starch.

Certain alluvial soils do not dry out rapidly enough after rain falls, and the water causes the roots to rot.

The resistance among the cloves is highly variable and some plants grow poorly in low alluvial soil: Criolina, H32, H44. Others, however, grow very well under these conditions and only die if there is very heavy flooding: H51, H55.

III. Regarding creation of an African Research Center on cassava

A process of selection undertaken on a very large scale would allow us to correct the faults in African cassava and therefore improve the yield. In order to get good results, each region and each soil type must have a variety perfectly adapted to it.

The improvement of cassava will only give tangible results if it is carried out on a high plane. This labor should be entrusted to an African Center, chosen among those that are already in existence; it should be given sufficient funds and good geneticists, pedologists, chemists and phytopathologists.

This Center should:

- collect all varieties of cassava grown in the world, and study them to discover their qualities and their faults;
- collect also all species of the genus Manihot;
- proceed to numerous and complex hybridizations which is the only way to get a large number of plants to choose from;

- improve cultivation techniques, study fertilization possibilities;
- coordinate their research with research carried on elsewhere in order to decide once and for all what plants should be distributed where.

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RESEARCH ON ROOT CROPS

P. Silvestre, IRAT

SUMMARY

In Africa, tuber plants are essentially used for food. Only cassava has industrial outlets, in the Malagasy Republic and Togo.

Economically, the most important are cassava and yams.

These species present very different problems for agricultural research.

Cassava, which is a well-known plant, can adapt easily to different ecological situations and farming conditions; further, in an agricultural development situation its uses can be diversified; apart from its food role it can find outlets in industry (starches) and in cattle feeding.

Most of the problems it presents, such as yield, starch content, resistance to mosaic disease and to rotting of the roots, and adaptation to different possible farming cycles, are related to genetic improvement.

Important work has been done in the Malagasy Republic in this field.

Yams, unlike cassava, are not widely known, limited to a particular ecological zone, and seem destined to remain a food crop.

The farming techniques required by the yam demand considerable work that cannot be mechanized and which is incompatible with an improvement in the standard of living and an increase in the cost of labor.

It can well be asked whether in an agricultural development environment yams will become a luxury product, cultivated with the same minute care given to vegetables, or whether they will remain an extensive cultivation crop.

For the second hypothesis to be realized, basic agronomical research is needed.

Preliminary research must deal with genetic improvement (floral biology, compatibility of cross-bredding between varieties and between species), physiological studies of the growth of tubers, photosynthetic activity, with and without support, and mineral nutrition.

* * *

1. Root Crop Situation in Africa

Several species of root crop are cultivated in Africa for different reasons.

Cassava is still the basic food of the forest regions of West Africa and Equatorial Africa, but its cultivation, thanks to the remarkable adaptability of the plant, extends well beyond those limits to the dry tropical regions, where it plays the role of a vegetable, of a complementary food or that of insurance against the possibility of bad cereal harvests.

This species can also be used industrially, as is the case at present in Madagascar and Togo, and it could be used in future situations for feeding animals.

Yams are often a basic food in Africa in the humid tropical climatic zones on the borders of forests and savannas; the economic requirements of this plant prevent its cultivation outside the more favorable zones.

Taros (Collocasia and Xanthosoma) are rather important for the nutrition of the populations of the West Cammeroon and are a complementary crop in the most humid regions of Africa and Madagascar.

Finally, the sweet potato, which is nowhere a basic food, is grown almost everywhere in the African continent and Madagascar as a complementary vegetable.

The most important research done in the francophone countries on tuber plants is that done on cassava by G. Cours Darne and his successors in Madagascar. Their findings are being presented as a separate paper. That work deals mainly with the genetic improvement of the species which has made it possible, by means of successive hybridizations, to create a range of clones with high yields, rich in starches, resistant to mosaic and adapted to various conditions of farming and able to put to different uses.

The problems of HCN toxicity and its evolution in relation to the development of the plant, of mineral nutrition, fertilization, and the technology of starch industries have also been studied.

In other countries IRAT has initiated studies, not too developed up to now, on: cassava, in Senegal, Niger, Dahomey, Central African Republic and Gabon; yams, in Dahomey and Cameroon; sweet potatoes in Madagascar and Gabon. It is to those studies and their future orientation that we devote this paper.

2.

2.1 Cassava

In Senegal cassava is being studied for possible crop-diversification. This plant will continue to be used as a nutritional complement, but one can foresee the extension of its use as animal feed, and it could have several industrial outlets for local uses (baking products).

The work consists mainly in clonal selections from seeds. The essential objective is productivity; since the climatic conditions of the country are not favorable to the mosaic vector, the characteristic of resistance to this virus is not taken into account. Clones of high productivity, suitable for these extreme conditions, have already been selected.

As regards fertilization, research has shown the importance of mineral fertilizers, especially those with a nitrogen or potassium base.

The best planting techniques have been determined.

At present studies are being made on the best time for planting cuttings and for harvesting, based on the proposed farming systems. Also, there are experiments being conducted on simple techniques for drying tubers that can be used in a family farming situation.

In Niger the objectives and conditions are similar to those of Senegal; the studies deal only with tests of local or selected varieties, mainly from Senegal and Madagascar.

In Dahomey, Central African Republic and Gabon, it is also essentially selective research: the local plants are compared with the selected varieties that have been introduced. In those countries resistance to mosaic, a factor on which the productivity of the plant is very dependent, is particularly looked for.

Through the work done in Madagascar and various other countries in the world, cassava is rather well known as to its ecological requirements, cultivation techniques and mineral nutrition requirements.

Research on this species must first concentrate on variety improvement, since research in the other fields will have to be tested for adaptation.

The variety improvement objectives are:

- Resistance to mosaic.
- Resistance to rotting of the roots (adaptation to heavy soils).
- Productivity in roots and starch.
- Depending on the situation, high or low hydrocyanic acid levels (high when what is desired is to avoid the damages caused by wild animals and when the roots are consumed after processing, industrial or otherwise, thus eliminating the toxic product; low in the opposite case).

Cassava adapts well to modifications in the farming calendar. Planting of cuttings can be made at different times provided that they are sufficiently humid, and cassava can be harvested a little before or a little after the optimum date. In that event, the small decrease in production that has been observed, is compensated for by economic advantages. Thus, in the case of industrial plantations, it is possible to stagger the operations in the field and the working period of a starch plant, and in the case of cassava for consumption, harvests can also be staggered.

Cassava's flexibility and ease of adaptation to different farming systems can still be improved through research of varieties with vegetative cycles of different lengths.

2.2. Yams

In the case of this plant, IRAT has only made some studies on the performance of local species and varieties, mainly in Dahomey.

Yams are represented in Africa by several species: *Dioscorea cayennensis*, with its two sub-species: *cayennensis* and *rotundata*; *D. Alata*; *D. Bulbifera*; *D. Esculenta*, each of them including several varieties that respond to particular food or farming requirements.

In its present state, yam-farming requires a great deal of work, for, in preparing the soil sizeable mounds must be made, sowing must be done with large tubers at a rate of two or three tons per hectare, supports must be set up, they need maintenance and care, and they can only be harvested by hand. Storage also presents a problem.

One can ask the question of what will be the future of yam production in a situation of economic development: will yams become a luxury product, cultivated with all the care given to fresh vegetables, as is the case at present in the French Antilles due to the high cost of labor, or will they remain a product of extensive cultivation?

For the second hypothesis to become a reality it seems that extensive research is needed. This can be summarized as follows:

a) Basic Research

- Gathering a large collection of assorted varieties from a survey on the uses of varieties grown.
- Studies prior to genetic improvement: research on fertile varieties; methods to induce blooming; study of compatibility of inter-variety and inter-species crossings.
- Varietal improvement, first through selection among varieties grown, then by genetic means.
- Physiological studies.

- Development: relationship between germination and size and features of seed tubers; photosynthetic activity and index of leaf surface of various variety types to find varieties that can dispense with supports.
- Dormance of tubers under conservation aspects, and artificial interruption of dormancy for early sowings and homogeneous planting.
- Respiration of the tubers for the improvement of conservation.
- Study of mineral nutrition.

b) Applied Research

- Experimentation of pure cultivation on ridges.
- Study planting density-interaction: preparation techniques x planting density x weight of seedlings.
- Study of supports.
- Study of conservation of tubers (anti-parasite and phyto-sanitary treatments, mode of conservation).

2.3. Other Tuber Plants

Apart from casava and yams, other tuber plants that are grown in any quantity in Africa and Madagascar are the sweet potato and taro.

The sweet potato is a species sufficiently well known in the world to have been the subject of rather advanced research, especially in the United States and certain other countries in America.

Considering the limited importance of this species in Africa, the studies to be made should be oriented only towards local adaptations of results obtained in varieties, cultivation techniques and mineral nutrition.

Taros (Colocasia and Xanthosoma), contrary to the sweet potato, are very little known, and their cultivation is much more climatically limited.

It does not seem likely that these plants will present important research problems.

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AFFORESTATION SPECIES FOR THE SAVANNAH

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It appears desirable before describing the principal reforestation species in the savannah zone to outline first some ecological data and then some economic considerations.

1. Ecological Factors

Taking the route from Abidjan—Bouaké, the savannah appears on the horizon from the point when descending the little pass of Singrobo where numerous cocoa trees still flourish. One then leaves in fact the high semi-deciduous forest to cross a totally different area composed of the principal grassland species (mainly Imperata), trees and spread-out shrubs and African palm groves (Palmyra) which are called the Baoulé vineyards. The following the road one again sees towards Yamassoukro high forest semi-deciduous species as well as cultivated coffee and cocoa.

In fact we have very different groups of plants. Two sectors can be distinguished going from north to south:

- the preforest sector
- the sudano-guinean savannah.

The preforest sector is actually an intermediate zone between the savannah and the semi-deciduous forest and, as the name indicates, comprises extensive areas of savannah overlapped with dense patches of forest composed of characteristic species such as Samba, Beté, Lingué, Iroko, Oualelé, Ako, etc.

This sector has a large area where a corner projects towards the south, which is customarily called the "Baoulé V" on account of its typical landscape.

On the other side there is another very dry zone located in the North which forms the sudano-guinean savannah; this is characterized by the presence of many woody species already met in the preforest zone but well-defined including kerketé (Anogeissus), baobab (Adamsonia digitata) and mahogany (Khaya senegalensis). In this zone the semi-deciduous forest has totally disappeared and is replaced by open forest with sau (Isoberlinia doka) and somon (Uapaca somon).

These vegetal formations are strictly dependant on ecological factors arising through:

Climate. Going from south to north leaving Singrobo it should be pointed out that the water supply does not decrease. On the contrary the rainfall increases as one approaches the Fouta-Djallon mountains from more than 1,100 mm in the East (Bouna) reaching 1,500 mm in the West (Odienné).

In fact the reduction of the humidity is felt largely through the severity and length of the dry season, under the violent action of the continental winds (Harmattan).

It should be mentioned that there are two dry seasons in Lower Ivory Coast, which become less marked in Middle Ivory Coast and which finally blend and produce only a single very marked dry season (with a single rainy season) in Upper Ivory Coast. These climatic phenomena strongly influence the growth and all the physiology of the tree (shedding leaves once or twice a year, flowering, fruiting, etc.)

Soils. The soils of the region under consideration are essentially of two types, schistous and granitic-gneiss, with locally very sandy zones (granitic sands, colluvial sands) like those observed in the Baoulé V.

These soils can be more or less eroded and it is for this reason that the plateaus are always richer than the slopes and particularly than the sandy alluvial soils of the river banks. Moreover the lateritic crusts can cover the surface to a greater or lesser extent.

They contain a greater or lesser proportion of lateritic stones with concrete horizons at a certain distance from the surface of the soil. This is important for the development of the main and lateral roots.

As regards the depth of cultivable soil, three types of soil can be distinguished on granitic-gneiss parent rock:

- soils of more than 75 cm depth, with little gravel and on which Imperata cylindric disappears three to four years after planting trees;
- soils of average depth between 40 and 75 cm with a dense gravel zone;
- shallow soils (less than 40 cm) in which Imperata is solidly established while all natural or introduced arboreal vegetation remains sparse and weak.

Human Factors. Fire, inconsiderate or badly carried out cutting and inappropriate treatment can entirely ruin the reforestations.

In sum one can say that the principal unfavorable factors for the satisfactory growth of artificially planted forests are:

- the length of the dry season and limitations on the available moisture. The selection of better soils and working them in depth

to aerate them would enable these faults to be remedied to a certain extent;
- the presence of Imperata grass which must be eliminated by the introduced crop or by tractor;
- termites (for eucalyptus) which can be protected against by the use of dieldrin;
- defective pruning which can be avoided by surveillance and management of the plots. This is possible by grouping the plots together.

2. Economic Factors

It seems indispensible to us to note that all forest plantings must be done within an economic objective of national scope. Apart from some plantations designed to satisfy local needs and which need not be included, we feel that all reforestation must be carried out with a well-defined objective. This implies planning, concentration of reforestation, determining the markets and establishing the profitability.

One cannot any more allow, in our opinion, at this time to make scartered disperse reforestation, difficult to control and for which the exploitation will be less convenient and therefore less profitable because of too great a distance from the ports or the sawmills.

I therefore believe that it is necessary to establish sizeable units, composed of conveniently chosen species, selected and planted under the proper climatic and soil conditions. In this type of operation the plantations could be surveilled, managed and exploited in order to supply the local factory (pulp-mills, sawmills, etc) or the current commercial outlets.

As a consequence, it is on the basis of existing (or projected) factories that decisions regarding reforestation should be taken. It should be noted in this regard that certain raw materials keep up more the transportation than others for it all depends, actually, on their commercial value. Thus for woodpulp, wood delivered to the factory should not cost more than around 2,000 francs per cubic meter (or 3,000 frs. a day ton); wood delivered to the sawmill would be around 2,500 to 3,000 frs. per cubic meter, and mahogany 15 to 20 frs. a kilogram.

Thus the distance of the plantations from the factory or the ports will be defined in terms of these economic factors.

On the other hand, it should be mentioned that it is perfectly possible to deal with only a few dozen hectares a year in a given region but then the program must be followed each year so that all of these works might be part of a whole.

Furthermore, it must be pointed out that the natural forest should be managed as underbrush growing under high forest; the large trees would maintain shade so that trees of smaller diameter would produce firewood and after cutting grow again to give, after a few years, perhaps poles and, in any case, new firewood. It seems to us sometimes

dangerous to want to proceed at all costs to artificial reforestation, for this type can vegetate and produce with difficulty while the wild forest, which is well adapted to the environment, can give abundant and valuable wood products perfectly well.

Finally there is another very important point to make; this is the treatment which the plantations have undergone. On this depends the quality and value of the forest products obtained. It is therefore essential to follow-up the reforestations after their establishment with maintenance care and management by successive clearings where necessary.

This process leads the forester to define:

- blocks with long turnover for the production of quality wood;
- blocks with short turnover for the production of wood pulp, stakes and poles, or firewood;
- blocks for the production of fruit (cashew).

3. Reforestation Species in the Savannah

Among the different commercially valuable reforestation species which grow in the savannah zones we will analyze the following:

- teak
- Gmelina arborea
- mahogany

in addition to some different local or introduced species such as pine and eucalyptus.

Teak. Teak, of Asiatic origin, is a species which is perfectly adapted to the African continent. It requires, however, that the soil be sufficiently loose, rich and permeable; it prefers climates with a single marked dry season (asiatic monsoon climate in this type of distribution) and a rainfall of between 1,300 mm and 3,000 mm. These requirements exclude its introduction into the perennial forest. However teak grows well in the semi-deciduous forest and in the pre-forest zone of the savannah.

In the sudano-guinean savannah, where it is drier, teak develops less vigorously but this can be remedied by working the soil more intensively (the use of tractors with rippers is advisable). Multiplication is easy after raising seedlings in dry nursery. It is commonplace to say that the more humid a zone is the more luxuriant the vegetation—but as we are coming to appreciate we cannot come down too far to the south because of the sufficiently acute dry season, which is fine since one can thus diversify the plantations following the ecological zones.

1.1 Method of Planting

Taungya reforestations, that is, in association with crops, are economic but only important to the extent that they are carried out on good soils and in substantial quantity (of the order of some hundreds of hectares, for example) which enables them to be controlled and managed. On village land these conditions are difficult to find, which led the administration to undertake plantations in neighboring forest reserves. The results obtained in the Bamoro reserve are an excellent example of what should be sought and achieved.

It should be noted that Bamoro is located near the urban center of Bouaké, which greatly aids the supervision of the plantations, the work of clearing and management, as well as the marketing of by-products.

Mechanization of the work, although very expensive, is foreseen in the case of the establishment of major plantation programs. The commercial value of the various products, obtained through the exploitation of the teak plantations, allows these relatively costly investments. The first trials with mechanized planting were undertaken in 1963-64, at Matiemba, then at Korhogo, and which led SODEFOR in 1968 to use this method of reforestation in the Cechi forest (opening of a fourth area).

1.2 Management and Production

The treatment to be applied to the teak forest certainly depends on environmental factors but equally on the products sought.

Thus on good soils it appears necessary to define two types of management according to whether telephone or electrical poles or high quality lumber is required. In the first case the trees are cut down in a 16-18 years rotation to produce about 400 to 500 good poles per hectare. Two hundred hectares will give annually of the order of 5000 telephone poles provided the rotation was lengthened. Teak grows new shoots easily from the stump, which enables poles to be cut at regular intervals, without requiring new plantings.

In the second case the production of high-quality timber is sought through successive clearings. These must be done in such a way that the stands left are the best examples with long and regular trunks surrounded by filler trees which are progressively eliminated. Future stands should have a developed cyme and a trunk of good diameter. The objective sought is a growth-rate of at least 1 cm per year to reach maturity in 55-60 years. The products from clearing are poles (roughly 100 per year) stakes and firewood.

On average soils in the preforest zone and on the sudano-guinean savannah where the climate is drier, the growth factors are less favorable. It is only possible to seek to produce firewood, stakes and poles—the rotation for pole production would be roughly 23-25 years.

2. Gmelina arborea

Gmelina arborea is a good forest species of asiatic origin like teak, which is equally well adapted to the Ivorien climate.

From an ecological point of view it develops on soils less rich than teak but its growth is evidently better on good soil. It requires for preference heavy schistose soils while teak grows on granitic-gneiss soils of average clay. The reforestation carried out at Bouaké and Dimbokro and particularly at Cechi, by SOTROPAL, are particularly interesting.

Easily multiplied by cutting, it has the advantage of producing much more rapidly than teak, giving a satisfactory cellulose pulp rolls well and is used for the manufacture of matches. Periodic pruning is nevertheless essential to clear away the stumps and reduce the number of knots in the wood. This is a good white wood, of very rapid growth but which unfortunately has a much lower market value than teak.

Its working qualities prevent its use for poles while its value as firewood is not great; this is what makes the products of clearing irrecoverable. The regeneration cycle is equal to 25-30 years.

It has never been made the object of international trade and its exploitation is limited at present. The match company (SOTROPAL) values its qualities above all for the manufacture of boxes; for the matches it is less satisfactory.

We believe, however, that this species could probably find some day important markets and then the establishment of large stands to ensure supply to the processing industries can be anticipated.

3. Cashew (Anacardia)

The cashew was introduced on several thousand hectares in the Ivory Coast first as a species for the protection of poor soils then as a species of fruit tree on soils in principal of better quality and as such has sometimes been called the coffee of the savannah.

This is, in fact. an important species, multipled in many countries for many years as a result of the results obtained in India.

Its cultivation is easy since one proceeds directly by sowing 3-4 seeds in a hole on the desired site. Fruiting is early, since it produces in 3-4 years.

We are currently conducting studies of yields in relation to density of planting, geographical location and the nature of the soil. These vary greatly and the first results indicate that at 6-7 years in the Bouaké region 500-600 kg are obtained per hectare on good soils while on poor soils the production only reaches 150-250 kg per hectare. At Korhogo the yields obtained in 1967 for the plots of that age were of the order of 200-250 kg.

The requirements of the cashew, particularly the conditions for the highest productivity in terms of ecological factors (soil, climate) must now be determined.

It should be mentioned that the cashew only controls Imperata to a limited extent and can therefore be damaged by fires.

In fact there exist three principal problems to be resolved to give this species its rightful place:

- an agronomic problem, which is being particularly studied by the IFAC station at Majunga;
- a problem of industrialization, for the nut of this species must be gathered preferably by machine rather than by hand (as it is done in India), which would obviate the necessity of using large numbers of low-paid manpower. Manufacturers, particularly Italians, are actively working on this problem;
- a problem of markets.

A CTFT-IFAC investigation in West Africa is projected, which should enable solutions for the multiplication of cashew to be found.

It is currently estimated that a factory must process of the order of 10,000 tons per annum to be profitable (5,000 tons at first operation). At 500 kg per hectare it would be necessary to have about 10,000 hectares planted. A higher per-hectare yield, obtained through selection of the seed, a naturally richer soil, or through the use of fertilizer, etc., would enable the areas to be reduced.

On the other hand taking into consideration that the cashew is a raw material of low value it appears essential to concentrate production in a particular area around the factory.

4. Various Species.

Among the various species we will particularly mention:

- Cassia, eucalyptus and pine.

4.1 Cassia siamea.

The Cassia siamea is a relatively demanding species which has been highly developed formerly for the production of firewood to satisfy the particular needs of the bakeries and the railways. It provides stakes but does not give poles. Its production is on a family or village scale for the want of industrial outlets—currently cassia is practically never used for reforestation.

4.2 Eucalyptus.

Eucalyptus only grows on proper soil, cleared of Imperata cylindrica and sheltered from termite attack, to which it is tremendously

susceptible. It is multiplied in polythene bags and requires a certain amount of care in the nursery (watering, sunshine). It is introduced into preferably light to moderately light soil, well cleaned and treated with dieldrin (anticipating emergency treatment in case of attacks).

The objective sought is the production of stakes and poles. This species is however much less important than teak and, in these conditions, we always prefer to establish teak.

On an experimental scale we have introduced it around Bouaké—where it has been confirmed to be without importance—around Korhogo where observations are being carried out and finally, recently, in the Baoulé V: at Bakakoumekro, on a light soil where there is no Imperata, and at Toumodi on sandy ground worked by SODEPALM. Eucalyptus on the latter two stations seems to do well, which, in the case of success, would enable an evaluation to be made of the Baoulé V zone.

It should be mentioned that a eucalyptus plantation with arable crops in the Sangoué forest, near Man, has been a success.

The most appropriate species are particularly E. camuldulensis, E. 12 ABL and E. citriodora.

4.3 Pine.

The pine, which is excellent for producing paper, is a mountain tree; certain species, however produce at low altitude in the humid tropical climate. In the semi-deciduous zone and in the savannah (preforest sector) we have introduced it recently on a small scale but it is not envisaged, at any rate for the moment, for large-scale plantation in Middle Ivory Coast. These might rather be located in Lower Ivory Coast where a cellulose factory is projected.

The species which seems best adapted to the tropical climate on the level, is Pinus caribea (var. hondurensis); the growth of P. Khasya, P. oocarpa and P. caribea (cubenis) is to be investigated.

4.4 Some Introduced Species.

Trials carried out with Peltophorum ferrugineum Albizzia Lebbech. Melia azedarach (Japanese lilac), Azairachta indica (neem) both at Bouaké and Ferkessedougou have had to be abandonned for lack of sufficient growth. We have attempted without result to introduce from Asia the Dipterocarpaceae.

4.5 Some Local Species.

Experiments have shown that the local species grow very slowly and multiplication trials with Lingué, Tali, the palmyra palm (Borassus flabelliformis) have not been pursued. As for the mahogany (K. senegalensis) and the larger-leaved mahogany (K. grandifoliola) they are attacked like the mahogany by the borer to the extent that the reforestation in open areas with these species has proved very difficult. On

the other hand as trees lining the street in the towns they have been planted with a certain amount of success (Bouaké, Ferkessedougou, etc.). The need to develop palms and bamboo in fresh locations should be pointed out. This latter species grows rapidly and is particularly useful in a number of ways.

CONCLUSION

The drier the climate, the more the vegetation reduces its growth to limit the transpiration and to adapt to the lack of moisture in the soil, during a greater or lesser part of the year. By way of example we can cite the Lophira which are great trees of the dense forest (Azobé) and the shrubs of the savannah (Mené); it is the same with the Detarium. Nevertheless the arboreal species can be progressively established producing light disperse populations--but their shape is often defective.

The local species produce too slowly to be artificially multiplied. Nevertheless there fortunately exists several exotic species, more adaptable than the others, which can adapt to this more severe invironment and increase the value of the soils. These are essentially teak, which should be developed to the maximum, then cashew and *Gmelina arborea*.

SOME PROBLEMS OF COCOA PRODUCTION IN GHANA

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SUMMARY

The present structure of cocoa farming in Ghana and the research problems confronting the industry are briefly discussed. It is considered that the present scattered nature and smallness of peasant holdings, the scarcity of labor, and the relatively low prices at which the crop is marketed, are not conducive to the maximum utilization of available research data and thus impede against the attainment of optimum production efficiency. It is suggested in conclusion that future reform measures might include the granting of better price incentives to the farmer, a rearrangement of the land tenure system to allow for the establishment of larger and more efficiently run unit holdings and the organization of better credit facilities in an effort to reduce the chronic state of farmer indebtedness.

INTRODUCTION

Cocoa production in Ghana is largely a small-holders' enterprise which exploits in the aggregate some 4½ million acres of land. Whereas this acreage has remained more or less constant over the last decade or so, a study of production figures covering most of the same period shows that yields have been increasing markedly, although at widely fluctuating rates. (Fig. 1). A probable inference to be drawn from this is that production is becoming more efficient. I propose in this short paper to examine some of the factors that have contributed to these production increases and to indicate further areas in which attention, aimed at stabilising production, might be directed in the future.

Liaison Between Research and Extension

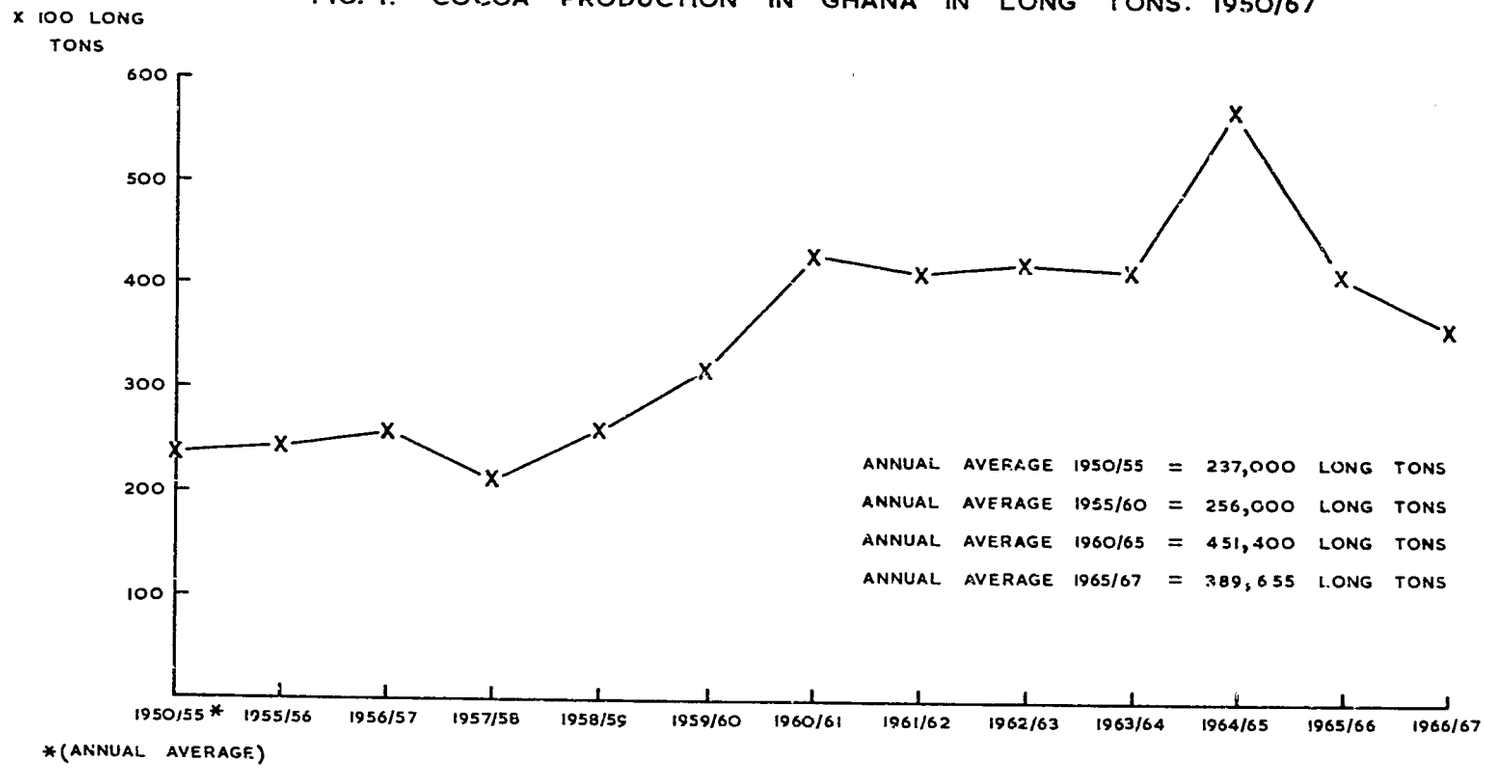
The Ghana cocoa industry is scientifically supported by the Cocoa Research Institute based at Tafo in Ghana. The Institute exists mainly to carry out basic research oriented towards solving the agronomic and disease and pest problems that confront the production effort. Whilst many of these problems, some quite formidable, like the swollen shoot virus disease and the capsid menace, have been tackled with some success over the years, many more remain and considerable research effort and foresight will be required if they are to be tackled successfully. But even in the problems for which reasonable scientific solutions have been found, it is not always that the requisite governmental support has been forthcoming to ensure that the findings were successfully applied in practical terms in the field.

Among the more important problems of cocoa production in Ghana, the spread of swollen shoot disease and capsid damage continue to be pre-eminent. Allied to these are further agronomic problems of rehabilitating vast acreages at present occupied by derelict cocoa.

Swollen Shoot Control

The swollen shoot virus disease has, since its discovery in 1936, been shown to be an important factor limiting cocoa production in Ghana. Following the recognition of this fact detailed studies on the vectors, symptoms, epidemiology, host-range, and the relative severity of different strains of this disease were made as part of the wider effort towards finding a cure. Although these studies have yielded a large body of valuable scientific data, the most important virus control measures proposed as a

FIG. I. COCOA PRODUCTION IN GHANA IN LONG TONS: 1950/67



*(ANNUAL AVERAGE)

result would have been resisted vigorously by farmers had government not taken emergency steps to assist. I am referring here to the cutting-out campaign.

This campaign, aimed at eradicating the swollen shoot menace, is based on the roguing of diseased trees and their apparently healthy contacts. With considerable government backing, including the award of replanting grants to farmers and the engagement of government-paid labor for the diagnosis, marking and cutting out of outbreaks, the campaign was fairly successful.

Between 1946 when the campaign was started and 1957, an estimated 63 million infected trees and contacts distributed over 124,098 farms had been cut out, and well over £7,000,000 in grant payments had been made to farmers. An additional 44.6 million trees were removed between 1957 and 1961, and during the period 1945/61, a total acreage of 55,928 in treated farms was certified to have been replanted.

On the supposition that farmers will themselves operate the "cutting-out" campaign with minimal government support, the government withdrew all its grants from the scheme in 1962 and virtually threw the campaign to the discretion of the peasant farmer. From then on the story became a pathetic failure to achieve any control. Farmers have always been loath to destroy live trees whatever their state of disease and were somewhat reluctant to do this, even when government was paying generous subsidies for the purpose. When therefore it was decided to leave "cutting out" to the farmers they did almost nothing. Thus of 1.5 million trees marked out for destruction in 1963/64 just a little over 100,000 were actually removed, the remainder being left to serve as future sources of further infection. For some five years virtually no "cutting out" was done.

It is difficult now to assess the value of the earlier swollen shoot campaign which held so much promise for the eventual control of this devastating disease. It certainly had the effect of limiting the spread of the disease during the period (1954/62) when it was actively pursued as a matter of government policy. The replanting programme which took place as a corollary to the campaign also had the effect of ensuring that at least a portion of the devastated acreage was replaced, even if this meant only a small fraction at a time. The more serious effect, however, lies in the cessation of the campaign itself, which has given rise over the years to the development of numerous pockets of outbreaks which keep spreading. Recently, the Cocoa Division of Ministry of Agriculture have again resumed responsibility for CSSV control and are currently building up their organisation to the same level as it was in the past. This will take some time and it may well be too late to prevent the disease reaching epidemic proportions in some parts of Ghana.

In the meantime, research continues on the swollen shoot problem and it is considered that a long-term and more permanent solution lies in the development of cocoa varieties that show a high degree of tolerance or, hopefully, resistance to the disease. Studies already in progress indicate that considerable variations exist in the reaction of different cocoa selections to infection by the virulent swollen shoot viruses. A sustained breeding programme is therefore expected to yield promising results in this regard.

It is suspected also that poor environmental conditions such as drought, capsid infestation, nutrient deficiencies and unfavourable conditions of insolation may be contributing greatly to the debilitating effects usually attributed to viruses alone in some outbreaks. A recent study at the Cocoa Research Institute, Tafo, has shown that under conditions of adequate mineral nutrition, higher light intensities (ca 40-60% natural light) do prevent the swellings and growth reduction due to CSSV infection from occurring. One of the replicates from this study which was planted 5 years ago in sand culture is still growing vigorously and both the infected and uninfected treatments have been producing a good and comparable crop, each year since 1965, the infected showing no signs whatever of vegetative deterioration. However, it is also known that excessive insolation is unfavourable to healthy trees. Obviously, therefore, careful shade manipulation is necessary for the attainment of optimum light balance in a plantation of infected or healthy trees.

Although there is less definite information on the effects of drought on infected cocoa particularly, circumstantial evidence prompts one to the view that this imbalance in the environment may accelerate death in infected trees. It has been shown that infection causes the death of lateral roots, thus severely restricting the plants' capacity to absorb moisture and nutrients - a state which may have particularly critical consequences for the plant during prolonged periods of severe drought. A breeding programme which aimed at combining light tolerance, virus resistance and drought resistance may therefore prove very useful in the long run.

Capsid Control

Capsids (mirids) constitute the largest single group of serious insect pests in cocoa in Ghana. Sustained attacks by them result eventually in large pockets of defoliated cocoa which die if unattended. Several such pockets may finally join together and form a vast continuum of complete devastation.

During the past decade it has been possible to achieve near total control of this pest through the mass application of insecticidal sprays

in the cocoa plantations. Lindane (γ BHC), the most effective of the insecticides tested, was used very widely and successfully for almost a decade until it was discovered five years ago that it was failing to achieve control in certain of the cocoa growing areas. It is now known conclusively that the lack of control is due to the development of lindane-resistant capsid strains, and current research effort in this regard is aimed at discovering an alternative insecticide for use in the resistant areas. The integrated approach to pest control, combining the use of insecticides with methods of biological control, is also being tried but so far the leads have been less than promising as regards deliberate biological control methods. It is known, however, that a certain measure of this form of control occurs in nature, some particular examples being the parasitism of some capsids by Euphorus and the observed association between the presence of Oecophylla ants and trees relatively undamaged by capsids. Meanwhile the most promising short-term solution to the capsid problem lies in finding effective selective insecticides which will not disturb the natural balance of such beneficial insects as Forcipomya spp., the presumed pollinators of cocoa or some of the known predators upon minor cocoa pests.

The loss incurred by the cocoa industry through the ravages of capsids cannot be determined with certainty. However, the capsid control programme during the decade 1954/64 is usually credited with the large increase in cocoa production from ca 200,000 tons to well over 400,000 tons during that period.

Fungal Diseases

This class of diseases represent a relatively minor hazard to cocoa in Ghana. The major one is "black pod" disease, caused by Phytophthora palmivora, and estimated to take about a 20% toll of the crop annually. Although chemical methods of controlling this disease exist, these methods usually consisting of spraying with copper-based fungicides are not considered economical owing to their excessive cost in relation to the value of the crop saved. Their value has therefore tended to be de-emphasized in favour of improved field hygiene resulting from a more frequent schedule of harvesting both good and diseased pods, and the destruction of the disease pods to prevent the build-up of infective fungal spores. Other fungal diseases are known such as the thread blights (Marasmius Equierinis and M. Scandens), root- and trunk-rotting diseases (Fomes noxious and F. lignosus), but these do not consitute a mjaor research or extension problem. Calonectria dieback considered to be due to a secondary infection by Calonectria rigidiuscula following capsid attack probably exists still in areas of

ineffectual capsid control but not where capsids are eliminated. The gall diseases (flowery gall and green point gall) presumed to be caused by *Fusarium spp.* and known to occur on cocoa in certain parts of Central America are virtually absent from Ghana, as is also the witches broom disease caused by *Marasmius perniciosus* in the Caribbean.

The Present Position on the Farms

In spite of the considerable advances that have been achieved in cocoa research in Ghana, the industry has been showing signs of declining in the last few years. Many farmers appear to have lost enthusiasm for cocoa production and this has resulted in farms appearing derelict and yielding less than can be expected. Annual national production figures for the years 1962/67 are summarised below in Table 1.

Table 1. Ghana cocoa production in tons*

1962/63	1963/64	1964/65	1965/66	1966/67+
421,966	421,389	571,759	410,397	368,913

*From Gill & Duffus Cocoa Market Report No. 206, August 1967.

+Estimated.

Although this apparent decline is partly due to capsids and a lack of effective swollen shoot control in many areas, its major causes lie in a general loss of farmers' interest arising from the low prices at which they have been compelled to market their cocoa in recent years. These prices are determined both by the world market position and by the Cocoa Marketing Board which takes account of the world market position before fixing the prices to be paid locally to farmers. Table 2 below provides a summary of the annual world and local price positions for the period 1962/65.

Table 2. Annual world and Ghana farmers' prices for cocoa during 1962/65

	World price	Farmers' price
1962/63	₵208 per ton	₵112 per ton
1963/64	₵191 " "	₵110. 2s. 8d. per ton
1964/65	₵90 " "	₵91. 15s. 6d. per ton.

The average world and local prices for the period 1962/65 come respectively to ₵163 and ₵104. 13/- per ton, the difference being used to meet the expenses of the Marketing Board and for building up reserves for stabilizing producer prices in unfavourable seasons. Working from this average local price, and also assuming an average national yield of 300 lbs. dry cocoa per acre, the average individual peasant producer will have to farm about 13 acres to earn a gross income of ₵200 per annum. This income is hardly adequate to offset the cost of labour, spraying and other overheads. By contrast, an unskilled Ghanaian labourer on the minimum wage of 7/- in some other employment stands to make ca ₵128 per annum, a lot more if he has the minimum educational qualification of a Standard 7 Certificate - all with retiring awards, too. This, naturally, has led to fewer youngsters being attracted into cocoa farming.

Farm labour has also tended to be scarce. Traditionally the cocoa farmer used to be assisted in his work by members of his family - mainly his children and nephews. He now has virtually no access to this source of labour, since the introduction of the fee-free education system and the general expansion of primary educational facilities have meant that the majority of children of school-going age are now attending primary school. Hired hands who also constituted an invaluable supplementary source of labour are also becoming less available as they are rapidly absorbed into other types of better paid industry. Furthermore, as many of the latter category of labour consisted of non-Ghanaian farm workers, the recent rapid development of nation states across West Africa and the consequent need for enforcing national immigration laws have tended to discourage their migration. Meanwhile the traditional Ghanaian cocoa farmer is growing older without any visible steps being taken to ensure his eventual replacement.

Prospects for the Future

One of the major requirements towards stabilizing the cocoa industry is to improve the farmer's motivation by increasing his incentives. Perhaps the recent announcement by Government of an increase in the producer price from ₵93. 6s. 8d. to ₵130. will achieve this. There are already signs of this happening as farmers now strive to bring back almost abandoned plantings into production. It is to be hoped that they will continue in this new spirit of enthusiasm.

The long-term prospects seem to lie, however, in recasting the structure of cocoa farming from its present peasant state into one involving a reasonable degree of estate management practices.

Even though the average size of cocoa farms is not known with certainty, cocoa growing in Ghana can accurately be said to be an industry in which an excessively large number of small-scale operators are engaged.

The average national yield of dry cocoa has been estimated (a on the generous side) at 300 lbs. per acre, based mainly on an estimated total national acreage in cocoa of 4½ million acres and an average annual production figure (1962/65) of 472,000 tons. With the experimental demonstration that yields of about 2,400 lbs. per acre are reasonably within the reach of the determined farmer at nominal extra cost, it is evident that the present traditional system cannot be relied upon to bring about any appreciable increases in output at costs low enough to conform with future trends in economic and social progress. Concrete plans are therefore sorely needed to bring about basic changes in the structure of the industry, involving such factors as land tenure reform, the movement and utilization of labour, the application of improved agronomic processes, credit facilities, and internal marketing reform measures.

Land Tenure

From a casual look at the system or (lack of system) of land holding in this country one has no difficulty in concluding that the absence of a properly defined means of land tenure, although this might have proved all right in muddling along in the past, could not make for effective improvements in the cocoa industry of the future. It can be said with much justification that one of the major drawbacks in the application of modern methods to the Ghana cocoa industry is the smallness and scattered nature of holdings; both a direct result of the impediments brought about by the traditional land tenure situation.

Labor

In order to increase the productivity of the average cocoa farm in Ghana it is imperative that the process of mobility of labour must be encouraged. The present practice of the young, energetic and educated folk leaving the farms for the urban areas, whilst the aged, weak and illiterate, are left to tend to what is, by far, the most important single industry of the country, cannot be considered a prudent commercial practice from the national point of view. Although the movement of labour from agriculture must progress in order to increase the level of productivity in the industry, this hope can only be realised through the improvement of the quality of the reduced labour force left in the cocoa industry. It is only

when young and educated men replace the old illiterates that conservative attitudes could give way to modern ideas in cultural practice.

Improved Agronomic Processes

The progress of science and technology has contributed much to the enhancement of agricultural production in other countries. Here in Ghana, the time has come when one has to start thinking in terms of a future cocoa industry with a sound structure as to make it possible - through its size and general efficiency - for the application of fertilizers and a certain degree of mechanization wherever necessary. It is important to stress here that the industry as at present organized cannot reap the full benefits of the researches being conducted at the Cocoa Research Institute at Tafo. The scale of operation and the level of technical and managerial optima on the local farms are too low to allow for this to happen effectively.

Credit Facilities

Past attempts to solve the acute problem of rural indebtedness have completely failed and future plans for the industry must take this into account. Moreover, the problem of cocoa farmers' indebtedness can only be tackled effectively, it is suggested, within an efficient internal marketing system through the medium of co-operative societies working alongside the Cocoa Marketing Board.

REMOVING OBSTACLES TO THE USE OF GENETIC BREAKTHROUGHS IN OIL PALM PRODUCTION: THE NIGERIAN CASE

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SUMMARY

In the past, wild oil palm varieties have been established in Nigeria by an ecological process in which man has participated as a biological organism but not as a manager. With the development of new highly productive varieties at the Nigerian Institute for Oil Palm Research (NIFOR), the problem becomes one of devising new man-managed methods of promoting and controlling the establishment of the new varieties. Currently Nigeria is experimenting with the following schemes to expand oil palm production: state-owned plantations, nucleus plantations, farm settlements, smallholder oil palm rehabilitation schemes and extension programs. However, marketing board pricing and taxation policies interfere greatly with the success of both public and private efforts to expand oil palm production. Thus needed research goes beyond farm management into public policy and marketing.

Full exploitation of the genetic breakthrough in oil palm research would likely involve regional and sectoral specialization. Tree crops, freed from present taxes and pricing policies, would probably dominate the rain forest areas in Southern Nigeria from an economic standpoint. As a consequence, food crop production would probably concentrate to the North. This suggests the need for both more marketing research and for more technical agricultural research on food crops for Northern Nigeria. Also, there is a distinct possibility that research on feed grains and forage crops would pay off handsomely in providing increased animal protein for the tree crop areas and for export. Research on pricing policies will also be required.

To acquire an understanding of how such transformation and increasing ecological specialization of production take place requires more than the study of biological aspects of ecology. Political, economic and sociological as well as biological processes are involved in the production and marketing of agricultural crops and livestock. A fundamental new technique of social science research is called "simulation". This technique promises to be helpful to scientists (both social and physical) and government administrations in predicting the consequences of alternative (and in devising new) policies and programs. Simulation is a highly specialized technical kind of research requiring the same level of development support as genetics, biochemistry and cytology. Research administrators should realize this need and, hence, support such fundament social science research as stimulation instead of expecting social scientists to work primarily as extension workers in getting

technical research results adopted. Adjusting social, political and economic systems to technological advance is a fundamental task requiring team-work among the best of the physical scientists instead of "flunky" work by one or two social scientists (probably junior, at that) who are brought in 10 to 20 years after a large team of top-notch biological scientists start their work. In the case of NIFOR, Zevens' ecological research in oil palm production in Nigeria should have been started earlier. His attempts to understand biological regeneration of wild species should have to be integrated with the work of economists, political scientists and sociologists to arrive at an understanding of how man can control the agricultural production process in Nigeria as technologists open up new opportunities. Simulation (graphic, tabular and algebraic) promises to be a useful technique to be employed by such teams.

INTRODUCTION

As an agricultural production economist, I have been asked to talk about oil palm production in a session on crop production. My qualifications as an oil palm man are those of a holder of a B.S. degree in general agriculture at the University of Illinois where they do not distinguish between coconuts and oil palms. There is also a session at this conference on production economics and marketing. Thus, when beginning this paper, I was a little concerned with where to start.

However, a little reflection revealed a long-standing helpful conviction. It runs like this: the solution of practical problems typically requires contributions from several disciplines. The problem of utilizing the backlog of excellent technical research on oil palm in Nigeria is a practical problem. Following this conviction, I will forget both academic disciplines and the conference agenda and deal, instead, directly with the problem of oil palm production in Nigeria.

The Problem

The problem of oil palm production in Nigeria is, simply stated, one of how to reorganize agriculture in Southern Nigeria to take advantage of recent genetic breakthroughs in oil palm technology. These breakthroughs were attained at the Nigerian Institute for Oil Palm Research (NIFOR, formerly WAIFOR). They are comparable, in some senses, to the development of hybrid maize in the United States.

Reorganizing agriculture in Southern Nigeria to take advantage of these breakthroughs involves questions concerning research, university education, adult education, public service, ecology, pricing policies, taxation, state versus private production, management, institutional changes, values and plain ordinary politics, to mention but a few. Presently, at least ninety percent of Nigerian palm produce is from the unimproved, so-called "wild palm groves" instead of from the recently developed improved strains. The improved strains are capable of out-

producing the unimproved strains 6 to 1 under experimental conditions and easily 3 to 1 under practical production conditions.

According to a recent ecological analysis by Zeven, there are three main types of wild palm groves in Nigeria: (1) secondary rain forest containing oil palm, (2) palm bush and (3) dense palm grove or farm land with palms. [1] In addition, there are groves planted by villages and individual peasants not to mention a few large commercial plantations.

Whether or not the wild unplanted oil palms can survive in the rain forest depends on the density of the human population as bush fallow or slash and burn operations are needed to keep the forests open enough for the oil palms to regenerate without being overtopped by rain forest species. Human population of 50 persons or so to the square mile in a secondary rain forest results in a thin stand of oil palms.

Palm bush results from heavier human populations in the rain forest area and from lower population densities and lower levels of rainfall in the derived Savannah area. In the first instance, short-fallow rotations permit still more rapid regeneration of palms while in the second the shortage of water eliminates rain forest species which would overtop the palms.

Dense oil palm groves and land with palm groves are found mainly in Eastern Nigeria. The dense palm groves sometimes develop around deserted compounds. When compounds are not moved and farming is quite intensive stands of palm develop on land which is regularly farmed.

The above summary of Zeven's analysis of oil palm ecology is relevant, here, as it explains the man/crop interaction which has resulted in the establishment of over ninety percent of oil palm productive capacity in Nigeria. The other ten percent or so is from eliberately planted groves, some the work of individual peasants and others the work of villages. Recently, some of these deliberate plantings have consisted of the new improved varieties. In addition, one private and several state-owned plantations have been planted to the improved varieties.

For the most part,then, the problem of exploiting the new varieties developed at NIFOR is one of replacing an unplanned, ecological process of oil palm regeneration, which man participates in but does not consciously manage, with a new and as yet undeveloped man-managed system.

The new man-managed system will be a complex one, not easily taught to peasants. It must include: the production of the improved seeds, planting, caring for and fertilization of seedling produced in nurseries after a germination process including both heat and humidity control, followed by planting, weeding and the processing of the fruit so as to (1) fully extract oil of the high quality demanded by

international markets and (2) recover the seeds for sale to kernel crushers located both in Nigeria and abroad. Thus, it is no simple task to take control of the almost automatic biological(ecological) system of palm grove rehabilitation in which man participates more as a biological organism than as a manager. The task was only begun, not finished, when NIFOR systematized the process of producing thin shelled, high yielding (tenera) varieties by fertilizing the flowers of selected palms bearing thick-shelled fruit with pollen from selected palms bearing shelless fruit. Nor can it be finished by the mere introduction of an extension service to transmit the "good news" of the technological breakthrough to peasants and governmental officials who neither adequately understand the ecology of the old system nor the political economy and sociology of the new system being developed.

This is not to say that the biological research establishments such as NIFOR and the extension arms of ministries of agriculture should be dismantled and their resources transferred to an institute for the study of the sociological, economic and political aspects of development. Instead, as it will be seen later, more biological research and more extension will be required <u>if</u> research is also done on the socio-political economic processes involved in transforming the more or less automatic and partly accidental, ecological process of wild palm grove regeneration into a new man-managed system designed to fully utilize the present and prospective breakthroughs of our genetists, plant breeders, nutritionists, and pathologists.

In the remainder of this paper I am going to discuss the following several kinds of research needed to exploit the genetic breakthroughs attained and attainable at NIFOR: farm management; tax reform; pricing policy; area, firm and sector specialization; research in technical agriculture and simulation of bio-political-economies. Obviously, each discussion will have to be brief and superficial if we are to obtain the objectives of this conference with respect to oil palm production. Those objectives were stated as answers to the following questions:

1. Is there a backlog of research findings in the field which have (<u>has</u>) not been generally implemented?

2. What are the important problems which have escaped resolution and which require some (re)orientation of research?

3. If there is a backlog of available research information, what are the factors which have prevented the implementation of the research into agricultural practice?[1]

Farm Management

Converting the ecological system of regenerating palm groves to a man-managed system requires new managerial units controlled privately

and/or publicly. The units will have responsibility for establishing the new varieties. Thoroughly tested production units for doing this under Nigerian climatic and cultural conditions do not exist. Most of the existing managerial units are harvesting and processing but not producing units for the so-called wild groves without responsibility for planting and regeneration. As such they are more like fishing than farming firms.

Nigerians now seek a new mechanism - a managerial unit - to be given responsibility for establishing groves of the new strains. In their seeking, Nigerians are experimenting with land settlement, schemes, state-owned plantations, extension exhortations and palm grove rehabilitation subsidy schemes.

Some research and feasibility studies have been done on farm settlements, state-owned plantations and smallholder subsidies. From these studies, it is clear that farm settlements - as presently organized in Southern Nigeria - are not an effective method of establishing large acreage of improved oil palm varieties on account of managerial shortcomings from overloading a limited number of civil servants, political desires to distribute largesse to constituents, etc. This is not to say that farm settlement schemes cannot do the job; it is to say, instead, that they have not been studied and modified enough yet to know whether they can be so used.

Extension exhortations to smallholders without subsidies have generally not been effective in getting large acreages of improved varieties planted. The main problem, here, does not appear to be one of inadequate extension though there are shortcomings in this regard. Instead, Nigerian taxation and pricing policies tend to nullify extension efforts. By reducing the value of palm produce, there is both a short and long term impact on persons planning palm grove rehabilitation projects. In the long run, lower prices reduce incomes from the palm products to be produced starting about four years after planting. In the short run, the existence of lower prices for palm products prevents non-bearing young groves from taking on their full capital value. Because such capital values develop less rapidly and are of smaller magnitude, individuals planting palms have to wait for production before having anything of value to show for their work or to pledge as collateral for loans, or, if they die, to leave to their families. This is not to say that the smallholder rehabilitation is unsuccessful; instead, it is to say that pricing and taxing policies do interfere with it to such an extent that subsidies are required to get smallholders to do what it would be advantageous for them to do in the absence of present taxing and pricing policies. Though Helleiner [1] has studied the impact of

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1 Gerald K. Helleiner, Peasant Agriculture, Government and Economic Growth in Nigeria, Richard D. Irwin, Inc., 1966, pp.55-75.

the decline in palm produce prices on the quantity and quality of produce marketed from wild palms, no one had yet thoroughly studied the impact of price changes on establishment of the new improved varieties by smallholders. One large private plantation has made such a study and, as a result, is converting its palm plantation to rubber. In the case of state-owned palm plantations, MacFarlane and Oworen found that they were quite profitable provided the state-owned farms were credited with the marketing board and/or tax revenues generated by the output.(2) The depressing effects of marketing board and tax revenues on plantings of improved palm by smallholders is implicitly recognized by smallholders participating in the palm grove rehabilitation scheme who receive subsidies designed to offset the isincentives of marketing board and tax revenues (3),(4). These incomplete brief notes indicate the importance of research on oil palm marketing board operations as they affect the establishment of improved palm plantations.

Palm Tax and Pricing Policy Reforms

The palm produce marketing board, set up originally to stabilize the impact of fluctuating foreign demand on prices, has become, in effect, a tax arm of Nigerian Governments by being given monopoly power to buy much below the world prices at which it sells the produce. The adverse effects of these operations are noted above. Research is needed on how total marketing board revenues would vary as the percentage take is changed. Other research is needed on the probable salutary effect of letting the capital value of groves and land build up and of then taxing these values in order to avoid the disincentives associated with taxes on prices. There are also other impacts of taxes on other export tree crops including cocoa and rubber, the latter of which is subject to export taxation but not to marketing board revenues.

One of the least understood and unmeasured impacts of marketing board revenues and export taxes operates through their depressing impact on the value of land, labor and capital used to produce export crops. By reducing the value of these resources in export crop production, the comparative advantage of the rain forest area in tree crop production is decreased. The probable result is to prevent the development of regional

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2 David L. MacFarlane and Martin A. Oworen, Investment in Oil Palm Plantations in Nigeria, Economic Development Institute, University of Nigeria, Enugu, Nigeria, 1965.

3 Carl Eicher, "Transforming Traditional Agirculture in Southern Nigeria," Annual Meeting of African Studies Association, Bloomington, Indiana. (Presently available from the author, Department of Agricultural Economics, Michigan State University, East Lansing, Michigan.

4 Malcolm Purvis, A Preliminary Report of Selected Findings for Participants in the Oil Palm Rehabilitation Scheme. The Economic Development Institute, University of Nigeria, Enugu, in cooperation with the Consortium for the Study of Nigerian Rural Development, USAID/Lagos.

and sectoral specialization. Hence, the rain forest continues to grow large amounts of soil-depleting food crops under bush-fallow rotations instead of specializing more in soil conserving tree crop production. Conversely, the derived Savannah and river-rains areas in Northern Nigeria are deprived of demand for food crops which, according to the recent FAO report on Nigeria, they have a great potential to produce.(5) Failure to develop fully the export crops of Nigeria also tends to restrict the development of specialization between the farm and non-farm sectors with urban people producing goods and services needed by rural persons and vice versa. Instead, underemployed school leavers either stay in agriculture or migrat to urban centers to become unemployed or underemployed urban slum-dwellers.

This suggests a need for research on specialization which will be discussed in the next section. That discussion will lead to a discussion of needs for additional, closely-related research in technical agriculture to be considered in the next subsequent section.

Area, Firm and Sector Specialization

The impact of economic adjustment leading specialization of output is not thoroughly understood by many despite the fact that the main principles have been well established for over 300 years and explain, in part: (1) England's emergence as a world power, (2) a substantial part of the increase in the productivity of U.S. Agriculture over the past one hundred years, and (3) much of the current upsurge in agricultural output accompanying the development of Europe's Common Market. Perhaps the reason for this low level of understanding is that the advantages of specialization grow, in part, out of technological advance and are made possible by institutional reforms such as England's free trade policy, the establishment of the U.S. with freedom from barriers to internal trade and, more recently, the establishment of the European Common Market.

The breakthrough in oil palm genetics provides a technical basis for ecological specialization. Professor Smith from the Consortium for the Study of Nigerian Rural Development is in the process of estimating the optimum patterns of specialization among six ecological areas in Nigeria which would first <u>feed</u> the populations at alternative standards of nutrition and <u>then</u> maximize the sum of foreign exchange earnings plus the value of agricultural raw materials produced for industry. It is anticipated that the results will be quite sensitive to (1) changes in marketing board revenues, (2) export taxes, (3) trade barriers erected by or cleared up by civil war, tribalism and international trade agreements. We also anticipate that Professor Smith's estimates will be

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[5]United Nations, FAO, <u>Agricultural Development in Nigeria: 1965-1980</u>, Rome, 1966.

sensitive to lively pay-offs for research in technical agriculture, particularly with respect to feed grains and food crops.

Research in Technical Agriculture

Further progress in the breeding, nutrition and pathology of palm oil is of direct relevance to the problem of exploiting the present breakthrough in oil palm. Less obvious but of possible greater importance is progress in (1), the technology of food and feed grain production for Sub-Sahara Africa, (2) the maintenance and improvement of tropical soils, and (3) understanding how the ecology of Sub-Sahara Africa is influenced by technical, political, sociological and economic changes.

It is likely that the present breakthrough in palm breeding would result in significant advantages to specialization of some areas in palm and of others in food crops. Further, the world's genetic banks for maize, grain sorghums and millets plus the skills of plant breeders promise results for Nigeria which may shift the comparative advantage in food grain production very sharply to the north of the rain forest and even away from root crops entirely. If followed by a regional reallocation of production, such a development would in time, change the pay-offs for research on soil maintenance and soil improvement. The bush-fallow, slash and burn problems of the rain forest would tend to be solved by tree crop production in the rain forest area while shifting food production to areas in Northern Nigeria for food. This shift would then accentuate the need for, and indeed would depend on the success of research to maintain and improve the soils between the rain forest and the Sahara desert. Soil maintenance in this area would be promoted by genetic breakthroughs in feed grain production which would permet, in combination with geographic reallocations of production, reductions in feed costs. Such reductions would permit dry season feeding and perhaps, middle-belt fattening of cattle for export and domestic use, not to mention expanded swine and poultry production. This, in turn, would permit the use of animal manure as well as night soil in maintaining soil fertility.

By now it is clear that the Zeven's ecological research mentioned at the beginning of this paper is but a start on what is needed if the biologically and socially feasible patterns of agricultural production are to be understood in such a way as to permit maximum utilization of the present breakthroughs in oil palm breeding. Sub-Sahara Africa needs to be examined ecologically with respect to several different crops, animal species, fertilizer programs and irrigation schemes in order to understand its potential.

But man in Nigeria is rapidly becoming more than a mere biological organism, as in Zeven's ecological analysis of the generation and regeneration of wild palm groves. He is a tribal, social, and nationalistic creature given over, among other things, to creating and attaining a wide, ever-changing variety of desires which he ther tries to attain

by redoing his tribal, social, national and technical environments and by economizing on the use of resources to attain those desires.

Presently he is writing and executing development plans, experimenting with new production units and is discussing, changing and creating both institutions and technology. This, in turn, indicates that ecological models useful for designing a new system of establishing and maintaining improve oil palm plantations are too narrowly biological; instead, the relevant systems are broader than the biological systems studied by the ecologists.

Stimulation of Bio-Politico-Economics

The relevant systems to be described, analyzed and used as a basis for devising policies to modernize the oil palm industry must include sociology, economics, and political science as well as biology. Further, man must be included in the system as a controller. Fortunately, simulation is a new research technique which promises to be capable of encompassing such diverse elements into a single system capable of predicting the process of establishing modern oil palm production under alternative policies and programs.

Simulation models promise to be superior to more purely economic models often programmed on electronic computers. They are capable of printing out the predicted consequences over a period of, say, thirty years of following alternative policies and programs. These consequences can be expressed in terms of several variables some of which measure sought after consequences. This ability to print out the predicted consequences through time of following different policies and programs has several advantages including those of not necessarily requiring:

(1) all of the "goods" sought and "bads" being avoided to be expressed in terms of some least common denominator of value such as money, utils or gross national product as is so typical of many economic models which attempt to maximize net advantage;

(2) dependent variables to be predicted consequences of maximizing processes which is also typical of many economic models; instead, biological variables can be determined by biological relationships and political variables can be determined by various political rules for making public decisions while sociological variables can be predicted from sociological relationships;

(3) that all adjustments be such that no one is hurt in order to benefit another, a characteristic also typical of many economic models.

As such, simulation models have a degree of flexibility not characteristic of the ecological model used by Zeven, the economic models commonly used by economists, or the models used by political scientists, sociologists and anthrologists.

In addition to the advantage of flexibility stressed above, simulation models also promise to be capable of providing a means whereby researchers, extension workers, and public policy makers, permanent secretaries, etc., can interact with each other in solving problems. This is particularly important for problems whose solutions are likely to damage some in order to benefit others. In the case of Nigerian oil palm problem, policy makers need to benefit from the knowledge of plant breeders, extension workers, agriculturalists, and social scientists who need, in turn, to benefit from the policy maker's and the politician's knowledge of how the Nigerian public will react to policies and programs which harm some persons despite the advantages conferred on others. Actually, a public decision maker can be made an integral component of a simulation program. This can be done by stopping the computer of hypothetical points in time corresponding to budget years or elections basis of computed results to that point in time. Such interactions among public decision makers, researchers and others via a simulation model promise, in turn, to help decision makers see the consequences of their "pet" policies and, in time, to become more objective and creative in designing new policies, programs, legislation, decrees and regulations.

The applicability of the above to the problem of getting the results of genetic breakthroughs used in the case of oil palm is clear. Presently, marketing board policies and taxation interfere with the establishment of groves of the modern varieties. We have also seen that there are related biological problems, extension and economic problems. A moment's reflection will indicate that the changing of tax structure and the furthering of area specialization in a country involved in civil war does involve a considerable amount of political science, sociology and anthropology.

It does seen safe therefore to conclude that simulation research should be explored as a means of extending Zeven's valuable ecological investigation of palm grove rehabilitation into a much broader type of investigation. A related conclusion is that biological research stations such as NIFOR should, from the beginning, be staffed with personnel from non-biological disciplines to further the process of adopting biological research results. The use of NIFOR research results has been delayed greatly because the problem was conceived narrowly rather than broadly from the very beginning.

Incidentally, at the end of this paper, one can see that its location in the agenda does make sense. It should be in a session on crop production which it is. Further an agricultural economist does have a little to say about the problems but not enough for his paper to have been placed in a section specialized on production economics and marketing where he would have probably overemphasized economics an least as much as NIFOR has neglected it in the past and as purely biological research stations are likely to neglect it in the future.

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IRHO CONTRIBUTION TO THE DEVELOPMENT OF INDUSTRIAL PALM OIL REFINERIES IN AFRICA

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SUMMARY

Faced with the fat shortage throughout the world at the end of the second world war, French authorities in 1947 decided to put into effect a plan for the efficient utilization of the vast resources available in the form of the natural African oil palm plantations.

The study of this plan was entrusted to the Institut de Recherche pour les Huiles et Oléagineux (IRHO). The institute was then asked to oversee the construction of eight industrial palm oil refineries planned in this connection (one in Ivory Coast, one in Togo, four in Dahomey, and two in Cameroon). This program was carried out between 1948 and 1952. These production units were then placed in the hands of private managers who took charge of the operation. The IRHO, however, retained management of two of them in Dahomey until 1961.

The initial plan called for the simultaneous construction of the refineries, the improvement of the natural palm plantation operating conditions, and their gradual replacement with selected plantations. Unfortunately, the project did not progress in this respect as would have been desirable; this in turn produced difficulties in the operation of the oil refineries because the supply of raw materials was not always sufficient. Today, however, the selected palm plantation development plans--although they are at different stages, depending upon the country--are well underway everywhere and the existing refineries are important factors in getting the output of these plantations started satisfactorily.

As in the field of agriculture, IRHO is currently acting as the technical advisor to the managers of the industrial portion of these projects.

I. CONSTRUCTION OF EIGHT OIL REFINERIES UNDER THE PLAN

At the end of the second world war and the occupation, there were two quite obvious facts bearing on the problem of fat supply in France and in the French Union:

- the general shortage in animal fats (butter, grease, lard, etc.) and in vegetable fats, both for food and industrial uses;
- the vast possibilities in terms of vegetable fats in the overseas territories, particularly Black Africa, a land of sun and water, above all a land of oil.

In 1945, faced with the serious fat shortage on the domestic and international market as a result of the world war, the overseas France planning directorate took the initiative in a vegetable fat production development program for Equatorial Africa and West Africa; this program

involved the three principal oil crops: palm oil (and palmetto kernels), peanuts, and shea butter. The directorate decided to ask IRHO to make a study; the institute had been set up several years before, with government support, upon the initiative of planters, led by R. M. Michaux.

In the area of oil palms, the plan--without overlooking the industrial plantations which alone were capable of producing optimum yields--was put on a crash basis and priority was given to the efficient operation of the vast natural palm plantations along the Gulf of Guinea, with the help of the establishment of modern oil refineries; through a radical modification of the traditional extraction conditions, these refineries would, from the very first moment onward, help achieve a rather considerable improvement in the output in terms of quantity (90% of the oil contained in the palm nuts will be extracted instead of the customary 50-60% with only one-twentieth of the manpower) and in terms of quality (4-5% acidity, instead of 20-30%, with the water content and solid impurities being practically negligible). As a matter of fact, this involved not only the refinery facilities as such but it also meant launching a vast industrialization and economic expansion movement for which the palm oil refineries would have to constitute the catalyst.

On the basis of these data and upon completion of a survey mission carried out in 1947 by three specialists, the planning directorate decided to develop in the African territories an initial group of 8 oil refineries with an initial output capacity totalling 16,000 tons of oil per year and 12,000 tons of palmetto; these figures could easily be increased through subsequent expansions to 40,000 tons of oil and 30,000 tons of palmetto. The location of these refineries was selected in each territory in full agreement with the administrative authorities and the technical services involved, The following locations and capacities were selected:

Location	Initial Capacity		Theoretical Capacity
	Tons of Palm Nuts Per hour	Tons of Oil per Year	Tons of Oil per Year
IVORY COAST			
ACOBO-DABOU	12	4,000	6,000
DAHOMEY			
AVRANKOU	16	4,000	6,000
G'BADA	8	2,000	6,000
BOHICON	4	1,000	3,000
AHOZON	4	1,000	3,000
TOGO			
ALOKOEGBE	4	1,000	3,000
CAMEROON			
DIBOMBARI	6	2,000	6,000
EDEA	3	1,000	3,000

Upon request of the Ministry of Overseas France, IRHO agreed to take over the study project, the establishment and installation as well as the equipping of these refineries and the ancillary construction projects, such as work shops, garages, operational buildings, etc.

This vast enterprise was launched in 1948 when the Dibombari construction site was opened in March; it was completed in April 1952, when the last of the construction units was turned over to the territorial authorities of Cameroon, at Edea; the construction of these last units had been started in January 1951.

All of these eight refineries and their subsidiary buildings and facilities represent a considerable effort which required the implementation of numerous plans, the award of a thousand orders with 250 suppliers and contractors, the delivery of 7,000 tons of material and miscellaneous goods, as well as the erection of 25,000 sq m of industrial and housing construction. The work on the spot employed thousands of African workers supervised by about 40 European engineers and technicians.

The total cost of these oil refineries, in their initial stage, and their subsidiaries, amounted to 1,700 million Old Metropolitan Francs; this represents an investment of at least 110,000 Old Francs per ton of oil produced per year; this same capacity corresponds to an annual output value (oil and palmetto) of more than 120,000 Old Metropolitan Francs; but the facilities now benefit the economy of the African States.

Fonds d'Investissement pour le Developpement Economique et Social des Territories d'Outre-mer (FIDES)provided the financing for this.

The mission initially entrusted to IRHO, the construction of these refineries, was accomplished in March 1952 with the delivery of the Edea oil refinery to the territory of Cameroon. All of the objectives which the institute had been given early in 1947 had thus been achieved and the program had been 100% completed.

We must emphasize that, by the end of 1967, all of these oil refineries together will have produced more than 200,000 tons of low-acid palm oil and 150,000 tons of palmetto kernels, representeding almost 300 million NF (New Francs), figuring on the basis of the current European market price.

Furthermore, we must also note that the development of the fat requirements on the market gradually led to the almost complete disappearance of the demand for the high-acid village oil; without the oil refineries built under the plan, the Francophone countries would have experienced the complete abandonment of the exploitation of the tremendous potential of the nautral palm plantations which would have had very fateful consequences on the living standards of the farm populations.

Finally, the existence of these refineries there proved to be a catalyst as regards the entire oil palm industry, in terms of the prepar-

ation of the development plans of those countries in which they have been set up. Once all of these programs are operational they will make it possible to process the bunches produced during the years in which the first planted areas were placed in production. We can thus delay as long as possible the construction of new oil refineries and, as soon as they have become operational, we can have a sufficient supply to keep them operating at normal profitability.

II. SUBSEQUENT ACTIVITIES IN THE VARIOUS FRANCOPHONE TERRITORIES

(1) Ivory Coast

After running the official tests for the Acobo refinery in October 1950, IRHO turned the installations over to the territorial authorities in November; the latter then entrusted provisional management of these facilities to the Fournier, Ferrier, Afrique Company, a branch of the Worms group. On October 1, 1959, management was completely turned over to the Campagne Fermiere des Huileries de Palme de Dabou (Dabou Oil Refinery Company) in accordance with deliberation 254/AC/58 of the Constituent Assembly of Ivory Coast on 9 January 1959; the Worms group participates with a large percentage of the shares in this company.

After its building mission had been accomplished, IRHO remained as technical advisor to the authorities and continued to manage the day-to-day operations of this refinery. It is still playing this role today. In this capacity, it particularly participated in the preparation of improvement and expansion programs which have turned out to be necessary and which have made it possible to increase the processing capacities to 20 tons of palm nuts per hour.

The IRHO refinery inspector regularly visits the Acobo refinery and he assists in the technical direction of the operations and helps solve the problems that arise there; in this way he provides indispensable technical supervision for the general management and he can make his own observations on the spot; he can also help resolve other questions that might require his special attention in this connection.

Within the framework of IRHO participation in the preparation and implementation of the various phases of the oil palm plan of Ivory Coast--"first program, 4,700 hectares," and "32,000 hectares project"--the Refineries Division furthermore played an important part in the accomplishment of the industrial portion of these projects, In the study stage, it prepared the sections pertaining to technology; determination of the general characteristics of the refineries, provisional estimate of investments, provisional operations budget, etc.

During the implementation stage--upon request of SODEPALM, which the government of Ivory Coast appointed the single manager for the entire palm tree plan, in agreement with the competent services of the European Fund--it worked out the entire international competitive bidding file for the first two refineries to be constructed at Eloka and at Toumanguie. It then participated in the commission which was supposed to judge the

offers that had been submitted by the various contractors in response to this competitive bidding appeal; afterward, in cooperation with another expert specially appointed by the Fonds Européen de Développement (FED), it participated in the further processing of the offer from the contractor whose bid had been accepted, Ateliers de Wecker. Fnnally it supervised the construction of these two refineries and recently participated in the official tests for the Eloka refinery which was commissioned on 4 January 1968 and which was able to start industrial production on 8 January. The other one at Toumanguie will be placed on operation during the last quarter of 1968.

(2) Dahomey

The official tests for the Avrankou oil refinery were run in October 1950 and the facilities were turned over to the local authorities in October 1951. Management of the operation was soon entrusted to the Société des Huileries Modernes du Dahomey (SHMD), a branch of the Worms Group, which likewise, took over the management of G'Bada refinery, after running the official tests there in September 1951.

The oil refineries at Ahozon and Bohicon were officially tested in December 1951 but they were not placed in operation until Janaary 1953 and January 1954, respectively. Several experts in effect believed that their supply of palm nuts was highly problematical; the most pessimistic opinions had been expressed on this subject so that there were no really meaningful applicants to run those facilities.

In view of this situation, the governor of Dahomey decided early in 1953 to return the Bohicon oil refinery to the "Union des Cooperatives du Dahomey" - which was later on replaced by the "Societe Indigne de Prevoyance D'Abomey" and he asked the IRHO "on an exceptional and temporary basis" to supervise the entire operation of the facility there.

In Janury 1953, IRHO conducted technical test at Bohicon for 6 weeks; the refinery was operating properly the moment it was started up - something which was quite normal, of course; but it was furthermore very easily supplied with palm nuts which was quite a surprise for many people. From the very first few days onward, the anxiety gave way to optismism and, at the very end of the 6 weeks of testing, the IRHO was asked to continue to handle the technical and commercial operation of this facility. In February 1953, the average daily output was already 18 tons of palm oil, nn March it was 20 tons and in April it was 30 tons. The harvest was then so organized as to enable the refinery to run even during the slack season, by eventually extending the collection network.

The IRHO had stated that it was possible - even during he very first fiscal year - to turn out at least 500 tons of oil; now, during the first 12 months of an operation without any preparation, production reached a figured of 800 tons, in other words 8/10 of the theoretical capacity of the facility which had been operating for 12 months out of the year and sometimes even 24 hours around the clock for several months.

On 26 November 1953, an agreement was signed, awarding the technical and commercial management of Bohicon to the IRHO, for three years, without any financial intervention and for the account of the Fonds Communs des Sociétés de Prevoyance." This mission was at the same time expanded to include the Ahozon oil refinery which had been officially started up on 11 January 1954.

From that date onward, IRHO thus, on the one hand, functioned as the technical advisor for the government of Dahomey and for the manager of the Avrankou and G'Bada operations; on the other hand, it also handled the technical management for Ahozon and Bohicon. In the course of this management effort, which extended until 31 July 1961, the capacity of each of these two refineries was increased from 1,000 to 3,000 tons.

IRHO felt, however, that its true mission was research and not industrial operation; and so, in May 1960, it asked to be relieved of this function the carrying out of which prevented it from playing its role as technical advisor to the government of Dahomey as fully and as independently as it would have liked to do. On 31 July 1961, management of the Bohicon and Ahozon oil refineries was thus transferred to the Societe Nationale des Huileries du Dahomey (S.NA.H.DA), which also reorganized the Avrankou and G'Bada refineries whose management the SHMD had relinquished on 30 June 1961 for a number of reasons.

After 1961, IRHO continued to give the government of Dahomey and the S. NA. H. DA. the kind of regular technical advice which they needed.

(3) Togo

The installation and assembly work for the Alokoegbe oil refinery was completed in December 1951; the official tests were run in April 1952; the facility was turned over to the territorial authorities in June 1952.

Rather pessimistic opinions had also been expressed on the possibilities of supplying this refinery; companies began to submit bids for the management contract, after a thorough study, only during 1953, on the basis of the results obtained by IRHO at Bohicon in Dahomey. After rapidly getting the approval of the authorities, they then set up the Compagnie Fermiere d'Alokoegbe which began operations on 7 December 1953.

From the very first year onward, in 1954, this facility produced 615 tons of oil, and the figure of 865 tons was reached in 1955. In 1956, it produced 711 tons.

Unfortunately, during fiscal year 1957, conflicts broke out between the manager and the farm populations in the surrounding area; these conflicts mainly sprang from the development of the political situation in Togo; a strike on the part of the producers interfered with the shipments

of palm nuts, and this was quite harmful to the initially very favorable results which had been obtained in the beginning. The situation deteriorated rapidly and the managing company found itself forced to stop operations on 3 June 1958; the company did not ask for a renewal of the management contract which expired on August 31 of that year.

In view of this situation, the Togolese authorities then decided to establish a cooperative organization consisting of all of the palm nut producers; this cooperative was supposed to operate the refinery. But it rapidly turned out that this formula was very difficult to carry out in practice. The cooperative did not have the necessary experience and maturity and it did not have the skilled personnel indispensable in managing such a facility. The producers who constituted the cooperative were not at all aware of the technical, commercial, and financial necessities of operation, and they were notoriously unprepared for this task; they were primarily preoccupied with selling their palm nuts at the highest possible price, rather than seeing to the profitable operation of the industrial installations which, without being encouraged, they had undertaken responsibility for running.

In fact, operational management--from the harvesting of the nuts all the way to the sale of the products--had always been handled in practice under the high authority of the Minister of Commerce and Economic Affairs and under the control of the Director of Economic Affairs, by the refinery manager appointed by the government. The legal situation of this state of affairs was settled by Decree No. 6581, dated 20 March 1965, and signed by the President of the Republic of Togo; this decree established the Société Togolaise d'Extraction d'Huile de Palme, a semi-private company with a capital of 100 million Fr CFA, entirely underwritten by the Togolese government, although 30 per cent of the shares may be ceded to private capital, if any turns up.

In spite of numerous difficulties, technical, financial, and commercial, this refinery has continued operating since 1961, thanks to extremely wise management--a point which must certainly be emphasized here; it has turned out 500-600 tons of oil per year under the control of the Togolese authorities. Although it no longer has any direct responsibility as regards this refinery, IRHO has always followed the development of the situation with the greatest interest and, whenever the occasion arose, or whenever it was asked to do so, it never failed to give its advice and help both to the Togolese authorities and to the refinery management--quite free of charge and in a very well-meaning manner.

A plantation program is currently underway in the region of Sio; on the basis of this we can hope that the supply of palm nuts to this oil refinery will be greatly improved in the near future and that this volume will be sufficient to guarantee a degree of profitability which may not be very great but which will at least be satisfactory.

(4) Cameroon

At Edea we have the last unit to be constructed; the official tests there were run in March 1952 and the refinery was turned over to the local authorities in April of that year. However, certain requirements of the territory in terms of management methods, for a long time caused any possible management contract bidders to hold back; a managing company could not be designated until the end of 1953; this was the Societé des Plantations Reunies de L'Ouest African (SPROA): its contract is still running. This company had the advantage of owning a rather large plantation; furthermore it was able to harvest the old German concessions within the radius of action of the refinery; these concessions had not been kept up and nothing had been harvested from them for many years.

The output climbed to 470 tons of oil during the first year of operation in 1954; it then increased progressively and slowly but regularly during the following years and finally reached a figure of 1,500 tons in 1967. Considering the favorable market conditions for these products, this refinery is being operated under satisfactory economic conditions; the oil can be sold entirely on the local market at a price considerably higher than the price that could be obtained on the international market; in addition, the managing company is running the refinery very efficiently and wisely. Since its construction, the processing capacity has been increased by the manager gradually, from three tons of nuts per hour to six and even nine tons per hour.

Through the reports which it regularly receives from the managing company, IRHO also follows (as it does for all the other refineries in the plan) the development of the situation at Edea; in this way it can offer the manager--wherever the latter so requests--its technical aid and advice.

Dibombari is the only one of the eight oil refineries built under the plan which is not in operation as of this date; the plant was shut down in July 1962.

We must state, above all, that this situation has resulted entirely from the development of the political situation in Cameroon in general and in the region of Mungo in particular, where this refinery is located. The potential of the palm plantation surrounding the refinery would in effect have been largely sufficient to operate this refinery at least normally; this is indicated by the results obtained in 1956; during that year the refinery processed more than 18,000 tons of palm nuts and it produced almost 1,800 tons of oil.

The official tests for this oil refinery were run on 13 March 1951; although it is located in the very heart of a magnificent palm plantation, whose potential represents several thousands of tons of oil, it nevertheless has been without a manager for more than a year; there have been a number of bidders but the discussion on certain clauses of the specifications have been inconclusive so far.

One manager, SOCFINOL, a branch of an important group with a high reputation in the oil palm industry, was finally picked on 4 April 1952; but processing did not begin until 24 June, that is to say, the beginning of the rainy season; because of this, the processing rate was rather low, since the production during the end of the harvest did not exceed 80 tons.

In 1953, the first year of complete operation, oil production was 637 tons; but this tonnage was far short of the processing capacity of the refinery and way out of proportion to the true potential of the surrounding palm plantation. The job of the manager had been rendered very difficult as a result of the notorious inadequacy of the feeder roads, their poor maintenance, and the absence and perhaps also the rather precarious condition of bridges that were absolutely necessary there. Furthermore, the major portion of the palm plantation had been invaded by bush which blocked access to the adult trees and choked the young palm trees.

After this rather difficult beginning and thanks to the combined efforts of the managing company and the authorities, the situation improved rapidly and became rather normal is 1956. During that year, the output was 1,760 tons of oil.

Unfortunately, the development of the political situation in 1957 produced conflicts between the growers and the managing company; faced with a situation which looked hopeless, the managing company suspended operations on 12 October 1957 and cancelled its contract.

The Cameroon authorities then entrusted the management to a "Société Africaine de Prevoyance," which held on to the European personnel previously employed by the managing company and which resumed operation on 1 January 1958.

The problem of regularly supplying the refinery however was not solved for the time being, and conflicts--more of a political than of a technical nature--continued to harass the refinery and the producers. Production thus dropped to 700 tons in 1958 and then increased slightly to 900 tons in 1959; at the end of 1959, new difficulties which mostly sprang from political factors, once again dogged refinery operations; all of the European personnel resigned during September.

From that moment on, the situation constantly grew worse in all respects as a result of the absence of responsible officials and supervisors. Production dropped to about 700 tons in 1960, 540 tons in 1961, and 330 tons in 1962. Parallel to this, the equipment of course was not properly maintained; it deteriorated very rapidly and the refinery had to be shut down during July 1962.

More than in the case of any other of the refineries and because of the difficulties reported above, IRHO followed the evolution of the

situation at the refinery with great interest; on every possible occasion, it tried to bring the attention of the Cameroon authorities to the most important points that determine efficient operation and to give them maximum possible technical aid; but its offers found very little acceptance among the responsible officials; moreover, as we said before, the causes responsible for the difficulties at Dibombari largely went beyond the framework of technical problems. In 1962, after 30 months of management of Dibombari by SAP the liabilities due exceeded 50 million Fr CFA and an expert report by M. Poujade, the inspector of refineries of IRHO, concluded that it was necessary to carry out 40 million Fr CFA of work in order to restore the installations.

However, the government of Cameroon had taken preservative measures in order to prevent the equipment from continuing to deteriorate, as far as was possible; but there is reason to fear that these measures will not be completely effective if the situation continues as it has--and this, unfortunately, seems to be the case.

The projects now in progress or under study in the oil palm industry in Cameroon of course do take or will take the situation at Dibombari very much into consideration and the existing installations will be repaired to the maximum extent possible within the technical limitations, at least in the useful time remaining. It is regrettable that outside causes paralyzed a refinery which had the most favorable conditions for harmonious development.

CONCLUSION

IRHO has thus played a rather prominent role in the development of the industrial oil palm refineries in Francophone countries in the tropical zone of the African continent.

The eight so-called "Plan" oil refineries, which were built between 1948 and 1952, until recent years have been the only high-quality low-acid palm oil production facilities. Without them, the producing countries would, in village industry as in the past, have continued to produce secondary-quality oils, with a very low yield, employing manpower of which there was a tremendous surplus; moreover, it would have become increasingly difficult to sell that oil on the international market--a situation which actually had been existing for a number of years in the past.

In those countries in which these oil refineries have been built, they furthermore make it possible to guarantee the launching of oil palm development plans under the best possible conditions, plans which are now being carried out.

PRINCIPAL PROBLEMS OF OIL PALM NUTRITION

R. Ochs, IRHO

SUMMARY

Twenty years of experimentation on oil palm have enabled IRHO to attain a knowledge of the mineral requirements which, with the help of foliary diagnosis, gives the fertilizer needs according to the given situation.

Supplementary nitrogen is generally recommended for the first two or three years of growth. At the adult stage, nitrogen deficiency is difficult to correct.

Potassium is the key fertilizer element. The requirements, critical at early stages of growth of savannah tertiary sandy soils, are critical everywhere towards the tenth year. Supplementary potassium, applied sufficiently early, prevents a drop in yield; in the case of a deficiency, it rapidly leads to improvement then to reestablishment of normal production conditions.

It can be necessary to supply magnesium from the time of planting, either because of a primary deficiency or because essential potassium supplements induce a magnesium deficiency. At maturity, if the need is revealed by foliary diagnosis, magnesium in combination with application of standard potassium fertilization will assure optimal production.

With a few rare exceptions it is seldom necessary to supply phosphate or calcium. Among the trace elements studied, only boron, on alluvial soil, has so far proved necessary.

Fertilizer tables, according to the age of the trees, give the requirements for each element and location. Experimentation, several years in advance of the development programs in each country, enable the fertilizer composition to be worked out in good time for application to the trees.

INTRODUCTION

IRHO has been studying mineral nutrition for oil palms over the past 20 years, primarily in the francophone countries of Africa. The principal problems have now been solved in those countries. Proof of this is the fact that tree nutrition can be improved by fertilizer and that this results in increased production.

For mineral nutrition research, IRHO used very extensively the method of leaf diagnosis. The experience gathered so far makes it possible today, with the help of this efficient tool, to generalize the results obtained

at the research stations very rapidly and reliably.

With the help of the latest experimental results, this report will try to convey the present situation with respect to each mineral element, in young or old plantations.

I. Nitrogen

(1) Young Plantations

In the lower Ivory Coast, at La Mé, the requirement for nitrogen application to a plantation established in a forest zone in 1959 has been studied. Also examined was the effect of spreading high levels of fertilizer over a large number of applications. Growth measurements were made one, two, and 2 1/2 years after planting and they are shown in Table I, below, along with a coloration index established six months after planting, (Table II).

Table I
LM-CP 14 — 1959 Plantings

	Index of vigor dm3			Coloration
	June 1960	Aug. 1961	Jan. 1962	Dec. 1959 (Note 0 to 4)
N_0 = no nitrogen	110	1.060	2.120	1,14
N_1 = simple dose	140*	1.190*	2.370*	2,41
N_2 = double dose	140*	1.230*	2.390*	2,55
N_3 = double dose spread out	150*	1.230*	2.490*	2,40

It appears very clearly that applications of nitrogen very rapidly led to an improvement in the coloration of the leaves and to much more vigorous growth. On the other hand, the double dose, both spread out and applied at once, does not prove to be superior to the normal dose.

At present, IRHO recommends that the plantations in lower Ivory Coast, set up in the forest zone or in a newly reforested area, apply 125 grams of urea during the planting year and 250 grams the following year. These doses enable N contents of 2.75% per No. 9 leaf and 2.50% for the No. 17 leaf to be achieved, and this also gives the foliage a satisfactory coloration.

Still in the Ivory Coast, but in the savannah the zone (Dabou), it is also necessary to apply nitrogen during the early stages; in a test of 1962 plantings, the most favorable levels and forms of nitrogen to be used (urea or ammonium sulfate) were compared. Then, 3 years after the beginning of the test, leaf diagnosis, whose results are given in Table II, did not bring out any differences between the first 6 treatments. We can

therefore conclude that urea acts like ammonium sulfate and that it is not necessary to spread out the applications. Treatments 7 and 8, which could not be included in the statistical analysis because they involved only 2 repetitions instead of 4, showed a slight advantage on the part of the triple doses over the simple or double doses; but the contents obtained with the single or double doses are satisfactory (higher than the critical level), (Table II).

Table II
Dabou, DA-ES 41, 1962 Plantings
Leaf Diagnosis — N Content

Treatments	9th Leaf	17th Leaf
1. Ammonium sulfate, simple dose	2,71	2,56
2. Ammonium sulfate, simple dose, spread out	2,71	2,49
3. Urea, simple dose	2,77	2,56
4. Urea, simple dose, spread out	2,76	2,53
5. Ammonium sulfate, double dose	2,82	2,58
6. Urea double dose, spread out	2,75	2,62
General average	2,731	2,555
Coefficient of vigor	2,17 %	3,11 %
F-Test: not significant	F.N.S	F.N.S
7. Urea, triple dose, spread out	3,22	2,96
8. Urea, triple dose	3,01	2,95

For all of the similar zones in the Ivory Coast — the Savannah in the lower part of the country — IRHO recommends the application of 250 g. of urea, per tree, during the year of planting, 375 g. during the next year, and 500 g. during the 3rd year.

In Cameroon (La Dibamba) — on soils very closely related to those of Ivory Coast on which the two tests described above were conducted — a test comparing several forms of nitrogen did not demonstrate the superiority of any particular one, (Table III).

Table III
LD-ES 15, 1960 Plantings

	Index of Vigor (dm3)	
	Sept. 1961	Sept. 1962
Ammonium sulfate	225	848
Nitrate	176	975
Urea	170	800
Azorgan	159	876

The levels of nitrogen, which were adopted by IRHO for the young plantations in Cameroon, are—per tree—100 g. of urea during the year of planting, 150 g. during the following year, and 200 g. during the 3rd year.

Thus we see that—on soil types corresponding to the ferrallitic tertiary sands—the early applications of nitrogen are absolutely essential; a relatively low level is sufficient and the urea acts like ammonium sulfate.

In Congo (Brazzaville), on soil types that are quite different because the clay content can amount to as much as 75%, the forms and levels of nitrogen on 1959 plantings were also studied. The growth measurements, which were made at the age of 3, 4, and 5 years, are shown in Table IV. It is obvious that applications of nitrogen are essential and that urea and ammonium sulfate have the same effect; a high level of ammonium sulfate is no better than a low level, (Table IV).

Table IV
SI-ES 12 — 1959 Plantings

	Levels	Index of Vigor dm3		
		3rd quarter 1962	1st half 1963	June 1964
Ammonium sulfate	2 Kg	568*	1.410	2.170
	0,5 Kg	491**	1.440	2.290
Urea	0, 25	493**	1.250	2.150
Ammonium nitrate	0,5	291	710	1.460
Control		273	540	1.470

All of the above considerations and the results of numerous leaf analyses made in various situations on young plants enable us to conclude

it is necessary to apply nitrogen during the first years of planting; the case of Dahomey is more complex and will be studied below (mature plantations).

(2) Mature Plantations

There was no response to the applications of nitrogen, in terms of production, on the tertiary sands of the Ivory Coast, where experiments have been underway for many years at La Mé, Dabou, and Grand-Drewin.

At La Mé, where an experiment was set up in 1954 on 1946 plantings, the application of 2 kg of ammonium sulfate, per tree and per year, did not result in an increase in production, (Table V).

Table V
LM-CP 7 — 1946 Plantings

Period	Kg bunches per tree, per year	
	Without N	With N
1957 to 1960	79	77
1961 to 1965	84	79

At Dabou, in the first experiment set up in 1946, the two treatments which received potassium from that date onward can be compared: one of them also received 2 kg of ammonium sulfate per tree per year, (Table VI).

Table VI
DA-CP 1 — 1930 Plantings

Period	Kg bunches per tree per year	
	Without N	With N
1950 to 1955	64	67
1955 to 1960	83	83

At Grand-Drewin, the trees which had been getting 3 kg of ammonium sulfate per year since 1955 (1948 plantings), are not producing any more than those that did not get any nitrogen. (Table VII)

Table VII
GD-CP 5 — 1948 Plantings

Period	Kg bunches per tree per year	
	Without N	With N
1957 to 1960	73	75
1961 to 1965	57	56

In Cameroon, on essentially similar soils, no effect is observed either with applications of nitrogen in an experiment launched in 1952 on 1951 plantings. (Table VIII)

Table VIII
LD-CP 1 — 1951 Plantings

Period	Kg bunches per tree and year	
	Without N	With N
1957 to 1960	57	58
1963 to 1967	88	86

For these 4 experiments, the leaf diagnoses for the plots without nitrogen are always higher than the critical level, which IRHO evaluated at 2.50% nitrogen in No. 17 leaves [leaves in sequential rank position No. 17].

Until proof is furnished to the contrary, there is therefore no need to apply nitrogen to adult plantations in the Ivory Coast and Cameroon.

In Dahomey, where the critical nitrogen level is rarely reached, we do find responses to applications of nitrogen. In a trial begun in 1959 on 1947 plantings, the average output of 4 harvests from 1961 to 1965 gives the following results. Here we also have the leaf diagnosis values for this entire period (Table IX)

Table IX
PO-CP 17, 1947 Plantings

Treatments	N Content	Kg bunches per tree per year
Control	2.41	32
K	2.46*	35
NK	2.46*	36
2 NK	2.52**	40**

In other words, it took 2 kg of ammonium sulfate per tree per year to reach the critical level and to obtain a significant production increase.

In order to reduce this deficiency at maturity—and considering the N contents found in the leaves at young age—IRHO recommended for Dahomey continuous application of nitrogen fertilizer from planting up to the 6th year or until the particular area has become productive. This means the successive application of 125 g, 175 g, 250 g, 300 g, and 300 g, per tree per year

The nitrogen deficiency at maturity can be corrected by the application of nitrogenous fertilizer but the increases are very small and rarely profitable; likewise, IRHO recommends the application of nitrogen on adult plantations only in cases where the deficiency is very marked.

Indeed, we find that, when a legume cover crop is correctly sown and when it covers the soil properly—the nitrogen nutrition is satisfactory. Applications of nitrogen, recommended during the first few years following planting, are specifically intended to provide additional support when the cover is still insufficient, pending the elimination of Imperata grass, pockets of Eupatorium, as well as the improvement of the soil, if necessary (drainage).

II. Potassium

(1) Young Plantations

In the Ivory Coast, the problem of potassium fertilization of the young plantations differs, depending on the prior cultivation, for soils that are pedologically very closely related. At Dabou, in the savannah, it is thus necessary to apply potassium from planting time onward to guarantee the palm tree satisfactory nutrition. On the other hand in the forest zone, the influence of potassium on growth, for example, is only weak and is not evident in the first crops, (Table X).

Table X
La Mé — 1959 Plantings

	Index of Vigor, dm^3		
	June 1960	August 1961	January 1962
Without K	130	1,110	2,190
Low Level	140	1,180	2,340
High Level	140	1,240	2,490*

Recommended potassium fertilizer levels will therefore vary according to the situation (see mature plantations).

In Dahomey, on soils that are better supplied with potassium than those in Ivory Coast but that also reaveal a higher retention capacity, the applications of potassium are very quickly translated into growth differences, (Table XI).

Table XI
Pondé — 1959 Plantings

	Index of Vigor, dm^3	
	June 1961	June 1962
Without K	130	448
Low Level	165**	593*
Medium Level	156*	563*
High Level	176**	629*

Potassium would therefore be applied here (see adult plantations, below).

In Cameroon, potassium nutrition is satisfactory at the early stages and it is not necessary to apply potassium prior to maturity (see below).

(2) Mature Plantations

The most spectacular discovery in the mineral nutrition of the oil palm is certainly the discovery of the need for applying potassium to the mature plantations, regardless of the soil type.

In the Ivory Coast, on the coastal savannah, an experiment set up in 1946 showed that the production of the non-selected palm plantations could be increased from 2 tons to 12 tons through the application of 1 kg of potassium chloride per tree and per year. Table XII gives the output in kg. palm nuts per tree for those plots which have received potassium since 1946, since 1950 or since 1956.

Potassium fertilizer does not produce its full effect until about 4 years after the first application; this is explained by the biology of the palm tree, since the sexual development of the inflorescences occurs 2 and a half to 3 years prior to maturation, [illegible].

Table XII
DA-CP 1 — 1930 Plantings

	Kg. palm nuts/tree/year					
	K since 1946		K since 1950		K since 1956	
1947	24		21		19	
1948	46	32	18	17	20	18
1949	26		12		14	
1950	72		36		22	
1951	42		50		21	
1952	63	64	55	59	21	17
1953	49		48		13	
1954	57		63		13	
1955	99		99		13	
1956	99		86		14	
1957	85		81		23	
1958	68	83	64	82	45	44
1959	77		86		64	
1960	87		91		76	

In order to take into account the need for supplying potassium in the coastal savannah, from early growth onward, the recommended fertilizer, adjusted after several years of observation on the evolution of the potassium content of the leaves and the harvest output, will be as follows in terms of kg of potassium chloride per tree: 0.250 during the year of planting, then, successively, during the following years: 0.750; 1.0; 1.25; and 1.5; this last dose can be increased later on as a function of the production output. Generally, an output of:

7 - 10	tons /	ha	requires	an	annual	application	of	1 kg /	KCl
10 - 14	"	"	"	"	"	"	"	1.5	"
14 - 18	"	"	"	"	"	"	"	2.0	"
18 - 22	"	"	"	"	"	"	"	2.5	"
22	"	"	"	"	"	"	"	3.0	"

In the forest zone of the Ivory Coast, similar important results were obtained at La Mé, the application of 2 kg of potassium chloride per tree per year increases production by about 60%, (Table XIII).

Table XIII
LM-CP 7 — 1946 Plantings

	Kg bunches per tree per year	
Period	Without K	With K
1957 to 1960	60	96**
1961 to 1965	63	99**

At Grand-Drewin, it also takes a very high level to get worthwhile responses, (Table XIV).

Table XIV
GD-CP 5 —1948 Plantings

		Kg bunches per tree per year		
Period	Without K	With K		
		0.8 kg	1.2 kg	1.6kg
1957 to 1960	69	67	76	83*
1961 to 1965	50	55	57*	64**

The foliary analyses and production results recorded to date necessitate, for the forest zone of lower Ivory Coast, classifying plantations, as regards their requirements for supplementary potassium, on the basis of previous production. On forest soil, application only begins about the tenth year, and is specifically determined according to production, as for the savannah described above.

For plantations on depleted forest soil, applications start the year following planting and are then increased annually:

Kg KCl per tree: 0.300; 0.500; 0.750; 0.750

and then from 1-2 kg. depending on production for the following four years. The general recommended level for mature trees is then followed.

In Cameroon, the effect of the application of potassium can be observed in terms of production output only 10 years after planting, (Table XV).

Table XV
LD-CP 1 — 1951 Plantings

Period	Kg bunches per tree per year	
	Without K	With K
1957 to 1960	56	59
1961 to 1965	64	70
1963 to 1967	82	92

The beginning of the effect coincides with a slow drop in the critical level after planting; this level drops below 1% after ten years. This is why applications of fertilizer should not be considered until the 7th year, in order to prevent this drop in the content of the leaves; 6 years after planting, 500 g of KCl per tree are applied, then, respectively, 1 kg and 1.5 kg during the following 2 years, before switching to the general scale established as a function of the production output.

Similarly on sand-bar land in Dahomey, it is potassium which provides the greatest increase in the yield, as results from an experiment set up in 1948 on a 1929 plantation show , (Table XVI).

Table XVI
PO-CP 7 — 1929 Plantings

Period	Kg palm nuts per tree per year				
	Without K	K	NK	PK	NPK
1953 to 1964	50	73	81	86	83

For reasons pointed out above (young plantations), the scale of potassium obtained for the plantations in Dahomey is as follows for the first 5 years; 200 g, 200 g, 500 g, 750 g, 1 kg per tree. Then 1.25 kg per tree is applied if the output is less than 10 tons or 1.5 kg if it is more than that figure. After the 10th year, the general scale is adopted.

In the experiments reported above, potassium fertilizer is applied in a ring around the trees. This localized application is suitable for clay soils (Dahomey) which have good retention capacity.

On the other hand, in the ferrallitic soils of the Ivory Coast, there is reason to anticipate heavy leaching of fertilizer applied in ring form as a result of the heavy concentration per unit of surface. It is preferable to spread the fertilizer on a larger surface in order to prevent leaching. Studies on the root system showed that the fertilizer should be arranged over the entire surface of a circle with the palm tree as the center. Mechanical equipment that will be capable of casting the fertilizer all the way to the foot of the trees should be investigated.

The form in which potassium should be applied has been studied and in several experiments potassium sulfate was compared to potassium chloride. At equal fertilizing units, no difference was established between these two potassium salts, either in terms of production or oil quality.

III. Magnesium

(1) Young Plantations

In Cameroon, magnesium deficiency is serious in young trees and is expressed by characteristic chloroses. The application of magnesium in various forms makes it possible to increase the Mg content of the leaves, (Table XVII).

Table XVII
LD-ES 15 — 1960 Plantings

	Mg Content		
	1961 Grade 1	1963 Grade 17	1965 Grade 17
Magnesium sulfate	0.282**	0.324*	0.280**
Calcined magnesia	0.259**	0.334*	0.282**
Dolosal	0.230	0.296	0.256**
Control without Mg	0.206	0.249	0.215

Although plant growth does not appear to be improved by these applications, the supply of this substance nevertheless must be started from planting time onward in order to guarantee balanced nutrition (see mature plantations, below), (Table XVIII).

Table XVIII
LD-ES 15

	Index of Vigor, dm^3	
	Sept. 1961	Sept. 1962
Magnesium sulfate	210	911
Calcined magnesia	178	843
Dolosal	169	875
Control without Mg	174	870

The magnesium deficiency in young trees can be found also in the Congolese basin (Congo-Brazzaville).

In the Ivory Coast, the principal deficiency is potassium. In certain savannah zones, applications of potassium on young plantations cause a magnesium shortage which manifests itself through the appearance of chlorosis. Magnesium-containing fertilizer makes it possible to suppress this chlorosis and also increases the strength of the plants. At Dabou, in 1964 plantations, magnesium applications, in an experiment where the plants regularly received potassium, increased the circumference at the neck, the length of the leaves, and the number of inflorescences, (Table XIX).

Table XIX. DA-CP 13 — 1964 Plantings

	Without Mg	With Mg
Circumference at neck in June 1967	167	179**
Length of leaf in June 1967	263	284**
Number of inflorescences August 1967	15.9	17.2

The applications of magnesium are therefore recommended for these savannah soils. This can be applied in the form of 27% Kieserite at the rate of 60 g per tree during the planting year and 125 g during the following year.

(2) Mature Plantations

The most acute magnesium shortages at maturity are certainly those in Congo - Brazzaville (Basin), (Table XX).

Table XX
ETOMBI — Mg Contents

1930 Plantings	Healthy	0.267
	Suffering from chlorosis	0.040
1941 Plantings	Healthy	0.280
	Suffering from chlorosis	0.005
1947 Plantings	Healthy	0.251
	Suffering from chlorosis	0.030

Applications of magnesium on plantations suffering these shortages will make it possible to raise the contents in the long run.

In Cameroon, where the deficiency is never as great, magnesium applications on mature trees lead to yield increases, (Table XXI).

Table XXI
LD-CP 1 — 1951 Plantings

	Kg bundles per tree per year	
	Without Mg	With Mg
1957 to 1960	57	59
1963 to 1967	82	92

These applications should be made from planting time onward and they will successively involve the following quantities of 27% Kieserite: 100 g, 150 g, 200 g, 300 g, 400 g, and then 500 g per three, during the following years.

On the other hand, in the Ivory Coast, it was never possible to obtain an output increase through application of magnesium.

At La Mé, the application of 2 kg of magnesium sulfate since 1956 has not produced any effect whatever, (Table XXII).

Table XXII
LM-CP 7 — 1946 Plantings

	Kg bunches per tree per year	
	Without Mg	With Mg
1957 to 1960	80	76
1961 to 1965	83	80

At Dabou, plots which did and did not receive potassium, were subdivided from 1950 to 1953 in order to study the possible action of magnesium. In 1959, no effect was found after 5 years of application, (Table XXIII).

Table XXIII
DA-CP 1 — 1930 Plantings

	Control Without K	K after 1946	K after 1950
Without Mg	13	105	100
With Mg	13	93	99

In view of these results, no application of magnesium is recommended for mature trees under the conditions prevailing in the lower Ivory Coast.

IV. Phosphorus and Calcium

Applications of high levels of rock phosphate in the savannah zone of lower Ivory Coast, prior to 1946 did not restore the production of the

oil palm. Potassium proved to be an indispensable element here. Also in the Ivory Coast, phosphorus has similarly had no effect in the forest zone. In an experiment at La Mé, where 2 kg of dicalcium phosphate were administered per tree per year, after 1954, the following output was obtained: (Table XXIV).

Table XXIV
LM-CP 7 — 1946 Plantings

Period	Kg bunches per tree per year	
	Without P	With P
1957 to 1960	84	72
1961 to 1965	85	77

On the other hand, in the region of Sassandra, there is an effect resulting from phosphorus application, (Table XXV).

Table XXV
GD-CP 5 — 1948 Plantings

Period	Kg bunches per tree per year	
	Without P	With P
1957 to 1960	68	80**
1961 to 1965	54	59*

Indeed, this effect is found only in the presence of potassium, as shown in Table XXVI.

Table XXVI
GD-CP 5

	Kg bunches per tree per year					
	1957 to 1960			1961 to 1965		
	K_0	K_2	K_3	K_0	K_2	K_3
P_0	65	64	75	51	49	59
P_1	73	87	91	49	65	69

In Cameroon, a similar observation was made in connection with an experiment set up in 1952. In the presence of potassium, phosphorus produces an increase of 18 kg of palm nuts per year per tree, whereas it has no effect whatever in the absence of potassium, (Table XXVII).

Table XXVII
LD-CP 1 — 1951 Plantings

	Kg bunches per tree and year (1961 to 1965)	
	K_0	K_1
P_0	66	61
P_1	63	79

In all of these experiments, phosphorus is applied in the form of dicalcium phosphate; the leaf diagnosis shows correlated increases in P

and Ca in the leaves; it is therefore a priori difficult to decide which element is really active here. However, partial correlation studies between the yields and the calcium contents—assuming that the other elements are constant—have shown that the output increase was in fact a result of the application of calcium.

Be that as it may, the question so far has not been sufficiently clarified and the yield increases are too transitory for IRHO to recommend the application of phosphorus or calcium to mature oil palms.

V. Trace Elements

The first attempts at fertilizing with trace elements were undertaken in the Congolese basin at Etoumbi in an effort to try to stop a disease which was developing on very light highly leached soils which, moreover, had a very low absorbtive capacity. The few results recorded with Mn, Zn, Cu, B, and Fe during the 2nd and 3rd years of experimentation were not confirmed; it seemed that the magnesium shortage alone was responsible for the losses and that it promoted the spread of tracheomycosis.

Manganese was also tried to an attempt to control the spread of fusariosis (tracheomycosis of the trunk). Around 1955-1956, it appeared that the Mn contents of the leaves were relatively low (150 to 200 ppm) in all of the plantations where the disease was noted. Subsequently it was learned that fusariosis can develop at Mn contents in the neighborhood of 400-500 (Dahomey) — in other words, values which can be considered frequent in the case of the oil palm.

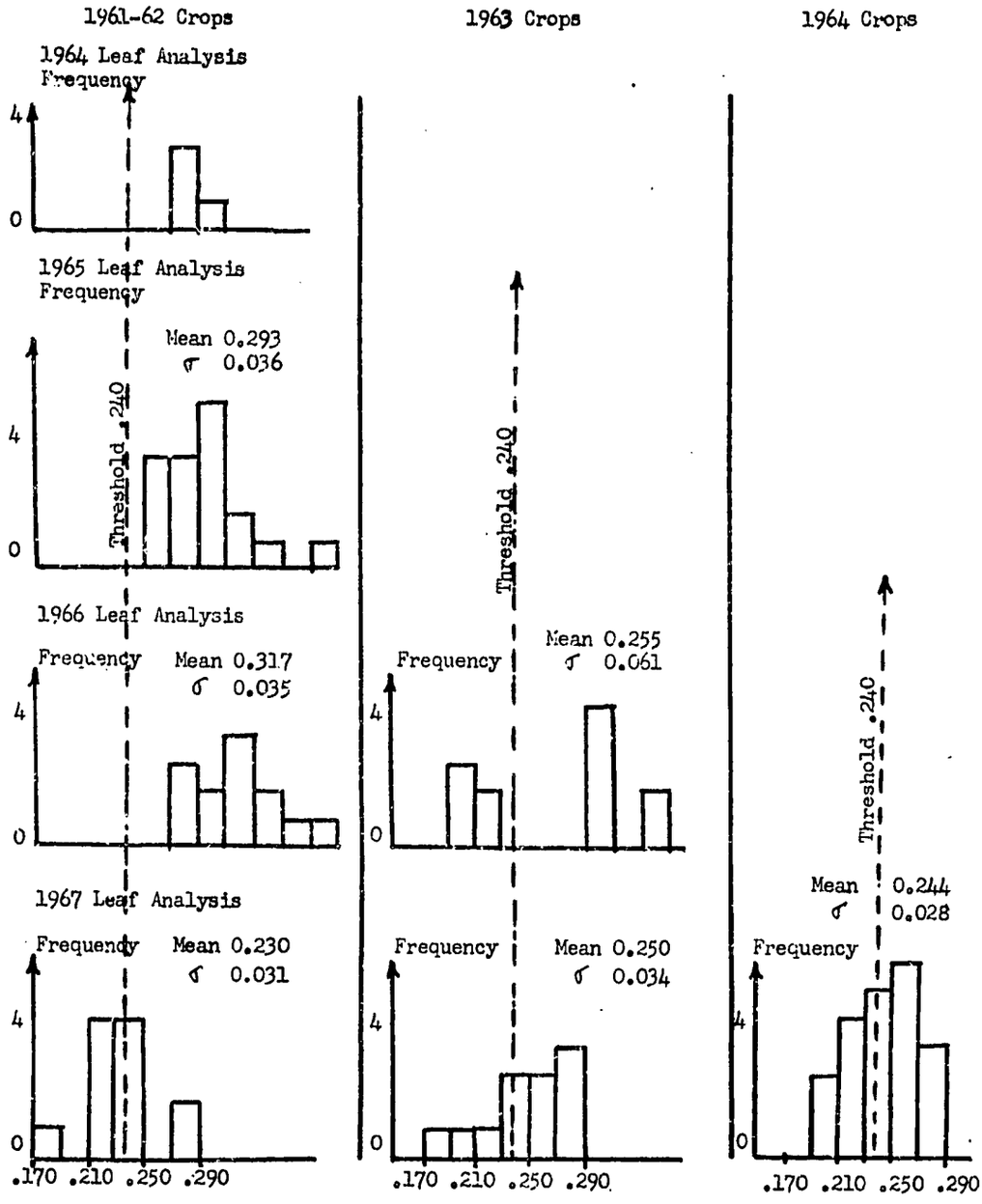
So far only boron has proved useful in reducing the symptoms known under the general but rather inaccurate term of "little leaf." No direct effect on production has so far been detected, at least in our experiments, which are very recent.

VI. Control of Nutrition

In connection with the study of each element, we have attempted to determine the fertilizer to be used in each country as a function of the age of the palm plantations. Wherever this was not done, this was due to lack of sufficient information, particularly numerical data, to propose a suitable scale. It goes without saying that, among the various formulas advanced here, leaf analysis will make it possible to select the most suitable method and to verify the justification of this selection later on. Through the combined use of agricultural experimentation and nutrition control by means of leaf analysis, IRHO was able to establish the various manure and fertilizer scales which have been used over the past several years on its plantations at Dabou, Drewin, and in the selection fields at its research stations. The institute manages the nutrition of large plantations, which have been set up in recent years in Ivory Coast and Dahomey, through the same process: leaf analysis, supplemented by experimentation in special situations.

Fig. 1

Magnesium Content - 17th Leaf



The nature of the soil, the precipitation volume and rate, as well as sunshine all have an effect on the element content of the leaves. If the level determines production, it is itself influenced by this production. We are thus forced to make judicious use of the simple notion of the critical level (1% of potassium in 17th leaf of the palm tree, for example) in order to take into account the very large number of phenomena involved here, because the level observed at a given moment represents a state of equilibrium resulting from the effect of various components.

The technique of leaf analysis, combines such factors as depth of the horizons, physical and chemical characteristics of the profiles, water supply, drainage, sunshine, etc, has proved to be highly superior to simple soil analysis.

When thus used, leaf diagnosis is a remarkable tool which enables us to work out the management of fertilizer programs for development operations on solid foundations, without having to set up an experimental network in advance.

Each year, samples are taken on 50 ha lots, in the plantations under control. We thus have a photograph as it were of the nutritional state of the plantation. Figure 1 gives us an example of the situation for magnesium, for different crops in a large plantation bloc. We can very easily read off the amount of the deficiency for each plantation campaign.

These problems will be solved at the right time with the help of the experiments set up by the IRHO at its La Mé and Dabou stations; these experiments are intended to provide the answers to such questions as: up to what age should we use nitrogen? At what age should we begin to apply potassium in the forest zone? Are applications of magnesium profitable in the savannah? And so on. These stations were established prior to the beginning of the major plantation programs of Sodepalm, Sonader, and, very soon, also the programs in Cameroon.

CONCLUSION

On the basis of the information obtained here, the principal needs of the palm tree in terms of mineral elements can be tentatively described according to the type of soil on which it is grown.

In the tertiary sands, which are abundantly represented in West Africa, the principal deficiency is potassium: it appears sooner or later, depending upon the previous cultivation record (savannah or forest) and it is sometimes combined with a magnesium deficiency.

On soils of granitic origin, potassium is again the most necessary element but phosphorus (at least in the form of dicalcium phosphate) sometimes has a beneficial effect in association with the application of potassium.

On alluvial soil, potassium and magnesium deficiencies are less noticeable but they are nevertheless quite frequent. Boron sometimes proved to be necessary to suppress symptoms of leaf malformation.

In all cases, the application of nitrogen is recommended at an early age. Nevertheless, this application should be suspended sooner or later depending upon the situation.

The experiments described in this report made it possible to work out fertilizer tables. These tables, when applied systematically to the IRHO plantations and to the other company plantations which are to be given the benefit of this advice are checked each year by means of leaf analysis.

A very minute interpretation of each situation will then make it possible to decide whether these tables should be modified.

The IRHO believes that it has demonstrated—on the basis of all of its research on mineral nutrition and with the help of the results obtained—that it was possible to modify the mineral composition of the oil palm plantations in order to increase their output. IRHO also believes that continuous control and its own experimentation program, several years ahead of the development programs, will enable it to provide the best possible solution to each particular situation.

OIL PALM CULTIVATION TECHNIQUES

P. Renault, IRHO

SUMMARY

The work carried out by IRHO at its research stations and experimental plantations has the particular objective of developing, on behalf of the planters, the most efficient cultivation techniques in order to provide the plantations with the best conditions for growth and production, to ensure good profitability.

The report contains a brief description of the various techniques recommended, techniques which could be tested on large areas and which involve all of the operations from the production of the vegetal material to the operation of the plantations and replanting.

It also establishes the evaluation and control criteria which practical operators need in order to make a judgment as to the state of their crops and the growth of these crops.

* * *

The work carried out by IRHO at its research stations and experimental plantations, have made it possible to determine those cultivation techniques which are best adapted to various ecological conditions and to give the planters the means to investigate and control which will enable them to determine the growth and production conditions in their palm plantations, on the basis of numerical data, and consequently to select the cultivation techniques to be employed in each particular case.

The paper contains a brief review of the essential elements, without being able to make a detailed description. The reader will, however, find a bibliography at the end of this article, listing the IRHO studies published in Oléagineux giving the necessary further details.

This summary will not deal with problems of fertilization or crop protection problems, nor will it cover soil and water management questions which are the subject of separate papers.

To refresh the reader's memory, it will therefore only briefly mention the following:

- preparation of forest soil with alternating swathing (1), manual or mechanical tree cutting which either can or cannot be combined with stumping (tree crusher or tree dozer) (2), or stump watering (Rome, KG water jet) (3, 4);

- mechanical preparation of savannah soils with Imperata grass (1, 5);
- drainage, terrace plantation (6), irrigation (7), and bare-soil cultivation.

The various techniques recommended by IRHO will be taken up in succession, from the plant material production stage to the production and replanting stage.

Production of Plant Material

In addition to the genetic factors and problems of selection, the quality of the plant material depends on the conditions under which it was obtained: quality of fertilization and quality of pollen used which may lead to anomalies of germination or growth.

All of the oil palm seeds produced by the institute (8 million per year) spring from artificial fertilization; their quality is thus controlled by the normal embryos—any lines having less than 95% normal embryos being eliminated. This elimination is completed by sorting out seeds with abnormal shapes or bad composition (flotation).

The severity of the controls thus makes it possible to obtain an average germination of 85% and to achieve a considerable reduction in the elimination rate in greenhouses and nurseries. These measures guarantee the very great homogeneity of the plant material delivered and make it possible to reduce by 12% the seed quantities required per hectare of plantation.

So far, two germination methods have been recommended: germination is isothermal seedbeds with or without substrate (8, 9); they make it possible to obtain rapid germination but this means that it is absolutely necessary to make sure that very strict moisture conditions are maintained for the kernels; this is why the so-called dry-heat method is preferred; here the germination is perhaps a little slower but it is more concentrated and better grouped and it is much easier to apply (one single soaking of 7 days prior to placement in hotbed). This method has already been tested out on large lots and it is currently included in the extension program.

After the seeds have germinated, they can be shipped over long distances in wooden containers and the delivery quality is perfect (10). These germinated seeds are then replanted in greenhouses in plastic bags (11,12); this is the only technique currently used which is very easy to apply.

The same principle (plastic bag, 40 X 40) is now recommended also for the nurseries (13) instead of and in place of open ground nurseries (14). The bag-nursery plants are more delicate to handle (watering) but they offer tremendous advantages in practical terms (speed of shipment and emplacement) and in agronomic terms (the plants are not injured and this facilitates faster recovery after planting out.) The norms for

fumigation, selection of the substrate and the fertilizer have been determined for greenhouses and nurseries, along with the eliminations which have to be made in each of these stages (15, 16).

To prevent losses due to blast in nurseries, it is recommended that the area be shaded during the critical period by palm trees; this shade can also be provided by an interspersed crop of castor oil plants whose cultivation conditions have been determined (recommendations to be published). At this moment the possibility is being studied of replacing the palm trees which are sometimes difficult to supply.

When the nurseries are located in open ground a dibble is recommended for transplantation, if the soils of the nursery are light, so that a mound of earth is obtained that will be large enough (17); before doing anything else, the roots should be cut (18), a technique which also leads to faster recovery of the young palm trees.

Planting Out

After the ground has been prepared a legume cover crop should be planted at the time of the first rainfall (19). They have a beneficial effect on the yield of the palm trees. The planting of the palm trees (20) must be carried out as soon as the rainy season is well underway.

The care to be given to the young palm trees has been described (21, 22), as have the means for protection against rodents with wire netting (23), supplemented with poisoned bait.

Maintenance and Operation

To facilitate the growth of the young trees and to guarantee their proper installation, it is a good idea to remove the first inflorescences (castration) (24). Indeed, the first bunches formed are small and rather poor in composition—and are of no economic interest at all. This castration, performed for about 12 months, enables a larger tonnage of bunches richer in oil to be produced during the first year of harvest. Certain precautions must be taken in connection with castration which can be performed with the proper tools. This technique offers other advantages, particularly in areas with little rainfall, where it makes it possible to stagger the production in relation to the seasonal weather variations. Highly selected material, placed under very favorable ecological conditions, sometimes produces an excessive percentage of female inflorescences, during the first harvest years, at the expense of male inflorescences, leading to insufficient fertilization. It is then necessary to perform assisted pollination, whose various steps have been spelled out (quantity of pollen per tree and frequency of passages). The results obtained in experimental plantations have made it possible to codify the harvest norms (organization, tools to be used) (25, 26), the transportation of the bunches on muleback (27) and also made it possible to select a trailer model for the shipment of the bunches in sterilation cases.

After long tests, a mechanical spreader equipped with apendulum lever or beam, was recommended for the application of fertilizer over large areas (28).

In terms of crop maintenance, tests currently are concentrating on the use of a herbicide, both for cleaning the rings and for selective or temporary weeding. These tests are intended to determine the minimum quantities to be used, in connection with the wise selection of treatment equipment and accessories.

Control of imperata grass under the palm trees must also be taken care of regularly; any resprouting must lead to treatment employing the wiping technique (5); the most important pockets here must be treated by spraying (29). The control of grasses in general can be handled through judicious grazing of cattle (30).

Replanting the Palm Plantation

This replanting requires the rapid destruction of the stems of the old palm trees, sites for the proliferation of many coleoptera or fungi, which constitute a serious threat to the new plantations. This fast destruction can be handled only through burning after cutting and blasting of the stems. The cutting can be done manually or mechanically and the trunks can be further cut [illegible] hand saws or mechanical saws. The work schedule must be coordinated with the seasons. This technique (36) makes it possible to reduce the period between tree felling and replantation; this is by no means negligible economic advantage.

Survey and Control Criteria

The selection of the cultivation techniques must be made on the basis of local conditions; it is therefore important for the planter to have survey and control criteria available which will enable him to make a situation estimate not in a subjective manner but on the basis of numerical data; in this way he can determine the growth state of the crops, the level of their nutrition, their water supply, and the climatic variations which influence the growth, the output, or the nutrition. These criteria will enable him to take action at the most opportune moment so as to remedy any defects whenever this is possible.

a) Growth Measurements

These measurements involve: the circumference at the neck; the number of leaves put out per month; the length of the largest leaf. They make it possible to follow the growth of the plants and the growth regularity during the various seasons with reference to average norms. They thus make it possible to determine the influence of ecological factors and of the techniques utilized, either in the nurseries (31) or in the young plantations; they make it possible to select those factors and techniques which prove to be best under the given conditions. These measurements in addition make it possible to determine the earliness of the young crops to be expected.

b) Water Supply

Water is one of the principal factors in palm tree growth and production; the water supply for the palm tree must be guaranteed regularly throughout the year; but this is rarely the case. It is nevertheless possible to influence these water factors either through supplementary overhead irrigation, when this is possible, or through suitable cultivation techniques. which will guarantee the economical use of water. In order to estimate the quantity of water available for the palm trees in relation to their needs, in a large-scale cultivation setup, we calculate the water balance is calculated in which the initial reserve in the soil, the rainfall volume, and the evapo-transpiration are taken into account. The most frequently obtained weather data pertain to rainfall (mm of water and number of days of rainfall); IRHO has worked out a formula for estimating the potential evapo-transpiration, based on the number of days of rainfall (32).

The planter thus has a very useful criterion for managing his palm plantation, for selecting the appropriate cultivation techniques, and for estimating future production.

c) Stomata Opening Test

This other method enables us to check on the water supply state of the palm trees under given situations (33). It offers the advantage of "querying" the plant directly. This test may be used to regulate the frequency and the quantity of water to be supplied through supplementary sprinkling or watering; it also makes it possible to follow the water supply for the plant during the dry seasons and thus to evaluate the true duration of periods of water shortage and to estimate, for example, the effectiveness of water economy techniques.

d) Useful Sunshine

This is defined as the sunshine occurring during periods of sufficient rainfall and it constitutes a good criterion for estimating the growth conditions. for figuring out the anticipated output, and for getting an idea on the potassium nutrition level of the palm trees. In fact, the critical level of potassium in the leaves varies according to the weather conditions, and the climate very often the first limiting factor (34).

e) Leaf Analysis

There is no need for emphasizing the importance of checking on plant nutrition, regardless of whether we are working with nurseries or plantations; this check can be performed by means of leaf analysis (35). The very large-scale use of this technique (more than 3,000 samples analyzed annually for oil palms) pertains not only to the determination of the evolution of nutrition in experiments but also covers cases of industrial plantations (on the average of one sample for every 50-100 hectares, depending upon the locations and the age of the crops as well as the heterogeneity factor). The leaf analysis results enable a determination to be

made of the required mineral supply and advice to be given the planters as to the most economical fertilizer.

CONCLUSION

IRHO has attempted to develop the best techniques for oil palm cultivation, in the light of the various ecological conditions, and to disseminate this information widely. The validity of the techniques recommended has been confirmed in large-scale plantations within the framework of the development operations to which the Institute contributes its technical advice.

These techniques must be adapted to the particular conditions in each sector; it is also important to give the planters criteria for making situation estimates so as to enable them to make a wise choice of the techniques to be used and the measures to be taken in order to create the best possible growth and production conditions for palm trees.

The criteria spelled out here thus make it possible to follow the growth of the trees, to determine their state of nutrition as well as their water supply, and to determine also the importance of the variations in climatic factors.

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OIL PALM SELECTION BY IRHO

J. P. Gascon, IRHO

SUMMARY

Through the International Experiment, conducted on the initiative of IRHO, the superiority of crosses between Far East strains (Déli) and African strains (La Mé, Yangambi, and Sibiti) and each of these parent stocks has been demonstrated.

The first crosses produced an average of 5.5 tons of bunches per hectare more than the Déli and 2 tons more than the African X African crosses. They are well adapted to a variety of conditions and have vegetative characteristics intermediate between the Déli and African strains.

The new IRHO programs are based on the principles of recurrent reciprocal selection and have been set up, starting in 1959. The first results of this first parent stock test demonstrate the early development and high productivity of the 1/2 Africa X 1/2 Far East crosses. The production from 3/4 Déli X 1/4 Africa crosses is less satisfactory. Self-fertilization within one or the other of these strains produce very low output, compared to crosses between strains.

This confirms the hypotheses which have been advanced on oil palm genetics. The new programs, which also involve the introduction of new strains, such as Elaeis melanococca, and the search for resistance to certain diseases (Fusariosis), already cover 800 hectares and plans call for planting an additional 500 by 1972. The first planting of the second generation trial will begin at that time.

INTRODUCTION

Over a period of 40 years, the output of African oil palm plantations has increased from 0.4 to more than 3 tons of palm oil per hectare in zones suitable for oil palm cultivation as a result of improvements due to experimentation and selection. Selection, in turn, is responsible for the increase in the output from 10 to 16 tons of bunches of palm nuts per hectare and the increase in the amount of palm oil extracted from the nuts, from 9 to 20%.

This report will discuss the recent results which greatly contributed to these improvements and the current policy and trend in selection.

IRHO Selection Process

From its very inception, IRHO has devised its programs on the basis of the principle that the oil palm, being an allogamous plant, should be expected to show improvement in production as a result of crossing with genetically different strains.

The International Experiment launched in 1947, which included many genealogical fields, demonstrated the correctness of this orientation by showing the superiority of the inter-regional crossings and the importance of the differences between the parental material.

On the basis of these results, recent programs (1958) have been aimed at finding the best combinations within the inter-regional crossings and call for the reproduction of the crosses in order to supply seeds.

A. Parental Material and Inter-Regional Crosses

(1) Parental Material

In 1947. IRHO took the initiative in an exchange of plant material between three of its selection stations (La Mé, Pobé, Sibiti), the INEAC station at Yangambi (Congo-Kinshasa), and the plantation of the Rubber Financing Company of Johore Labis (Malaysia).

This vast exchange, called "International Experiment," is an example of the importance of collaboration between various countries. Each of the 5 participants received the best pollens from the other four and used them to fertilize the best trees, then distributing the seeds obtained among the 5 members.

The introductions accomplished in connection with this experiment and those accomplished since then from Indonesia, Malaysia, and Nigeria, have made it possible to round up a sample of selections from oil producing countries.

IRHO thus currently has the following:

- Dura Déli from various sources:

Sumatra—old plant introductions (Dabou) and recent ones from Pabatu, Bangun Bandar;
Malaysia—plant introductions from Johore Labis, Layang-Layang, and Serdang.

The Déli palm tree revealed a certain number of unfavorable characteristics which make it advisable not to use it in a pure plantation. In Cameroon, Congo-Kinshasa, Ecuador, and Colombia, it has proved to be sensitive to magnesium deficiency. It very easily and readily shows the

outward symptoms of boron deficiency in Colombia and perhaps also in Malaysia. It is very sensitive to crown disease. Under severe drought conditions, its leaf growth rate is rapidly slowed down. Finally, its pulp oil richness is less than that of plants from other strains.

- Tenera from various IRHO stations, from Congo Kinshasa and from NIFOR.

Comparing the Déli, La Mé, Pobé, and Yangambi-Sibiti parent material, on the basis of the results of the La Mé station in Ivory Coast, J. P. Gascon, C. de Berchoux (5, 3) and G. Benard (1) have shown very definite differences between the original plants, in terms of such characteristics as production and vegetative system; they have made the hypothesis that these original plants can be classified in 3 groups: Déli, Yangambi-Sibiti, and La Mé-Pobé, belonging to different oil palm distribution centers.

To summarize the importance of the differences which are observed here, a summary of the characteristics of the original plants is shown in Table I.

(2) Inter-Regional Parent Stock Crossings

The production and vegetative characteristics of inter-regional crossings were studied by Gascon, de Berchoux (5, 3) and Benard (1): the results which they reported and commented on are reviewed here, in the light of the latest observations.

a) Oil Production

In making inter-regional crossings, IRHO had several purposes in mind:

- to increase the production of bunches through the combination of genetically different strains;
- to improve the bunch quality of the African strains with the help of Déli;
- to obtain material that will be better adapted to the various environments.

The results, which are contained in Table II show that these objectives have been achieved.

The production of bunches from the inter-regional crossings is definitely greater than that of their parental stock at all of the IRHO stations; the improvement obtained is about 5.5 tons of bunches per ha, compared to the Déli parent stock and 1.5-2.7 tons compared to the La Mé and Yangambi-Sibiti parent stock, under the ecological conditions at La Mé in the Ivory Coast; it is 4.6 tons compared to the Déli variety and 3.8 tons compared to the La Mé plants at La Dibamba in Cameroon, and it is 2.-2.6 tons compared to the Pobé parent stock at Pobé in Dahomey.

Table I: Mean value of characteristics studied at La Mé for Déli, Yangambi, La Mé & Pobé Strains per tree per year.

Character	Strain	Déli	Yan-gambi	Sibiti	Le Mé	Pobé
	Production characteristics 5 - 8 years					
No. of descendants observed		12	13	14	18	12
Production of bunches	No. of bunches/tree	6.0	11.2	11.9	11.4	15.6
	Tot. wt. of bunches (kg)	84	106	111	101	111
	Av. wt. of bunches (kg)	14.2	8.4	9.2	7.3	7.2
Quality of bunches *dura*	%fruit per bunch	67.0	64.5	63.2	64.7	61.0
	%pulp per fruit	57.7	52.4	46.4	44.7	40.0
	%kernel per fruit	10.3	10.6	12.4	12.7	16.4
	%oil in pulp (1)	49.6	54.3	(2)	51.6	(2)
	%palm oil in bunch	19.2	18.4	15.9	14.9	12.2
	%oil total in bunch	22.7	21.8	19.8	19.0	17.2
	Av. wt. of fruit	14.3	15.1	12.9	8.9	8.4
Quality of oil	Palm oil (kg)	16.1	19.5	17.6	15.0	13.5
	Vegetative characteristics 9/10 - 12/13 years (3)					
No. of trees observed		42	42	—	50	—
Leaves	Av. No. of leaves present	35	40.9	—	40.2	—
	No. of leaves/year	19.6	24.1	—	24.0	—
	Wt. of 17th leaf limb (kg)	8.1	6.7	—	4.9	—
	Av. leaf length (cm) (4)	6.4	5.6	—	5.5	—
	Av. width of leaf (cm) (4)	2.0	2.0	—	1.7	—
	Tot. wt. of leaf limbs (kg)	281.0	274.0	—	194.0	—
	No. of leaf scars/meter stem	43.5	52.6	—	69.2	—
Folioles	Tot. No. of folioles/ 17th leaf (kg) (5)	350	344	—	312	—
	Wt. of 17th leaf folioles (5)	3.0	2.8	—	2.1	—
	Tot. wt. of all leaf folioles (kg)	106.0	110.0	—	82.0	—
Petiole	Sectional area of 17th leaf petiole (cm^2) (5)	24.9	22.0	—	15.5	—
Percentage of female trees (4)		18.1	49.6	—	59.8	—
Percentage of abortive flowerings (4)		7.1	6.7	—	22.5	—

(1) No. of descendants observed - Déli 18, Yangambi-Sibiti 112, La Mé 8
(2) % of oil in the pulp estimated at 50%
(3) Observation of a line characteristic of the parent stock
(4) Average of three years 1962, 1963, 1964
(5) Average of two years 1963, 1964

Table VI. Production/hectare/year of inter-regional crosses and their original parent strains

Type of crosses	Number of crosses	Kg. bunches/ tree/yr 5-6-7-8	% palm oil		Production/ha./year			
			Dura	Tenera	Tons of bunches	Tons of Oil Dura	Tons of Oil Tenera	Tons of Oil Av.
LA MÉ EXPERIMENTAL STATION - IVORY COAST								
1) Within-region crosses								
Déli x Déli	23	87	18.9	—	11.7	2.0	—	—
La Mé x La Mé	20	100	15.1	21.0	13.5	1.8	2.6	2.2
Yan.-Sib. x Yan.-Sib.	27	109	17.0	23.7	14.7	2.3	3.1	2.7
Pobé x Pobé	13	110	12.2(2)	17.3(2)	14.8	1.6	2.3	1.9
2) Inter-regional crosses								
La Mé x Déli	15	120	17.9	24.6	16.2	2.6	3.6	3.1
Yangambi-Sibiti x Déli	7	120	19.6	25.9	16.2	2.9	3.8	3.3
Pobé x Déli	4	121	—	21.8	16.3	—	3.2	—
DIBAMBA EXPERIMENTAL STATION - CAMEROON								
1) Within-region crosses								
Déli x Déli	19	52	18.8(2)	—	7.0	1.2	—	—
La Mé x La Mé	3	58	14.4(3)	20.3(3)	7.8	1.0	1.4	1.2
2) Inter-regional crosses								
La Mé x Déli	5	86	17.4(2)	22.6(2)	11.6	1.8	2.4	2.1
PROBE EXPERIMENTAL STATION - DAHOMEY								
1) Within-region crosses (4)								
Pobé x Pobé plot 446	4	75	----	19.1(2)	10.1	—	1.7	—
Pobé x Pobé plot 455	3	21	----	19.2(2)	2.8	—	0.5	—
2) Inter-regional crosses								
Pobé x Deli plot 446	4	89	----	21.1(2)	12.0	—	2.3	—
Pobé x Déli plot 455	3	40	----	21.8(2)	5.4	—	1.1	—

(1) Production calculated on the basis of 135 productive trees/hectare and an industrial yield of 0.9
(2) Figures do not include the amount of oil in the pulp
(3) Figures from La Mé
(4) No Déli trees are planted in plots 446 and 455.

The improvement of the quality in the bunches of the African strains by Déli is something like 10-12%; it is due to an increase in the percentage of fruit in the bunch and the percentage of pulp in the fruit. The oil content of the pulp from the La Mé x Déli crossings is greater than that of the La Mé and the Déli, by a figure of 53 as against 51.6 and 49.6; the oil content of the pulp of Yangambi-Sibiti X Déli is very close to that of Yangambi-Sibiti but it is very much greater than that of Déli, with 53.4 against 54.3 and 49.6.

The adaptation capability of the inter-regional crossings to the various environments is better than that of their parent plants; they produce more than the latter under ecological conditions that are as different as those at La Mé in Ivory Coast, Pobé in Dahomey, and La Dibamba in Cameroon. At Pobé, where the variations due to the soil and the water table are quite considerable, the inter-regional crossings behave better than the local parent stock.

All of the improvements which have just been discovered, mean that the inter-regional crossings feature a palm oil production significantly greater than that of their parent plants.

They exceed them by 0.7-1 ton of palm oil per ha and they guarantee an output on the order of 3-3.5 tons of palm oil in Ivory Coast, under conditions similar to those at the La Mé station, an increase of 2-2.5 tons of oil in Cameroon, and 1-2.5 tons in Dahomey, depending upon the location of the plantation.

The wide dissemination of inter-regional crossings guarantees the planters an additional profit of 25-45% in Ivory Coast, about 70% in Cameroon, and more than 35% in Dahomey; the last two figures should have to be determined more accurately on the basis of a larger number of results.

b) Vegetative Characteristics

The first observations covered one line representative of each parent strain; apart from the important differences between the La Mé and Déli strains, which were reported earlier, they demonstrated that the vegetative characteristics of the LT (La Mé X Déli) crossings are, overall, very close to the average between SOC 1386 (Déli) and LM 6 (La Mé) and that the "photosynthetic efficiency coefficient" (kg of bunches produced per 100 kg of leaves) definitely differs from one line to the next; it is low for SOC 1386 (Déli), it is high for LM 6 (Le Mé), and for LT (La Mé X Déli).

B. Current Trend in Selection

(1) Basic Scheme

The superiority of inter-regional crossings has thus been brought out and selection was of course oriented toward the improvement of these

crossings; the recent programs have two objectives:

- find the best types of inter-regional crossings and, within these types, find the most productive combinations;
- reproduce the best combinations and supply them to the planters;

To achieve these two objectives, the so-called recurrent reciprocal selection method (4) was adapted to the oil palm and it was supplemented here by a self-fertilization program.

After the material described above had been broken down into two groups, A Dura Déli and B Tenera and Pisifera La Mé or Yangambi-Sibiti, a test of the A X B parent stock was made in order to determine the individuals of A which could best be combined with those of B and vice versa.

Gradually, as results from the parent stock tests came in, we self-fertilized or crossed the best ancestors of A, selection Dura, and the best ancestors of B, selection Tenera.

In order to reproduce the best combinations found for the planters, the crossings Dura x Pisifera are made between the Dura of the Dura selection and the Pisifera of the Tenera* selection.

The continuation of this selection effort will involve a second recurrent reciprocal selection cycle, a test of ancestor plants followed by Dura X Dura and Tenera X Tenera crossings and, possibly, a second generation of self-fertilization.

(2) Implementation

The first parent stock test was made with 80 Dura ancestor plants (37 Déli from Dabou, 23 Déli from Socfin, 10 Déli from Guthrie, and 10 miscellaneous Dura) and 172 Tenera and Pisifera plants (32 originating from La Mé, 100 from Yangambi-Sibiti, 4 from Nifor, and 36 from African X Déli crossing); this involves 446 crossings, 311 Tenera X Dura and 135 Dura X Pisifera, at La Mé.

Figure 2 shows us the proportion of the representation of each type of crossings in the plantings at La Mé, between 1960 and 1965.

The other stations or plantations of IRHO planted several hundred hectares with these same types of crossings. The Dura and Tenera selections, for the time being, used only the parent stock of the test

*The INEAC recommended the reproduction of a worth-while combination based on self-fertilization in 1956.

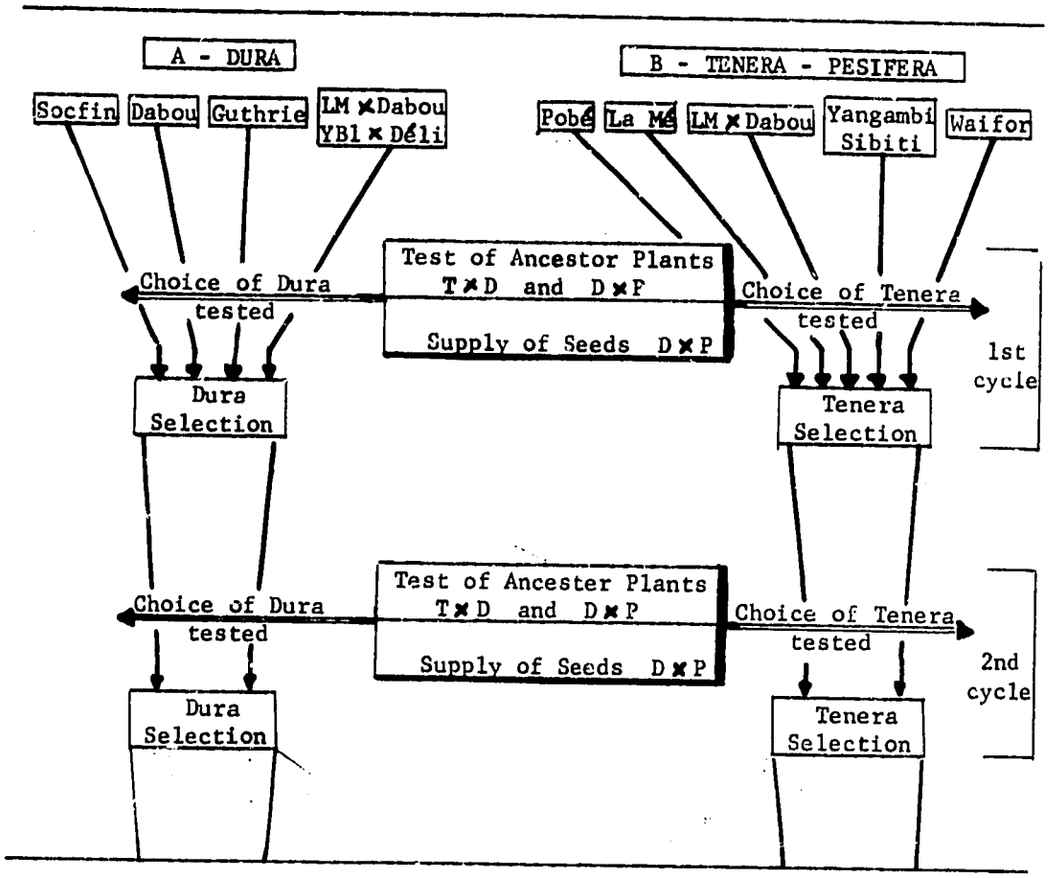

Fig. 1. Diagram for recurrent reciprocal selection.

which offered good guarantees, in other words, stock proven by prior inter-regional crossings in the test or parent plants which in turn are descendants of a proven parent plant; they involved 51 Dura X Dura crossings and 34 self-fertilizations of Dura for the Dura selection, 42 Tenera X Tenera crossings and 32 self-fertilizations of Tenera for the Tenera selection at La Mé; at the other stations, Tenera X Tenera, and Dura X Dura crossings and self-fertilizations of Dura and Tenera were planted, gradually, as the parent stock was tested.

The scope and the importance of these programs would have been greatly reduced if they had not been the result of excellent cooperation between the various IRHO stations at La Mé, Pobé, and Sibiti, as well as the stations in other countries which participated in these programs by sending pollen and by performing fertilizations on their own parent stock. The smooth operation of these programs likewise is also due to efficient collaboration between the various stations since the programs of each station effectively supplemented the programs of the other stations and since data were exchanged among the stations so that all of them could benefit.

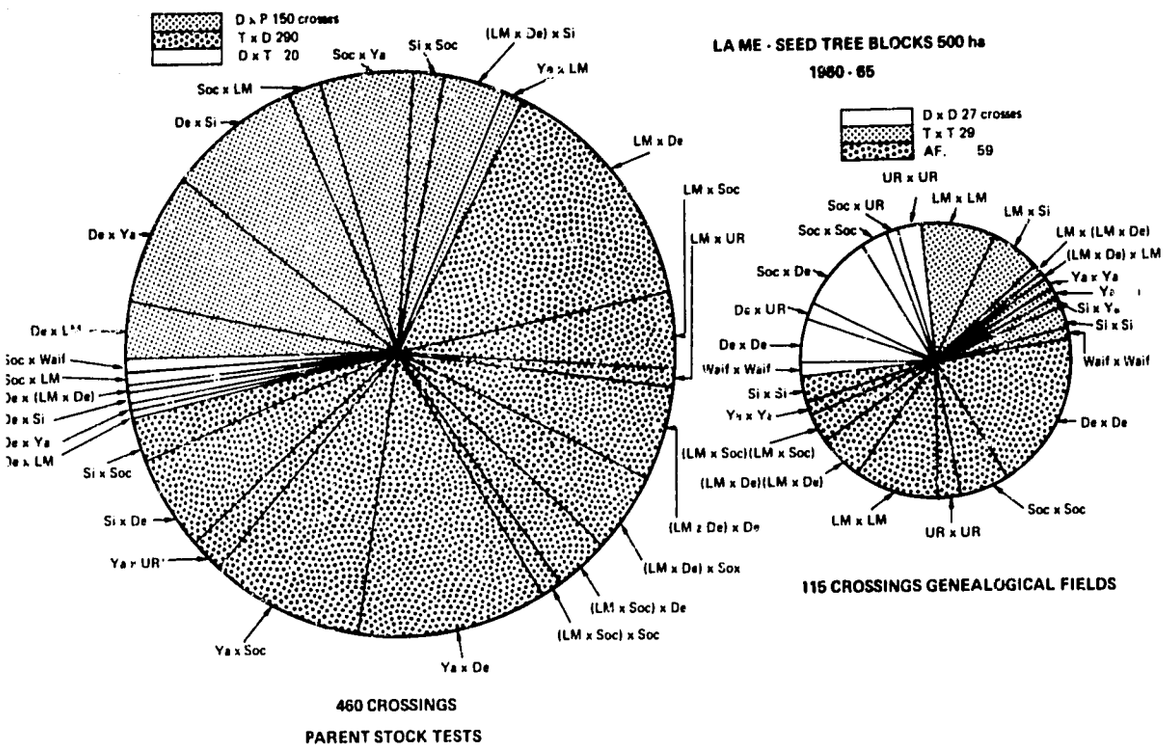

Fig. 2 Composition of La Mé seed-tree block

(3) First Results

Table III shows the first results in terms of tons of bunches per ha. We note the good early maturity of the various types of inter-origin crossings, one-half African X one half Déli. The crossings where the proportion of Déli "blood" reaches 75%: (LM X DE) X DE reveal an output that is not as good.

Table IV compares the output from self-fertilisation to the output from inter-regional crossings whose female trees are the same.

These two tables thus provide large-scale confirmation for the assumption set up on the genetics of the oil palm.

Table III
Tons of Bunches per Hectare
(Calculated on basis of 135 producer trees for 143 trees planted)

		3 to 4 years	4 to 5 years	5 to 6 years	6 to 7 years	7 to 8 years
Le Mé X Déli	1959	10.2	9.9	12.5	15.8	12.8
	1960	5.3	6.5	11.4	11.1	
	1961	8.-	9.7	10.2		
	1962	7.7	13.-			
	1963	8.5				
Yangambi or Sibiti X Déli	1961	7.4	7.2	11.5		
	1962	6.6	12.7			
	1963	8.4				
(Le Mé X Déli X Déli (backcross)	1961	6.3	6.7	7.2		
	1962	4.9	10.7			

Table IV
Output in Kg of Bunches/Tree

Self-fertilizations		Inter-regional Crossings	
La Mé parent stock	17.6	65.8	Le Mé X Déli
Déli parent stock	12.9	51.1	Le Mé X Déli and Yangambi Sibiti X Déli
La Mé X Déli parent stock	14.4	47.0	Backcross (La Mé X Déli) X Déli

(4) Other Programs

Parallel to this principal program, we might mention the existence of several other programs which are intended to solve special problems.

In 1955, IRHO—in certain zones of Ivory Coast and Dahomey—found a palm tree killing disease called fusariosis (or wilt). The initial studies left little hope that a solution might be found through a modification of the nutritional conditions; IRHO then concentrated on the

selection of resistant crosses. After several years of research, it was possible to find about a dozen individuals—among the parent stock used for the supply of seeds—which transmitted resistance to their offspring. This naturally led to the establishment of a selection program designed to develop resistance to fusariosis. On the basis of the nursery test involving the artificial innoculation of all crossings placed in the greenhouse at Dabou, which accommodates plantation expansions, this makes it possible to select the most worthwhile trees. These are then subjected to new tests in various crossings involving each other and they are self-fertilized for the ultimate production of large quantities of resistant seeds.

For several years now, all of the plantations in Dabou have been handled with crosses that best passed the nursery test and we are now using more and more crosses between trees that have proved their resistance. The self-fertilizations or crossings between resistant Dura are then tested once again and planted in the area of an old palm plantation, where the disease has been identified.

A similar project, similar to the one at Dabou, was launched in Dahomey in 1958. The 30 best Déli ancestor plants at this station will be fertilized by sensitive or resistant Pisifera. The crosses will then be tested by artificial innoculation. It is hoped that new trees can be found quickly for the supply of seeds that will resist fusariosis and that will be necessary in certain zones of Dahomey.

Other programs have been proposed to judge the value of hybrids between E. guineensis and E. Melanococca (an American species introduced in Africa). The first results are rather promising and the introduction of material should be continued.

We might also mention here programs intended to measure the inheritability of the transmission of characteristics such as number and average weight of bunches, to verify the possibility of reproducing a crossing on the basis of the descendants of self-fertilizations of two parent strain plants, to determine the best trees in one self-fertilization, etc.

All of those programs together, the principal ones and the subsidiary ones, will enable the institute to plant almost 750 ha between now and 1972; of this area, 160 will be earmarked for the Dura selection and 90 for the Tenera selection: these 250 ha, together with the 100 ha already planted and now beginning to produce, will give us 350 ha of seed tree fields. The first plantings of the 2nd parent strain test will begin in 1972.

C. Seeds Currently Produced by IRHO

Bernard and Malingraux discussed the production of selected oil palm seeds from the IRHO in a recent article (2), which is summarized below.

The seeds produced here belong to inter-regional crosses between Dura and Pisifera; those that are most frequently used right now—because

of their excellent results—are crosses between the Déli strain and the La Mé or Yangambi-Sibiti strains. These crossings, in equal portions, involve the Déli inheritance and the African inheritance. They guarantee an output of 3-3.5 tons of palm oil per ha and 4 tons of oil, overall, under the ecological conditions of the La Mé station.

The crossings are made between parent stock selected from lines whose characteristics are most worthwhile for the particular parent-plant considered and, whenever we can, they are selected within lines that descend from proven parent plants. These crossings are handled on the basis of a crossing plan which takes into account the characteristics of the lines and of the parent plants, as well as the heretitary transmission of characteristics which determine production and quality; we select the best combinations with respect to the number, the average weight, and the quality of the bunch in order to obtain a good bunch output and in order to guarantee a minimum extraction rate of 20.

The authors then studied artificial fertilization: they discussed the method used and called attention to the precautions and the controls that are indispensable in getting highly-quality seeds (control of insolation of inflorescences, control of pollen viability, control of disinfection of isolated parts, and control of seed quality).

IRHO annually produces more than 8 million seeds of Dura X Pisifera, revealing all of the guarantees mentioned above. When the new seed-tree fields enter into production, it will undoubtedly be possible if necessary to increase the annual output to more than 25 million seeds. Depending upon the results of the parent stock test, we will then be able to work out a rigorous solution in the choice of parent stock. The proportion of seeds assumed to resist fusariosis, currently hardly sufficient for the needs of the institute itself, will increase very rapidly when the self-fertilizations, planted in 1960 and 1961, become productive. This seed will be used for the replantation of certain zones in Ivory Coast and Dahomey.

The output potential of plantings from seeds currently delivered is very high. In an irrigation test at Grand-Drewin, 26 tons of bunches per ha were obtained, or more than 5 tons of oil per ha, between 6 and 7 years. At Dibamba, where voluminous straw cover was available to save ground water, 24 tons of bunches per ha were achieved at the same age. In Colombia, the early maturity of the inter-origin crossings furnished by IRHO has been confirmed by the results obtained on 1,500 ha of an industrial plantation:

6.5 t of bunches/ha at age 2-3 years
15.2 t of bunches/ha at age 3-4 years
16.8 t of bunches/ha at age 4-5 years.

It will thus be possible to meet all of the requirements for seeds including all of the guarantees in terms of quality, output, and disease resistance.

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COCONUT PALM SELECTION

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SUMMARY

Although progress in the selection of coconut palms is slow for reasons pertaining to the length of the unproductive phase, its low multiplication coefficient (particularly through artificial fertilization), the size of its fruit, and its vast geographic distribution, quite noticeable improvements have been obtained over the past 15 years at the Port-Bouet station.

In the first phase, IRHO—in all states where it was responsible for the selection of coconut palms—set up seed gardesn intended to produce local or exotic dwarf and large hybrids which are always earlier and more productive than the local coconut palms.

One of the biggest seed gardens of the world is now being set up in Ivory Coast; this garden will make it possible to achieve significant results within a very short time; the economic importance of this project is undeniable, both to Ivory Coast and to the Francophone African countries as well as other countries throughout the world.

* * *

I. General Remarks—Basic Principles of Selection by IRHO

Our knowledge of the genetics of the coconut palm is still extremely poor, in spite of the many studies that have been accomplished over the past 40 years and in spite of the great emphasis which the research stations are giving to the entire problem of selection.

Progress is rather slow for a number of reasons, all of which have something to do with the nature of this palm tree:

- the duration of the unproductive phase reduces the number of generations that can be observed during the lifetime of one research worker;
- its low multiplication coefficient, aggravated by real material difficulties in carrying out controlled artificial fertilization;
- the considerable volume of its seed and the ease with which it germinates, without depending very much on outside conditions, complicate and make the shipment of seeds very difficult and very expensive;
- its allogamous character, in the case of the large varieties, promotes the birth of highly heterozygous individuals;

- its vast geographic distribution over widely differing ecologies does not facilitate the evaluation of those factors that are due to the genetic inheritance and those that are a result of the environmental conditions.

In spite of these obstacles, it has been possible to determine the main trend of research here as a result of the perseverance and tremendous patience of the oldest research stations, particularly the work done in Ceylon and India; these basic research directions henceforth enable us to be somewhat bolder in our speculations and to have more confidence in the results.

The object of selection is to increase the quantity of copra produced per hectare or, more specifically, the volume of oil, after the desired development has been accomplished.

The factors on which production depends are:

- the number of leaves produced annually;
- the number of female blossoms;
- the seed setting and fruiting coefficients on which depend the number of bunches per tree and the number of nuts per bunch;
- the ratios of copra to nut and oil to copra.

There is very little chance of increasing the number of leaves produced annually through selection; even if the ecological conditions are good, this characteristic or factor varies very little, both between individuals of one and the same population and between populations of widely differing origins. Similarly, there is no reason to expect an increase in the number of female blossoms which is rarely a limiting factor.

On the other hand, the number of bunches, the fruiting and seed setting coefficients, whose variations are quite extensive, offer a much better prospect here.

In practice, the selector considers first of all the number of nuts and the copra per nut and only secondarily the other characteristics.

Parallel to this, the selector tries to improve the earliness of production.

II. Selection Method Used in the Ivory Coast

1. General Remarks—Basic Data

For the most part, the IRHO selection work is done in Ivory Coast at the Port-Bouet station.

The other stations are not engaged in any basic research and confine themselves to adapting the basic principles and the methods worked out in Africa to local conditions, unless there are some specifically local problems with which they have to cope.

It is obvious that the point of departure for any selection resides above all in as complete a knowledge as possible of the characteristics and their variation.

The coconut palm in West Africa, a tree that grows relatively slowly (the semi-large variety), is reproduced by cross-fertilization, although a small percentage of self-fertilization may be possible during the dry season. The first harvest, on the average, occurs during the 7th year.

The table below summarizes the most important characteristics (based on a sample of 950 trees).

Characteristic	Phenotype Average	Variations as % of Average	Observations
Copra total	12.7 Kg	42.1 %	Poor inheritability
Number of nuts	78	65.9	Very poor inheritability
Copra per nut	162 g	16.2	Strong inheritability
Number of bunches	9.4	49.7	
Number of female flowers per bunch	22.4	72.0	
Fruiting coefficient	0.68	32.1	
Seed setting coefficient	0.321	28.3	(New Herbides 0.25) (Malaysia 0.22)
Weight of copra per weight of shelled nuts	0.32	?	Rennel Bellona 0.20 Polynesia Attollo 0.30
Nut germination time	112 days	15.1	
Number of leaves per year	13.8	11.2	
Length of petiole	169 cm	7.9	
Length of limb	468 cm	6.2	

These values, which are representative of local populations, describe the West African coconut palm. This is a palm tree which produces a rather large number of nuts whose copra content is not at all high; this relates it rather closely to the ordinary coconut palm of the New Hebrides (large number of small nuts) and contrasts it with the most highly cultivate Polynesian coconut palms which produce a small number of very large nuts.

This coconut palm issued from a rather restricted strain—a few nuts imported by the Portuguese during the 17th century; it was subjected to accentuated inbreeding for several generations and now reveals rather poor genetic heterogeneity compared to that of the populations in Asia and the Pacific.

In sum, the economic imporatance of the Ivorien coconut palm is satisfactory but the outlook for a genetic improvement, without external enrichment, is rather poor.

2. Search for Better Producers Among Local Populations

Although they are relatively homogeneous, the most closely-related local populations are no less far removed from the pure line. The first selection phase thus consisted in discovering the trees whose genotypes had the best chances of representing productive combinations. The evaluation of the genotypes through the phenotypes is particularly difficult in the coconut palm because its sensitivity to environmental influences is very great. We must therefore be content with statistical definitions.

The systematic prospection in existing coconut palm plantations, accomplished on the basis of the criteria listed below, has made it possible to achieve an initial selection:

- number of nuts greater than 100, based on crown count;
- copra per nut, judged acceptable visually;
- large number of bunches;
- stems straight, leaf scars close together;
- tree vigorous, canopy short and decumbent.

The performances in terms of number of nuts, copra per nut, total copra, as well as those of a certain number of secondary characteristics were observed very rigorously for a minimum of 3 years.

After this period of time had elapsed, a new classification singled out those trees whose yields and combination of characteristics, combined with good yield, were phenotypically the best.

For example, out of 600 trees observed, 18 were temporarily retained for the supply of seeds and five were retained for the subsequent continuation of selection by means of crossing. Here are the average characteristics of these 18 trees:

Total Copra per tree and per year	= 17.2 Kg (2.5 t/ha)
Number of nuts per tree and per year	= 90
Copra per nut	= 190 g
Ratio between pericarp and kernel	= 2.0

These first two phases correspond to a simple bulk selection which undoubtedly is made very strictly but on whose effectiveness we should not be too optimistic. Although it certainly permits an improvement in the copra per nut (strong inheritability), it is limited in terms of range by the rather poor variation. It is not at all effective in terms of the number of nuts due to the fact that it does not enable us to estimate the value of the genotypes with sufficient accuracy.

In an attempt to continue along this line of research, the illegitimate offspring of the best subjects—selected mother-trees—constituting the G_0 are planted according to a suitability adapted statistical pattern.

The comparison of the phenotype performances of each family gives us a rather good picture of the genotype of the mother-tree from which they have sprung or, more specifically, they give us a picture of the aptitude of this genotype for cross-breeding, since the offspring do come from free fertilizations.

The best trees, thus isolated, are then used for various purposes. The first step here consists in crossing them with each other.

In practice, to gain time, the offspring tests and the G_o X G_o crossings are made simultaneously. Similarly, the G_o mother-tree candidates are judged in comparison to the descendants issuing from free fertilizations and not from self-fertilizations because of the desire to move ahead quickly as well as for other reasons which would require an excessively long development.

3. Importance of Introductions—Notion of Adaptation

The genetic poverty of the West African coconut palm certainly justifies the efforts that have been made to expand the foundation for its improvement.

The essential purpose of introducing imported varieties is to expand the collection of available genes, without in any way harming the behavior of the trees once they have been planted in a new environment and without speculating on the results which they will produce as a result of cross-breeding.

The introduction of imported varieties is furthermore considered even more satisfactory when it is representative of the variation existing at the place of origin and when it is not confined to a few subjects constituting the local elite.

We might nevertheless point out that the Ivorien coconut palm has little copra per nut and that preference is therefore often given to exotic strains with large amounts of copra.

Port-Bouet currently has a rather wide range of original specimens here: dwarf apricots from Cameroun; yellow, green, and red dwarfs from Malaysia; greed dwarfs from Brazil; greenish-yellow dwarfs from Guina; yellow dwarfs from Ghana; Niu-Leka from Fiji, etc. It also has the large variety from Mozambique, Vietnam, Cambodia, Thailand, Polynesia, Jamaica, Malaysia, etc.

The introduction of new genotypes is not confined to imports of nuts which, as we know, are very difficult to handle and very expensive, but also covers the import of pollen, a practice that is now quite widespread.

The introduction of pollens offers the advantage of enabling inter-variety crossings to be made immediately and it also makes it possible to eliminate most of the health risks. It does involve the inconvenience—compared to the introduction of seeds—in that it is rather limited and

that it excludes any direct judgment as to the phenotype behavior of the material introduced.

Indeed, seeds and pollen complement each other and the ideal would be for each introduction to be available at the same time as each one of these two sources of genes.

Exchanges of nuts and pollen should develop during the years to come through the "Coconut Germ Plasm Exchange," which is the result of a resolution adopted by the "F.A.O. Technical Working Party on Coconut" at Trivandrum, India, in 1961; this framework of exchange is the result of the desire of many researchers who have felt a need for international cooperation in order to achieve the genetic improvement of the coconut palm. F.A.O. is responsible for promoting this effort and its primary objective is to draw up a list of existing material in the various regions, along with the pertinent characteristics. Such a list should make it possible to constitute genotype collections.

In general, these introductions turn out to be inferior to the material on the spot. The yields of the "Mozambique" or "Polynesia" varieties which have been planted at Port-Bouet are on the average lower than those of the local material, whereas their susceptibility to Oryctes and to fungi is greater. Similarly, at Rangiroa (Polynesian Atoll), only the original plants coming from a coral environment can adapt to the limestone soils which have a tremendous deficiency in iron, manganese, and nitrogen.

The West African coconut palms would not survive the very humid conditions which we find in certain other places (Cambodia, Thailand, etc.).

Adaptation to dought is evident for certain strains from Mozambique and for some strains from the northeastern part of Brazil.

This is a very important notion which the selector must take into account, becoming aware of the fact that it is not possible to introduce a variety irrespective of its origin and location.

4. Dwarf x Large Crossings

Although the importance of the hybrid of the dwarf x large varieties was recognized rather early, particularly in India, this type of crossing has not yet been completely explored. Currently, it is believed to produce the following:

- a gain in copra per nut and in the number of nuts, which is the result of the existence of a manifest effect of heterosis;
- an improvement in early production, compared to the large variety; the trees become productive around the 5th year and this is half way between the 4 years for the dwarf variety and the 7 years for the large or semi-large varieties;

- better adaptation to drought, very close to that of the dwarf green variety.

The hybrid thus combines the advantages of each of two parents from which it comes.

A certain number of points, however, are not known much less understood.

The hybrids cannot be likened to an F 1, which is homogeneous by definition. The very large variation observed in terms of F 1 leads us to think primarily in terms of crossing a heterozygote with a homozygote; by the same token, this type of crossing probably constitutes a method of genotype analysis permitting the evaluation of the aptitude for combination on the part of a particular tree.

Be that as it may, the dwarf x large hybrid is an easy way of increasing the plasticity, the early maturity, and the production, above all if—as is now being done in the seed gardens in the Ivory Coast—the large type parent stock has come from crossings between large-volume producer subjects.

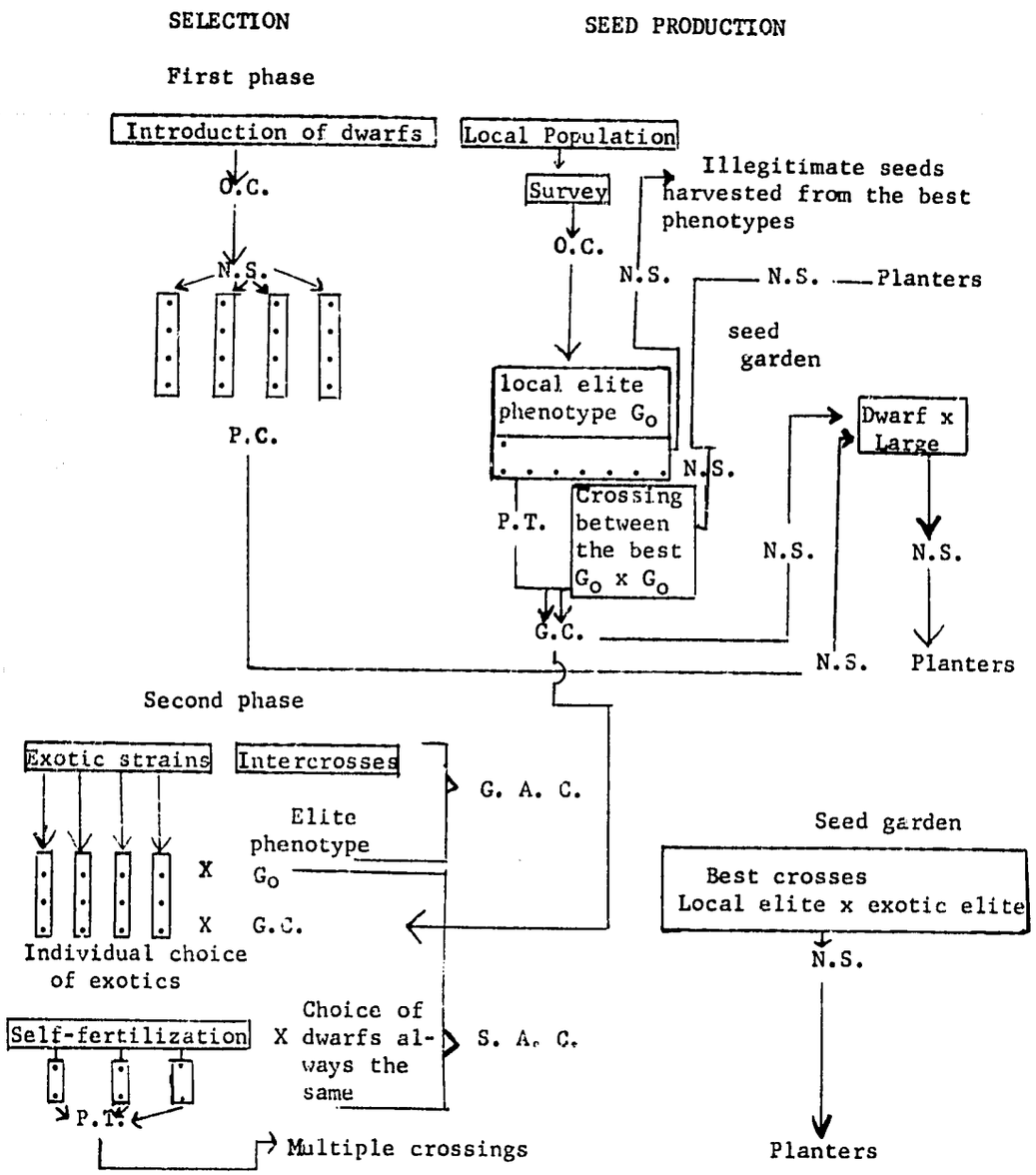
5. Crossings Between Strains of Different Genetic Origins—Heterosis

The manifest hybrid vigor, resulting from dwarf x large crossings, the spectacular progress made with maize as a result of the utilization of the heterosis phenomenon, the substantial gains in production obtained as a result of the combination of different genetic inheritances in the oil palm—these constitute very good arguments in favor of the adoption of this method for improving the coconut palm.

The work done on maize shows that the combinations between closely-related strains, issuing from different parents, generally give us greater hybrid strength than the strength resulting from crossings between parents that greatly resemble each other. At any rate, the performances of the hybrids are superior to those of either one of the parental strains.

An experiment which was started in 1962 is still underway at Port-Bouet. The purpose of this experiment is to establish the average performances of a certain number of exotic origins, either with respect to each other, or with relation to the local, ordinary strain. The primary purpose here is—from a general viewpoint—to evaluate the most productive interactions and in this sense, this particular investigation is very closely tied in with a test of the general attitude for combination. These crossings, on the other hand, are intended to establish the extent to which the compensation of characteristics is effective; and, finally, after increasing the gene diversity, the purpose is then to expand the foundations for selection and to maintain a certain heterzygosis rate (heterosis).

DIAGRAM OF STUDIES UNDERTAKEN AT PORT-BOUET



G. A. C.	General aptitude for combination	G. C.	Genotypic choice
S. A. C.	Specific aptitude for combination	P. C.	Phenotypic choice
P. T.	Progeny test		
N. S.	Nursery selection		
O. C.	Observation of characteristics		

The arrangement used here furthermore makes it possible to estimate the value resulting from the two by two crossing of a certain number of individually selected trees whose phenotype of performances are known (specific aptitude for combination).

Without in any way judging this effort in terms of future development, this experiment—involving two-way crossings (A X B)—might eventually be prolonged in the form of three-way crossings (A X B) C and even four-way crossings (A X B)(C X D).

Currently, only the results of all of the first studies in Port-Bouet have been made known. Although they involve only observations made in the nursery, they are no less encouraging at that.

According to all appearances, the heterozygosis of each of the two strains cross is great and it increases as the heterosis phenomenon is further accentuated.

It is also hoped that an improvement in the early maturity of the production will be paralleled by a reduction in the germination time.

The future will tell how well-founded these hypotheses were and will then allow an overall interpretation.

6. Crossing Between Individuals from Populations with Different Genetic Origins

After discussing the mixtures of original plants which give the best hybrids, it is also necessary to find out what the most advantageous particular combinations are.

The principle here consists in using—as test objects—a group of trees that will always be the same, trees that will be as little heterozygotic as possible, and these are then fertilized with pollen from the trees to be tested.

In Ivory Coast advantage is taken—of the homogeneity of the local strain and the relatively very homozygotic state of the various dwarf races. A correct estimate of the specific aptitude for combination will make it possible to come up with predictions as to the value of the three-way or four-way crossings, thus supplementing those which were made on the basis of the general aptitude tests.

7. Self-fertilization

The value of self-fertilization—as a genotype exploration technique—has already been mentioned earlier. When repeated, it also makes it possible to reduce the heterozygosis by one-half in each generation and to arrive at purified lines; this is true in the case of the dwarfs, many of whose characteristics are fixed.

Finally, self-fertilization is a means for multiplying the possibilities of using a genotype.

It is primarily this latter viewpoint which is important in the case of the coconut palm with its low multiplication coefficient.

3. Results

Fully aware of the limited genetic potential of the local coconut palm, Port-Bouet over the past 10 years has built up a rather large reserve of genes on the basis of the introduction of a large number of foreign-origin plants:

LARGE FORM - Mozambique
Vietnam
Cambodia
Thailand
Polynesia
Jamaica
Malaysia
Ceylon
Solomon Islands

DWARF FORM - Apricot from Cameroon
Yellow, red and green from Malaysia
Green from Brazil
Green from Spanish Guinea
Green from Tahiti
Yellow from Ghana
Niu Leka from Fiji

Although this material is insufficient, it has made it possible to plant 15 hectares of dwarf x large local hybrids whose production results are quite remarkable; this planting effort was started in 1962, 12 years after the establishment of the station.

In 1965, the first large local x large exotic and large exotic x large exotic hybrids were planted. On the basis of their germination rate and their vegetation vigor, they had the advantage over the large local x large local crossings, from the very beginning.

If we compare these results to those obtained by foreign stations—for example, Lever's Pacific Plantations—then we can be sure that the hybrids will produce much more than the local populations and that it is therefore necessary to do everything we can so that the planters will have them available as quickly as possible.

This is why it was decided to lay out a 500-ha seed-tree block at Port-Bouet.

This block should facilitate the complete and rapid utilization of all of the improvement possibilities offered by the introductions that

have already been made and by those which are to come in the future, in other words,

- it should bring out the best types of hybrids and, within them, the most productive individual combinations; only large-scale comparisons can give us the certainty that we can rapidly achieve this objective;
- it should demonstrate the high productivity of these hybrid coconut palms on large surfaces;
- it should satisfy—in terms of quantity and quality—the tremendous needs of Africa for selected seeds (right now, the ordinary-quality seed possibilities are barely sufficient to cover the needs of the Ivory Coast).

III. The Seed-Tree Field at Port-Bouet

The implementation of the programs spelled out above can be broken down into two simultaneous operations;

Introduction of foreign strains and search for the best interregional crossings;

Reproduction of the latter on a large scale.

A. Search for Best Hybrid Combinations

1. Introductions

On the basis of the principle discussed earlier, the original plants which are introduced have different qualities which also complement those at the Port-Bouet station.

(a) Nuts

The following table lists the nature of these introductions:

Country of Origin	Varieties	Comments	Quantities
Cambodia	Tuk Sap	Good copra/nut ratio, adaptation to nearby water table	
	Kampong Trach	Adaptation to drought	
	Kolbe	Hardiness—early maturity	
	Kopal	Thick copra	
	Kampot	Femininity—hardiness	5,000

Country of Origin	Varieties	Comments	Quantities
Samoa		Good copra/nut ratio, high yield	1,000
Solomon Is.	Rennel Bellona	Exceptional size of nut, tree very hardy	1,500
	Local	Hardiness, good combination aptitude	1,000
Polynesia	Rangiroa Island	High copra per nut	5,000
Thailand and Malaysia		Excellent proportions of nut—high production Good adaptation to nearby water level	1,500
India	Laccadive	Number of nuts—early maturity	
	Maldive	Number of nuts—early maturity	
	Gandabondam	High copra/nut ratio	
	Kappadam	High copra/nut ratio	
	Giant Andaman	Size of nut—feminity—large number of bunches	1,000
Indonesia	Takome	Hardiness of tree—very high copra/nut ratio	
	Kapala Bali	Feminity—high copra/nut ratio	
	Kalappa Parva	Vigor of tree—early maturity	5,000
Wallis Islands		High copra/nut ratio high output	2,000
New Guinea	Kardar	Big nuts—fast growth	500
	Markam Valley	Exceptional size of nut	1,000
Fiji	Niu Leka	High copra per nut ratio for dwarfs—hardiness—large number of bunches	500
			25,000

Their planting on the basis of a special arrangement of pattern makes it possible to use them immediately for the production of hybrid seeds.

A gain of at least 15 years could thus be achieved.

(b) Pollen

The IRHO station at Port-Bouet gets pollen from the Solomon Islands (Unilever), from Jamaica (Coconut Industry Board), from Cambodia (Tuk Sap Station), from the New Hebrides (Saraoutou Station), from Polynesia (Rangiroa Station), and from India (Indian Central Coconut Committee).

It is also hoped to obtain some from Ceylon (C.R.I); Thailand (Sawee Station), New Guinea and Papuasia (Department of Agriculture), and from Indonesia (Research Institute for Coconut).

These foreign pollens increase the availability of genes and permit testing of some of the crosses made in the seed fields without delay.

2. Hybrid Value Tests

The method here consists in comparing various combinations of introduced material with the help of a suitably adapted statistical method.

3. Production of Hybrid Seeds

The plantations responsible for the production of seeds are of three different types:

- introduction gardens;
- seed-tree fields;
- certain tests contributing also to the production of seeds.

C. Recapitulation of the Use of the Area

	Seed Supply (ha)	Selection Area (ha)	Total
Introductions	110	—	110
Tests	80	97	177
Seed-tree fields	205	—	205
	395	97	492

CONCLUSIONS

For the past 15 years, the Port-Bouet station has played a preponderant role in the improvement of coconut palm yields; by completely altering the economic significance of this industry, it has turned it into a first-rate means of development.

However, further progress can be made in the near future by increasing the proportion of the high-yielding varieties and, in the much longer run, with the help of recently acquired genetic knowledge, it should be possible to come up with more highly productive hybrids which will also be early maturing and better adapted to the various environments in Africa.

Of course, there is no doubt that our knowledge today is still inadequate for engaging in any kind of speculation as to the choice of parent material which must be crossbred to be sure of obtaining one result or another.

It is, however, understood how to get coconut palms which will be best adapted to the rather average soil and climatic conditions (Dahomey, Togo, central Ivory Coast, Madagascar, etc.)—trees that will be better producers.

It is also known that yields definitely exceeding 3 tons of copra/ha, with fruit-bearing after 4 years or perhaps even less, are henceforth possible.

The principle on which these new prospects are based is simple, having introduced the maximum number of varieties and races of economically worthwhile exotic coconut trees, these are crossed with each other in order to regroup the desired qualities in the offspring. Moreover, such crossings produce an increase in the vigor and hence in the output.

In practice, the future of coconut palm selection and the speed with which new progress is made will depend to a great extent on the effort devoted to it.

Without the establishment of the genetic block at Port-Bouet, it would take decades to get the same results. The economic importance of these results is quite obvious for the Ivory Coast, primarily, for the other Francophone states of Africa, and even for other countries all over the world which are asking the Port-Bouet station for help in matters pertaining to the coconut palm (Cambodia, New Hebrides, Polynesia, Peru, Mexico, Mozambique, etc.).

MINERAL NUTRITION OF THE COCONUT PALM

Y. Fremond, and
M. de Nuce de Lamothe,
IRHO

SUMMARY

IRHO research on the coconut palm was begun in 1949; since that date, 50 strictly planned experiments have been conducted; of these, 32 are currently in progress in nine countries, on four continents. Leaf analysis has been used to study nutritional problems.

The most important shortages are: nitrogen deficiency in the dry regions (Dahomey, Mozambique, Northwestern part of Madagascar), which can be corrected, depending upon the situation, by the addition of fertilizer or by planting a legume cover crop; potassium shortage in the coconut palm plantations which have been grown on littoral sandy soils (Ivory Coast) and trace element deficiencies on coral soils (Polynesia, New Hebrides).

The effect of each type of fertilizer on the various production factors and on the mineral element content has been established and the interactions between the various mineral elements introduced has been observed.

* * *

The study of the mineral nutrition of a perennial plant is always a difficult task because the ecological factors (climate and soil) have a more or less rapid and lasting effect on production. The wide dispersion and multiplicity of points to be studied fortunately might help us in overcoming this difficulty. IRHO research on coconut palms was started in 1949; since then, 50 rigorously planned experiments have been set up; of these, 32, currently in progress, are distributed over nine countries on four continents. The diversity of problems encountered has made it possible to expand our knowledge and has led to practical generalizations which would not have been possible within a narrower framework.

In tackling the problems of nutrition, leaf analysis enables a determination of the needs of the plant to be made and rapidly measure the effect of fertilization. The type, form, and time of fertilizer application that would be best for the soil and the plant can be established by this method.

The critical level (content of leaf below which the application of the corresponding element leads to an economic increase in the

production has been determined for each element. The first stage of research on mineral nutrition for coconut palms thus consisted in determining the deficiencies and in discovering their causes so that means of correcting this situation could then be studied.

I. MINERAL DEFICIENCIES IN COCONUT PALMS

The critical levels adopted by IRHO for a 14th leaf, expressed as a percentage of the dry matter content, are:

N = 1.80 to 2.00			Ca = 0.500		
P = 0.120 to 0.130			Mg = 0.300		
K = 0.800 to 1.000					

Nitrogen Deficiency

In the coconut palm, this appears as a yellowing of the growing point in varying degrees. When the deficiency is acute, the old leaves have a rather uniform golden yellow color which in extreme cases spreads to the young leaves.

There are various causes for nitrogen deficiency: it may be due to unfavorable soil conditions reducing microbial activity and the absorption possibilities of the root system, as, for example, in the coconut palm plantations on atolls where the pH is highly alkaline or in periodically choked areas. It can also be due to poor cultivation methods, particularly to the presence of grass.

But the main cause of nitrogen deficiency is climatic in nature. Comparing the coconut palm plantations in Dahomey and Ivory Coast, they are situated on identical soils, heavily leached littoral sands, but receiving, respectively, 1,200-1,500 mm and 1,800-2,000 mm of rainfall; the former shows a nitrogen deficiency which is not found in Ivory Coast (Table I).

Table I

N Contents as Percent of D.M. (IRHO Survey)

	Dahomey	Ivory Coast
Adult coconut palm plantations on coastal sand, not fertilized with nitrogen	1.52	1.83

In zones of low rainfall or where the rainfall is poorly distributed, the nitrogen contents are low. Along the northwest coast of Madagascar, there is a nitrogen deficiency, whereas on the east coast, which gets abundant rainfall throughout the year, the deficiency is either very low or nonexistent.

The analysis of leaf samples regularly taken every two months showed that there is good agreement in Mozambique between the rainfall volume and the level of N, two months afterward. At the end of the dry season, the levels of this element are at a minimum (Figure 1).

Phosphorus Deficiency

The seriousness of phosphorus deficiency is never comparable to those of nitrogen and potassium. Very often, moreover, because of the strong connection between the N and P contents of the leaves, correction of the nitrogen deficiency will raise the P content. However, in Ivory Coast, on 10-year old trees, we can observe an effect due to the application of dicalcium phosphate (Table II).

Table II

P Deficiency--Leaf Analysis, 1966-1965/1966 Production

	(-)	P
P content as % D.M.	0.114	0.123**
Copra per tree in kg	14.3	15.8*

The same applies to adult trees in Ceylon (Table III).

Table III

P Deficiency in Ceylon (1965)

	(-)	P_1	P_2
P content	0.116	0.130**	0.134**
Copra per tree in kg	13.1	14.1	14.6*

At Seme Podji, in Dahomey, a correlation was found between levels of P and the copra per tree, for which r = 0.876***.

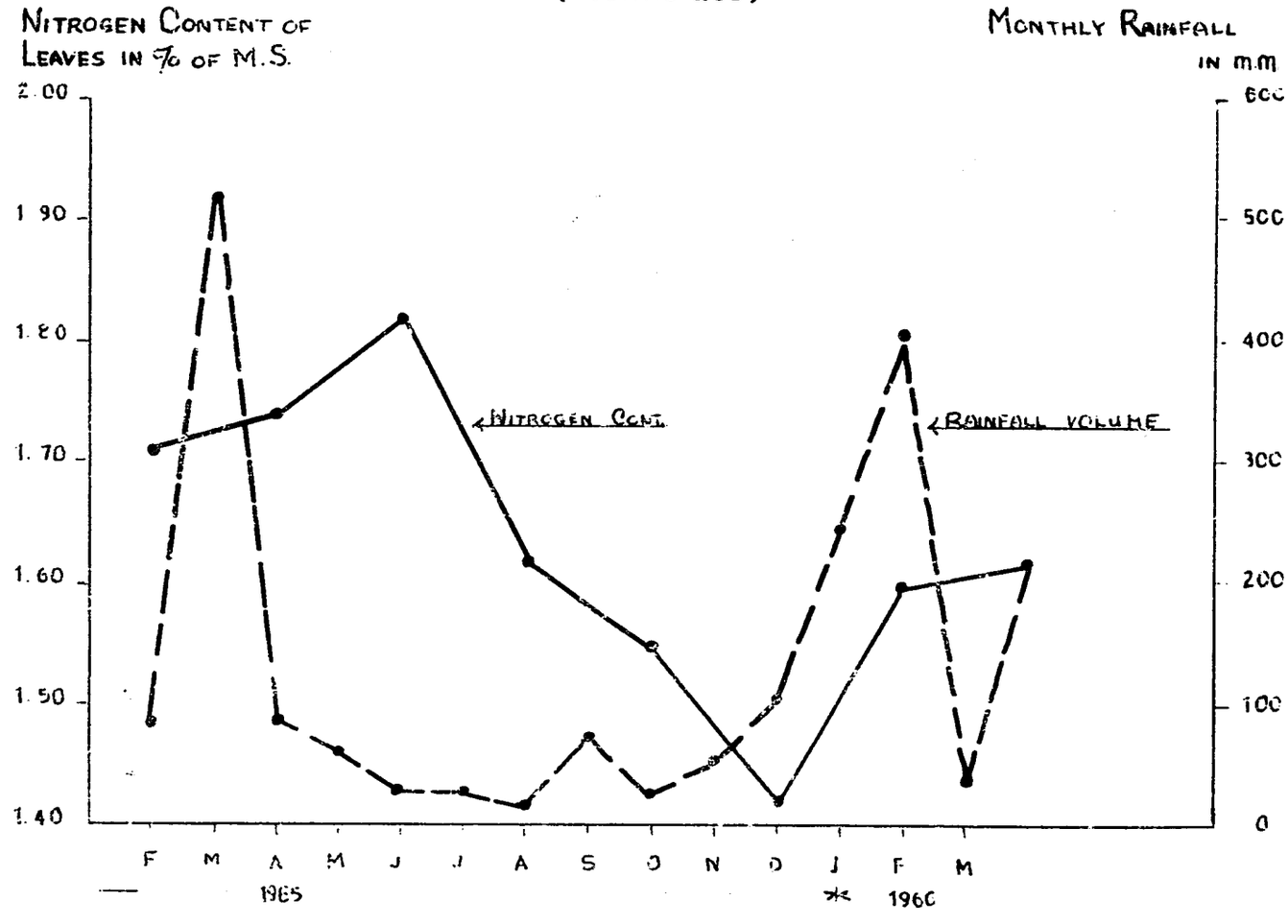
Potassium Deficiency

Potassium is the element which the coconut palm requires in the largest quantity. Pillai and Davis (1963) calculated this quantity at 85 kg of K_2O/ha/year, as against 56 kg of N and 27 kg of P_2O_5. It is therefore rare to find soils that are sufficiently supplied with K_2O and potassium deficiency is therefore the most frequently encountered. Sometimes it is so acute that the application of potassium fertilizer

Fig 1

NITROGEN CONTENT IN LEAVES & RAINFALL VOLUME

(MOZAMBIQUE)



alone, will multiply the yield three or even four times. This is particularly true on heavily leached sandy soils.

It nevertheless happens that the lack of potassium is not immediately apparent because of the existence of another deficiency which, by limiting production, also reduces the requirement for K: iron on the atoll of Rangiroa, nitrogen on the west coast of Madagascar or in Mozambique, are examples. The K content of the leaves is then relatively good but drops considerably as soon as the primary shortage has been corrected and K becomes the principal limiting factor (Tables IV and V).

Table IV

Mozambique--K Levels and Production

	Average level of K as Percent D.M.	Production in kg copra/tree/year
1961	----	10.7
1962	1.120	6.6
1963	0.860	13.4
1964	0.919	10.6
1965	0.719	9.9

Table V

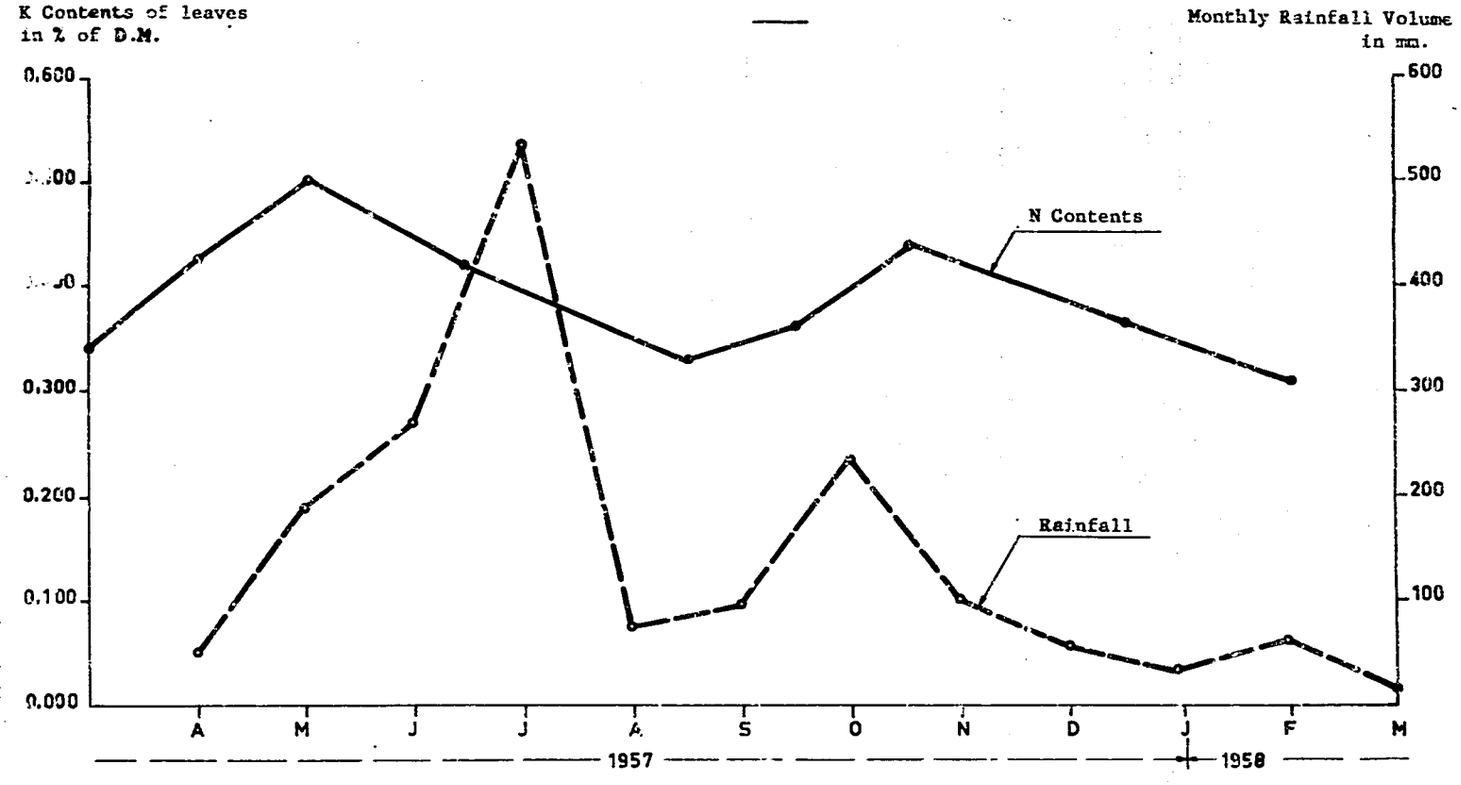
Rangiroa--K Levels and Production

	Average level of K as Percent D.M.	Production in kg copra/tree/year
1959	0,542	---
1960	0,544	7,2
1962	0,456	11,2
1964	0,404	9,0
1965	0,400	7,4

The climate plays a role in the assimilation of potassium. There is a relationship between seasonal variations in the K contents and the distribution of the rainfall (Figure 2). But potassium nutrition depends essentially on the type of soil; in the New Hebrides, the following conditions are found under the same climate: the so-called plateau soils which

FIG 2

POTASSIUM CONTENT IN LEAVES AND RAINFALL VOLUME



are very clayey (40-65% clay in the surface horizon) and the coral soils. Potassium deficiency is quite marked in the latter whereas it does not appear in the plateau soils.

On the marine sands in Ivory Coast and Dahomey, which are very poor in exchangeable bases, the potassium deficiency is quite generally widespread.

Magnesium Deficiency

The magnesium shortage is visually reflected by a yellowing of the folioles which is more accentuated on the portions exposed to the sun.

Response to application of magnesium fertilizer is only rarely observed. Most often, the deficiency is induced by heavy potassium fertilization; as a matter of fact, there is a K-Mg antagonism for the leaf content of these elements (Table VI). This cause is much more frequent than the deficiency of Mg in the soil.

Table VI

Ivory Coast. K-Mg Antagonism

	Level of K	Level of Mg
1961	0.729	0.333
1962	0.837	0.267
1963	1.137	0.291
1964	1.082	0.222
1965	1.273	0.181

Trace Element Deficiencies

Trace element deficiencies are found above all under certain very particular pedological conditions, for example, on the atolls. Calcium which is very abundant in these soils, blocks the iron and the manganese which then become very poorly assimilable as far as the coconut palm is concerned. The total iron analysis--not distinguishing here between physiologically active and inactive iron--did not make it possible to establish the critical level of this element. In effect, sign of deficiencies are observed on trees with contents of 38-40 ppm but not on other trees with lower contents (28 ppm).

Boron deficiency is rather rare; it causes the lysis of the meristematic tissue, accompanied by the rotting of the heart.

II. CORRECTION OF DEFICIENCIES AND EFFECT OF FERTILIZERS

Once the critical levels have been determined and the deficiencies established through leaf analysis, the effectiveness and profitability of various types of fertilizer can be examined.

Nitrogen

There are two ways of correcting a nitrogen deficiency in the coconot palm plantation: either application of mineral fertilizer or by a legume cover crop.

(a) Mineral Fertilizer

The application of nitrogen in mineral form raises the level in the leaves, if this is done at the optimal time. In spite of the risk of leaching, it seems that this period is at the beginning of the rainy season (Table VII), a time at which the absorption ability of the tree is at a maximum.

Table VII

Mozambique. Optimal time for N Application

Treatments	Leaf N Content as Percent D.M.
2 kg of ammonium sulfate at beginning of rainy season	1.75*
2 kg of ammonium sulfate in middle of rainy season	1.68
Control without nitrogen	1.65
2 kg. of ammonium sulfate at end of rainy season	1.70

(b) Legume Cover

Under certain conditions it is useless to try to raise the N level by applying mineral fertilizer; this is true particularly on Rangiroa where the soils are stony, often very poor in organic matter and obviously too rich in limestone. It is then necessary--if we want to correct the nitrogen shortage in the adult coconut palms economically--to plant a legume cover crop; under these conditions of texture and pH, this planting effort is by no means easy but research on the cover crops which are best adapted for this type of soil is now beginning to show returns, and some selected strains of *Vigna marina* have produced good results.

The use of cover crops to correct a nitrogen deficiency is not limited to such soils; it is worthwhile in all cases where the plants have numerous and active nodules fixing atmospheric nitrogen.

Effect of Nitrogen Fertilizers

In young coconut palms in the nursery, no effect was observed with ammonium sulfate except on the coloration of the plants. On the other hand, ammonium nitrate has shown a definite effect on the size and color of the plants in the nurseries on the atolls.

In adult plants, the effect varies according to the level of K; when the content is low, ammonium sulfate reduces the number of nuts and the level of copra/nut (Tables VIII and IX). But, when the potassium shortage has been corrected, nitrogen acts upon the number of nuts, whereas the depressing effect on the copra/nut level, although less marked, nevertheless does persist.

Table VIII

Ivory Coast, 1966. Adult Trees--N-K Relationship.

Number of nuts per tree			Content of Copra/nut g.		
	(-)	K_3		(-)	K_3
(-)	34.7	56.9	(-)	172	223
N	20.4	67.8	N	165	199

Table IX

Dahomey, 1966. N - K Ratio

	Number of nuts per tree	
	(-)	K
(-)	10.8	51.5
N	7.9	66.2
K content as % of D.M.	0.289	1.123**

Phosphorus

The application of dicalcium phosphate raises the phosphorus content (Table X). It is, however, necessary only when--in the case of sufficiently high N and K contents--the P contents remain low (N and K, in effect, help raise the P content level).

Table X

Effect of Dicalcium Phosphate on P Contents as Percent of D.M.

	(-)	P_1	P_2
Ivory Coast	0.114	0.123**	
Dahomey	0.106	0.118**	
New Hebrides (1)	0.141	0.145	0.146*

(1) 4th leaf.

The critical level lines between 0,120 and 0,130 %; below this value, the phosphate fertilizer increases the number of female blossoms per bunch and per tree, the number of nuts, and the amount of copra per tree (Table XI).

On trees which are well supplied with N and X--when a P deficiency appears--significant correlations are obtained between the P levels and production.

Table XI

Ivory Coast. Effect of Dicalcium Phosphate (12-Year Old Trees)

	(-)	P
Number of female blossoms per bunch	21.5	23.2*
Number of female blossoms per tree	246	270**
Number of nuts per tree	81.6	88.3
Copra per tree in kg	14.3	15.8*

Potassium, Calcium, Magnesium

The severe potassium deficiency found in littoral sands can be easily and rapidly corrected by applying KCl.

On sandy-clay or clay soils (Mozambique, New Hebrides), potassium fertilizer does not seem to increase the content, but experiments here are still entirely too recent and it is probable that we will have to wait a number of years before the absorbant complex has been saturated.

In the nursery, potassium increases the strength and the weight of the plants.

At early age, potassium fertilizer is very important: at 12 years, plots of land fertilized with K since planting, produced (a cumulative total of 3,410 kg of copra/ha more than plots which had been deprived of fertilizer up to the age of 8 (Table XII).

Table XII

Production at Twelve Years of Plots With and Without K During Early Growth

	Plots with K for 12 Years	Plots without K to 8 Years and K Subsequently
Cumulative production since beginning in kg of copra/ha	8,740	5,330

Table XIII

Ivory Coast. Effect of K on Production of Eight-year Old Trees

	(-)	K
No of inflorescences per tree	5.8	8.2**
No of female blossoms per tree	84	136**
No of nuts per tree	11,6	37.0
Copra per nut in g	143	159**
Copra per tree in kg	1.7	5.9**

On trees that in production, potassium fertilizer gradually causes the disappearance of the deficiency symptoms: the young leaves become longer, the tree becomes green again, and the number of living leaves is increased. Potassium fertilizer acts more rapidly on the amount of copra per nut (1-year) than on the number of nuts (18 months to 2 years); it acts upon all of the factors of production, increasing the number of inflorescences and the number of female blossoms, the number of nuts, and the amount of copra per nut (Table XIII).

The optimum quantity of KCl to be spread on an old coconut palm plantation to be restored has been determined in Ivory Coast and Dahomey. This was the most urgent problem to be resolved in those countries. The optimum levels for new plantations, using improved plant material, cultivated on various types of soil, have now to be determined. These levels will certainly vary with the climatic conditions; the profitability of a fertilizer increases as the climate enables the trees to make better use of it.

A study of potassium has brought out the K-Ca and K-Mg antagonisms. In the current state of knowledge, it does not seem that the critical level of calcium, which has been fixed at 0.500, should be modified. Furthermore, it is not so much a question of critical level as "good levels," since definite cases of calcium deficiency have never been encountered.

The K-Mg antagonism is very marked and, with the help of potassium fertilizer, the Mg content can be reduced to the level of acute deficiency (Table VI).

The values can be raised by applying magnesium sulfate to the soil. In coconut palms in the nursery, Mg increases the vigor; on trees entering production, it increases the number of bunches, the number of female blossoms, and the number of nuts (Table XIV).

Table XIV

Ivory Coast. Effect of Mg on Production

	(-)	Mg
No. of bunches per tree	10.0	11.2**
No. of female blossoms per tree	154	168
No. of nuts per tree	50.7	57.4*
Growth index at age 1 (1)	4.49	5.14**

(1) For growth index, see annual IRHO report.

Sodium

It has often been said that the coconut palm has a particular predilection for sodium. There are no solid facts to justify this statement; however, the coconut palm adapts itself to soils that are rich in Na. Under conditions of severe potassium deficiency, sodium can be partially substituted for that element and increases the principal components of production.

Trace Elements

The Coconut palm's requirements for iron and manganese are very low but the necessary amounts must be supplied very regularly. Correction techniques are now well known in Polynesia: application of ferrous sulfate and manganese sulfate to the soil in a hole dug at the base of the stem for the adult coconut palms and in the fiber of the nut of plants in the nursery.

Iron acts upon the strength of the young plants. The other elements act upon the growth; N and K in particular have no effect, once the iron deficiency has been made up.

On the adult tree, iron increases the number of nuts and the quantity of copra per tree.

Manganese has a less marked effect than iron. However, a positive interaction has been found between iron and manganese with respect to the number of nuts per tree; but this effect will have to be investigated further (Table XV).

Table XV

Rangiroa. Mn-Fe Interaction on Number of Nuts Per Tree

	(-)	Mn
(-)	24.2	38.9
Fe	42.0	65.2

CONCLUSION

The coconut palm's requirements for mineral elements are highly disproportionate which explains the frequency of certain deficiencies; the coconut palm is a tremendous consumer of potassium, for example, but rarely finds soils adequately supplied with this element.

Although the quality of the soil is one of the essential factors in mineral nutrition, the decisive role of the comate, on which depends the assimilation of elements present or applied to the soil, must be equally emphasized.

Leaf analysis provides rapid information on the tree's reaction to any modification in the environment; it is therefore a tremendous help to the agronomist. It enables him to determine which types of fertilizer are best suited for each particular ecology, it enables him to follow the effects, and to determine the profitability.

There is thus no master formula for the fertilization of coconut palm plantations and it would be illogical to recommend a particular fertilizer without first having estimated the deficiencies and studied the remedies under existing ecological conditions.

AGRICULTURAL RESEARCH AND THE INTENSIFICATION OF BANANA CULTIVATION TECHNIQUES—THE CASE OF THE IVORY COAST

J. Champion, IFAC

In this country the intensification of banana cultivation is the result of continuous efforts of farmers, scientists and the government, for more than twenty years. IFAC has established a crop research station at Azaguié especially to conduct research on bananas. In fact this organization has laboratories in France near Paris, from which it is also directed, and an extensive network of stations distributed throughout the African and American inter-tropical zones. This gives it the capacity to carry out research in diverse ecological conditions and amass a great variety of information.

It is not possible to differentiate between fundamental studies, basic studies and applied research. All of these are carried out with a view to useful application sooner or later. Experience of twenty years has shown that very detailed knowledge of the plant with which IFAC is concerned is as important for finding ways of improving qualitative and quantitative yields as permanent contact with the farmers. It is not possible to work without this contact, to stay in the laboratory. The results are confirmed in the field, on field research stations, and finally tested in large-scale production.

It is not possible in a short note to detail the research carried out over twenty years which has enabled the technical principles to be established. Only some aspects can be described. The following all refers to the "Poyo" type of banana and similar varieties. This variety is being rightly adopted generally throughout the world as had already been done in Central American countries, and more recently in the Ivory Coast. Comparative trials have shown the potential superiority of the Poyo and the very short varieties of the Cavendish group.

Since the title of this paper contains the term "intensification" it is necessary from the beginning to clarify the reasons for the need for this. In certain equatorial countries the rich soil and constant humidity favors intensive banana growing. The incidence of disease and other pests has created increasing numbers of obstacles to simple fruit gathering. Currently there is beginning to be interest in yields per unit area. In the Ivory Coast extensive cultivation comes up against the climate which has dry seasons, of which one is prolonged, and by the acute drying out of the soil. This adds up to an uneconomical annual production, and only produces low-weight bunches. The land must be managed, drained and fertilized; irrigation must be installed, and feeder roads. Investments are so high per hectare that profits are only possible with high yields, a minimum of 25 tons of bananas per hectare, and often more. Since the ground is poor in minerals and there is often moisture deficiency, these requirements must be supplemented. In

addition crop protection measures are most often applied over an area, making increases in unit yield a concern.

Thus the need for intensification is clear, and it is the only way in which the price of the product can be reduced.

Considered as a whole, banana research is carried out on the plant individually and on a population of plants—a collection forming an artificially cultivated ecosystem, the banana plantation.

The study of the banana has been primarily concerned with the normal stages of growth, in defined conditions from cuttings or suckers. In passing it should be mentioned that natural growth of the banana left to itself does not concern us; it produces many suckers, forms a clump, and the inflorescences remain small. By the budding process, a single sucker is selected and, through this controled vegetative multiplication, only one stem succeeds the plant which produced it. The number of functional leaves and their growing dimensions are determined, and flowering will take place without the banana slowing it down through production of supplementary leaves. The relationships between the characteristics of the vegetative and flowering stages ha been determined. The adventitious root system has been studied in their length and life-span are known. It is known that their distribution in the soil is limited by physical factors and by severe parasitic infestation. Measurements of the mineral requirements at different ages have given a dynamic picture of the growth needs of the major elements. The intensity of potassium requirements prior and subsequent to flowering is known. In addition, in work carried out at the Azaguié station in the Ivory Coast, the reaction of the banana to total, partial or periodic deficiencies of major nutrients (and some trace elements) has been carefully observed under various conditions, and an atlas of deficiency symptoms which can be used everywhere is now available.

The reactions of the banana to ecological conditions must be better understood. This is a broad program which is now being carried out.

Studies of evapotranspiration and transpiration are in progress, to ascertain the moisture requirements which until now have been determined empirically. A study of the influence of temperature and light on the growth of the plant and the development of bunches has been established. When for other annual or perennial crops priority is sometimes given to one method, fertilization for example, or the control of a particular parasite, it must be recognized that intensive banana cultivation requires a number of essential conditions such as control of parasites, mineral nutrition, irrigation and maintenance. Only a few factors, such as temperature and light, are difficult to modify.

The control of parasites has been made the object of intensive studies during the past few years. The methods which have been selected are only those which lead to high yields. For example cercospora (Mycosphaerella musicola) very rapidly destroy the leaves at certain times, which limits the growth of the bunches and the quality of the fruit. The disease is

treated by application of light mineral oil with an atomiser. This technique was discovered by IFAC specialists and is now in general use not only in the Francophone countries but in foreign banana-producing countries. The disease has not spread badly in the Ivory Coast, but the professional organization is constantly alert to control outbreaks through aerial spraying.

Today the damage caused by weevil larvae (Cosmopolites sordidus) can only be recounted from memory, whereas for some years it was a serious problem. The population of the insects is kept at a very low level by the application of insecticide around the base of the plant at least once a year. This is a routine method. IFAC laboratories are nevertheless studying new products and looking for resistance phenomena.

Finally the parasitic nematodes of roots are extremely dangerous and abound in the Ivorien soils. Control methods have been developed involving injection of nematocides into the soil (DBCP - 30L/Ha/year) and improved methods of application, reduction of amount required are being investigated as well as trials with new products.

Thus fundamental knowledge of the plant, its development, its reactions to the inert and living environment has been sufficiently developed—although carried out well in advance—to provide criteria for judgement, when the plant is put into production conditions. This knowledge has not been acquired by the work of a team of specialists, physiologist, entomologist, phytopathologist, etc. It is the agronomist, working with field trials, who must make the synthesis and study the best conditions of production.

It can be said that the first principle has now been recognized as being valid in all the banana-producing countries. A plantation must consist of a single plant stratum. Mixed cultivation with other species has been rejected, as well as the presence of ground cover, either natural grass or cover crops, or of shade, even light shade provided by high trees. Bananas will not tolerate being cultivated with the presence of other root systems and even more, demands maximum light.

The second principle is that this stratum must consist of a dense cover, creating shade conditions below the leaves, which limits the growth of grass and provides a warm and humid environment. In fact an optimum compromise must be achieved such that the suckers growing at the base of the plant are not retarded by the lack of light. The very numerous trials carried out on this problem have shown that high densities of plants give very high production at the first production, under the express condition that the planting material must be extremely homogeneous. It is recognized that heavy material clearly gives increased production. The climatic conditions must be taken into consideration; for the Poyo banana, in sunny climates (more than 2,000 hrs/yr) (2,500 - 2,800 plants per hectare can be planted). In cool areas (Tamatave, Madagascar) or cloudy conditions (Cameroon) it is not possible to work with more than 2,000 stands to the hectare. Occasionally planting in double rows is used to improve the interior light. Nevertheless,

generally speaking, increasing the density is the most straightforward means of increasing unit production.

The life of a banana plantation can be very long, since vegetative reproduction guarantees permanence; however in practice, and particularly at high density, a certain number of late plants become unproductive while others are destroyed by the wind in spite of supports (10% on average in the Ivory Coast). After three or four years, it becomes profitable to replant (without fallow) particularly since it is possible to choose a date at which production will begin at a favorable time.

For the given region, the optimum density of planting is the first consideration. Then it is necessary to establish the best cultivation methods for this area. It is characteristic that in the Ivory Coast one is practically obliged to develop particular methods for each plantation. These should take into account everything which has been done in the way of preparatory work and improvement. Field trials on the research station serve as a basis and as a control, as well as the various analyses which are applied.

The nutritional conditions are very important. For normal root development, they must be in an environment both aerated and provided with moisture. Drainage must be effective, and structural defects, slow percolation and compaction are often encountered. These are certainly the most complex problems which have to be resolved at present. Faced with the difficulty of keeping the root systems intact, the role of the root system of the suckers in relation to the system of the main plant should be studied, and new techniques are under consideration to maintain the working part of the suckers without allowing them to develop their shoots to any great extent.

If the root problem can be appropriately resolved, support should be given to regular nutrition; in the case of deforested or recently cleared land, the agropedologist (a laboratory has been established at the Azaguié station) should determine the basic improvements which should be applied; this will entail a certain amount of reduction of the desaturation of the complex and fertilizing at the level of one to two tons of organic matter a year to increase the absorbant complex, most often in the form of a thick mulch of leaves or branches. The development of the soil is followed by periodical analyses; practice has proved their importance and profitability. In general in the Ivory Coast the attainment of high yields on new land requires several years. It is necessary to provide a supply of organic matter until the correct level has been reached. When the banana plantation growth has become satisfactory a maintenance level is reached, since a hundred tons of green matter remain on the ground each year.

The need for supplying all the plants' normal requirements for nitrogen and potassium is well understood. In fact higher levels than are necessary (2 kg nitrogen per ton of bananas produced and 5 kg of potassium) are provided since the losses due to leaching are enormous.

Recent studies made at Azaguié show that leaching is intense, for example, during the heavy spring rains. Currently 10 kg of nitrogen and 20 kg potassium are provided per ton of fruit produced. Various economic procedures are being studied at the various locations. In practice distributing the fertilizer in small amounts throughout the year gives a greater effect, and the state of growth of the banana can be much more taken into account. Soil analysis provides an understanding of soil deficiencies, particularly of bases. The provision of phosphate is reduced, since deficiencies are exceptional; the plant requires less of it than magnesium. Deficiencies of trace elements become increasingly frequent with length of cultivation, and more constantly repeated on the same soil.

Fertilizer mixtures are modified on the basis of leaf analysis (samples of leaves and petioles analyzed at the central laboratory in Paris) which are particularly useful since there may not be an external symptom which could permit visual diagnosis. These analyses reveal imbalances or antagonisms due to excess cation. The role of the agronomist has also been to determine all the practical methods, which are most important, of running the plantations and cultivating the bananas. Keeping the soil bare is accomplished increasingly through the use of chemical defoliants which must not have a toxic effect on the banana; these products are being extensively studied. Currently contact herbicides such as "paraquat" which are satisfactory and economic are being used more and more (4 applications of 2 liters for 400 liters of water). In general these avoid working the soil if the surface is loose.

Overhead irrigation at the rate of 125mm/month in 5 applications is the general practice.

The inflorescence remains suspended for three months after its emergence until a bunch of bananas develops suitable for harvesting and export. The banana plant, having only a small part underground (20 - 40 cm) with weak roots, is unbalanced by the 20 - 40 kg bunch hanging at one side. It is accordingly extremely sensitive to gusts of wind and must be supported. Furthermore the pericarp of the banana is very sensitive to bruising, and to all contact with debris, insects or small animals. Experiments with colored polyethylene bags have given fruit of very good appearance; in the cool season, this allows an increase in time for the bunch to mature. The profitability of this technique is increased by the removal of the male part of the inflorescence at an early stage. The rest of the female flowers, at the apex of the banana, should also be removed. These are the steps necessary to obtain high quality fruit. The bunches should be transported with the greatest precaution until they reach the packing plant. There they are cut into hands into specially constructed cartons. In all these aspects research has been carried out and is continuing. The phytopathologist again provides information on the best means of protecting the banana (during transportation and ripening) against fungi after harvesting. Promising results have been obtained at the specialized laboratories at the headquarters of IFAC. Although it is always evolving, it may be said that banana

production requires good technique, and one cannot talk of one particular method but of a collection of linked methods. The results of research which have been reviewed are published regularly in "Fruits," a journal published by IFAC, and also in various other places, including a number for extension purposes. It is clear that the research is essential for the development of banana production in the Ivory Coast (130,000 tons at present) which holds a not insignificant place in the economy of the country.

INFLUENCE OF RESEARCH ON PINEAPPLE YIELDS

M.A. Tisseau, IFAC

INTRODUCTION

In 1938 no Francophone country appeared in the world pineapple production statistics.

In 1950 the Ivory Coast produced 5,000 tons and in 1965 50,000 tons. The exportation of fresh fruit was 100 tons in 1950 and reached 10,000 tons in 1967.

Fresh pineapple in 1950 was a luxury fruit produced on a very small scale and consumed by a privileged class.

The consumers of preserved pineapple, sliced or juice, obtained their supply mainly from foreign producers, particularly American. Some more figures are: in 1966, 56% of French imports of fresh pineapples and 47% of preserved came from the Ivory Coast. The same year the Ivory Coas provided 16% of preserves imported by the European market.

The West Coast of Africa provided 74% of the fresh fruit on the French market in 1966.

This rapid growth was stimulated by a consumer demand for this delicious fruit, the demand itself both the result of the quality of the produce and the consistency of that quality as regards presentation and organoleptic properties. The producers were only able to provide the markets with the required quantity and quality by transforming the market gardening methods of production in 1950 into intensive industrial cultivation.

Following fact-finding visits of a number of IFAC experts, and through the coordination of their observations, from 1950 a variety of experiments was begun leading to a better understanding of the plant and its behavior in terms of different conditions, which in turn would lead to the development of specific cultivation methods.

In addition the various possibilities of packing and transportation of this delicate fruit as well as the whole gamut of processing and preservation of pineapple were studied.

In all the areas studied, the results obtained and related from one field to the other, contributed each in its particular way to making industrial pineapple cultivation a rational process leading to improved quality and lowered market prices. Some of these points will be discussed.

On all the IFAC stations in the intertropical area, the development and cultivation cycle of the plant in terms of climatic conditions during growth and in terms of the nature of the plant material were observed in a preliminary study for information and as the basis of further experimentation.

This resulted in information on the natural plant cycle and favorable dates of planting for a given weight of shoot.

Cultivation methods

First the disposition and optimal density of planting according to climate, soils and desired objective (fresh or preserve) were studied. Densities were effectively increased from 15,000 to 50 and even 70,000 stands per hectare. The yields, as a result of this and also due to fertilizer and care and attention increased from 25 tons to 60, 75 and even 90 tons per hectare.

At the same time cultivation methods (intensive either with or without fallow) and the basic principles for soil preparation and control of erosion were developed, including

- the adaptation and development of a polythene film to cover the soil for certain growing areas and under certain conditions was made the object of a number of studies

  These dealt with the color of the polythene in relation to temperature and sunshine, its role in leaching of fertilizer and in the constancy of soil temperature.

- irrigation, essential in certain zones, was studied from the angle of its effect on growth. The necessary periods, rhythms and amounts of water to be applied were investigated.

- second standing crop production, practised currently in several producing countries, is very attractive in theory but poses very difficult problems in practice requiring special infrastructure and equipment. Research is being continued into it.

Fertilizer

Progress made in this area of investigation has been most important and spectacular. Information has been gained in terms of the various soils, climate, plant material employed, not only of optimum levels but also their distribution in time and the composition of the fertilizer mixtures.

This work is far from complete, for if the types of formulae have been developed from the point of view of the nature of the fertilizer and the balance of the nutrient elements of which they are composed,

their exact role in the development of fruit quality, and the influence of each element on that quality remainds to be determined. The range of trials is very extensive, and includes:

- study of soil depletion in terms of fertilizer types ;
- role of nitrogen, its effect at different vegetative stages, optimum type, levels and methods of application. It appears that urea, for example, is preferable when applied in repeated sprayings and that too large applications shortly before the differentiation of the inflorescence risks inhibiting this.
- the form of potassium fertilization, levels and most favorable growth period for application; linked to the balance with the other elements, nitrogen and magnesium.
- is phosphate essential if the assimilable fraction in the soil is adequate and if not, in what form should it be provided?

  The study of this is in progress and results will undoubtedly lead to modifications in the fertilizer practice in certain plantations.

- the role of calcium, its effect on the pH, and the inter-action of calcium and boron are being studied particularly on the quality of the fruit;
- the important role of magnesium has been demonstrated and it is now included in pineapple fertilizer. Its balance in relation to potassium has been studied and the effects of an excess on production and quality confirmed. The visual symptoms of the absence or deficiency of magnesium have been demonstrated as in the cases of nitrogen and potassium by means of hydroponic cultures which enable imbalances in fertilizers to be precisely identified. Deficiencies of secondary elements, sulfur, iron, zinc, copper, boron, manganese and molybdenum, have also been produced through hydroponics and their symptoms observed.

Each production sector, each plantation itself, is a special case from the point of view of fertilizers. However the data from all the fertilizers trials enable the IFAC agronomists to effectively orient elementary fertilizer programs at lower cost.

Flowering

Once the natural cycle of the pineapple was known, it was said to be suited neither to marketing the fruit fresh nor to desireable distribution of supply to the cannery.

A method of controlling flowering and stimulating it artificially was known, but the means of applying it linked to such imponderables as day-length and weather conditions made its use risky. The percentage of successes could reach 75% but could equally well be below 30-35%, seriously affecting the planned production. The technique consisting of applying a solution of acetylene during the night, at three o'clock, and renewing it after two or three days, enabled the percentage to be

increased to 95% and even 100%.

This method, which resulted from numerous observations carried out in other countries, has been made the object of precise investigations on the IFAC stations, so that it could be used by the majority of planters. These studies relate to the type of nutrition and various flowering stimulating products, as well as to the time of application.

Stimulating a satisfactory percentage flowering by this treatment no longer poses any problem to the pineapple grower. Mechanical techniques which are risk-proof must now be developed for this operation.

Maintenance

Precise and very sensitive studies of the root system have demonstrated the danger of mechanical weeding with very deep penetrating tools. Chemical herbicides are now preferred. However if products are used and aecommended today, all these proposed for use have been carefully checked for phytotoxicity, effectiveness, specificity and residual effects. Ultimately the cost price of effective doses must be studied. This group of studies and trials should be often repeated in relation to farming conditions, mechanization, the nature of the soils and the dominant adventitious species.

Other maintenance techniques, such as reduction of top-cover and protection against direct sunlight, which are practiced today by fresh fruit producers result from research work which was aimed at developping effective methods which are also as economical as possible.

Parasitism

As it is the subject of other papers, parasite control will only be mentioned. Here, too, as for herbicides, innumerable products must be tested and checked to give satisfactory results.

Harvesting-Packing

This heading particularly refers to pineapple exported fresh. The fragility and sensitivity of the fruit to the slightest shock is well known, and all appropirate methods of protection from harvest to arrival at the retail outlet must be rapidly developed. From this comes constant evolution not only of the method of packing but of the theoretical principles. .

From the wooden crate with straw or fiber we have now the carton, much lighter but also resistant, in which each fruit is kept upright, unable to knock against its neighbors, secure from blows against the side of the carton.

To give these honeycomb fruit-cartons dimensions adapted to each category of fruit, thousands of measurements were taken, in different

climates and at different seasons, of the weight and diameter and correlations were obtained enabling a fruit of a given weight to be accomodated in a given volume. Improvements currently envisaged particularly concern the quality of the cartons and the method of wrapping the fruit.

CONCLUSION

Research on pineapple,carried out all over the world and adapted focussed in the Ivory Coast by the IFAC team has undoubtedly resulted first in a stimulus to production and subsequently in improved techniques and lowering of the market price through greater knowledge of the fruit and rationalization of each cultivation technique. The basic fundamental techniques of what can be called "industrial market gardening" have now been developed.

However the climatic conditions of the areas of cultivation of pineapple in the Ivory Coast are not ideal and research effort is now directed towards improved quality, studying the constituents affecting quality and the effects of cultivation practices and applied nutrients on these. This program will make this succulent fruit a crop of constant and lasting quality.

ARABICA COFFEE RESEARCH IN AFRICA - A NOTE

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SUMMARY

Coffee research in Africa has achieved a great deal over the last three decades and there is a considerable amount of information which remains to be more fully implemented in the field. However, against a background of rising costs and world overproduction of coffee there is a need to reappraise existing coffee growing methods so as to produce better quality coffee simply, more intensively, and at reduced cost levels.

An effective and economical control for coffee berry disease is required urgently if these countries with a high economic dependence in Arabica coffee are not to suffer severely before their crop diversification programs take effect. There is also a vital need to pursue both the short and long term aspects of quality research.

For long term projects mutually beneficial associations between coffee research groups and University departments are to be sought. The former could provide a fund of scientific skill and experience in practical problems, the latter could contribute special equipment and some form of continuity through the establishment of post-graduate schools of research.

INTRODUCTION

Arabica coffee provides a high proportion of the national income of a number of African countries and research on this crop has received detailed attention in the continent for the last 30 years or so. A very considerable body of agronomic knowledge is available and, with one notable exception, information about control of the more prominent pests and diseases has attained a fairly satisfactory level. Because of the perennial nature of the crop plant selection and research into nutritional requirements are necessarily long term projects in which there is still much to achieve but, in general, systems of cultivation have been well developed. Up to now these have provided adequate rewards for the inputs of investment and labour of both large and small scale farmers. However, this situation is rapidly changing as costs of production rise and world coffee prices fall.

Apart from the fields of research mentioned above, significant advances have been made in nursery work, the more practical approaches to pruning, coffee processing methods and certain aspects of the physiology of the plant. The overall picture is one, therefore, of a large body of information which, in many cases, requires more successful implementation in the field, especially among small scale growers.

RESEARCH PROBLEMS OF IMMEDIATE URGENCY

1. Coffee berry disease

Coffee berry disease, caused by Colletotrichum coffeanum is a potentially devastating disease which is now causing immense concern among Arabica coffee farmers in many African countries. It is prevalent across Central Africa and occurs as far south as Angola. In Kenya for example, the annual loss attributable to this disease is probably 20% or more of the crop and some individual coffee farmers in environments favourable to the disease now appear to be suffering almost a total crop loss. The disease is causing acute hardship to small-scale farmers whose cash income is often solely derived from coffee and there is now grave concern among large scale producers, some of whom have suffered severe financial loss over a consecutive number of seasons.

There is no completely effective method of control as yet, and the present recommendations for reducing disease incidence by the use of fungicidal sprays add considerably to the costs of production without always guaranteeing an economic return for the time and money spent. Thus, although there is now world overproduction of both Arabica and Robusta coffees, increasing economic stress will be felt at both the national and individual levels if this disease is not overcome in the near future.

2. Coffee Quality

Another major concern of Arabica coffee producing countries is the improvement of quality so that they can maximize their income by selling competitively both within the framework of the International Coffee Organization's quota system as well as to the 'non-quota' markets. Research on factors which affect the quality of coffee thus holds a high priority. The problems range from the definition in physical and chemical terms of quality attributes to an understanding of the ways in which these can be influenced genetically and by management and environmental factors. Some progress has been made to date but the scope of this problem is very large and a concentrated long term effort is required.

THE FUTURE

1. An effective and economic control for coffee berry disease must be found soon if Arabica coffee production is to remain an economic proposition in certain African countries.

2. In general, Arabica coffee is grown by both high and low cost producers on land of high agricultural potential. Because of a world situation of decreasing *per capita* food production it is essential to obtain a maximum return per unit area of such land. Considering also the present state of world overproduction of coffee and the very slow annual increase in coffee consumption, the need is to produce the same or a lower level of crop more economically and to use the minimum amount of high potential land to do this. That is, coffee growing has, somehow, to be made much more intensive but less costly.

   To achieve this requires the solution of research problems of a more sophisticated nature than has been necessary during the period when the basic agronomy of the plant has been under study. This is particularly the case as quality holds such a high priority.

3. A more thorough understanding of the physiological and nutritional bases of yield and quality can lead to practical suggestions for revised systems of management which could be less wasteful ecologically and more productive economically. One has only to point to the major changes towards highly intensive production methods in certain top fruit growing areas in Europe over the last decade to obtain an example of how an apparently stable agricultural sector can soon devise more effective methods when under economic pressure. High density planting combined with restrictive but simple pruning systems require more detailed investigation. This is, again, clearly a long term project which requires continuity of effort. If current plant breeding programmes succeed in producing selections of high quality coffee with a high degree of field resistance to coffee berry disease, as it is hoped they will, then it would be of considerable advantage to have pursued investigations into new management systems to a stage where they could be adopted before much progress had been made in replanting.

4. Coffee is overproduced and too many African countries are too dependent economically upon coffee. Crop diversification is therefore a prime need. This can take place in two ways, by total replacement of existing coffee areas with another crop, or crops, or by the partial replacement of coffee by means of the introduction of a mixed cropping system. The latter is, of course, an age old African farming method and there are sound ecological reasons why more attention should be given to it. The result of some previous work on mixed stands in which coffee has been one of the components has not always been interpreted correctly in terms of total production per unit area of land. With the modern techniques now available it is possible to ascertain the fundamental basis of competitive effects and so approach this type of research more soundly than by the entirely empirical approach of the past.

THE IMPLEMENTATION OF RESEARCH RESULTS

There is no doubt that tremendous strides could be taken to improve the efficiency of the coffee industries of many African countries if existing research information was more fully implemented. Apart from common hindrances to the dissemination and application of knowledge at the farmer level, e.g., lack of education and capital resources, a critical factor for a perennial crop such as coffee is a general lack of properly trained field advisory staff. Special skills are required for the cultivation of perennials and thus there is an essential requirement for a higher level of effort and basic quality of training on the part of advisory staff. The Kenya Department of Agriculture has recently taken steps to

overcome this problem by establishing specialist coffee advisory staff.

COLLABORATIVE RESEARCH WITH UNIVERSITIES

There are still many relatively simple and immediate problems which must engage the attention of coffee research workers. On the other hand, for the very reason that coffee research has progressed so successfully over the last few decades, some areas of work are becoming more complicated. This means that long term planning now becomes even more important than in the past. There has to be an appropriate mixture of applied and oriented fundamental studies to satisfy the needs for answers to both immediate and long term problems. Without some attention being paid to the latter, few major lasting improvements can be expected. It is just in this type of work that sound, mutually beneficial cooperation should be encouraged between coffee research groups and the appropriate University institutions. The former can provide many examples of advanced levels of practical research effort and the latter can often now offer modern equipment and a degree of continuity of effort through the establishment of post-graduate schools of research. Indeed, the closer association of agricultural research centres in general and the Universities in Africa would appear to offer the most economical way of using available resources and it could be essential to the continuity of advanced levels of agricultural research and a proper appreciation by University graduates of their country's agricultural problems (see "Priorities in Arabica Coffee Research in East Africa" by P.A. Huxley, 1966, East African Academy of Science Symposium).

CONVERSION TABLES

Currency

US $1.00	245 CFA francs or FMG or 4.94 NF or 492 FM
	8.33 UK shillings, 7 Nigerian or East African shillings
	1.02 Ghanaian New Cedis
100 CFA francs	40.51 US¢, 3/4d UK or 2.85 Nigerian or East African shillings

Area

1 hectare	2.471 acres
1 acre	0.4047 hectares
1 sq. km	0.3861 sq. miles
1 sq. mile	2.59 sq. km

Dry Measure

1 liter	61.02 US cu. ins.	0.908 US quart
100 liters	3.53 US cu. ft.	2.84 US bushels
1 US bushel	2150.42 US cu. ins.	35.238 liters
1 Imp. bushel	2219.36 US cu. ins.	0.036 cu. m

Liquid Measure

1 liter	1.057 US quarts	0.22 Imp. gallon
1 Imp. gallon	1.2 US gallons	4.545 liters
1 US gallon	0.833 Imp. gallon	3.785 liters

Weight

1 kilogram	2.2046 lbs	
1 lb	0.4536 kg	
1 US short ton	2000 lbs	0.907 metric ton
1 US long ton	2240 lbs	1.016 metric tons
1 metric ton	2204.6 lbs	1.1 US short tons
		or 0.984 US long tons
1 US short cwt	100 lbs	45.359 kg
1 US long cwt	112 lbs	60.802 kg
1 quintal	100 kg	220.46 lbs

Ratios

1 quintal/ha	89.2 lbs/acre
1 long ton/acre	4.11 metric tons/ha
1 metric ton	892 lbs/acre
100 persons/sq. mile	38.6 persons per sq. km
100 persons/sq. km.	259 persons per sq. mile

GLOSSARY OF ACRONYMS AND ABBREVIATIONS RELATING TO AFRICAN AGRICULTURE

ADB	African Development Bank (Ivory Coast)
ADC	Agricultural Development Council
AID	Agency for International Development (United States) Agence International pour le Développement (Ivory Coast)
ARCCA	Agricultural Research Council of Central Africa
BAD	Banque Africaine de Développement
BDPA	Bureau pour le Développement de la Production Agricole
BIRD	Bureau Internationale pour la Reconstruction et le Développement (Ivory Coast)
BIS	Bureau Interafricain des Sols
BNETD	Bureau National d'Etudes Techniques de Développement (Ivory Coast)
CBD	Coffee Berry Division
CBPP	Contagious Bovine Pleuropneumonia
CCTA	Commission for Technical Cooperation in Africa South of the Sahara Commission de Coopération Technique en Afrique au Sud du Sahara
CDC	Cotton Development Corporation (United Kingdom)
CEA	Commission Economique de l'Afrique des Nations-Unies
CEEMAT	Centre d'Etudes et d'Experimentation du Machinisme Agricole Tropicale
CEK	Centre d'Elevage de Korhogo (Ivory Coast)
CFDT	Compagnie Française pour le Développement des Fibres Textiles
CFRB	Centre de Formation Rurale de Bingerville
CGOT	Compagnie Générale des Oléagineux Tropicaux
CIMMYT	Centro Internacional de Mejoramiento de Maïz y Trigo
CMAOM	Comité du Machinisme Agricole d'Outre-Mer
CNRST	Comité National de la Recherche Scientifique et Technique (Madagascar)
CNZRS	Centre National de Recherches Zootechniques de Sotuba (Mali)
COMACI	Commission et Approvisionnements de la Côte d'Ivoire
COMEX	Comité d'Expérimentation pour le Mécanisation des Cultures (Ivory Coast)
CRA	Centre de Recherches Agronomiques de Bambey (Senegal)
CRAC	Centre de Recherches Agronomiques de N'Kolbisson au Cameroon
CRC	Cotton Research Corporation (United Kingdon)
CRI	Coconut Research Institute (Ceylon)
CRIG	Cocoa Research Institute of Ghana
CRIN	Cocoa Research Institute of Nigeria
CRST/OUA	Commission de la Recherche Scientifique et Technique de l'Organisation de l'Unité Africaine

CSA	Scientific Council for Africa Conseil Scientifique pour l'Afrique
CSNRD	Consortium for the Study of Nigerian Rural Development
CSSV	Cocoa Swollen Shoot Virus
CTAB	Centre Technique d'Agriculture de Bingerville (Ivory Coast)
CTFT	Centre Technique Forestier Tropical
DRPLC	Département des Recherches des Plantations Lever au Congo
EAAFRO	East African Agriculture and Forestry Research Organization
EACSO	East African Common Service Organization
EASIR	East African Institute of Social Research
EATRO	East African Trypanosomiasis Research Organization
EATU	East African Testing Unit
EAVRO	East African Veterinary Research Organization
ECA	Economic Commission for Africa of the United Nations
ECGC	Empire Cotton Growing Corporation
EFSA	Ecole Fédérale Supérieure Agronomique
ENCR	Ecole Nationale des Cadres Ruraux
ENSA	Ecole Nationale Supérieure Agronomique
ENSG	Ecole Nationale Supérieure Agronomique de Grignon (France)
ETSSA	Ecole Technique Secondaire Supérieure d'Agriculture
FAC	Fond d'Aide et de Coopération
FAO	Food and Agriculture Organization of the United Nations Organisation pour l'Alimentation et l'Agriculture (ONU)
FED	Fond Européen de Développement
FEG	Fonds d'Entraide et de Garantie
FIDES	Fonds d'Investissement pour le Développement Economique et Social des Territoires d'Outre-Mer
GAS	Ghana Academy of Sciences
HSIU	Haile Sellassie I University (Ethiopia)
IBAH	Inter-African Bureau of Animal Health (Bangui, CAR)
IBRD	International Bank for Reconstruction and Development
IEAAC	Institut d'Etudes Agronomiques d'Afrique Centrale
IEMVT	Institut d'Elevage et de Médecine Vétérinaire des Pays Tropicaux
IFAC	Institut Français de Recherches Fruitières Outre-Mer
IFCC	Institut Français du Café, du Cacao et Autres Plantes Stimulantes
INADES	Institut Africain pour le Développement Economique et Social

INEAC	Institut National pour l'Etude Agronomique du Congo (Kinshasa)
INRA	Institut National de la Recherche Agronomique
IRAM	Institut de Recherches Agronomiques de Madagascar Institut de Recherches Agronomiques de la Republique Malgache
IRAT	Institut de Recherches Agronomiques Tropicales et Cultures Vivrières
IRCA	Institut de Recherches sur le Caoutchouc en Afrique
IRCT	Institut de Recherches du Coton et des Textiles Exotiques
IRHO	Institut de Recherches pour les Huiles et Oléagineux
IRLCS	International Red Locust Control Service
IRRI	International Rice Research Institute (Philippines)
IRSAC	Institut pour la Recherche Scientifique en Afrique Centrale
ISABU	Institut des Sciences Agronomiques du Burundi
ISAR	Institut des Sciences Agronomiques de Rwanda
ITEPAT	Institut pour la Technologie et l'Industrialisation des Produits Agricoles Tropicaux
ITERG	Institut des Corps Gros (Paris)
IUCN	International Union for the Conservation of Nature
LDC	Less-Developed Country (ies)
MRS	Maize Research Station (Kenya)
MSIRI	Mauritius Sugar Research Institute
MSU	Michigan State University (United States)
NARS	National Agricultural Research Station
NAS	National Academy of Sciences (United States)
NRC	National Research Council
OAU	Organization of African Unity
OCAM	Organisation Commune Africaine et Malgache
OCDE	Organisation de Coopération et de Développement Economique
ODM	Ministry of Oversea Development (London)
OECD	Organization for Economic Cooperation and Development
OICMA	Organisation Internationale contre le Criquet Migrateur Africain
OIE	Office International des Epizooties
ONI	Office National des Irrigations
ORANA	Organisme de Recherche pour l'Alimentation et la Nutrition en Afrique
ORSTOM	Office de la Recherche Scientifique et Technique Outre-Mer
PNUD	Programme des Nations-Unies pour le Développement
PPR	Peste des Petits Ruminants
PVD	Pays en Voie de Développement

REMVPT	Revue de l'Elevage et Médecine Vétérinaire des Pays Tropicaux (Paris)
RTAC	Regional Technical Aids Center
SAG	Station Agricole de Guetalé
SAL	Scott Agricultural Laboratories
SAP	Société Africaine de Prevoyance
SHMD	Société des Huileries Modernes du Dahomey
SNAHDA	Société Nationale des Huileries du Dahomey
SODEFOR	Société pour le Développement et l'Exploitation des Forêts
SODEPALM	Société pour le Développement et l'Exploitation du Palmier à l'Huile
SOGETA	Société Générale des Techniques Agricoles
SOMALAC	Société Malgache d'Aménagement du Lac Alaotra
SOSUMAV	Société Sucrière de la Mahavavy (Madagascar)
SOTROPAL	Société Tropicale des Allumettes
SPROA	Société des Plantations Réunies de l'Ouest Africain
SREA	Station Régionale d'Expérimentation Agricole
SRU	Soils Research Unit
STRC/OAU	Scientific, Technical and Research Commission of the Organization of African Unity
TPI	Tropical Products Institute
TPRI	Tropical Pesticides Research Institute
TRIEA	Tea Research Institute of East Africa
TSGA	Tanzania Sisal Growers Association
UNCC	Union Nigérien pour Crédit et de la Coopération
UNDP	United Nations Development Programme
Unesco	United Nations Educational, Scientific and Cultural Organization
USAID	United States Agency for International Development
WAIFOR	West African Institute for Oil Palm Research
WAITR	West African Institute for Trypanosomiasis Research
WAMRU	West African Maize Research Unit
WASPRU	West African Stored Products Research Unit
WHO	World Health Organization
WMO	World Meteorological Organization

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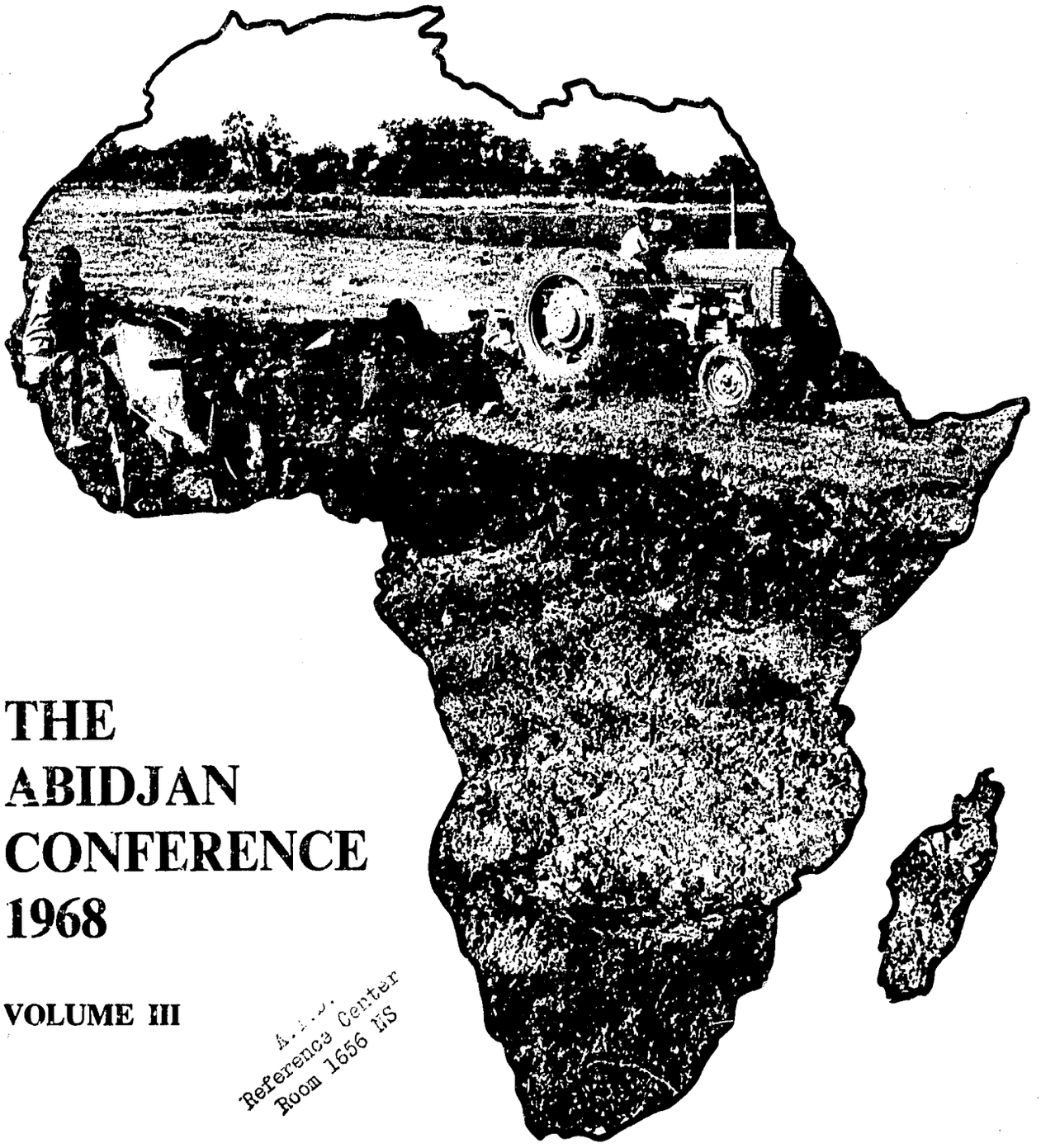
Agricultural Research Priorities for Economic Development in Africa



THE ABIDJAN CONFERENCE 1968

VOLUME III

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CONFERENCE ON AGRICULTURAL RESEARCH PRIORITIES FOR ECONOMIC DEVELOPMENT IN AFRICA

Colloque sur les Priorités de la Recherche Agricole
Dans le Développement Economique de L'Afrique

ABIDJAN, IVORY COAST
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Soil and Water Management:
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ESTABLISHING RESEARCH PRIORITIES FOR LIVESTOCK PRODUCTION IN AFRICA

H. Michels, Lovanium University

SUMMARY

It appears that an analysis of the main problems pertaining to the development of animal breeding in Africa would center around the following:

1. The animal in the tropical and sub-tropical environment;

2. Choice and selection of species and breeds within a species;

3. Production and marketing possibilities

The study of the first point should concern the direct and indirect influences of the various climates found in Africa on the homoiothermic animals, especially ruminants.

The physiological antithesis between tolerance to heat and milk-production ability among bovine breeds originating from temperate zones shows how important basic research is in the area of heat tolerance of mammals and poultry to the climatic conditions prevalent in the various ecological zones of tropical and sub-tropical regions.

Problems relating to the nutrition and health of the animals show particularly how complex and varied are the problems of the rational exploitation of grasslands. Seasonal variations, for example, cause both quantitative and qualitative problems. These problems should get most of our attention in the framework of experimental research on the development of animal production in Africa.

The second point of concern is with finding animals which will give the highest possible production of animal protein per year and per hectare.

This type of research is involved in making comparisons of different species, but it seems that attention should be given first to the best species that have already been domesticated, within the framework of a given ecological region.

The second choice should be of the best breed within a species. This problem is inevitably linked up with the selection and formation of this breed as a function of an environment that will be increasingly improved and controlled by justified economic means.

Before proceeding to any cross-breeding between a local breed and an exotic one, it appears that one must first examine the genotypical variability within a so-called autochtonous race and the possibilities of steering this variability, through adequate selection, towards a genotypical potential corresponding to the phenotypical

performance sought by man.

In discussing the third point we briefly go into the possibilities of beef production in the Congo in order to illustrate the tremendous potential which should exist on an "all-African" level. Problems which occur when one applies the research to reality are multiple and involve both the productivity of the herds and the adequate marketing of the production.

INTRODUCTION

In this paper it is proposed to analyze the main problems relating to the development of livestock breeding in Africa. This analysis will mainly concern the ruminants, which could change millions of hectares of savannah into productive ranches useful to man. However, it will also touch upon the mongastric mammals and poultry in dealing with basic problems relating to homoiothermic animals in tropical regions.

It would appear that the logical sequence of this analysis is in three stages:

1. The animal in the tropical and sub-tropical environment.
2. The choice and the selection of species and breeds within a species.
3. The possibilities for production and marketing.

A. The animal in the tropical or sub-tropical climate

1.a. The Climate

According to Koppen's classification, the main climates found in Africa are the climates A (Af., Am., Aw. , B (Bs., Bw.), and C (Cf., Cw.)

In Central Africa we find climates A and B, the latter being found in mountainous regions. The dry season can vary from zero to six months.

The B climates are characterized by wide daily variations (up to 30° to $40^{o}C$) in the temperature and by temperature extremes to which the animals are exposed during the summer, under a generally hot sun. The relative humidity is generally low and rarely exceeds 60%.

Solar radiation in A, B, and C climates rises easily to 700 $Cal/m^2/$ hour.

Climates A and C are in principal favorable for livestock breeding. Climate B presents special problems because of its lack of rain during the year, which means that forage supplies are continuously or periodically inadequate.

1.b. Direct influence of the tropical and subtropical climate on the animals

One fundamental factor making it possible to produce animals in the tropical regions is the homoiothermic quality of mammals and poultry.[1]

The basic facts of thermodynamics and energetic metabolism of the so-called "homoiothermic" animals explain the necessity of having sufficient temperature difference between the environment and the surface of the organism so that animals can eliminate the heat production inherent in its metabolism, including basal metabolism.

Many workers have shown that as the animal consumes a supplementary amount of food energy in order to produce net energy in the form of milk, meat or foetus, the possibility of giving the environment the surplus calories produced increases. If the temperature between gradient body surface and the environment is too small, another exhange mechanism, sweating, takes place as a necessary consequence to allow for elimentation of the heat produced.

Research workers at the Missouri Agricultural Experiment Station of Columbia University in the U.S. have gone deeply into the heat tolerance of various breeds of cattle in comparing the milk breeds originating in temperate climates such as the Friesians, Jerseys and the Swiss browns, with the "Brahmin" dark breeds of the Zebu type.

The great basic difference from the outset (at a temperature in the neighborhood of 10°C) between cows originating from temperate zones and those from subtropical zones, was the heat production, which reached 150 Cal/m^2/hour for the former (with a milk production varying between 15 and 25 litres of milk per day) and 80 Cal/m^2/hour for the Brahmins, and these only gave a milk production of 3 litres per day or were dry. This difference probably explains why the heat production from Brahmin cows did not start going down until an external temperature of 27° to 32° C was reached (with 65% humidity, 800 meters of convection per hour, no artificial solar radiation in the room) while for cows originating in temperate zones, heat production had a tendency to diminish starting at an external temperature of 21°C. This reduction brought on a corresponding lowering of milk production.[1]

The correspondence between the results obtained by Brody and his collaborators in the artificial conditions of their climatological chambers at 18 to 21°C and those obtained by INEAC under the bioclimatological conditions of Nioka (1,750 meters of altitude, 2° North of the Equator) are startling. The results obtained from Nioka and Keyberg show that it is possible to maintain milk breeds of cattle Friesian at these high altitudes, especially the Jersey

and Swiss browns, at production levels similar to those attained in temperate regions (4,5) Tables 1 and 2.

The problem of thermotolerance of milk cows has been discussed at length to show the physiological antithesis which exists between tolerance to tropical heat and aptitude for particular zootechnical production. A discussion of the problems created by high relative humidity and intense solar radiation at high temperatures would merely underline this situation.

TABLE 1 MILK PRODUCTION

Nioka Station - 1956 - 2^0 North - 1,50 meters altitude

Race: Friesian Grading up

		Production in litres	Fat %	Days of Lactation
Grading up	1/2	2,526	3.26	226
	3/4	2,672	3.56	238
	7/8	2,862	3.54	246
	15/16	2,869	3.28	249
	31/32	2,950	3.25	230

TABLE 2 KEYBERG STATION - 1950-1958

11-12° S. 1250 meters altitude

Race : Friesian Pure breed

Year	Number of Lactation	Milk Production Kgs	Days of Lactation	Fat %
1950-51	49	3,326	300	3.55
1951-52	46	3,694	305	3.68
1952-53	36	3,465	305	3.57
1953-54	32	4,172	305	3.54
1954-55	53	3,939	305	3.60
1955-56	28	3,758	305	3.68
1956-57	29	3,487	305	3.71
1957-58	41	3,867	305	3.69

Here double questions can be posed:

1. In the tropical and sub-tropical zones should one tend toward milk production on a competitive basis with production in temperate regions outside of the so-called "microclimatic zones?

2. If this must be done, through what species and what breeds within a species should this be done?

The problem of the direct influence of the climate is relevant to all species of mammals and poultry which could give high production in the different ecological regions of the tropical zone, and this is true whether we are speaking of the production of meat or milk of ruminants or monogastric animals or of the production of eggs, wool, transportation or traction.

The observations and data collected on heat tolerance are sufficient, it appears, to demonstrate the importance of fundamental research in the field of heat tolerance (thermoneutrality zone) of mammals and poultry in relation to the conditions prevailing in the different ecological zones of the tropical and subtropical regions. This research should be carried on both in the field and in climatic chambers, and should show us particularly the adaptation possibilities of the various species and exotic breeds.

In this context it is important not to forget the importance of the thermal energy of the ration in the heat tolerance of the species. It is thus important to determine at the same time the most adequate rations which give as low a production heat energy as possible and consequently giving better energetic efficiency, better heat tolerance, higher nutritional comsumption and thus a higher production efficiency. This research, moreover, fits perfectly with research on heat tolerance, to which it is directly linked.

1.c. Indirect influence of the climate on the animals

The indirect influence of the climate is especially manifest in the nutrition and maintenance of health of grazing animals.

A problem that immediately faces the livestock producer in savannah zones is that of seasons. During the hot and wet season the vegetation is luxuriant and abundant but may rapidly lignify if not eaten at the optimal vegetative stage. During the dry season, the vegetation is gnnerally greatly reduced.

Under these conditions, what should be the optimum stocking-rate per hectare? How do the animals know how to recuperate after a period of pronounced loss of weight and how do they catch up with animals which have been given supplements during the dry season? In what measure should we and can we improve the vegetation

produced per hectare of pasture and preserve good vegetation during the dry season, in order to avoid this marked period of undernourishment? Should we plan on fodder crops and other supplements (crop by-products, flour concentrates) or should we also look into an irrigation system for certain pastures? How should we use fodder crops, especially for the dry season (pastureland, silos, artificial drying)? How can we improve the irrigation possibilities and thus economize on the large amount of energy expended by the animals in travelling long distances?

As our experimentation goes on, it seems that the most economical solutions to these problems are very complex and depend both on the ecological zones (rainfall, temperature, etc.) and the soil quality which is linked to the ecological conditions, and on the vegetation and the animals available, as well as well as on the economically profitable results to be obtained.

INEAC has already made great efforts in the Congo in the area of pastureland improvement, which has led to increased stocking rates and in reased production in live weight per hectare per year (6, 7, 8, 9, 10, 11).

The experiments undertaken at the livestock Experimental Station of the University on the influence of food levels and mineral supplements have shown that the N'Dama breed, when in good health, has a great recuperative capacity after a period of undernourishment. (12, 13)

It is not possible to say at this time whether a fodder supplement and/or flour concentrates, administered to young animals of the N'Dama breed either during the dry season alone or during all seasons, would show a marked advance of the supplemented over the non-supplemented animal if the latter had an abundant supply of good-quality fodder from the beginning of the wet season.

TABLE 3 Stocking rate and production per hectare per year (INEAC)

	Non-improved savannahs	Improved savannahs
	Wt. of cattle (kg.)	
1. Nioka Station (2° N. 1750 m alt.)		
Rate per hectare	325.00	328.00
Production per hectare	121.00	152.80

TABLE 3 (continued)

	Non-improved savannahs	Improved savannahs
2. Gandajika Station (5° S. 750 m alt.)		
Rate per hectare	343.16	313.95
Production per hectare	34.70	67.37
3. M. Vaazi Station (4° S. 500 m alt.)		
Rate per hectare	?	620.10
Production per hectare	134.00	269.00

An experimental research project undertaken recently by one of our students shows that animals supplemented with brewers grains for eighteen months from the age of ten months on kept their advance to the end, but that this advance diminished rapidly as soon as the low-level animals were allowed to recuperate on a higher level, that is, through supplements. This advance completely disappeared among the heifers that we kept for breeding (13). As the rate per hectare was limited to one animal during the eighteen-month period, we can well ask if the supplemented animals would have kept their lead to the end in the case where the rate would have been lower. A fortiori, we can ask ourselves the same question in the case of what would have happened if we had limited the supplementation to the dry season alone.

In our grassland we have found the sodium level varying slightly around 150 ppm (150 mgs per kg of dry matter), while the needs of growing bovines, according to the NRC norms, is in the neighborhood of 1500 ppm (14). This sodium deficiency seems to be general in Africa, according to the research of Hennaux and Compère (15). Other important deficiencies are phosphorus, discovered by the same authors (16) and by Bisschop (17), and cobalt, discovered by Suter (18).

It is relatively easy to remedy these deficiencies by administering the required elements to the animals, but the problem of adequate administration remains very real. The quantity of the element that must be supplied depends upon physiological needs, the quantity present in fodder resources, and the food level. We have already proved during one experiment already cited that a calcium and phosphorus supplement was indicated during the dry season, but lost all significance during the rainy season and was even harmful to the growth and probably to the development of supplemented animals. priority of bony tissue during a period of undernourishment would explain the observations.

Thus the problems in the area of the rational exploitation of grassland deserve all our attention in the framework of experimental research pertaining to the development of livestock breeding in Africa. Other speakers will analyze these problems more minutely.

The influence of climate on maintenance of health is also very real. The head and humidity of the A and C climate tropical regions are favorable to the development and multiplication of internal and external parasites which continually menace livestock in Africa. These problems will be dealth with in the section which studies the problems relating to the health of animals in Africa.

2. The choice and selection of species and races in each ecological zone.

Having described the animal in its environment it is necessary to find the animal that, under man's direction, will give the highest production of animal protein per hectare per year.

The solution to the problem is determined:

1. by the production man wishes to obtain: milk, meat, etc.
2. by the mastery man has over the animal and vegetable kingdoms that surround him.

2.a Domestic animal species and species to domesticate

It seems to us that in Africa especially, we should not limit ourselves to the species that have been traditionally domesticated and often imported into the regions at times of human migrations. Outside of these species, of which the local varieties are relatively well-adapted, thanks to natural selection, there are many species of ruminants in the forests and savannahs such as the okapi, antelope and buffalo, which man has not really successfully dometicated up to now.

Are some of these species possibly better adapted and better, more easily improved than the domesticated species? Is man capable of domesticating them rapidly and using them for his purposes under exploitation conditions that he will determine himself and which might eventually be less costly than those he has been able to set up until now? Actually, we have few facts on this subject, but we allow ourselves to pose the problem nevertheless. This is important in view of the considerations we were stating above on the neat tolerance of mammals and poultry. If, for example, we could find a sufficiently hardy ruminant species with a capacity for sweating approaching that of man, we would immediately study and test that species for its growing and lactation capacity per chectare of grassland per year in the A and B climatological zones.

Nevertheless, if we are involved the development of research in this domain, we must, while waiting to find better species, turn to the ones that have already been domesticated.

2.b. Choice among the domesticated species.

Much of the research related above and mentioned later shows that the domestic species have generally not produced optimum phenotypical performances as a function of their actual genotype in Africa.

The choice among the various domestic species is a difficult problem to resolve in terms of the speculations to be investigated and the need for perfecting the environment.

For example, it is not clear which species traditionally adapted to the climatological conditions in Africa should be selected from each ecological region to transform the savannahs, as economically as possible, into meat-producing areas. Goats are considered generally too destructive but is this not a sign of good transformation capacity which we should study further and guide towards rational exploitation? Sheep have certain advantages over the bovines: they are easier to manipulate they mature earlier, they often reproduce twice a year twins are numerous. Sheep therefore generally need less costly equipment, their economic return is more rapid, especially since investment can be geared to the period of ascending growth. Nevertheless under our conditions, sheep show a greater susceptibility to disease, especially parasitic diseases and food poisoning.

The domesticated buffaloes of Pakistan, imported into the Congo by INEAC in 1965, show great possibilities as dual-purpose animal. They are docile, they weigh 60 to 70 kilograms as adults, they acclimatize very well to the climate and fodder conditions of the Yangambi center. In 1958, one of them produced around 3000 litres of milk of 7% fat in 270 days (19).

We believe that research aiming at a rational choice of the best species, taking into consideration all the elements of the problem in an ecological region, merits all our attention.

2.c. Choice and selection of breeds within a species

As we have already stated above, it is necessary to produce animals capable of transforming the available fodder resources into as much net energy as possible. Can we attain this goal through selection, basing our efforts on the hereditary variability existing between breeds and within breeds? (20)

The following questions immediately come to mind. Is there sufficient individual genotypical variability within autochthonous breeds to direct that variability toward a genotypical potential corresponding to the phenotypical performances followed by man? Or should we look to exotic breeds to fulfill this goal, either by absorption cross-breeding of the autochthonous races or by cross-breeding followed by mixtures, in order to create new breeds?

Or should we simply radically replace the local breeds, of which some were but recently imported, with other breeds considered more productive?

We have studied a great number of cross-breeding trials conducted throughout the tropical and subtropical regions between local or autochthonous bovine races and exotic races. (1)

In our opinion, these experiments were carried on in an overly empirical manner in most cases; as the desired end-product was success, the assumptions and methods of experimentation were set up accordingly. As a result, the experiments generally terminated in failure, with the exception of the following instances:

1) Absorption cross-breeding (grading-up) in a micro-climate resembling the climate of origin and accompanied by environmental improvement, in order to fulfill the nutritional and hygenic requirements of the new breed. This was the case for the "black-footed cow" at the INEAC station in Nioka.

2) Cross-breeding, followed by mixture of a great number of individual breeds, until the optimum formula was arrived at. The case of Jersey-Zebu on the Island of Jamaica in 1921 and 1952 can be cited as real success-story as can the case of the Santa Gertrudis breed in Texas. In the Congo we can cite the Mateba breed, produced in the micro-environment of the Island of Mateba.

It seems to us that the line to follow for research in the cross-breeding of local races and exotic races is the following:

1) Before proceeding to any cross-breeding, research workers should study the aptitudes of the local breeds (for heat tolerance transformation ability, growth aptitudes, reproduction, lactation, hardiness, resistance, longevity, etc.) and test them in an environment constantly improved and controlled in a economically justifiable manner. The degree to which rational selection based on classical methods can lead us to the desired results should also be investigated.

2) Before proceeding to grading-up of the local breed with an exotic breed, the two breeds must be compared in the local environment and under identical conditions for several generations, which, for the bovine breeds, means for fifteen to twenty years.

3) Before proceeding to cross-breeding and mixtures for creating a new race, experimenters should examine the possibilities of a large number of each race at different levels of breeding; in this way the statistical methods of population genetics may be applied, and the experimenter may deduce, may making a judicious choice from a group with a sufficiently large genotypical potential, the optimum combined genotypes; for, example, the characteristics of indigenous hardiness with exotic productivity.

3. Production and marketing possibilities

By referring to what was said above and to the previous observations made by other authors, especially Curasson (21), we note that the possibilities of milk production are very limited in the tropical and subtropical regions, unless a bovine breed or a ruminant with greater heat tolerance can be found. In this regard, the Zebu and the buffalo cited above may be considered.

Thus, we should mainly consider meat production, both on the level of improvement of existing ranches and on the level of extending raising of ruminants to the millions of hectares of unoccupied savannahs.

In a preceding study, we had the opportunity to study the productivity of cattle, sheep, goats and pigs in the Congo from 1957 through 1959 (22). The results of these studies show that the productivity of technologically advanced ranching (A) is far superior to that of ranching done in a more traditional manner (T) Table 4.

The possibilities for extending ruminant production in Africa seem very great. If we take the example of the Congo, it is merely to illustrate with figures the considerable potential which exists for a large country of Central Africa, and which probably applies to most of Africa, if based on calculations adapted to each country.

The density in the Congo in 1958 was only 0.42 head of cattle per square kilometer as compared with 33 for France and 85 for Belgium. If we could increase our density to 12.7 head per square kilometer, we could increase our holdings to 30,000,000 head.

Leaving aside the equatorial forest, which is about 40% of the total surface of the country, and the land used for cultivation (of which certain products and by-products are usable for livestock), we estimate that it is possible to use 100,000,000 hectares of savannah for meat production. If the savannahs were occupied by 30,000,000 head of cattle, the rate per hectare would be in the neighborhood of one animal to three hectares. If each hectare could produce 30 kilograms of liveweight per year instead of 10 to 15 as at present, meat production would increase to 3 million tons per year, of 100 kilograms per head instead of 50 kilograms, which is the current figure for good production.

By extrapolating the increase in cattle which took place between 1945 and 1958 (514,229 to 1,005,762) we would only reach 30 million head at this rate by the year 2030. It does not seem impossible to us to increase our cattle one-hundred-fold (double it) every five years and therefore reach 30 million head before the year 2000.

This poses great practical problems and difficulties, however, when one goes to put this into practice. The needs for capital are

enormous, the breeders must be sufficiently well-trained and supervised so that they will run their herds accordingly to the three basic stock-breeding rules: selection, nutrition, health. Besides this, transportation possibilities, transformation, conservation, preservation, local consumption and export factors must all be taken into consideration at the same time as new livestock breeding systems are thought up. (24)

TABLE 4 Average live weight in kilograms per slaughtered animal in advanced (A), and tradtional (T) ranches or breeders

	1957		1958		1959	
	A	T	A	T	A	T
Large cattle	349.8	94.3	360.8	86.8	370.9	34.0
Pigs	82.1	47.9	85.1	46.5	85.8	49.1
Sheep	27.9	20.0	30.9	20.5	33.3	20.7
Goats	24.8	20.7	24.8	20.9	26.4	21.4

Productivity of the herds, expressed in kilograms of meat on hoof per herd of animal, total of the year, for advanced and traditional ranches or breeders.

	1957		1958		1959	
	A	T	A	T	A	T
Large cattle	42.7	17.3	44.6	18.5	55.8	21.1
Pigs	66.5	18.4	75.8	20.6	75.6	18.1
Sheep	6.0	2.0	7.0	2.0	8.0	1.4
Goats	16.9	1.8	6.1	2.0	4.0	1.4

CONCLUSION

It seems to us that research priority for livestock production in Africa can be expressed as follows:

1. Comparative ecological research is needed both in the field and in the laboratories on the mammalian and poultry species capable of making an important contribution to animal production in Africa.

Nevertheless, until improved species are found, especially among the ruminants, the best of the species already domesticated should be chosen, and the best possible breed within a species should be developed, taking account of all the elements of the problem within a given ecological region.

2. This research should be conceived in terms of the actual and future possibilities of the environment, which should be more deeply and carefully studied, taking into consideration the economic and social needs.

3. The results of this research can lead to large-scale application, if the problems relating to increasing returns from animal production through adequate marketing are solved, thus guaranteeing the profitability of production.

In our expose we have thus tried to underline the main ideas which should guide our research priorities. These are presented as a basis for discussion.

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THE NEED FOR RESEARCH TO ASSESS THE PRODUCTION POTENTIAL OF AFRICAN LIVESTOCK

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SUMMARY

There is such enormous variation between livestock, the conditions under which they live in Africa and the opportunities for their production, that no one breed of animal or bird will meet all conditions satisfactorily. From nomadic systems to intensive peri-urban units, and intervening husbandry levels, differing productive levels and marketing aspects are required, yet animal production is often considered too prosaic to merit expenditure of funds on research.

Traditional emphasis on survival ability instead of on productivity still exists in extensive regions and only when a relatively safe health situation has been created are nutritional, management and genetic improvements justified. The varying nutritional levels have induced considerable heterogeneity in external characteristics with a wide range in productivity. Attempts to improve populations through artificial insemination must be linked with performance testing.

Properly trained staff is the key to future animal production and research activities. The latter will be associated with superior sire identifications, feed conservation, balanced rationing and measurements of performance for varying management systems. There is no need for emphasis on breed purity but on productivity. Steers from certain dairy breeds can produce valuable beef. Desirable genetic resources should be conserved but new breed formation efforts should be on a sufficiently large scale. Fodder conservational research and the possible distribution of grains to selected stock need investigation.

Herd structures should be examined and altered, water supplies developed and the place of livestock in different vegetative communities should be studied. Land tenure situations need examination alongside studies to settle transhumant populations. Management philosophies must be assessed, tsetse problems resolved and there is a need for increasing animal products to parallel demands from increasing populations.

Expenditure on research should be increased and its ramifications should include housing, the cost/labor situation, investigations into nutritional deficiencies and the means for correcting them. Destocking recommendations often need re-examination so as to be less discriminating and to be more generally applicable.

INTRODUCTION

To avoid misconceptions, let it first be clarified what is understood by the word 'research', in the title of this paper, because research can cover a wide range of meanings. It can refer to investigations in depth into the pure or fundamental nature of things but, because such research cannot be guaranteed to yield results of commercial importance, it is rarely undertaken in developing countries with restricted finances and a shortage of qualified personnel. For such countries, applied research is a more realistic possibility but, again, there must be a clear distinction between the application of basic principles, for the clarification of unresolved situations on the one hand, to studies mounted on the other hand, to determine which of several of such resolved circumstances would be most economic or suitable within a given environment. It is the last two types, and often only the last kind of 'research' that is envisaged in this discussion. Consequently, progress in animal production in developing countries will depend less on fortunate discoveries than on the results derived from a methodical use of a disciplined examination of the causes and their effects.

Turning now to the livestock scene in Africa, the first point to be made is that there is a terrific variation between the sites and intensities of livestock production. There are still the traditional nomadic entities, the transhumant tribal units, the mixed livestock and crop husbandrymen transferring to new sites as their old cultivations become exhausted, the more intensive (often foreign) mixed farmers, the intensive dairy and poultry ventures as well as the many possible intermediate combinations of these different types.

With such a kaleidoscopic range of husbandry systems, there are corresponding variations in disease situations, feeding regimes, management practices and breeding programs. The problems of the nomadic groups are completely dissimilar from those of intensive dairy or poultry units and the investigations required for the latter are quite unrelated to the problems of the former. Similarly the minimum productivity required per animal or bird rises progressively with increasing intensification. Consequently, it is necessary to define more precisely the title of this discussion. Because of the wide range of environmental, feeding and management circumstances, no one breed or type of livestock or bird will meet all conditions satisfactorily. Consequently, the productive potentials needed will vary with the circumstances under which the African stock are kept and with the purpose for which they are maintained.

For example, hard environmental conditions and a shortage of water have dictated a persistence of age-old nomadic systems in several regions, though minor differences inevitably occur between them. Attention is focussing on the need to improve the lot of these extensive units, in which survival ability is a more dominating selection factor than productive potential. In such limiting circumstances, natural selection encourages the less productive animals. In intensive egg-producing or peri-urban dairy unit, selection is for the more economically productive animals and genetic potentials are allowed a free expression because of the satisfactory

health, nutrition and management environments. Between these extremes, varying emphases are placed on the different factors involved and differing productive potentials have been developed. Each set of circumstances, including the marketing aspects, must receive individual attention and there is no single developmental activity which can be universally applied for their amelioration.

Traditional practices often need changing to hasten augmentations in productivities. In developed zones, improvement of animal quality is the challenge whereas, in developing areas, it is the production of animal products which is of paramount importance. Too often in Africa sustained and economical production is jeopardized by the shortage and unreliability of rain. Prolonged droughts force survival at subsistence levels, whilst the communal use of grazing land discourages any animal improvement or the conservation of herbage. There is no balancing of stock numbers against the quantity of grazing available and, ultimately, the vegetative cover becomes degenerated. Unfortunately, animal production is often regarded as too prosaic to merit expenditures on research and development. Consequently, changes in extensive areas occur so insidiously that they may be appreciated only in retrospect. With progressive intensification, changes are copied from more technologically developed countries and sometimes without regard to the different climatic, cultural and economic circumstances which are involved.

The present African deserts and semi-arid areas include some of the world's hottest and driest zones. Surviving cave drawings, dating back to between 10,000-20,000 years ago, illustrate a fauna which no longer exists in these regions, and suggests that a gradual desiccation has succeeded the more temperate climatic conditions which previously must have existed. The variation from the Mediterranean climatic zone to arid steppes, tropical rain-forests and to the temperate conditions near the southern part of the continent suggest a wide range of ecological conditions. As is actually the case, a varied fauna accompanies these climatic changes and different breeds of livestock have evolved to meet these natural circumstances.

Against the background of hard environmental conditions, so frequently accompanied by large annual and irregular, but devastatingly large, livestock losses it was natural for an accumulation of stock numbers, irrespective of quality, to be built up, as the only insurance policy within the grasp of the people. Livestock survival ability was then a more dominating factor than productive ability. This tendency still persists and only where a market provides the necessary incentive are better livestock introduced.

Animal production aims in Africa thus segregate sharply into efforts (a) to stimulate highly productive animals in artificial circumstances and (b) to ameliorate the hardships of stock in extensive zones. Far too frequently the enthusiasm for breed improvement from the former gets carried over into the latter, with the consequent failures that have been widely encountered.

Before considering livestock improvement, the health situation must

be assured, otherwise the animals may be destroyed by disease or, if they survive, may be so susceptivle to local parasitic attacks that they live in a sub-optimal productive state. Only when a relatively safe disease position has been created are improvements justified in nutrition, management and genetics. Just as it is unwise to engage in animal production where disease is uncontrolled, so it is equally unprofitable to save animals from disease so that their numbers become so excessive that ultimately many die from starvation.

Animal production activities must be established to follow and take advantage of disease control achievements but, because past emphases were so focussed on securing this control, many countries lack the necessary numbers of trained animal husbandrymen to take advantage of and to exploit the safer conditions being introduced by veterinarians.

Once disease control has been established, even in relatively small pockets, the primary need is for adequate nutrition. Lack of this will for long remain the basic factor over larger parts of Africa.

Because of exposure to adverse conditions, over a long period of time, many indigenous stock exhibit slow rates of development. Growth, however, may be resumed after periods of subsistence to a later age than is possible with earlier maturing imported breeds. Indigenous stock have developed in harmony with their physiological, heat adaptive functions and the ambient thermal stresses so that they can withstand greater radiant solar energy uptakes than less adapted imported stock.

In response to the varying nutritional levels and the thermal stresses to which they have been exposed, African livestock exhibit considerable heterogenity in external characters. One has only to think of the enormous variation between the small West African Shorthorn or N'Dama and the large Africander cattle to appreciate this. The same big difference in body size exists between the dwarf and savannah goats in a number of countries which again emphasizes the differences which exist in the intrinsic ability to grow. In the same way, appreciable size variations, due to varying nutritional levels are encountered in the same breed as, for instance, in the shorthorned zebu in the Masai and Mbulu districts of Tanzania.

When considering livestock productivity the average values for African countries are low, but this does not preclude the existence of small pockets of high yielding potentials. Often the herd compositions are unbalanced and contain excessive numbers of aged females and adult males. The undulating curves of liveweight indicate the seriousness of seasonal weight losses and the excessive and wasteful use of nutrients to achieve the ultimate slaughter weight. The delayed maturity small average yields, low reproductive rates and weakened resistance to intercurrent diseases, reduce the potential off-take of beef. Birth rates may fall below 40% while losses during early life from disease, malnutrition and predators can reach the same proportions. Statistics are often inaccurate and incomplete yet, to achieve the required increase in animal protein production will necessitate an almost explosive augmentation in livestock numbers and efficiency.

Genetic improvement in a breed is equivalent to the replacement of an existing gene-type population with one superior in some respects. But with larger stock the cost is high, the generation intervals are relatively long and progress is frustrating unless the population size is large. In order to maximize the effect of good sires in the population, artificial insemination (AI) is now used because it is unprofitable to retain sires that have served their purpose, are unproven or have been used in a layout which cannot permit statistically valid information to be gathered. Attempts to improve population structures by the use of AI must be linked with performance recording and the elimination of sub-standard producers. Comparisons between daughters in the same year is a satisfactory and simple evaluation technique for routine bull testing. Selection on heifer lactations should provide as much information as would tests on later lactation yields.

Milk performance varies between individuals under the same conditions due to hereditary differences on which are imposed variations in reactions to environmental factors. The proportional effects from these two causes will vary with traits and between populations. Greater variability is usually encountered in these factors among tropical than temperate cattle. Differences between European and Zebu stock, for most parameters studied, appear to be less of a husbandry than a genetic nature. The proving of sires is an urgent need in African countries.

Basic research is as creative as art but the dominating need, even in developed countries, is for the application of knowledge. In developing countries the need is more often for a person to solve problems. Hence the need is for educational systems which offer the improved technical knowledge that is required to break the vicious complex derived from a combination of ignorance, poverty and a non-critical reliance on traditional practices. The key to development and future research is a properly trained staff, comprising a nucleus of teachers, research workers, extensionists and facilities for training people, from the short-course instructions at the farm level to the post-graduate university standard.

The research needed may be very varied from the detection of superior sires, to the methods for the conservation or balancing of feeds, the use of dung and other fertilizers for increasing farm productivity, the determination of which breeds or crossbreeds are best suited for milk, meat or work production, the assessment of consumer needs and the determination of suitable marketing and holding systems. Further investigations will be needed to determine the best husbandry methods to secure optimal financial returns and to achieve desirable means for apprising livestock producers of ruling price structures and so free them of the present grip of middlemen and butchers.

There is no one breed which is best under all circumstances and the modern caution in grading-up indigenous with exotic breeds reflects this factor. Also too, it is now being increasingly recognized that past preoccupations with breed purity for certain unimportant factors were

unjustified. Stock in developed situations are being selected more for productivity, and their ability to transmit this to their progeny, than for fancy body points. As indicative of the change in outlook that has been brought about by research into animal production, one may contrast the arid zones where people survive as parasites on their livestock, which derive a meager sustenance from the natural herbages, with modern peri-urban intensively managed livestock, which rely entirely on man for all, or for the major portion, of their nutrient intake.

Further, it is axiomatic that research and the acquisition of knowledge take place at a rate which exceeds the speed with which they can be applied. Powerful economic and social factors can sometimes operate against the immediate application of knowledge. This interplay between the acquisition and the application of knowledge determines the overall pattern of development in many countries, but lack of knowledge must be corrected so that it [illegible] allowed to inhibit changes that are necessary economically. In this way, traditional shibboleths must not be allowed to impede the acquisition of newer knowledge and experience. Too frequently it is believed that beef must be derived from traditional beef breeds whereas, with modern purchasing and consumer tastes, perfectly acceptable meat can be derived from surplus steers of certain dairy breeds. Such research trends are altering the emphasis placed on certain established breeds and, throughout the world, there is a steady reduction in the number of economically viable breeds and particularly in the numbers of dual and triple purpose animals.

With such a reduction in breed numbers there is an increasing realization of the value of good genetic make-ups and much research is needed on the conservation of desirable genetic resources in the form of sperm. There has been less work on the induction of multiple ovulation and the transfer of ova but this may be a profitable line for future investigation particularly since it is necessary to increase the numbers of offspring per animal.

Many African breeds are so slow in maturity and so low in productive output that they must be improved. Many small experimental herds are established in a number of countries for studying certain breeds or for improving them by up-grading. Often, deliberate attempts are made to develop new breeds from these cross-bred origins but much of such genetic work in Africa suffers because it has been conceived and is conducted on too small a scale to yield any practical results. Irrespective of the type of research being conducted, sufficient numbers must be included if the findings are to have statistical significance and so be able to contribute to the future economy. In fact, all research into livestock and animal products must be related to certain basic problems, namely: (a) consumer acceptance and demand, (b) efficiency of production, (c) quality of the product, (d) ease of storage and transportation and (e) costs of production, handling and distribution.

Periods of feed shortage will for long hamper livestock improvement in many countries. Research is needed on the means for establishing

economical reserves of fodders and concentrates at strategic points, on the appropriate times for their use, by which types of livestock they will be eaten, and of the effects of such reserves on the productivity of milk, meat, offspring and on the rates of growth and survival from diseases and starvation. Such reserves would logically be ear-marked for certain types of animals in the lean periods and their use should be conditional upon the off-take of a certain percentage of specific classes of livestock, and their sale to the meat trade. Quite apart from the economic importance of the timely marketing of livestock, there is a serious need for investigation into the herd structures, to get a more balanced herd composition and to permit a more effective utilization of the available herbage. Also, if range and pasture improvements are to be undertaken, their management and that of the grazing herds must be improved. For this, considerable applied research will be necessary. So often, reports emphasize the gross overstocking of certain ranges or the inability to utilize others in the dry season because of lack of water. This lack of water certainly restricts the use of grazings but it is sometimes argued that this is a blessing in disguise. The core of this argument being that if water were made available it would mean the overgrazing of much more of Africa. Thus, alongside any programme for pasture improvement and water development must come considerable investigations as to how to preserve the herbage and prevent its exploitation.

In the same way, studies are necessary for evaluating the place of livestock in land usage programs in different vegetative communities. There is a competition between man and his animals for the better land and livestock are traditionally relegated to the grazing of land that is unwanted for the cultivation of food or cash crops. This means that with the ever increasing demand for these crops, the areas available for livestock are dwindling and the latter are confined to resting, weeded and exhausted arable land or are pushed more and more on to less fertile, more remote regions which, in the past, have been regarded as legitimate forest areas. The need for investigation to re-evaluate the needs is urgent in view of the increasing human populations and the rising demands by them for more protein of animal origin.

Tied with this problem is that of the need for study on land ownership and land tenure systems. With so many people lacking a permanent right to land, with traditional systems for dividing the limited land rights, with the many hectares under shifting cultivation or nomadic use, the difficulties are tremendous. In fact, the lack of title to land, restricts herbage improvement and renders useless attempts to improve the quality of livestock in communally managed herds. Where efforts are being made to introduce a settled agriculture, on individual fenced plots and with the livestock maintained within the farm boundaries, considerable research and training is needed, if the flocks and herds are to be adequately managed and fed. It is easy for visiting experts to give opinions on how existing husbandry systems could be improved but these efforts often neglect the psychological factors involved and the difficulties of getting such outside ideas accepted by

the conservative populations. This emphasizes the need for a careful planning of field research, so as to integrate the results of such investigations into systematic and practical husbandry. It also highlights the dilemma created by the multiple ownership of land and livestock, and throws into sharp contrast the conflict between modern needs and the traditional patterns of exploitation.

Management philosophies must be constantly adapting to evolving and sometimes rapidly changing circumstances. Unfortunately, the less developed countries have less similarity in their livestock development objectives than do the more highly developed. In such circumstances, research is needed but, whereas great care and precision may waste time, off-the-cuff decisions can involve greater risks. Again one is forced back to the need for trained personnel who will provide the necessary impetus to allow the animal husbandry to break out from its low level of productivity and establish an equilibrium on a higher plane of output and efficiency. It is unfortunately true that the greatest demand for professionally trained animal productionists comes from the more highly developed regions and that administrative officials in developing countries have only a limited awareness of the need for an increased training of animal husbandry personnel. This lack of graduates reduces research possibilities, its quality and quantity, and the application of knowledge to existing systems.

In one problem, however, Africa cannot draw on experiences in the more developed countries. This refers to the scourge of trypanosmiasis spread by tsetse flies. For the mitigation of this problem, considerable research activities are required. It can be argued that the fly prevents the exploitation and ruin of large areas, but the increasing need for animal foods requires the proper use of all available land. Fly-infested country contains many areas which could be of immense value for livestock and investigations into economical reclamation measures are not only urgently needed but will eventually become essential.

The complexity and urgency of current animal production problems can perhaps be well illustrated by referring to a world situation. An additional 8000 lactating cows would be required to come into lactation every day if the present daily increase in the human population were to be provided with only 1/2 a glass of milk per day. Apart from the problem of finding such animals, their feeding, management and housing could require considerable investigation. This problem affects Africa even though certain populations prefer imported, tinned to fresh milk. There are similar problems regarding eggs and meats so that there is an important need to terminate the negative phase of overstocking and replace it with a balanced, economically productive husbandry. Often the problem is most acute in areas which possess the smallest scientific and economic resources and which have the greatest need for investigational studies. Even in developed countries, expenditure on research and not just on animal research is extremely low (often around 3% of the gross national product) although in some instances, it is slowly rising towards the levels reached by expenditures on health and housing.

This mention of housing reminds one of the need for research into housing for livestock. So often animals and birds are housed under appallingly inefficient conditions, even in intensive peri-urban circumstances, and much needs to be done from the provision of simple shelters to elaborate milking parlors or laying units. With rising labor costs, it is essential that labor charges included in the selling prices of animal products should be minimal, hence the need for further investigations.

There are, in parts of Africa, overt symptoms of deficiencies in minerals, proteins and energy in the diets of livestock. Research is needed not only to eliminate these but to remove the far greater financial losses caused by sub-clinical and therefore less obvious deficiencies.

It is essential that maximum use be made of whatever reliable information can be found. So often the available data must be regarded with suspicion because, as with simple stock censuses, figures may be understated with a view to evading tax collection or avoiding biased destocking orders. Destocking is often badly needed but, in the absence of conclusive evidence to the contrary, it should apply equally to all livestock and not be enforced for a single species such as the goat. One is aware of the vociferous discrimination against the latter animal by foresters but one rarely hears the good arguments for keeping this animal tethered. Here again, investigations are needed. Even where elimination of goats is recommended, no or inadequate, steps are taken to avoid concomitant increases in sheep and cattle numbers so that the overstocking problem is unaffected.

This paper has ranged over a number of animal production problems but all are relevant to the needs for research into the productive potentials of African livestock under varying climatic, nutritional and management stresses. Size and productivity vary as much as the breeds and conditions under which they are maintained, so that there can be no single, simple, research need but instead an interweaving chain, dealing as much with the external factors as with the animals themselves. But, as was said by Churchill "....the past must be studied if the future is to be successfully encountered".

PRIORITIES IN SCIENTIFIC RESEARCH APPLIED TO ANIMAL PRODUCTION AND VETERINARY MEDICINE IN THE TROPICS

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SUMMARY

The geographic distribution and support of animal species in the tropics depend largely on climatic factors, some of which handicap the development of livestock production.

In the choice of research options, only an analysis of the objectives of development plans adopted by the governments and continual communication with the planning authorities can provide a satisfactory basis; those which the author mentions are only general indications, the purpose of which is to make available to those responsible for selection of the objectives all the information which they require to make their decision and subsequently evaluate the results.

The improvement of animal production will be found through improving the environmental conditions; health protection, nutrition, water-supply, management and by upgrading the genotype through selection crossing or importation of improved foreign breeds. Environmental conditions must be such that the animals can develop phenotypes representing all their genotypic potential.

INTRODUCTION

Although large herds of domestic animals live in countries south of the Sahara and in Madagascar, these two areas are among those considered unfavourable for animal production because of several factors that can be grouped under three headings: climate, disease, and human factors.

Climate affects animals directly, high temperatures and atmospheric humidity being unfavourable to physiological equilibrium, or indirectly by profoundly altering the quality of forage and the water supply during the course of the year, abundance of both forage and water during the rainy season follows famine and drought of the dry season when the animals have difficulty in meeting their minimum requirements.

Diseases, the list of which included almost all those of the Temperate Zone, plus other typically tropical diseases, constitute an almost unsurmountable obstacle to livestock production.

Certain traditions in human society stand in the way of the adoption of scientific methods of livestock improvement and marketing.

The features of animal production and its geographic distribution in Africa which are conditioned by climate can be described briefly.

In the Sahelian and Sudanian Zones, transhumance is practised, the marketable products of which supply cities or areas where animal resources are in short supply.

In the Guinean Zone, sedentary livestock raising of low productivity does not supply enough for the population living there.

Improvement of animal production can be effected either by altering the physical, biological or social environment or the makeup of the animals themselves. Chronologically the measures taken to develop animal production have been:

a) bringing contagious diseases under control;
b) providing water supply;
c) genetic improvement;
d) improvement of marketing facilities; slaughterhouses; refrigeration plant, curing of hides and skins, canning;
e) improvement of pastures and dissemination of knowledge about forage crops.

At the same time training of professional men and skilled technicians, veterinarians, health and production assistants, has been pursued continuously.

Much criticism could be voiced on the subject of the wisdom of the above choice. Although some consider that an entirely different order of priority should have been followed, the results are there: epizooties have practically been wiped out, herds have grown tremendously in number, the availability of commercial products has rendered possible the establishment of the meat-packing houses; countries which a few decades ago were importers of meat and animal products are now planning to export their products.

With their own budgets and bilateral and multilateral aid, countries have been enabled to make investments under six headings: research, education and training, animal health protection, rural water supply, improvement of marketing channels, and upgrading of stock.

Most investments have been conceived of on an ecological basis and have been put into practice in regions with Sahelian and Sudanian climate where stock-raising was already customary; in the Guinean zone where animal husbandry had to be introduced, investment has been smaller.

Francophone countries in the inter-tropical zone have long considered their livestock a source of wealth, not merely potential but actual, and have exploited it accordingly. Governments give stock-raising a leading place in their development plans. Consequently a discussion of research priorities in the field of animal production boils down to discerning trends in such plans and defining the sectors where there are gaps in knowledge on certain points so that the policy makers who are obliged to take decisions may, with full knowledge of the facts, realize what options they have open to them.

In the Francophone countries of tropical Africa research in animal production and veterinary medicine is considered from regional and ecological standpoints, the existing infrastructure allowing for implementation of programs of general and even worldwide interest and as well as projects of concern to only one or two countries. International solidarity actually works in this area.

What are research priorities at the present time?

Outside the context of national development plans, it is difficult to establish them for although there are innumerable problems the study of which might arouse the enthusiasm of research workers, the financial means of these countries themselves and external aid are limited. Research is therefore, necessarily confined to attempts to solve concrete problems without, because of this necessity, being relegated to mere confirmation of the findings obtained in other countries in elementary technology.

In approaching the problem of development of research in the field of animal production, one is confronted with the matter of establishment of priorities; the dilemma faced is: animal health or genetic improvement?

The lines of this academic problem are further drawn by the dogmatic positions taken regarding education and training.

However no such choice is feasible; both aspects must be dealt with equally, it being understood that genetically improved stock cannot be raised on a wide scale if it faces the hazard of being decimated or wiped out by the ravages of diseases.

Hence the absolute necessity of a very accurate knowledge of tropical pathology.

Laboratories in the intra-tropical Francophone zone have identified these diseases and devised medical prophylactic techniques; to show how much progress has been made, it suffices to recall that in 1940 it was necessary to kill a calf to obtain only 200 doses of rinderpest vaccine, whereas nowadays, using a kidney taken from a fetus at the slaughterhouse, it is possible to produce 200,000 doses.

Present-day research is attempting to work out conditioning methods for the keeping of vaccines at normal temperatures for a sufficiently long period of time to make their use possible in the bush.

Research on other virus diseases covers diagnosis and the development of polyvalent vaccines - a single dose of which protects livestock against several diseases.

Although there are several vaccines against pleuropneumonia, there still has to be found a single sure cure; in fact, programs on which there is international co-operation are underway in all research laboratories of countries where this disease still rages (Australia,Ethiopia, Senegal, Chad, etc.); the last three countries actually have an integrated program.

Control of bacterial disease no longer raises special problems, research being concerned merely with improvement of details of vaccine manufacturing.

However research on Streptothricosis which causes considerbble losses of hides and skins, and which seems to affect crossbred animals (zebu X races of the Temperate Zone or zebu X brahman) more severly than pure breeds, is being pursued in the hope of discovery of effective treatment or prophylactic techniques.

Whereas in the field of parasitology and entomology inventorying is a permanent task, research on new control methods is necessarily based on ecological and applied biological studies.

Of the utmost interest is the complex field of the connection between the tsetse fly and trypanosome diseases, as also anything having to do with the phenomenon of tolerance of trypanosomes. Development of livestock production in areas hitherto declared unsuitable because of trypanosomiasis indicates that the results have been far from neglibible but they are not yet satisfactyry.

Chemical and biological control of diseases transmitted by vectors (ticks and insects) has become a burning issue with the recent discoveries on the arbovirus.

Thus the field of research on factors of biological aggression is vast. It is comforting to note that research findings are now being applied. Since 1967 the animal production and industry services in Francophone countries of tropical Africa used 41 million doses of vaccines produced in the laboratories of Dakar, Farcha-Fort Lamy and Tananarive.

Once livestock is protected against disease, it becomes pratical to try to improve output.

At this point a factor becomes involved that is neglected in the field of pathology - time. Whereas stock-raisers are able within a few months to reach their own judgment on the effectiveness of a vaccination technique, in the field of animal breeding it takes generations to see results so that the time factor is of quite different significance. Furthermore the application of advanced animal husbandry requires treatment the value of which stock-raisers do not always understand.

Moreover, the adoption of new techniques raises psychological problems among stock-men, whence the necessity, in preliminary work of the fullest comprehension of the psychological, sociological and economic motivations of those who will be expected to apply the techniques.

For research in animal husbandry there are two alternatives:

1) preliminary improvement of the environment and particularly care and feeding, and

2) upgrading of livestock by selective breeding or cross-breeding with improved races or by importing of foreign races to replace native breeds.

The first alternative can produce results most rapidly, because unfortunately animals in extensive stock-raising suffer from drought during the dry season and often lose condition. Among the highest priorities, we would list means for creating, close to major marketing or consumption centers, intensive feed lots where irrigated forage crops combined with by-products of food and industrial crops would be utilized to bring the animals up to slaughter weight.

To those feed lots would be brought livestock raised by extensive methods combined with transhumance.

Technical research has already produced results particularly in the field of forage crops.

We do not consider ranching among the top priorities because, at least in West Africa, it would be advisable to first have information on the results of recently established ranches and feed lots or those that are now being set up.

Ranches and intensive feed lots can be established in a country without there being any need for inducing stock-men in the area to improve their techniques. Hitherto whereas the reason for using animals for draft power and manuring and technology of mixed farming has been studied, there is still much to be done to convince farmers to introduce forage crops into their rotations and possibly to find species which, once they are grown, raise no problems in rotation schemes.

As regards the second alternative, namely genetic improvement it must be recognized that breeds or races of animals in the tropics today get along on poor grazing and rather successfully withstand certain aggressive factors - heat, atmospheric humidity, diseases, blood parasites (piroplasmosis among the zebu and trypanosomiasis among certain cattle).

Selective breeding for upgrading of native breeds is a slow process but it conserves the available genetic potential adapted to the tropics, the fruit of natural selection that has taken centuries to produce; study underway on maximum potentialities of these genotypes should be intensified.

Results obtained in Madagascar, the Ivory Coast and Senegal prove that zebus and native taurines, if well fed, give excellent financial returns.

Cross-breeding with highly specialized races should not be excluded but it is worthy of note, that, if one analyzes the reasons for failure of cross-breeding trials, one finds every time that there are underlying nutritional or pathological factors.

It therefore seems to us that, before any operation of large-scale cross-breeding research is undertaken, one must clearly define the requirements of imported breeds and precautions that have to be taken in raising the young; a whole herd of pure-bred animals male and female, needs to be introduced to keep a pure lineage going.

Among priorities we would urge are climato-physiological studies on animals of improved milk and beef breeds, kept in the open and not in air-conditioned conditions in order to judge their ability to adjust to tropical conditions, once their feed requirements are satisfied naturally. Such trials with pure-breeds might be made on bovines, sheep, goats, swine and poultry, and would be useful in establishing standards for their care and housing.

Such scientific research should be supplemented by economic feasibility (cost/benefit) studies. No extension work to disseminate knowledge of a new technique should be undertaken unless it increases not only the output but also the income of the stock-raiser or the overall income of the production-and-processing chain of which it one link. In addition to these economic studies, technological work on processing and preservation of meats and animal by-products should be undertaken.

Finally choice of priorities in research in the field of animal production and veterinary medicine will be based on the following steps:

1. Making available to the responsible authorities all the information necessary to enable them to make choices among options for development programs.

2. Once such decisions have been made, programs should be framed in the light of development, obstacles to be surmounted.

3. Fullest utilization of findings obtained in comparable ecological conditions.

4. Of two possible types of research, that one should be selected which offers the greatest prospect of yielding results that can be disseminated rapidly and economically.

ANIMAL PRODUCTION IN AFRICA MEETING NUTRIENT REQUIREMENTS OF RANGE CATTLE FOR OPTIMUM YIELD

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SUMMARY

The nutrient requirements of range cattle for optimum yield in either the humid or dry tropical climatic zone of Africa are not known with any reasonable degree of certainty. Although animals in these areas vary considerably in type, they have one thing in common, namely, that the levels of their productive efficiency for both meat and milk are appreciably lower than those of temperate cattle under well managed range conditions.

The first major task confronting the researcher on improved nutrition of cattle relates, therefore, to the assessment of the nutrient requirements in terms of energy, protein, minerals and vitamins for maintenance and productivity. This is necessary since the accumulated information from research activities in temperate climate does not necessarily apply to tropical conditions of Africa. In making these assessments, the techniques and instrumentations in use in temperate areas are probably indispensable to the research workers in Tropical Africa.

Of the many techniques proposed or adopted which are described in the paper, the following require priority attention in order to estimate nutrient in [illegible] in relation to nutrient requirements of range cattle for optimum yield:

(1) Determination of chemical composition of pasture.
(2) Evaluation of herbage quality from:
  (a) herbage digestibility
  (b) nutritive value, and
  (c) availability indices.
(3) *In vivo* estimation of digestibility of consumed pasture and the evaluation of Total Digestible Nutrient as a measure of digested energy and digested nutrient.
(4) Estimation of metabolizable energy system.

In the case of range cattle, it is necessary that the quality of grazed herbage consumed be known in order to relate this to the requirements of the animal for maintenance and adequate growth. For this purpose, the grazed pasture is assessed by measuring the faeces voided, through dozing the animals with known weights of chromium sesquioxide impregnated craft papers as the indigestible external tracer. The digestibility of the herbage consumed in the field by the grazing animal is estimated from

regression equation based on the data derived from indoor *in vivo* digestion trials. Using this method, it is shown that the quality of pasture mixtures developed under experimental condtion at the University of Ibadan is capable of meeting the nutrient requirements of grazing cattle for desirable optimum growth.

INTRODUCTION

No one knows, with any reasonable degree of precision, the nutrient requirements of cattle for optimum yield in either the humid or the dry tropical climatic zones of Africa. It is, however, well known that under these conditions, the level and efficiency of production of the indigenous cattle (*Bos indicus*) for both meat and milk are appreciably lower than those of temperate cattle (*Bos taurus*). Under well-managed range conditions, for example, White Fulani Zebu and N'Dama breeds of cattle in South West Nigeria, can now attain slaughter weight of between 272 and 454 kg (600 and 1000 lbs) at between 2.5 and 5 years of age (unpublished data). These are considerable improvements on the performance of nomadic and other cattle, grazing natural and improved savannah herbage, which do not reach these weights until they attain the ages of between four and seven years (Oyenuga, 1966). Less marked and consistent improvements have so far been made in the case of milk cows, the average yield of which tends to range between 250 and 500 gallons per lactation of 305 days; production of up to 700 gallons being rather rare achievements.

Under these circumstances, not only are desireable and optimum yields in terms of flesh and milk still a goal far out of reach, the nutrient requirements for optimum yields and their supply from pasture still form major areas of basic research, demanding considerable skill, energy and financial resources to tackle in tropical Africa.

ASSESSMENT OF NUTRIENT REQUIREMENTS FOR OPTIMUM YIELDS

The first major task is to assess the nutrient requirements in terms of energy, protein, minerals and vitamins for growth, maturation, fattening and milk of the indigenous breeds of cattle and of the exotic ones and their crosses under local climatic and management conditions. It will be necessary, simultaneously, to estimate the nutrient quality of the range pasture on which cattle subsist to meet these requirements. These are stupendous tasks. Information accumulated from decades of research in temperate climates cannot necessarily be applied to tropical conditions for many reasons, important among which is the basic fact that the matabolic rates and needs of tropical African cattle and of the acclimatized exotic ones are not unlikely to be different from those inhabiting areas of cold climate (Oyenuga, 1958; Kehar, 1954). The many other reasons accounting for the inapplicability to tropical cattle of research results conducted on nutrient requirements of temperate ones have already been summarized and classified under "direct" and "indirect" climatic effects. The subject has been fairly well reviewed (Payne, 1966; Williamson and

Payne, 1959; Oyenuga, 1958), and it need not be further belabored here. It is, however, helpful to know that the technique and instrumentations in use in temperate areas can readily be adapted to similar investigations on estimating the nutrient requirements and supply of tropical cattle. In this connection, one of the following two alternatives appears to offer itself to the dedicated tropical African researcher for consideration. Either:

(a) Determine, under the particular prevailing conditions, the metabolic rate of different types of indigenous cattle or of the acclimatized exotic ones or of the offsprings from their crosses in relation to temperate ones for weights, age groups, production objective and obtain therefrom regression equations or correction factors which could be applied to estimated requirements already obtained for temperate breeds in similar state of production. Or:
(b) Estimate afresh, using accepted techniques, the requirements of these animals for the different production purposes under the varying tropical climatic conditions.

Whichever method is adopted, the use of basic equipments sometimes requiring considerable cost, skill, technique and efforts, for example, respiration calorimeter, to estimate energy balances, would be involved.

The many techniques, proposed or adopted, for estimating nutrient requirements and the nutritive value of pasture in advanced countries and which are either applicable or appear applicable to the solution of similar problems in the tropics can be summarized as follows:

(a) The determination of the chemical composition of pasture and the application of regression equations to predict digestibility and availability. (Schneider and Lucas, 1950; Schneider, Lucas, Pavlech and Cipolloni, 1951; Nordfelt, 1954; Kivimae, 1950; Claucy & Wilson, 1966 and Dijkstra, 1966); and the estimation of digestibility of species from their chemical composition (Kivimae 1960).
(b) The evaluation of herbage quality:
   i. From herbage digestibility (Irvins, 1960)
   ii. By the "Nutritive Value Index" (Crampton, 1960; Donefer, Crampton & Lloyd, 1966)
   iii. By the use of "Availability Index" from the chemical composition (Van Soest and Marcus, 1963; Van Soest, Wine & Moore, 1966)
(c) The estimation of the digestibility of consumed pasture and the evaluation of the Total Digestible Nutrients as a measure of the digested energy and digested nutrients.
(d) The estimation of the net energy system involving either the determination of the Starch Equivalent values of the pasture or of the balance experiments of livestock.

(e) The metabolizable energy system.
(f) The use of the Comparative Slaughter method (Lawes & Gilbert; Davidson et al, 1964; Mitchell et al, 1928; Milford & Manson, 1965; Morris & Moore, 1963).
(g) The use of the factorial method for estimating the minimum requirements of cattle for protein and for mineral elements.

The technique(s) adopted and the degree of priorities attached to them would depend on the financial and personnel resources and on the facilities available at any particular time and place and the degree of importance and priority attached to animal improvement in the particular area. In many African countries, particularly on the West Coast, the research priority needs would be on (a), (b), (c), and (e) above.

(a) Chemical composition as a measure of nutritive value of herbage

Knowledge of the chemical constituents of forage and pastures is basic to measuring nutrient content of range pasture and the nature of cattle feed, since both in vivo and in vitro digestibilities involve knowledge of chemical constituents of the herbage fed and nutrients produced. Facilities and skill for chemical analyses are therefore prerequisites to other quantitative means of assessing potentialities and quality of nutrients and animal needs for them. It is for this reason and for the impracticability of measuring in vivo digestibility of all classes of range pasture at all times and places of feeding that many attempts have been made to evaluate, by regression equations, the digestibility and quality of nutrients from chemical composition.

Many laboratories in tropical Africa are now fairly well equipped for proximate chemical analyses of pasture based largely on the Weende Method, from which ideas of the amounts of protein, ether extracts, crude fibre, soluble carbohydrates, total and silica-free ash and some of the major minerals - Ca, P, K, Mg, Na and Cl - have been obtained. Published information is accumulating rapidly in this area (Anderson, 1963; Ahlgren, 1959; Oyenuga, 1957, 1958; 1959 a&b; 1960 a&b; 1966; Oyenuga & Hill, 1966; Oyenuga & Olubajo, 1966; Okorie, Hill & McIlroy, 1965; Adegbola, 1966; Ademosu & Baumgardt, 1967; Lansbury, 1960, Whyte, 1962; Payne & Hutchinson, 1963; Bredon & Horrell, 1961; 1962; Miller and Rains, 1963; Miller, Rains & Thorpe, 1964; Nusangi, 1965 a&b). French (1957), has reviewed the earlier work on the chemical composition of tropical grasses. Many factors, including species, soil fertility, manurial treatment, climate, weather conditions, water relations, the stage and age of growth at cutting or grazing tend to influence forage composition and the nutrients potentially available to animals. It is well-known that tropical grasses tend to be high in crude fibre and low in proteins and minerals. Information obtained earlier tend to show very low amounts of protein in tropical pastures due probably to the mature stages of cutting samples of pasture grass. Due to high heat intensity, tropical grasses, when grown in well-watered environments or during the wet season in arid zones, grow fast, becoming rapidly mature, fibrous

and lignified, resulting in material of reduced digestibility and nutritive value. Table I contains a summary of 190 analyses of samples of pasture grass grown in Ibadan and comprising Giant Star Grass (Cynodon plectostachyum), Pangola grass (Digitaria decumbens), Centrosema pubescens and stylosanthes gracilis under range management. It will be noted that the average crude protein content is of the order of 12 percent while the crude fibre is about 34 percent. This content of protein is lower than in temperate grasses. Application of fertilizers have resulted in raising the level considerably. (Ahlgren, 1959; Oyenuga & Hill, 1966).

The validity of the crude fibre and the nitrogen-free extracts components of pasture, as guides for assessing its carbohydrate values have been questioned by many investigators. The Weende scheme is based on the assumption that the crude fibre is the indigestible and the NFE the digestible fractions of the feed. It is now fairly well established that this is not necessarily so. The crude fibre could be as digestible as or even more digestible than the NFE fractions and this would seem to apply in both the tropical and temperate pastures. (Lander et al, 1924; 1927; 1928; 1929 a&b; 1930; Warth, 1926; Warth et al, 1930; Brunnich et al, 1921; Crampton & Maynard, 1938; Nordfeldt, 1954; Ely et al, 1953; Richards & Reid, 1953; Van Soest, 1964; Kivimae, 1960; 1966). Knowledge of the relative digestibility and value of these two fractions in tropical forage is needed since crude fibre components tend to rise rapidly in tropical grasses and, sometimes, assume the same proportion as the NFE and the ability of indigenous cattle to digest crude fibre may be high relative to that of temperate cattle, a subject on which clear information is called for. A solution in this direction would contribute to the usefulness and reliability of chemical constituents of pasture now being produced in many parts of West Africa.

(b) Herbage quality

While knowledge of the chemical composition of herbage is useful, it is by no means an entirely reliable guide for estimating the supply of nutrients from pasture for ruminant productivity, since a substantial portion of its indigestible constituents, voided in the faeces, are unavailable for absorption. Part of its energy is lost in the rumen and gut as heat of combustion of fermentation gases, while portions of the absorbed nutrients are non-metabolizable and are therefore lost in the urine. The portion of the food digested, though not totally utilizable, is an indication of availability and is assessed by measuring the degree of digestibility. Facilities for digestion trials, although increasing in East, Central and West Africa, continue to be limiting in relation to needed information, in view of shortage of technical personnel, cost and low economic position of the countries concerned. There is urgent need to expand facilities in this area, as a realistic and valid method of evaluating pasture nutrients for meeting animal needs.

Several workers have proposed various methods of measuring herbage digestibility and quality, without resort to in vivo digestion trials, which would facilitate the calculation of digestible nutrients of pasture from its chemical composition. Since Jarl (1938) showed the

Table 1

Summary of the Chemical Composition of the mean of the block Replications of grazed pasture consisting of Cynodon plectostachyum Pilger and Centrosema pubescens Benth during the wet and dry seasons. May 1963 and June 1965.

(% Dry Matter)

	Dry Matter	Organic Matter	Crude Protein	Ether Extract	Crude Fibre	N-free Extract	Silica-fr ash.
22 May 63 - 30 Nov. 63 (Mean of 53 analyses)	92.2	84.5	11.3	1.2	37.0	35.5	4.9
1 Dec.63 - 28 Feb. 64 (Mean of 29 analyses)	93.0	86.4	9.8	1.2	35.7	39.6	4.5
1 March 64 - 21 May 64 (Mean of 27 analyses)	92.4	84.9	12.2	1.1	34.3	37.5	5.2
1 June 64 - 30 Nov. 64 (Mean of 33 analyses)	91.5	81.8	12.1	0.8	32.4	36.4	5.7
1 Dec. 64 - 28 Feb. 65 (Mean of 21 analyses)	89.8	82.9	9.4	1.1	32.0	40.5	4.2
1 March 65 - 19 May 65 (Mean of 27 analyses)	92.5	84.6	12.3	1.0	31.9	39.4	5.3
Overall mean of 190 analyses	91.9	84.2	11.2	1.1	33.9	38.1	5.0
Mean for rainy season growth	92.2	83.9	12.0	1.0	33.9	37.2	5.0
Mean for dry season growth	91.4	84.6	9.6	1.1	33.8	40.0	4.2

existence of a high negative correlation between the content of crude fibre and digestibility of forage, several workers, using regression equations have predicted, for both Northern Europe and North American pastures, the digestible organic matter or digestible energy from the crude fibre, lignin, crude protein, nitrogen and methoxyl group content of the pasture. (Mitchell, 1942; Lancaster, 1943; Duckworth, 1946; Hallsworth, 1949; Phillips and Loughlin, 1949; Forbes & Gerricus, 1950 a & B; Schneider & Lucas, 1950; Schneider et al, 1950; 1951; Richardson & Reid, 1953; Nordfeldt, 1954; Kivimae, 1959; 1960; Sosulski & Patterson, 1961; Minson & Kemp, 1961; Van Soest & Marcus 1963; Blaxter, 1964; Armstrong, Blaxter & Waite, 1964). The fact that the crude fibre contents of tropical grasses tend to be higher and the crude protein lower than those of temperate pastures at comparative similar periods of growth make it unrealistic to apply with any degree of dependability to tropical pastures, the regression coefficents so worked out for either Northern Europe or North America. (French, 1961; Butterworth, 1963). The regression coefficient for tropical pastures worked out by Duckworth (1946) showing the possible relationship between crude fibre and digestible organic matter, was significantly different from those for the temperate countries and this provides additional evidence in support of the fact that differences exist in the chemical compostion of tropical and temperate grasses. It would be a useful contribution if reliable regression equations could be worked out which would readily be applicable to tropical pastures. Inherent in such calculations, however, is the conduction of a large number of in vivo digestion experiments with cattle or with sheep.

Other techniques of evaluation have similarly been proposed. These include the "Nutritive value Index" (Crampton 1960), the use of the "Availability Index" (Van Soest & Marcus, 1963; Van Soest, 1964), the use of the "In Vitro" digestion technique (Walker 1959; Reid et al.,1959; Donefer, Crampton & Lloyd, 1959; 1966; Tilley et al, 1966 Ademosu & Baumgardt, 1967). Walker (1959),incubated dried herbages with rumen contents and obtained in vitro dry matter digestibility values which were said to be in agreement with their in vivo values for sheep. Reid et al, 1959, showed that the relationship between the dry matter in vivo digestibility (Y) and of the in vitro digestibility (X) for herbages can be expressed by the regression equation:

Y 20.5 0.778X (R 0.98*^).

Several workers have since modified this procedure (Tilley et al., 1969; 1963; Van Soest, 1966; Donefer, Crampton & Lloyd, 1966). In order to take account of the in vivo digestion, particularly of protein, below the rumen in the digestive tract, usually unaccounted for, Tilley et al., (1960), included the use of a secondary stage in vitro digestion with the proteolytic enzyme, pepsin, resulting in still greater accuracy than that obtained by Walker (1959); Van Soest (1966) further modified this latter technique by accounting for the undigested herbage cell-wall constitutents, by assuming that the faecal, non-cell wall constitutents represent the combined bacterial and endogenous losses from the animal. Expression of these losses as a percentage of animal intake and the addition of this value to apparent digestibility was claimed to yield true digestibility. If the difficulty of providing fistulated animals can be readily overcome in some of the

laboratory centres in tropical Africa, the tested application of *in vitro* technique, would speed up accumulation of information on herbage digestibility by ruminant animals in tropical Africa.

(c) In Vivo Digestion & T.D.N.

In vivo digestion technique, though laborious, still offers the most direct and reliable method, not only of evaluating digested nutrients in consumed pasture, but also of measuring pasture palatability, suitability and the animal requirements for dry matter consumption.

Apart from the extensive trials conducted in Tanganyika (French, 1957) and a few others in other parts of East Africa, some of the information now available on herbage digestibility in tropical Africa, particularly in English speaking tropical West Africa, accumulated only within the past ten years and data in this field are still very limited. Most of the digestion trials conducted with either sheep or cattle were carried out on individual forage species (Lansbury, 1958; 1960; Miller & Rains, 1963; Miller, Rains & Thorpe, 1963; Bredon & Horrell, 1961; 1962; Mucangi, 1965; Ademosu & Braumgardt, 1967). Some information have emerged from the extensive study of the nutritive value of grasses/legume pastures, started at Ibadan in 1959 and still in progress, some data from which are summarized in Table 2 on the digestibility of range pasture under conditions of humid tropics of Ibadan. (Okorie, Hill & McIlroy, 1965; Oyenuga & Olubajo, 1966; Oyenuga, 1966). In general, the apparent digestibility of crude fibre by White Fulani Zebu cattle was consistently as high or higher than that of the NFE, irrespective of the pastures examined (Oyenuga, 1966). Results of digestion trials with the local sheep were similar (Okorie, Hill & McIlroy, 1965). This confirms for West Africa, observations already made for Tanganyika (French, 1957). In all the pastures considered, crude protein digestibility was high in contrast to previously reported results.

Results of digestion trials enable the estimation of total digestible nutrients of a feed with reasonable degree of dependability. When this is assessed on the voluntary consumed pasture by grazing stock, using the faecal-index technique for measuring herbage intake and productivity, the nutrient requirements by the grazing cattle, for a given level of animal yield can be estimated. Table 3 summarizes the information obtained in this way at Ibadan. (Oyenuga, 1966; Oyenuga & Olubajo, 1966).

ESTIMATION OF NUTRIENT INTAKE BY GRAZING ANIMALS

The data contained in Table 3 were obtained from estimations of pastures consumed by grazing animals. Since animals graze selectively, they probably eat the more digestible portions of the sward through selective grazing. Pasture intake by grazing animals is measured by the faecal index method (Raymond *et al*, 1954) and the weight of faeces

$$\text{Herbage intake (I)} = \text{Weight of faeces voided (F)} \times \frac{100}{100 - \%\ \text{digestibility of herbage eaten (D)}}$$

TABLE 2

Summary of Coefficient of apparent digestibility of grass/legume pasture given in between 1960 and 1967

Pasture Mixture		Dry Matter	Organic Matter	Crude Protein	N.F.E.	Crude Fibre	Ether Extract	Source
Early rainy season May 15-30, 1961	B	75.5	76.3	83.2	73.9	76.4	53.6	Okorie, Hill & McIl Roy(1965)
		72.7	74.1	80.4	72.6	74.3	50.0	
	C	74.8	75.7	82.8	73.7	74.3	52.7	
	D							
Late rainy season Oct. 17 - Nov.1,1961	B	68.1	69.3	79.2	62.8	73.7	26.5	Conducted with Dwarf sheep
	C	68.4	69.3	77.0	63.2	74.8	36.1	
	D	68.7	69.4	77.0	62.2	75.4	32.8	
Mid rainy season June, July, August 1964, August, Sept. & Nov.,1963 (Mean of 36 trials)	E	58.8	61.2	60.0	56.3	65.8	27.4	Oyenuga and Olubajo (1968) Conducted with Zebu cattle
	F	60.3	62.2	61.5	57.9	68.8	25.0	
	G	61.4	63.6	65.5	63.5	59.8	27.8	
		61.4	63.					
November,1966	H	76.4	78.1	80.0	78.6	75.5	0.8	Oyenuga (unpublished) Conducted with F White Fulani cattle
	J	76.3	77.1	82.8	75.2	76.9	32.1	
	K	73.9	76.0	76.6	74.5	77.4	14.6	
	L	79.6	81.7	80.5	81.5	79.4	58.2	

Notes on Table 3

B Cynodon plectostachyum + Centrosema pubescens.

C D + chloris gayana and Digitaria decumbens

D C + stylosanthes. gracelis

E Same as B.

F E + stylosanthes gracelis

G Digitaria decumbens, centrosema pubescens and stylosanthes gracilis

H Cynodon plectostachyum, centrosema pubescens and stylosanthes gracilis

J Pennisetum purpureum, centrosema pubescens and stylosanthes gracilis

K Pennisetum purpureum, Panicum maximum, centrosema pubescens and stylosanthes gracilis

L K plus cynodon plectostachyum

TABLE 3

Summary of daily nutrient intake and liveweight gain of Zebu and N'Dama cattle grazing different grass/legume pastures in Ibadan during 1963-1966

	1963-1964				1964-1965				1965-1966				
	E	F	G	MEAN	DE	F	G	MEAN	H	J	K	L	MEAN
Mean live-weight (lb)	540	560	500	533	850	870	800	840	550	540	530	530	537
Mean daily live-weight gain (lb)	0.44	0.50	0.43	0.46	0.48	0.47	0.46	0.47	0.65	0.53	0.74	0.79	0.68
Dry matter intake (lb)	15.60	15.60	13.40	14.90	20.70	19.90	18.90	19.83	14.08	13.34	11.78	16.71	13.98
Dig. dry matter (lb)	9.00	9.60	8.00	8.86	12.40	11.80	11.70	11.97	10.76	10.18	8.67	13.30	10.73
Dig. organic matter (lb)	9.40	9.80	8.30	9.17	12.90	12.30	12.10	12.43	10.20	9.18	7.83	12.19	9.85
Crude protein (lb)	1.17	1.2	0.83	1.06	2.05	1.79	1.38	1.72	2.17	2.11	1.47	2.57	1.65
Dig. Crude protein (lb)	0.7	0.76	0.48	0.65	1.2	1.05	0.95	1.08	1.73	1.74	1.13	2.07	1.65
Total Dig. Nutrient (lb)	7.80	8.80	7.10	7.90	10.70	10.20	9.60	10.17	6.60	6.58	6.48	6.95	6.65
Digestible Energy (M.Cal.)	15.6	17.6	14.1	15.8	21.5	20.4	19.2	20.4	13.2	13.2	13.0	13.9	13.3
Metabolizable Energy (M.Cal.)	15.4	16.0	13.6	15.0	21.1	20.1	19.8	18.7	16.7	15.0	12.8	19.9	16.1

voided by grazing animals is estimated indirectly by dosing the animal with known weights of indigestible external tracer using, for this purpose, a chomium sesquioxide impregnated craft paper (Corbett et al, 1960). The digestibility of the herbage consumed in the field is estimated from regression equations based on data derived from indoor digestibility trials. Details of the methods used, the stocking rates and mode of samplings of pasture were as already previously described (Oyenuga, 1966; Oyenuga & Olubajo, 1966).

The daily nutrients consumed by the grazing stock are compared with NAS/NRC recommended allowances for beef steers and heifers of similar ages but higher growth rate in Table 4. It will be seen in Table 4 that while the amounts of feed, dry matter, TDN, DE, crude protein and digestible protein consumed by Ibadan herd compare favorably with the NRC recommended allowances, the daily liveweight increases of the former amount to only about half of the latter. Relative to NRC/NAS recommended allowances, therefore, these range animals at Ibadan consumed and absorbed sufficient nutrients for optimum growth. These results, though tentative, represent a summary of data obtained for three years grazing trials at Ibadan.

TABLE 4

Daily nutrient intake by growing and fattening Zebu and N'Dama grazing beef herd at Ibadan compared with NAS/NRC requirements for normal growth of heifers and steers of similar liveweight.

Body Weight (kg)	Average daily gain (g)	Dry matter (kg)	Crude protein (g)	Dig. crude protein (g)	TDN (kg)	DE (Mcal)	ME(2) (Mcal)
			Mean of Zebu and N'Dama Ibadan Grazers				
242	209	6.8	499	272	3.6	15.8	15.0
244	308	6.4	953	771	3.0	13.3	16.1
381	213	9.0	771	499	4.6	20.4	18.7
			NAS/NRC (1963) Normal growth heifers and steers				
227	454	5.7	590	363	2.9	12.6	
272	635	7.4	680	408	3.7	16.4	
363	544	8.7	680	408	4.4	19.1	

(1) DE was calculated from TDN on basis of 1 lb TDN 2,000 kcal of TDN

(2) M.E. was calculated by attributing to 1 gm digested organic matter the ME value of 3.6 kcal (Blaxter, 1964).

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ANIMAL NUTRITION RESEARCH

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SUMMARY

Research which has been carried out over the last few decades into pathological infections and preventive measures in livestock has made a large increase in herds possible. Livestock has thus become, for most African countries, an important investment, but an investment which remains very often unproductive.

In order to improve livestock productivity it is necessary to improve livestock feeding and to undertake research to that end. This research should principally concern studies of grasslands and their improvement, and the value and utilization of crop production by-products, which are often plentiful and mostly wasted.

The author then describes work which has been carried out on this by the IEMVT.

* * * *

If forty years of research and intensive preventive health activity has not made the contagious diseases of African livestock totally disappear, nevertheless, one must recognize that the widespread epidemics that used to decimate the herds are now a thing of the past.

This does not mean that we should become complacent and neglect them, but research has led to the discovery of good, effective vaccines, and the control of disease is now a matter of personnel and organization rather than one of new, intensified research.

This health victory, although incomplete, has led to a marked increase in the number of animals in areas where livestock production had always been a primary occupation. Beyond this, in other countries where trypanosomiasis had been a major obstacle to livestock breeding, the discovery of trypanocides has made it possible not only to cure diseased animals but also to vaccinate herds against parasites; also the perfection of methods for controlling the vectors of the disease has made it possible to raise ever-larger herds.

For the entire African continent, therefore, livestock is now a very important resource, albeit in varying degrees, and an almost unequalled source of protein.

Unfortunately, livestock production is not as profitable as one might be led to expect, because even though most of the types of cattle

have great possibilities and a high production potential (milk or meat)--as was apparent from various studies such as those done on the Zebu Azawak (5,8) and the N'Dama (9,11) for milk and on the Zebu Gobra (10), the Renitelo (1) and the Brahma crosses (3) for meat--these qualities are rarely maximized and they do not have much of a chance to become manifest under traditional conditions of livestock management.

So that the genetic potential of the different races can be exploited for the best interests of all, it is absolutely essential that care of the animals be improved and this improvement, especially the feeding of the animals, is a priority research area--perhaps the most important priority. This is because there will never be profitable, productive livestock production if the animals do not have proper food, both as to quantity and quality.

This important theme of improvement of livestock feeding has many facets. First, one must consider the two types of livestock-rearing in the tropical environment: nomadic and sedentary, and realize that care of the animals and feeding them is so different for these two types that they have practically nothing in common.

As far as nomadic livestock is concerned, research should concentrate on studying natural pastureland and its rational utilization, so that the livestock can be guaranteed adequate food the whole year around.

An inventory should also be made of the exploited and exploitable zones and estimates should be made of the resources that they have to offer. Studies of the evolution of the pastureland as a function of its exploitation should be made. Further:

- studies of their improvement potential should be made and methods of carrying out the improvement
- studies should be made of the content of essential trace elements in pastures, as well as studies of mineral deficiencies and methods for correcting the deficiencies
- the number of waterholes must be increased and they must be carefully located.

For sedentary livestock-raising, pasture must undergo the same type of research, but the research on their improvement must also include other research such as:

- the introduction of improved species
- the action of threshing, clearing and crop rotation on the evolution of pastureland, as well as the proper time for allowing a field to lie fallow.

The creation of artificial pastureland must also be investigated, and this will be related to the introduction of new species, which depends on the climatic and soil conditions, and the adaptability of various species will have to be studied with care.

Beyond this, the regions where sedentary livestock-breeding goes on are primarily agricultural. Agriculture often leads to food crop by-products (millet, sorghum, maize, manioc and other roots and tubers, fruits, etc.) which are neither used for human consumption nor exported. Other crops are processed before they are consumed, which processes yield by-products which can be used by families or industry. Other crops are grown only with industrial purposes in mind (peanuts, cotton, copra, cocoa) or commercial purposes (pineapples, bananas for export, etc.); in all these cases, they leave by-products or products that are unfit for export or human consumption.

All these residues and left-overs can be used for animal food and would go far to improving their diets. Part of these by-products are already used for feeding small livestock, but usually under bad conditions; others are exported (cottonseed, for example), but nevertheless, large quantities are not used or scarcely or badly used, or are used for other things than food (cotton by-products are sometimes used as fertilizer, for example).

Finally, in large centers, remnants and bits left over or rejected from slaughterhouses can be made into meat-flour, and in coastal cities fish-flour can be made from fish that is not, or cannot, be sold.

It is inconceivable that at a time when there are so many countries in which the people suffer from famine so many food-products would be wasted.

Research must be intensively pursued on these food resources and their proper utilization. This research would involve:

- studies of available food resources for feeding livestock in all the countries of continental Africa and Madagascar; this should be done through deep inventories, primarily envisaged from an economic viewpoint: immediate volume of production and goals for the future, price at which sold, transportation cost, commercial exchange, etc.
- studies of the chemical composition of the different available products and computation of composition tables;
- studies of their digestibility and their food value for different animal species;
- studies on methods of conservation and preservation of products that spoil easily;
- studies of methods of utilization for animal feeds.

IEMVT has undertaken for a number of years research of this kind. At the requests of many African countries, many studies of pasture were carried out (botanical and chemical composition, value, improvement, utilization, trace-element deficiencies) as well as studies on the introduction of improved species and the establishment of artificial pastures.

In addition, the Ministère de la Coopération has requested a study of tropical products to be used for livestock feeding in Francophone West Africa. An economic and technical study was carried out in 1964 (4) and all the harvested products were analyzed chemically. The Food Chemistry

Laboratory continues to regularly receive samples for analysis (nutrients, macro- and trace elements, amino acids).

One study has been undertaken on rice by-products and is nearing completion.

Finally, research on the digestibility of fodder and tropical products is in progress at Dakar. Some results obtained have already been published.

IEMVT has the task of improving and helping tropical livestock production and the various studies on animal nutrition are part of its research program.

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GRASSLANDS AND PASTURES:

PROBLEMS OF UTILIZATION AND IMPROVEMENT

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SUMMARY

Grasslands and pastures can be adequately described only in relation to their products and to the general environment and the agricultural system in which they are situated. An attempt has been made to view production from grasslands in the general agricultural perspective, to pinpoint factors tending to retard or prevent production and progress, and to suggest possible approaches to the problems described.

A brief account is given of environmental conditions in the grassy tree savannas where most African livestock are produced. The general situation of the peasant producer in a subsistence type economy is described in relation to grassland utilization, management and improvement.

Brief reference is made to previous research and the main accomplishments and deficiencies are outlined. The author's view is that most specifically agricultural problems can readily be solved; that the major factors limiting production and progress are not agricultural but social and economic in nature. The immediate problem is to make proper use of abundant resources which we already possess and to stimulate sluggish economies. The results of much research work cannot be used by the peasant farmer in his present state of social and economic development.

The change from the present system of separated crop and animal farming to integrated mixed farming is seen to be of the greatest importance, not only in releasing the peasant farmer from the drudgery of hoe cultivation and the country from the limitations of a subsistence economy, but also in recognizing grass as a crop, in beginning proper husbandry via positive feeding of livestock, and to managing grassland and establishing pastures specifically for that purpose.

It is suggested that the immediate effort should be concentrated on developing effective extension education amongst peasant farmers and to the task of utilizing existing resources to the best advantage. Research work should continue in order to produce information and techniques that farmers will need when they are equipped to use them.

INTRODUCTION

Almost all of the states represented at this conference were under colonial rule as recently as ten years ago. They achieved their independence and entered a highly competitive modern world at a time when their own populations are rapidly increasing and food shortages on a world scale are predicted before the end of the century. Most are poor peasant-populated countries with sluggish economies; they are technically backward, under-developed, non-industrialized and barely able to close the gap between food production and consumption. They are agricultural nations and it is clear that their greatest efforts must be directed towards raising agricultural production to the highest level in the shortest time, with the twin objectives of feeding their own populations and of financing their future development. Time is running out.

With a subject as complex and diverse as agriculture, which begins with the basic facts of climate and geology and ends with considerations of human societies and international trade, it is misleading to view a particular facet of the subject in isolation. One must appreciate the interplay of many forces at work, retain the essential perspective, and view the subject as a whole. I cannot separate production from grasslands from the other subjects that are so closely connected with it.

My task, as I see it, is not merely to explore the restricted technical field concerned with inducing two blades of grass to grow where only one grew before. A problem of greater urgency is to show how to utilize at least one of those blades of grass to the best advantage, which is a different matter. Why are we not producing more from the abundant resources at our disposal? Can we manipulate physical, biotic, social and financial factors in new patterns to achieve maximum production? I shall try to view grasslands and pastures, and production from them, in the general agricultural perspective, to examine some factors which limit their full use and development and, where possible, to suggest approaches and solutions. What I have to say is based largely on my experience in West Africa and cannot be applied to all territories. It is also a personal point of view which may conflict with others. But differences of fact or opinion will emerge during discussion.

THE SETTING

Climate, vegetation and soil

The enormous variation in climatic conditions across the continent has produced a corresponding array of vegetation types ranging from hot

humid coastal rain forest to hot arid desert steppe, grassy highlands, or cool montane forest. With the exception of the closed forest of the Congo Basin and its extension along the West African coast, the montane forests of the East African peaks, and areas of desert shrub, most of the remainder can be regarded as savanna, more properly as tree savanna, here defined as continuous grassy ground cover with scattered trees and shrubs of variable size and density. The grasses, varying widely in height are, for the most part, coarse tufted perennials. These are the natural grasslands to which I shall refer and are quite distinct from pastures which are here taken to mean areas deliberately cultivated and planted directly, or after cropping, with selected grass or grass-legume mixtures.

The grasslands in general occupy areas where environmental conditions tend to be extreme, particularly in regard to temperature and to the erratic volume and distribution of annual rainfall. Their ecological status is usually secondary and they have been strongly influenced, both in structure and distribution, by fire and cultivation. Soils over wide areas are frequently senile, strongly leached and deficient in nutrients, especially in nitrogen and phosphorus, a characteristic transferred to the grasses growing on them.

Livestock disease

Such, very briefly, is the physical environment in which livestock are being produced. But biotic and other factors, especially disease, may be responsible for controlling their distribution. Most important of these is trypanosomaisis, coincident with its tsetse-fly vectors (Glossina spp.), which has denied many thousands of square miles of good grassland to the livestock producer and is probably responsible, in some degree, for the absence of mixed farming over most of Africa so affected.

The various tsetse species occupy specific ecological niches - humid forest, riverine microhabitats of deep shade and high humidity, and the moister types of tree savanna. Livestock production, difficult or impossible in these infested areas, became concentrated in tsetse-free areas or those of mild tsetse challenge in dry or high situations. The driest zones of all produced the nomad pastoralist who follows the seasonal flush of grass behind the early rains. Crop production on the other hand, tended to gravitate in the opposite direction towards areas of higher more reliable rainfall - the moister tree savanna, the savanna-forest transition zone, and the forest itself.

With the exception of trypanosomiasis, most livestock diseases have now been brought under control.

Social and economic circumstances of production

Excepting contributions made by mining industry, the economies of all states are basically agricultural. The grassy tree savannas are inhabited by peoples of diverse origins, languages, customs and beliefs, most of whom are peasant cultivators engaged in subsistence-type food-crop farming. They rely on the simplest hand tools, fire and human muscle power to operate a system of shifting cultivation. Except in certain areas such as Kenya, where clear policy and methodical extension work

over many years has produced a new generation of practising mixed farmers, crop and animal production have rarely been integrated in a single mixed farming system. There are doubtless several reasons for this peculiar farming dichotomy, including the over-riding compulsion exerted by trypanosomiasis.

Unlike the nomadic and other pastoralist tribes to whom animal husbandry resembles a religion and is certainly a way of life, crop farmers, though they may own livestock, are hunters by practice, seldom animal husbandmen by tradition. They have little feeling for animals, or understanding of their needs, or skill in handling them. Though livestock are now being produced, bought and sold more frequently than in the past, and production may be said to be commercialised in this respect, animals cannot truly yet be regarded as part of the agricultural system. Their status is more akin to that of gleaners or scavengers; their function is largely that of a bank; they are adjunct to, not a part of, the system.

Land is generally owned jointly by the tribe or community. It may be presided over by a special custodian of the soil and allotted by him or by a chief to individual farmers for cultivation. Under conditions of divided crop and animal farming, crops are seldom manured and soil fertility is replenished by a system of shifting cultivation. When crop yields decline after two or three years of cultivation, the farmer is allotted new fields and his abandoned lands revert to bush and slowly regain fertility thereby. There is no conception of "grazing rights" and herds may be grazed anywhere provided that growing crops are protected from damage. Livestock are obliged to fend for themselves and are rarely positively fed. There is no direct bond between the man and the soil, and no profit motive. Under such conditions, questions of individual land ownership and inheritance do not and cannot arise.

Such a system of land tenure, based on scattered plots and short-term cultivation, gives rise to questions of the greatest importance to agricultural development. First, the crop farmer has no possible incentive to improve land so soon to be abandoned and which he may never till again. Second, the grazier likewise has no incentive to look after grassland which is not directly under his care and over which his own and other livestock may wander at will. Third, the grazier accepts grassland merely as part of the general environment. He is not obliged to, and does not, regard grass as a crop. The recognition of grass as a crop, as a basic agricultural resource subject either to damage or improvement, is regarded as an essential point of departure leading from positive animal feeding to the notion of conserving wet season surpluses for dry season use, to improved methods of husbandry, to quicker maturation higher yields and bigger profits, and ultimately to introduction of high-yielding stock on high-yielding pastures and intensive mixed farming.

With rising population pressure all arable land available for allotment is taken up, cultivation-fallowing cycles shrink and become too short to restore soil fertility, and shifting cultivation gives way to a "fixed" system of agriculture. At this point two important things happen: first, regular manuring of the soil - imperative if crop yields are to be maintained - must commence and second, land is generally held and inherited,

according to local custom, within a family system. Both offer ways of escape from the tyranny of the hoe, the unproductive subsistence economy and "single track" systems of agriculture.

Plough cultivation by animal traction, rare prior to the colonial era has not, even now, displaced the hoe over very wide areas. To large numbers of illiterate subsistence farmers, the use of power machinery is today as far beyond their competence as it is beyond their means. In some countries where the myth of immediate mechanization of peasant agriculture was pressed with the vigour and enthusiasm that so often accompanies ignorance of basic principles and even of local conditions, the results have been disastrous; they are littered with the corpses of tractors that arrived before their time. Such, very briefly, is the general environment in which production from grassland takes place.

The process of transition from separated crop and animal farming to integrated mixed farming systems is believed to be of great importance to the development of efficient agricultural production. Although some areas will never lend themselves to such development, mixed farming is generally regarded as the key to the ultimate release of the peasant from the unproductive drudgery of hoe culture to the freedom of machine powered farming. It is important to remember that almost all agricultural production is based on the peasant farmer and if significant improvements are to be achieved, it is at peasant level that the attack must be made.

The product

Grasslands and pastures have no intrinsic value and are important only in relation to the livestock they support. The most important classes of livestock are non-milking types of cattle, goats and sheep which have been selected, for survival only, by many centuries of environmental challenge, and their productivity is consequently low. Goats and sheep are probably at their best in arid areas like the Sahel and Sudan zones immediately south of the Sahara. Cattle, principally Zebu types, thrive best in tsetse-free areas of the West African Guinea Savanna and Sudan zones north of the 14th parallel, in comparable areas elsewhere, and generally in highland areas of low tryps challenge. Particular types of all three classes, however, occur in small isolated groups (at least in West Africa) in areas where the trypanosome challenge is high. Amongst them are the Ndama cattle of the Fouta-Djallon highlands of Guinea, the Lagoon cattle of the West African littoral, and the Shorthorns derived from them. All exhibit dwarfing to a greater or lesser degree which is thought to represent the price paid for acquiring partial resistance to trypanosomiasis, most strongly developed in the Ndama. Zebu types are highly susceptible.

In recent times, prolonged extension work in East African territories has resulted in the beginnings of a promising native dairy industry based on established pastures, high-yielding imported breeds, selected indigenous stock and on hybrid offspring. In West Africa there is no dairy industry of any significance.

RESEARCH

Agricultural research in the colonial era was concentrated on export crops such as cocoa, palm oil, coffee and cotton. Work on grasslands and pastures was consequently meagre. I shall not attempt a detailed continental review of research on grasslands and pastures but merely refer to fields where work has been done and to outline knowledge available for use.

Grasslands

The exploratory phase is complete and the grass floras of most countries are now well known. All common species and most others have been collected and described in standard works of reference.

Descriptions have been made in a number of territories of the major plant communities, their general ecology and the dynamics of plant succession, which must form the basis of any system of range management. Widespread observations and a few critical studies have been carried out on the effects of fire on vegetation and plant succession, and the work has been adequately reviewed. Fire can be used with a degree of confidence as an aid to management of tree savanna under grazing in several major areas.

A fair amount of information has been published on the productivity and nutritive value of range grasses in relation to seasonal change throughout the year. Similar information is available for a variety of shrubs and trees normally browsed by livestock. Taken together these records emphasize the serious nutritional deficiences of dry season grassland and the mitigating influence (at least in some areas) exerted by deep-rooted evergreen protein-rich browse shrubs and trees: the necessity for supplementing livestock feeding in the dry season is clear.

The carrying capacity of natural grassland has been the subject of many observations and a number of objective practical studies in various countries. They cover a range of climatic and vegetational conditions and provide valuable information for planning commercial projects.

The East African countries have a longer history of grassland investigation than most others and a body of useful information on the ecological basis of range management has been established and reviewed. Similar but less extensive knowledge has been built up in a few West African states. However, despite the fact that almost all livestock are produced by peasants in the tree savanna country under extensive management conditions - a situation which is bound to continue for many years - far too little work has been done in this field.

Established pastures

More work has been done on introduction of grass and legume pasture species into the high rainfall environment of the forest zone than into the difficult conditions of the tree savannas. The key factor in the savanna zone is the volume of rain received and its distribution throughout the year. The longer the dry season and the more erratic the rainfall,

the more difficult pasture establishment becomes. Environmental conditions (rainfall and trypanosomiasis) tend to force a polarisation, of livestock to the drier areas where pasture establishment is difficult, of crops (including pastures) to wetter zones where livestock are excluded. The problem is to bring livestock and pastures together in both situations. However, as tree crop production in the forest zone offers a greater return than identical acreages under pasture, the tree savanna is the logical place for livestock production at the present time.

Besides a large number of selections of indigenous species of Pennisetum, Panicum, Andropogon, Hyparrhenia, Cynodon, Setaria, Brachiaria, Digitaria, Cenchrus, and others that have been made in various localities from time to time, many improved varieties of the same species bred in Australia and elsewhere, have been imported for trial. A group of tropical legumes including species of Centrosema, Stylosanthes, Pueraria, Calapogonium, Desmodium, Dolichos, Glycine, Phaseolus, Lotononis and others was imported at the same time. East Africa is one of very few areas where new varieties of pasture plants have been bred or selected for specific purposes, and one of the few where such varieties can be effectively used at present.

It is estimated that varieties of about 40 species of grasses and about half that number of legumes are available for use in various situations at the present time. Most of these, however, are probably adapted to moist or moderate conditions and few could withstand the long periods of draught under grazing that operate over such large areas of rainfed tree savanna. Varieties of Cenchrus ciliaris and Stylosanthes gracilis and S. humilis appear to offer the best prospects of success in extreme savanna conditions at present.

A limited amount of work has been conducted on selecting compatible varieties of grasses and legumes for combining in pasture mixtures. Very few suitable mixtures have emerged in West Africa but Centrosema pubescens and Cynodon dactylon (previously C. plectostachyus) or Giant Star Grass, and Pueraria phaseoloides and varieties of Pennisetum purpureum perform well under suitably moist conditions. East African trials have produced a larger number of mixtures suitable for a wider range of habitats.

The yield and carrying capacity of various types of pasture has been investigated under different fertilizer and grazing treatments. The indications are that, given suitable fertilizer and adequate rainfall or irrigation, yield and carrying capacity can be extremely high.

General observations and some objective studies have been made on aspects of grazing management of pastures. In West Africa some preliminary studies indicate that active growth of particular pasture species, notably Panicum maximum, may be extended well into the dry season by manipulating grazing or mowing to suppress flowering.

It is clear that grassland and pasture work has lagged behind research on the money-spinning export crops and has seldom been consistently pursued or viewed in the general agricultural perspective. It is also clear that, given the right conditions, the knowledge and material

already available - meagre though it is - could be put to immediate good use. With the probable exception of some advanced areas in East Africa, however, the peasant farmer is not now in a position to make use of these resources. Where precisely do the difficulties lie?

I incline to the view that there are few specifically agricultural problems that will not yield to investigation by a competent team of scientists within a reasonably short time. It is true that we need to know a great deal more for instance, about many aspects of grassland management, drought resistant pasture species, nitrogen fixation and soil fertility under tropical dryland pastures, the role of farmyard manure as fertilizer in tropical conditions, the economics of beef production and so forth. This is a matter of clearly identifying the problem within a particular context, setting an efficient team to work, and producing the result. But the serious problems, those which limit present production or block future progress, are closely linked with human beings: they are largely social and economic, not agricultural. The initial advances will come, I believe, not from a dramatic breakthrough in agricultural research, but from enabling the peasant farmer to make full and proper use of existing resources which are now being misused, not used to good advantage, or not used at all.

It has been demonstrated, for example, that the total production of food crops in some West African countries could be doubled if farmers were in a position to use mineral fertilizers that have already been tested and accepted in the field. This is not a matter for research, nor does it involve any significant change in peasant farming practice. It is a question of arranging the initial loans to farmers to buy fertilizers, of distribution of fertilizer, and of organizing transport and marketing. Such an advance would lift the peasant out of subsistence farming and place him in a cash economy where the profit motive provides its own stimulus to greater effort and further advances. It has also been estimated that the potential carrying capacity of tree savanna grassland under year-long grazing conditions in at least one West African country is double the number of livestock running there today. The potential could be achieved by selective clearing of woody growth and consequent encouragement of grass, by use of tryps-tolerant livestock and the more intensive use of available grass. Examples of this kind could be multiplied many times.

I do not suggest that research should cease. Far from it. On the contrary, it should be pushed forward to produce the information and methods that farmers will need when they have, so to speak, served their apprenticeship and are equipped to make use of techniques that are today beyond their grasp. What is needed is a shift of emphasis. We appear to have worked too much on types of production which can successfully be employed on research stations but have no meaning to the peasant in the bush. These results will be needed perhaps a decade hence. What can be done <u>now?</u>

The immediate effort, it seems to me, should be concentrated on determining the facts of the peasant's existence, on problems surrounding

such matters as human and animal populations, custom law and religion, systems of land tenure and inheritance, agricultural systems, methods of production, utilization of products, transport, markets, demand for consumer goods, means of accumulating capital, medical, educational and other services. The basic problems or factors limiting production or blocking progress can then clearly be identified. Lastly an integrated plan can be drawn up to tackle the problems at their root, namely through practical guidance in the field. This implies the training and deployment of an effective force of extension officers.

OBJECTIVES, PROBLEMS, APPROACHES

The essential objectives are to stimulate sluggish economies by replacing human-powered hand-to-mouth subsistence production with animal- or machine-powered production for profit and sale.

The peasant's existence is ruled by the compelling logic of environmental demands and his production by methods, evolved over many centuries of trial and error, which he has devised to meet them: his survival is an expression of the success of those methods and he will not abandon them without good reason. The basic problems then, are to enable the peasant producer to use improved methods of production within the environment (physical, biotic, social and economic) in which he has to exist. If new tools, methods, ideas have not been tested, proved and accepted in that context, then they have no relevance to present needs.

"The farmer should cut and conserve fodder in the growing season to feed his livestock in the dry season." How often one hears this sort of advice. And excellent it is too. But how and by whom is it to be carried out? How does a man, equipped only with a cutlass, cut and carry over several miles, enough grass to feed a herd of cattle through a six-month dry season? His own reply strikes deeper than that - "Why should I try to feed my animals when I cannot even grow enough food to feed my own family?" - and there is no adequate answer to it.

Of the inescapable problems set by the environment, that of water supply is the most important. Given government participation, however, it is generally possible to locate and map all sites suitable for water storage and to drill or dam appropriately. The next is that of bridging the gap in the dry season feed supply, referred to in relation to intensive and extensive farming systems.

Fixed types of agriculture emerge under severe population pressure when contracting cultivation-fallowing cycles no longer maintain soil fertility, no more land is available for allotment, and there is no grass available for the grazing animal. It is in such situations that mixed farming and planted artificial pastures can be pioneered. The mixed farming system implies partial or complete integration of crop and animal farming to their mutual benefit. It offers ways of escape from the drudgery and limitations of hand labour and from declining soil fertility. It may have implications of equal importance in the field of animal husbandry and pasture development.

The mixed farmer of heavily populated areas, manipulating his new source of animal power, acquires a familiarity with working animals, practice and care in handling them, and ideas about proper feeding which lie at the beginning of improved animal husbandry and open the way to properly managed grassland and established pastures as sources of feed. Conversely, the traditional crop farmer of under-populated areas (the shifting cultivator of communally-owned land, hunter, banker-on-the-hoof) cannot be introduced to improved methods of animal husbandry in the same natural way because there is no common meeting ground between parallel systems of crop and animal feeding. He must be taught. Without an improvement in the general low standard of animal husbandry, without an awareness of animal needs or any idea of profiting by positive feeding, efforts to introduce grassland management or to establish pastures can have neither meaning nor utility.

Although some nations have achieved spectacular advances in productivity by direct transition from hand labour to mini-tractor, I personally doubt whether it is possible, or even desirable, to try to emulate their example here. The growth of power from hoe to tractor, it seems to me, will be obliged to evolve through an animal stage. It is during this stage or period of apprenticeship that a better knowledge of animals, and skill and care in handling them, can most easily be built up. There seem to be few if any short cuts.

At what point can established pastures be fitted into the mixed farming system? There seem to be two possibilities: to introduce them either as temporary grass or grass-legume leys in a fenced crop rotation system on individual farms, or, as permanent pastures on communal grazing grounds at some distance from unfenced village crops.

A typical mixed farming scheme introduced into northeastern Ghana about thirty years ago will serve as an example. Government loans for buying a pair of trained ploughing bullocks, a light plough and a cart were granted to any farmer who would first build a kraal to house the bullocks and manufacture compost. All crop and animal residues converted into compost were transported by ox-drawn cart, spread on the fields, and turned in by ox-drawn plough. Here at last was a way of escape from the limitations of the hoe and a means of maintaining soil fertility. The plan started slowly but by 1960 was rapidly spreading of its own accord, when political interference and Government-sponsored tractor worship brought about a temporary collapse. With the removal of political pressures the scheme revived and in some areas was carried a stage further, first by the introduction of a cheaper multi-purpose implement incorporating plough, ridger and cultivator; and second, by persuading local blacksmiths to manufacture the simpler components in the village.

The integration achieved is only partial, however, and the scheme has obvious limitations. Notably, there is no provision for growing grass to feed the livestock, which still carry on an emaciated existence outside the cropping system. But, in spite of short-comings, it has worked surprisingly well. Working oxen, however, should be brought to peak condition for ploughing at the end of the dry season when grass is

normally in shortest supply. The planted grass or grass-legume ley could supply this need, provided that fragmented holdings could be consolidated in workable units, that sufficient land were available to achieve the proper proportion of crop to pasture land, and that crops could be fenced against livestock damage. Fencing could be financed on the same basis as loans for bullocks and implements. But research is badly needed on questions of land tenure, consolidation and inheritance; on suitable pasture legumes; and on the economics of bullock ploughing.

In some heavily populated areas with a fixed agricultural system, grazing land may no longer be available amongst the crops but is still to be found on the outskirts of the main cropping area. There seems no reason why such land should not be fenced, planted, developed and managed as communal pasture for all village livestock, not only for grazing but - as animal traction opens the way both to mowing and to transport - for hay production as well. Hay or silage conservation for dry season feeding can hardly be accomplished without the aid of machine or animal power.

During the period of apprenticeship, cattle should be limited to beef type animals. Only when husbandry has been greatly improved and livestock feeding accepted and practised, would it be opportune to introduce dairy cattle and the highly productive nutritious pastures they would require. In the meantime, several satisfactory species of grass are available for use but research is needed to find suitable varieties, especially of legumes, for use in extreme environments. These may be found amongst annual self-propagating species, as also amongst deep-rooted indigenous perennial evergreen browse trees and shrubs.

Underpopulated areas farmed under separate systems of shifting crops and extensive grazing on communally owned land face similar but less acute problems of dry season feed supply. Woody vegetation is denser, grass more abundant than in overpopulated areas, and the poor quality of dry season grass is to some extent offset by a limited supply of nutritious palatable evergreen browse trees and shrubs. Livestock consequently survive the dry season in fair condition.

As compulsions due to lack of land and declining soil fertility do not operate in such situations, improvements can probably be brought about only by sustained efficient extension education aimed, as before, at integration of crop and animal farming. Given the necessary incentives and encouragement, some innovations could be made immediately in the grassland field. These might include gradual expanding selective bush clearance (leaving shade trees and all palatable browse trees and shrubs) to encourage grass and raise carrying capacity; institution of controlled bush burning; demarcation (but not fencing) of upland and lowland grazing areas for seasonal grazing and burning rotations; and propagation of selected palatable browse plants in suitable sites (possibly in hedgerows along borders of demarcated grazing grounds). All these are within the capacity of the peasant with his present equipment and, using communal labour the question of cost does not arise.

Immediate research problems are those connected with methods of selective bush clearance, and the requirements for establishing a variety of nutritious browse species. Research is also needed on the problem of establishing self-propagating herbaceous legumes (Townsville Lucerne or similar species) without cultivation, in existing grassland. If suitable legumes and establishment techniques are found, substantial areas could be sown under state aid, and grassland productivity could be raised without any interference to existing farming patterns.

In all situations the question of extension education is vitally important. It is clear that much could be done now to make full or better use of existing resources, provided the peasant could be convinced, by practical example, on his home ground. He cannot afford to experiment himself because that would be akin to trifling with his own survival. The itinerant extension officer from headquarters, immaculate in white coat, sun glasses and solar topee, ensconced in his chaffeur-driven Mercedes, rouses little enthusiasm in the heart of the peasant farmer. What is needed is a corps of dedicated workers who are ready to spend long periods in remote villages, who endeavour to know the peasant from the inside, and identify themselves with his problems. There is, finally, another aspect of production worth examining.

Underpopulated undeveloped countries with land suitable for extensive livestock production could well consider inviting competent expatriate ranching companies to set up projects on medium to long term contract terms. This is one way to raise production in a short time, simultaneously to work out and demonstrate the practical problems of animal husbandry, to develop local markets, and to pass the knowhow to local people.

PROBLEMS RELATING TO FORAGE CROPS

IRAT

SUMMARY

This paper deals first with the three basic characteristics which differentiate forage crops from industrial or food crops. These are:

- mode of utilization which requires the intervention of a transformer (the animals), so that one cannot discuss forage crops without also talking about livestock production;

- the great need for preserving soil fertility through a fallow period in which the field could be planted with a forage crop;

- the integration of crop and livestock production, corollary and synthesis of the two preceding points.

Regional situations are then discussed and the factors limiting the development of rational livestock production integrated into the various zones under consideration:

- Arid Africa
  - -wet tropical climate zone
  - -dry tropical zlimate zone

- Humid Africa
  - -forest zone
  - -wooded savannah zone

- Madagascar

The current establishment of forage crop research in Francophone Africa is then described and the respective roles of the Veterinary Medicine Institute for Tropical Countries (IEMVT) and IRAT are defined.

The paper ends with suggestions of a number of research topics that could be undertaken within a regional framework:

- stocking-rate trials
- development techniques for producing forage-crop seeds
- producing animals for slaughter using agricultural by-products
- forage crop production in the arid zone with irrigation
- genetic improvement and selection of forage-crop plants
- studies of root nodules

Forage crops display special characteristics which distinguish them from food or industrial crops and which give them a special physiognomy; among these characteristics, probably the most important one is the mode of utilization which requires a transformer, livestock, which supplies commercial products either directly from meat obtained after slaughtering the animals or indirectly as milk secreted by the animal. Thus one cannot discuss forage crops without also speaking of livestock production, especially in the first analysis of the problem. Forage crops are grown to be consumed through grazing of the animals on pasture land or through feeding them in stalls; a rational exploitation system combines these two methods, so that production can be geared to consumption. The excess crop gathered at the rainy season harvest is kept and stored for use during the dry season when there is a marked lack of grazing. In the traditional African and Madagascan agricultural systems, growing plants for feeding livestock is practically unknown.

A second aspect of the problem of forage crops which is less immediate is the preservation of soil fertility. Under conditions of low or average mineral fertilization which is generally the situation in tropical climates, it has been found that a period of reconstitution is absolutely for the fertility of the soil. The concept of this fallow period is very variable as to frequency, duration, use of the land, climatic and economic conditions. It is a concept that for correcting soil deficiencies, forage crops have an eminent place, as research has proven time and again that these crops are very beneficial to the physical structure and the chemical characteristics of soil. Utilizing the field planted in forage crops (that have been repeatedly proven as so beneficial) for grazing livestock make the "cure" profitable as well. Thus we are confronted with a third aspect of forage crop cultivation, which is in effect the synthesis of the other two; the integration of crop and livestock production.

Animal traction gives the farmer better control over his land by making it possible for him to do the various tasks at the required times on the necessary areas. The presence of animals in farming also infers the preparation of manure, which, when used correctly, reconstitutues or at least maintains the level of organic matter in the soil. Then forage crops make it possible to feed the animals adequately and correctly. Thus a very articulate theoretical schema is arrived at and an agricultural constraint can be turned into a productivity factor. As a matter of fact, this is a type of farming which is still common in Europe and which was even more universally seen there a half-century ago before mechanization and the use of mineral fertilizers were so widespread. This system was practically non-existant in Africa at the same time and very little of it exists today for various reasons, some of which are outlined below.

1. Regional Situations

In outline form one can distinguish the following:

1.1 Arid Africa

In tropical climate zones (arid and humid - Senegal, Niger, Mali, Upper Volta, Chad, Northern parts of Cameroon, Dahomey, Ivory Coast, and the Central African Republic) livestock production is transhumant; the farmers use very few animals for farming and if they have them, they consider them as living capital, a reserve for bad days. This difference between farmers and livestock breeders and this difference is reinforced by ethnic differences, the breeders (Fulani, Bororos, Moors) are not farmers and still today only rarely become sedentary or farmers. This zone is relatively free from sleeping sickness (trypanosomiasis), and the zebus that live there are quite sensitive to the disease. Progress in veterinary medicine and especially in chemotherapy have made it possible for these animals to thrive even at the southernmost limits of this zone where the risk of infection is greatest.

1.2 Humid Africa

In equatorial climates (forest zone or wooded savannahs) such as part of Dahomey, the Central African Republic, Gabon, the Ivory Coast, Togo and most of Cameroon, trypanosomiasis makes zebu breeding all but impossible; a taurine breed is substituted in these areas (N'Dama. Lagunaire, etc... of smaller size). The number of head of cattle per unit area is lower than in the preceding zone. Breeding has become sedentary as feeding is no problem or little problem, even during the dry season.

1.3 Madagascar

Madagascar is distinguished from the African continenty by the absence of trypanosomiasis, the variety of climatic conditions and by the infusion of many blood varieties in the local bovine race. On the southern part of the main island the main characteristics of livestock production in arid Africa, including transhumance, can be found. These characteristics can be found, but in an attenuated form, in the high altitude zones to the West. They disappear in the central pleateaus, where beasts of burden are used for plowing and for working in the rice fields. Around the towns there are small-scale dairy farmers.

2. The present situation of forage-crop research in Francophone Africa

Research on livestock is carried on by the Institute for Veterinary Medicine of Tropical Countries (IEMVT) which is found in countries that

have pastoral livestock production (Sénégal, Niger, Chad, Northern Ivory Coast, the Cameroons, Northern Central African Republic, and Madagascar). They carry on research activities in all phases of veterinary medicine, zootechnology, nutrition, entomology, and agrostology. This last aspect of the IEMVT's activity deals primarily with studies of spontaneous savannahs and their exploitation and secondarily with forage crops, at experimental stations. IRAT studies forage-crop cultivation at stations under headings: soil action, productivity, possibilities of integrating livestock breeding and agriculture, farming with animal traction. The two organizations, starting with different outlooks aimed at different "customers" (the livestock breeder for IEMVT, the farmer for IRAT) meet on common ground and overlap on certain points, especially on the matter of integration of crop production and livestock breeding, a favorite theme for development program.

IRAT works in the following countries, on varying scales: Sénégal, Niger, Upper Volta, Cameroon, Dahomey, Togo, the Central African Republic, Gabon, the Ivory Coast, and Madagascar. It is obvious that many problems were not covered as they should have been and only Madagascar reached the research stage where animals could be used for controlling the productivity of pastures. A regional research center should be organized in order:

1. to investigate more thoroughly certain problems that have only been scratched on the surface;

2. to look into new and different problems, especially fundamental ones.

3. Examples of research themes that can be undertaken in a regional framework

3.1 Experiments in stocking capacity of seeded pasture.

Experiments of this type have only been carried out by IRAT in Madagascar. They require experimenting with rather large areas of seeded, fenced pasture land, on which varying quantities of animals and herds are allowed to graze. These experiments are long, tedious and onerous. It is impossible to repeat them at too many places. An experiment of this kind in each of the climatic zones under observation would be necessary (three for Africa, one for Madagascar).

3.2 Perfecting forage-seed production techniques.

The extension of forage crops is restrained (among other things) by the lack of seeds or, what amounts to the same thing, by the excessively high price of seeds if one buys them from commercial sources. The

multiplication of the seeds requires some research and experimentation in the various ecological zones. If seeding levels spacing fertilizers and phytosanitary treatments are known,nevertheless the influence of the climatic factors must still be determined, although it is believed that conditions will be best in zones with a very definite dry season. Once the first steps in forage-crop research will have been accomplished, it will undoubtedly be possible to envisage setting up one or two centers for the multiplication and diffusion of forage seeds.

3.3 Producing animals for slaughter using agricultural processing by-products: from sugar cane refineries, rice mills, oil mills.

In the dry zone there could be experiments on oil-mills (peanut expeller- cakes, cotton seeds or cake) and in the humid zone for the sugar by-products (molasses, bagasse); for rice, the experimentation could reasonably take place in Madagascar. Basic information on this kind of experimentation is already available, but valid economic facts obtained from a test or pilot project are lacking.

3.4 Production of forage crops or pasture in the dry zone with irrigation.

Here, too, there is valuable information at the scientific level, but the determination of the economic parameters has not been made as yet. Setting up such an experiment would be very costly, whether the proposed irrigation would be by gravity or by sprinklers (for the former involves digging canals, etc., for the latter investment in pumps,pipes and sprinklers) which limits the areas where such experiments would be possible; however, the results obtained in one particular place could easily be extrapolated.

3.5 Genetic improvement and selection of forage plants.

This work has been started in Upper Volta (especially with regards to Pennisetum pedicellatum, Andropogon gayanus and Rostbellia axalata)but it is obvious that in terms of what exists for cereals, there would have to be geneticists devote to exclusively forage crops.

The research would require detailed study of the floral biology of the dozen or so species studied, selection of types tested for their productivity and seeding qualities, and eventually hybrids would have to be created. As for all genetic work and vegetal improvement, this is a long and tedious process. Here too, work carried on in one center of the zone would be applicable to the entire climatic area, as local adaptation could be verified by simple behavior experiments.

3.6 Study of root nodules in legumes.

This last example brings us to a section on experiments of a basic nature, many of which could be undertaken. Research on the root nodules of legumes in tropical environment has important agricultural consequences. It would require experiments in the laboratory and in the field and would require sufficient equipment and specialized researchers.

A STUDY OF NATURAL GRASSLAND

G. Boudet, IEMVT

SUMMARY

The study of natural grassland that aims at their improvement and use naturally starts with an inventory and cartography of such land that is available.

The IEMVT has, for the last several years, made a certain number of studies of this type, prior to formulation of plans for development of water points and the organization of ranches.

The research programs must take the following into consideration:

- the ecological conditions of the place, and resulting limitations and scope of its agricultural potential;
- the activities of the peoples occupying the area that is being studied;
- the local economic conditions which fix the maximum possible production costs.

In the intertropical regions of Africa and Madagascar, there are four main types of pastureland: steppes, savannahs with mainly annual grasses, savannahs with mainly perennial grasses, and dense forests.

In conclusion, research on tropical pastureland, conceived in terms of the diversification of the possibilities and problems of the large intertropical zones should make it possible to arrive at a rapid synthesis of results obtained, easily exploitable by interested governments.

* * *

When the governments of the Sahel zone undertook the planning of the development of livestock industry, they came to the conclusion that traditional livestock raising made the fullest use of natural grassland resources but that one of the primary reasons why exploitation was inadequate was because of the scarcity of water: wet season ponds disappeared as soon as the dry season arrived and the number of wells did not make it possible to utilize all the grazing area during the dry season.

Improvement in the exploitation of forage resources and the development of coherent plans for their use required that the pastureland be inventoried and mapped. Thus, one priority item became techniques for taking inventories of pastureland, adapted to tropical conditions. Until 1948-1950, most studies done on pastureland zones were concerned with the flora and its human uses, and very occasionally studies were

made on fodder-crop potentials of the zones and on methods for their rational use for feeding livestock. A number of governments of the tropical regions of Africa and Madagascar asked the IEMVT (8) to make studies on natural grassland so that they could use this in the elaboration of their rural water resources development and ranching programs.

Each research program is determined by the objective defined by the interested government:

The criteria taken into consideration for establishing research programs are threefold:

- the ecological conditions of the area, limiting its agricultural potential;
- the activities of the peoples occupying the regions being studied;
- the local economic conditions, fixing the maximum production costs.

For the intertropical regions of Africa and Madagascar, this means that the research can be subdivided into four main grassland groups:

- steppes;
- savannahs with predominantly annual grasses;
- savannahs with predominantly perennial grasses;
- dense forest.

1. Steppes

Grasslands in the tropics can be further divided into three subgroups:

1.1 "Contracted" steppe grassland, with average annual rainfall of less than 200 mm. Grazing is ephemeral here, and exploited by nomads (10) who breed camels.

Research on this type involves only studies of the botanical composition and phenology of the ephemeral species and makes no very great pratical contribution.

1.2 Steppe pastureland with an annual average rainfall of between 200 mm and 400 mm is the area suited to transhumance, food crops being confined to a few areas.

Research on this grassland (7, 15, 18, 21) involves:

a) the composition of the botanical climax and its evolution under the influence of browsing and grazing;
b) the seasonal and perferential use of herbaceous and ligneous species by various animals: cattle, sheep, goats;
c) the yield of main varieties and the nutritive value of the forage consumed at various stages;
d) a synthesis of the research, including productivity and possible stocking rate, optimal exploitation seasons, eventual danger of deterioration and means for controlling it.

This type of research, in correlation with the inventory of water resources, results in a utilization plan for these grazing areas:

- rainy season pasture in association with temporary ponds;
- pastureland of the beginning of the dry season near groundwater, available just below the surface;
- dry season pastureland with annual and perennial grasses in equilibrium and where the woody species can bring food complements through their fruits and their leaves; this type of pastureland completes the transhumant cycle or can be used for creating ranches for maintaining the cattle in good condition until they are marketed during unfavorable seasons. (20)

1.3. Steppe grassland with an average annual rainfall of from 400 to 550mm where transhumant livestock-breeding is carried on in association with short cycle food crops (1, 19, 23)

The study of this type is more complicated in that certain types of fodder are used as the focus of sedentarization by breeders. Food crops and permanent herds limit the dry season fodder possibilities and are the reason for spectacular degradation of the grassland.

Research must then be complemented by: studies of the introduction, growth and utilization of short cycle fodder crops, creating fodder reserves at low cost.

- ethnological and socio-economic studies in order to elaborate a land-use plan in accord with the customs of the ethnic groups involved so that sedentarization is no longer synonymous with degradation.

2. Savannahs with predominantly annual grasses

These savannahs have an average annual rainfall of from 550 to 1000mm distributed over approximately four months, and their exploitation varies with the ethnic groups involved: strict livestock raisers, combined crop and livestock producers, crop producers with herds.

If the savannahs (14) are still exploited transhumantly by strict livestock breeders and sporadically by the herds of other types of group, pasture is made up primarily of fields used for dry season crops, lying fallow during the wet season, and fields for flood-crops during the dry season.

In order to appreciate the fodder-crop potential of a particular region, it becomes necessary to add the fallow-fields to the usable savannah. Their botanical composition and fodder-crop value will depend on the original vegetation and the local type of agriculture.

All these interdependent factors mean as many research themes and the synthesis of the observations and the probable evolution of agriculture furnishes the basis for a rational land-use plan in which the two types of peasant agriculture can harmoniously develop.

As the development of agriculture will undoubtedly pass through a stage of using animal traction (5, 13), the evaluation of natural fodder resources must be carried on alongwith research on dry cultivation fodder crops, hay and silage and with research on floodable crops, exploitable during the dry season as pasture (reserves where animals can be put to graze) or can be collected green and fed to animals.

3. Savannahs with predominantly perennial grasses.

These savannahs have an average annual rainfall of 900-1500mm, distributed over a period of six months in one cycle or even two not highly distinct cycles.

Cattle breeding is very localized, a few farmers have herds and there are nomadic breeders in particular areas, free from trypanosomiasis (the high plateaus).

Studies of the land will include:

- a botanical inventory;
- the relative seasonal palatability;
- the development of the vegetation cover due to grazing and various stocking rates;
- fodder-crop potential of various stages of evolution and perfection of exploitation techniques capable of maintaining an optimal fodder potential;
- perfecting of regeneration and upgrading techniques for depleted land.

This type of research (2,3,4,22) has high priority for traditional livestock-breeding regions and in under-populated regions favorable to the creation of large livestock-breeding establishments (6).

The development of farming with draft animals and the real possibilities for intensifying livestock-breeding in this zone mean that research on dry and wet fodder-crops must be actively pursued. (11, 12, 16, 17)

4. Dense forest

In dense forest zones, that are constantly hot and humid, certain savannahs can be used for extensive livestock-breeding as well as the vegetation of oil-palm and coconut plantations, but research will be primarily concerned with types of crops and the use of adapted fodder-crops.

CONCLUSION

Research on tropical pastureland conceived in terms of differentiation of the possibilities and problems of the large intertropical zones (defined by climate and vegetation) should make it possible to quickly synthesize the results obtained (9) in a manner readily usable by the various interested governments.

Proposals and recommendations

1. It would be worthwhile if the research integrated for rational land-use planning were to include a study on the pastoral potential of the region and its interaction with the various peasant activities in the area.

2. As meat and milk needs of the tropical countries must be met as soon as possible at the lowest possible cost, it would be worthwhile to set up an international "grassland" research program in order to coordinate the research undertaken in the homologous phytoclimatic zones; this research should be oriented towards production marketable locally.

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PRIORITIES IN ANIMAL PRODUCTION IN EAST AFRICA

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East Africa is a country of tremendous climatic and ecological extremes. Its altitude varies from zero at sea level to over 19,000 feet on top of Mount Kilimanjaro in Tanzania. The rainfall distribution is just as extreme, varying from less than 5 inches in some areas of Kenya and Uganda, to as high as 100 inches p.a. near Lake Victoria. There is thus in East Africa a bewildering variety of local conditions in two or three localities within a few miles of each other. The best example I know is around Mount Kenya. On the Northern slopes of this mountain the country passes from alpine at 17,000 feet, to tropical rain forests near Meru at about 6,000 feet; and from that to desert or nearly desert conditions in a distance of less than 100 miles northwards.

These kinds of varied local climatic and ecological zones present conditions which make it almost impossible to draw up a general agricultural plan that will satisfy even the majorities of areas in East Africa region. The limitations in generalization of planning will perhaps be more evident in crop farming but they equally apply, when extended to livestock development.

Like the climates the main characteristic of livestock industries in East Africa today is their extreme diversity. It is possible to find here traditional systems of animal husbandry which are among the most primitive in the world. On the other hand each country can boast of farms and ranches which are as well managed and productive as any in the world. Sometimes one can move from one extreme to the other in the course of only a few miles. So great a range of conditions would be expected in a region where climate, soils, vegetation, population densities, land tenure system, education, soil customs and wealth vary widely. Thus anyone who would like to plan livestock development on a regional basis finds the job very difficult and complex because the pattern that works well in one area may prove difficult, and sometimes a failure, in a different region.

At first sight it may appear necessary to treat each locality as a separate and distinct entity, with its own special problems and requirements. There may seem little if any relation, for example, between the development needs of the nomads like the Masai and the Karamojong on the one hand and the settled farmers like the Wachaga and the Wakikuyu on the other. In fact this was more or less the attitude in the past. Because of this attitude it is not surprising to find that the stimuli which have initiated the growth of livestock industries in East Africa have been the efforts of certain individuals, particular tribes, sometimes technicians or administrators, and occasionally enlightened politicians, who have urged with persuasive and persistent eloquence the merits of new stock routes, cattle markets, fencing, rural dairies, or

farmer training centres. Sometimes this kind of local and isolated stimulus has met with success, but unfortunately, more often than not with failure.

It is my conviction that we in East Africa, can no longer afford to leave livestock development to chance circumstances which can neither be controlled nor forecast. There must be planned development and concentration of effort in certain areas which are of crucial importance now. There are two reasons for my conviction.

In the first instance I find East Africa like many other parts of Africa, is well endowed with a wonderful potential for livestock development. A good percentage of East Africa area is suitable for mixed farming. The majority of area, however, is only suitable for animal production. Whether certain areas could profitably be used in leaving it to wild animals or to domestic livestock or both, has still to be investigated and decided by the animal scientists and ecologists. As would be expected it is in the areas where mixed farming has been possible that most of the development has been concentrated. Not much has been done in the past to tap the vast potential of beef industry which has been proved to exist in the semi-arid areas of our country. The few exceptions to this statement have been promoted by a few individuals and groups who have persistently worked under conditions which are still unattractive, to say the least. Their experience is an asset to East Africa.

The second reason for my conviction that we must plan and give preferences to certain areas of our livestock development, is even more imperative. East Africa is still regarded as under-developed. It has just become independent, with financial resources hardly sufficient to meet even the essential services of education and health. Our people have low incomes and are hungry. They are likely to expect quick and good returns from any development plan into which their little and hard-earned currency is invested. Expenditure on any project and especially of research, must be carefully scrutinized and merits assessed.

With Governments struggling under budgetary difficulties, there is a likelihood of regarding research as a luxury. Fortunately East Africa has not yet fallen to this temptation. Perhaps I could illustrate my point if I quoted an excerpt from a speech on "Financing of Research" by one of our Ministers, the Honorable Mwai Kibaki, at the Conference on International Support for Research in East Africa, held at the then EACSO Headquarters in Nairobi on 20th to 21st February, 1964:

> "The combination of many demands and limited resources means that, of necessity, research tends to be concentrated on practical problems, in an endeavour to get results which can be applied quickly and give an early return. All the Governments put the greater part of their research effort into schemes which can be expected to increase production, particularly in the basic agricultural industry."

I have made the above remarks knowing too well that they may seem to contradict the principle and freedom of fundamental or academic research so much valued in universities. In the field of agricultural research and especially in the field of animal production which I know best, I see no conflict. I believe I have good reason for taking this line. Most of the problems that have been worked on by scientists in East Africa for the last 60 years have been unknown or little known to the scientific world of Europe and America. The problems are new, exciting and above all, challenging. A lot of basic research has had to be done before any practical solutions to the problems were found. Today the remaining problems in East Africa are still a challenge to livestock industry. They represent the hard core of problems that have been fully or partly solved within the last half century. Some will require fairly advanced type of technology. I am certain a lot of fundamental research has to be done to unravel the mysteries that have escaped us for the last 60 years. Furthermore experience has now shown that what is basic research today becomes applied research tomorrow.

The tackling of the major animal production problems in East Africa today demands the efforts of the best scientists. I feel it is essential for Universities to be involved in this battle. If we get an answer, our efforts will be well rewarded both mentally and very likely financially. Our services to the public will be openly recognized.

I have so far indicated in very general terms the potential, and the kind of problems, scientific as well as social, that face animal industry in East Africa. I would like now to turn my attention to the main purpose of my paper, i.e., priorities in animal production. I propose to tackle this subject by dividing it into two major sections. These are extension and research priorities.

EXTENSION SERVICE PRIORITIES:

It may seem odd that I am brave enough to introduce extension service as a priority in what is essentially a scientific meeting. To most scientists who tackle problems of applied research, extension service and research are complementary. In the first place, laboratory tests and results, no matter how promising they may be, remain locked up in files and journals unless there is a good extension service ready to pass them to the man who needs them most, i.e., the farmer. Secondly, because the majority of livestock producers in Africa have no agricultural training or experience—not even in general principles of farming—it is most essential that they be supported, especially for the first few years, by a large and efficient extension service.

It is the job of extension service to change the basic attitude of the farmers and especially the nomadic or semi-nomadic pastoralists, so that they will trust the proposed scientific methods of farming as progressive and desirable. They will have to be convinced that the new ways of livestock management suggested from the laboratory are likely to be better than the local and traditional ones. Even the more advanced

farmers who for example may have accepted the control of some animal diseases by vaccination as a matter of course will in the beginning require the services of extension workers before such farmers can manage to vaccinate on their own.

One can give a long list of various services that an extension worker must give to the farmer. It would be an impressive list but I have no intention of reciting it here. Let it suffice for me to say that extension workers are the salesmen for our research products to the farmer. They are our eyes in the field. They form an essential link between the livestock keeper and the researcher in the laboratory. The task they tackle is a difficult one and deserves encouragement, recognition and credit.

Perhaps I ought to say in passing that there is a need for the researcher and extension worker to frequently meet and frankly exchange views on the unforeseen problems that may arise in connection with their endeavours. In this connection, I have often wondered whether a small but high powered information service modelled on, but not necessarily identical to, the extension service departments in the Land Grant Colleges in America could not serve as well in our country. It seems to have paid good dividends in America. Let me warn you here that I am not advocating a wholesale adoption of extension methods which have been developed outside East Africa. I am aware that such a blind imitation could be disastrous.

Finally, in this all-important field of extension service, as well as research, the most important factor apart from finance which restricts a faster rate of development in animal industries throughout East Africa, is the shortage of trained manpower. This shortage of experienced personnel is to be found at every level including the farmer, the technicians, and the professionals. Although there is a big effort by the Governments and the University of East Africa to train these people, I wonder how soon it will be before we can catch up with the fast growing demand. The situation is even more hopeless when one considers the number of local scientists who would be available for high powered research.

RESEARCH PRIORITIES:

I would now like to turn my attention to the priorities in research. These are grouped for convenience sake, into animal husbandry and animal disease priorities. I say, for convenience, because animal husbandry and animal diseases are so closely interwoven in the field that it would be illogical to try to deal with them as separate entities.

Animal Husbandry Priorities

Let me from the start draw your attention to the fact that much has been accomplished in East Africa, both by experience and research, in the area of animal husbandry. Probably this statement applies to other parts of Africa as well.

What is required of extension agents in these circumstances is to help livestock keepers in interpreting and applying our present knowledge into practice. I must however warn against a false assumption that all the knowledge now needed by the extension service is available, and we need spend little or nothing on research in most areas of animal husbandry, until producers begin to catch up with our research workers. All that I am stating is that our limited manpower and finance should first be directed towards the problems in animal husbandry which are today known to be a limiting factor in livestock production. The two areas that I feel should have a priority are pasture management, reproductive efficiency and breeding.

While I see a great need to extend pasture research in both the higher as well as lower rainfall areas, I am of the opinion that there is a great need to concentrate our efforts more on the drier areas which have been neglected in the past. In this connection I note with satisfaction that the Governments of Kenya and Uganda are seeking external assistance in the development of beef cattle production and range management.

In the rangeland, the pasture research should concentrate on improving not only the quantity but also the quality of grasses. If this were done we probably would be able to reduce the number of acres required per animal. The safe carrying capacity of our arid regions is normally considered to vary between 15 to 20 acres per head of cattle. Perhaps I ought also to emphasize in passing that there is a great need to settle the conflicting interests which seem to exist between the domestic and game animals in rangeland. It is my conviction that the problem ought to be tackled scientifically and not sentimentally.

My next and last priority in animal husbandry is the study of reproductive efficiency. The animal most involved in this area is the cow. One of the most important limitations to the rapid expansion of the dairy and beef industries throughout East Africa is the shortage of good stock. Each Government in East Africa is planning to develop the beef industry potential in the drier areas as rapidly as possible. Thus ranching schemes are proposed, for example in central and southern regions of Tanzania, the Ankole Kingdom and Acholi, Teso and Lango Districts of Uganda. Several areas in the Coastal Province of Kenya are also expecting to have ranches. The dairy industry is also expanding at a terrific rate in Tanzania and Uganda. Kenya is also trying to save every dairy calf born to maintain her national herd that has been dwindling within the last few years. In all, one sees a great demand for both dairy and beef stock in East Africa. For this reason everything should be done during the next five to ten years to increase stock physiological, pathological as well as environmental factors which may be limiting the breeding efficiencies of cattle. Sheep and goats should probably be included in this study.

The main question is: Why is the calving interval so long? The period of about a year is normally acceptable between one calf and the next from the same dam. Many farmers in East Africa are having to face uneconomic calving interval of two years and even more! Researchers

ought to give an urgent consideration to this problem. The problem of achieving maximum conception rates with artificial insemination also requires immediate attention. The best methods of rearing young stock must be found to minimize their mortalities.

While breeding of animals is normally a tedious and a long process, there is a great need in East Africa for a coherent breeding policy. This policy should aim at producing animals suited to our climates and farming conditions.

Animal Diseases Priorities:

I would now like to deal with my final priorities in animal production. These priorities are in the area of animal diseases.

The past history of animal disease control and research in East Africa is relatively encouraging. It is dotted with noteworthy achievements. Thus we record with satisfaction that rinderpest, African swine fever, anthrax and black-water which decimated livestock numbers at the early part of the century have now been put under control. With exception of African swine fever, East Africa can now afford to boast of having reliable biological products to prevent these diseases from spreading, if and when they occur.

Despite the above record, one finds in East Africa a number of major diseases whose effective control or curative measures have escaped the scientists. Among these diseases four are directly of great economic significance to East Africa. They should be given priority in research with a hope of putting them under control or where possible eliminating them. The four diseases are East Coast Fever, Food and Mouth Disease, Trypanosomiasis and Contagious Bovine Pleuropneumonia. Each condition is dealt with briefly below:

East Coast Fever - This disease is caused by a protozoan parasite Theileriparva. Transmission from cattle to cattle is by a tick (Rhipicephalus appendiculatus). Although research has been done on this disease for more than half a century, the life cycle of this parasite in both cattle and the tick is not well known. Considerable success in control has been achieved with acaricides aimed at the vector. Control by this method however is not easy and is fraught with all kinds of difficulties and frequent failure. This disease is probably the most killing disease of cattle in East Africa today. The few animals that recover become immune.

It is hoped that fundamental research into the life cycle and immunology of this disease will probably lead us to an effective measure of control against this deadly disease.

Trypanosomiasis - There are several species of the parasite involved in this disease. Some, as is well known, affect animals while others are in humans. A recent finding in East Africa that cattle can harbor the human parasite without themselves being sick, has made this parasite more significant in the field of public health. The disease could be a killer

unless treated with specific drugs. Unfortunately the parasite can become drug resistant.

Trypanosomiasis occurs enzootically in all areas of tse-tse fly infestation, which amounts to nearly a third of the entire continent of Africa. In East Africa, Tanzania is rather badly affected. Permanent animal husbandry is difficult, if not impossible, in areas affected by tse-tse flies. With increasing human population and consequent food requirements, there is an obvious need to control this disease and its vector so that more land can be brought under animal and crop production.

Support of research is needed in two areas. The first attack should be intensified towards the vector control. In addition to the past methods that have been used against the vector, I think there is a case for trying radiosterilization of tse-tse flies as a means of control in East Africa. The second approach I feel should be towards immunology which might eventually lead us to a vaccine production against this disease.

Foot and Mouth Disease - This is a viral infection which occurs almost everywhere in East Africa. Although it is not a killing malady, and hence less spectacular than the two previous diseases, nevertheless, it is of great economic importance to us because it is an impediment to international trade in livestock products.

There are three main types of this disease affecting livestock in East Africa. All of them can be controlled by specific vaccines whose immunity is unfortunately of short duration. All these vaccines are imported and are too expensive for most of our farmers. All efforts in research on this disease should be aimed at producing a cheap, potent and preferably multivalent vaccine.

Contagious Bovine Pleuropneumonia - This disease is caused by Mycoplasma mycoides. Like Foot and Mouth Disease it is important because it affects our trade of animal and animal products. The more advanced and wealthy nations have managed to eliminate the disease from their countries.

In East Africa a considerable measure of success has been achieved in its control. Departments of veterinary services in East Africa have managed to contain this disease into several small areas. One is in Masailand on both sides of the border between Kenya and Tanzania. Another is in the north on either side of the border between Kenya and Uganda. Because of the small area of distribution of this disease in East Africa we have now a chance of eliminating it. Before we are able to do this I feel more research work must be done to elucidate the mode of infection and spread. We also need to perfect our diagnostic techniques. Lastly, research to test the efficiency and to improve our present vaccine should be done intensively.

EVALUATION OF CATTLE BREEDING IN THE SAHELIAN ZONE OF WEST AFRICA

J. Libeau, I.E.M.V.T.

SUMMARY

Although situated in an area considered "unfavorable for animal husbandry," the sahelian countries of West Africa should nevertheless be considered for exploitation of their livestock, their major resource.

The climate is the most important limiting factor, especially because of its effect on the plants on which the animals live.

The zebu cattle, particularly well adapted to heat and drought, suffer most during four or five months each year from shortage of food during which they lose a large part of the weight gained during the favorable period.

Moreover, with their resistance lowered by these privations deriving from mineral and nutritional deficiences, the animals are very susceptible to contagious, parasitic and metabolic diseases.

The direct effects of nutritional deficiences are exhibited particularly by osteoporosis, growth retardation, hormonal derangement, and sterility. Pica due to these deficiences in certain areas has caused endemic botulism.

The National Laboratory of Animal Husbandry in Senegal, which has worked on the consequences of nutritional deficiences, has been able to outline the difficulties likely to be encountered in the field when trying to apply theoretical knowledge on the subject of improvement of the dietary conditions of the animal.

For this reason, before disseminating any information, it is proposed to carry out an investigation on the composition of the herds of the zone in question and on incentives for the breeders, as well as studies of a rational diet for the area. This investigation and study, conducted by scientists at the Laboratory, will enable them to recommend only the most applicable and effective methods.

Nutritional studies in the field will utilize only local products. They should ascertain whether the expense incurred by the farmers obtaining supplements would yield additional profit because of weight increase of the animals, lower mortality rate, satisfactory birth rate, and the possibilities of commercialization less dependent on climatic factors.

This investigation and these studies in the field will allow the various offices of the Laboratory (zootechnical, agrostological, physiological, chemical) to be constantly in direct contact with the breeders and to change the direction of research at any moment.

The title of this research is "control of mineral deficiencies, study of nutritional problems, and improvement of the zebu Gobra". This work is already underway; it has only just reached the stage of field application.

LIMITING FACTORS

Although the exploitation of domestic animals constitutes one of the principal economic resources of the populations of the countries of West Africa, nevertheless these territories are all designated "unfavorable for husbandry" because of numerous limiting factors, which are here grouped under three headings.

The climate which is the most important because it affects the others, acts directly on the animal and indirectly by its effect on the environment.

The sahelian climate which concerns us here is characterized by:

a/ the constant heat, which nevertheless exhibits radical variation between day and night.

b/ the extremely low relative humidity during the dry season (November to July).

c/ low rainfall (300 to 700 mm. along the isohyet).

d/ a rainy season of two or three months

e/ irregularity of the rainfall during each rainy season and from year to year

The zebu, the only type of cattle encountered in this area, is well suited to the climate, but it goes without saying its production capabilities have been severly affected by it, since, over the years, its natural selection has been toward developing resistance to the climate to the detriment of other qualities.

The natural grassland in these territories being annual and almost the sole food source for the cattle, it is possible to understand the importance the climatic conditions and particularly the rainy season have on maintenance of the animal.

The nutritive value of the grassland is continually changing and is strictly influenced by the abundance and distribution of rainfall.

The grassland, composed principally of annual grasses, has a very short vegetative cycle often no longer than two months. The nutritive value reaches a maximum at the end of the rainy season (September-October) then, with the rain stopped, in several days the grasses have withered and become straw. For several months

(November to February), the abundance of this straw, together with several plants still growing (Zornia, Tephrosia, Indigofera, Cassia) found in it, keeps the animal in good health, especially if the rains have been plentiful and well distributed.

At the beginning of February, with the increase in temperature often accompanied by hot, dry winds, the stems lose their last leaves. The other plants also wither and become too tough for consumption. Only the largest inedible stems still stand, the delicate parts of the plants are smashed imbedded in the soil or mixed with sand. Then begins for the animals the period of scarcity which last until August.

During these five months of deprivation, not only does the animal look for food which becomes more and more scarce, but it also suffers from great heat and long forages for occasional and insufficient water.

A limiting factor for the adults, the climate is even worse for the young. Since the unfavorable conditons cause the cows' milk to dry up the calves incapable of following the herd and eating the coarse grasses are the first victims of malnutrition, parasites and contagious diseases. Investigations made in the sahelian zone estimate that the mortality rate of young animals under two years is 50%, 40% of those during the first year.

Some observers believe that there is a relationship between the abundance and distribution of rainfall and the birth rate, birth weight, and mortality of the young, most especially in the years of greatest deficiency.

Having barely passably reached two years of age, the animals suffer all their lives from periodic deprivation during which they lose a large part of their weight gained in the favorable period.

This malnutriton is found in cattle raised by both herdsman and arable farmers. It is accentuated when the animals are concentrated around wells and water-holes. On the other hand, its effects are less severe when the herders change grazing land in search of better pasturage.

Disease

The second factor limiting livestock production in the sahelian zone, disease, is also plainly influenced by the climate. If certain diseases are able to bring about a large mortality rate, it is often because the animal's resistance is lowered by the climate. However, control of the many deadly organisms has been very effective, particularly during the last twenty years. The constant use of vaccines has evidently reduced the number of breeding places and the mortality rate. This is especially true of rinder pest, contagious bovine pleuropneumonia, anthrax, and pasteurellosis.

Other diseases, particularly parsitic diseases, are still very deadly to the least resistant animals, because of the difficulties of effective prophylaxis at the farm level, although the methods of treatment are known(trypanosomiasis and intestinal parasites).

In addition to the contagious and parasitic diseases, nutritional deficiences occur, chiefly evident in livestock which do not change their grazing areas. The direct effects of nutritional deficiencies are osteomalacia, retardation of growth, hormonal derangements, sterility and its indirect effects, and botulism caused by the animals eating infected carcasses.

The human factor

Finally, the third limiting factor is the cultural tradition of the livestock producers themselves. Their poor technical ability is a considerable obstacle to improvement. In addition extension of more economic methods of husbandry clash with traditions and existing systems of land tenure. In numerous cases, the equilibrium which had been established between the hostile environment and the migrating herds was recently upset by settlement of the herds around wells or deep water-holes. The now sedentary herds, no longer content with poor pasturage, should be managed with different methods; failing this, a qualitative and quantitative regression of the herds is hastened.

Progress can only be made through extension agents, living under the same conditions as the farmer, working not only through advice but by example.

Otherwise, the organisation of economic livestock production crowded with retailers, is unfavorable to the breeders who, because of poor yields, receive little profit on their sales.

EXAMPLES OF NUTRITIONAL DEFICIENCIES FOUND IN SENEGAL

In order to illustrate the previous point, there are occurences which have happened in Senegal during the past few years concerning a disease which seems to be new and for which the National Laboratory of Animal Husbandry at Dakar had to determine the cause and recommend methods of control.

At one time, the vast plain of Ferlo, situated south of the bend of the Senegal River, was uninhabited for most of the year.

In the rainy season the formation of temporary ponds provided the migrating herds excellent grass which also reconstituted the coarse sand soil.

When these ponds dried up, the herds moved toward the permanent rivers and abandoned under grazed grassland which was then destroyed by bush fires.

At the end of 1950, thanks to establishment of a network of deep water-holes, the livestock raisers are permanently settled there. A great many tribes and herds of animals occupy the land.

The grassland suffers more each year from over-grazing and trampling. The cattle trails become barren. The bush fires, unable to spread over the plains, no longer destroys the brush which is overrunning the grassland.

Little by little, the area of useable grassland is reduced and progressive signs of dietary deficiency and imbalance appear among the herds.

No longer prevented by the variety of food and salt cures which transhumance provided, mineral deficiencies become established, immediately causing a variety of conditions including death of the animals.

The symptoms are identical to those described in 1920 by Theiler, under the name of Lamsieke in South Africa. Analogous afflictions are encountered at the present time in Australia, New Zealand and Louisiana.

In 1962 the National Laboratory of Animal Husbandry and Veterinary Research at Dakar asked the Rural Economic Ministry of Senegal research on these problems be undertaken under the deliberately imprecise term of "bore-hole disease" or "Ferlo disease".

Research already carried out has been able to define that the disease originates in deficiences, principally of phosphorus. This particular deficiency is responsible for pica, osteophagy, and necrophagy observed in the animals, which leads to a secondary toxemia caused by Clostridium botulinum type C.

In 1966 the Office of Bacteriology developed an effective antitoxin vaccine and produces enough vaccine for the manufacture of more than 200, 000 doses.

Vaccinations made in the field establish 100% effectiveness of the vaccine by eliminating mortality in the inoculated herds.

During the rainy season of 1967, 57, 500 vaccinations were performed by the Animal Health Service.

The Office of Physiology, carried out research on mineral deficiencies, developed supplementary formulas by salt licks and supplements with which experimentation was made in the field. It concluded that these forms of supplementation are effective and that herds using them remained immune, whereas numerous losses occurred in adjacent herds.

Studies on mineral deficiencies and nutrition pursued at the Laboratory as well as observations made during field trips showed

that the animals suffered not only a mineral imbalance but a qualitative and quantitative dietary deficiency.

It is apparent that while it a simple matter to combat the most apparent pathological manifestations by application of vaccination and distribution of mineral supplements, it is a great deal more difficult to combat permanent malnutriton. Indeed, application of reasonable methods of feeding already used at the Laboratory and at the station are incapable of implementation in the field because of economic imperatives.

It is thus necessary to communicate to the people established to explore ways of applying them in the field, and to dispense with those which prove unprofitable, within the current economic situation in Senegal.

Certain methods such as mineral supplementation can be immediately introduced, necessitating no new experimentation, while formulas of rationing and supplementation using local products which have been developed at the Laboratory of Husbandry should be experimented with further in the field to ascertain whether the investment the farmers put into improvement of their animals will be economic.

For this reason, a project having for its reseach objective the economics of the operation designed to determine in what measure the known methods of breeding and feeding are applicable to the rural and agricultural environment, has been laid down under the title "Improvement of the cattle stock in Senegal by rational feeding."

PROGRAM OF IMPROVEMENT OF THE CATTLE HERDS

The project of improvement of the herds has as its objective to begin a long-term program of herd improvement which will complete work already in progress. Its principal role is to succeed with the breeder.

The primary work consists of:

a/ carrying out a precise investigation to determine both the composition of the herds of the type for which economists can establish estimates, and also to determine the variations of this composition. It will be concluded at the human level, to determine the incentives and needs of the breeders and to study the best ways to approach them.

b/ to study possible utilization in the rural and farm environment of feed rations developed at the Laboratory or the station, in order to:

1 - alleviate feed deficiencies during the dry season which bring about mineral and nitrogen deficiencies in all the herds.

2 - reduce the mortality rate and the retardation of the growth of young animals.

3 - promote a genuine integration of crop and livestock production. These supplementary rations in addition to grazing will be composed of locally available products such as, millet, sorghum, maize, bran, peanuts, pulp, molasses, fish flour, blood, residues from breweries and refineries, phosphates.

c/ establish an extension service to advise the farmer on how to use dietary rations, to better distribute his herds, to cull worthless stock, to use the stud bulls available at the research stations, to protect the grassland or fallow land at his disposal or to improve this fodder cultivation, and to establish feed reseaves.

d/ finally, in the final stages, to market the animals having an increased value more rapidly either directly or by the intermediary of feed lots or butcher shops situated near the slaughterhouses.

Seasonal fluctuations in the value of the carcasses marketed will be eliminated and thus provide to the breeder more substantial and regular profits.

THE ROLE OF VETERINARY RESEARCH IN THE PROGRAM OF LIVESTOCK PRODUCTION IMPROVEMENT

The research now in progress at the Laboratory of Animal Husbandry at Dakar and at the Center for Zootechnical Research at Dara are concerned with finding solutions to the problems raised by the above plans. They include:

- controlling mineral deficiencies
- study of nutritional problems
- selection of the Senegalese zebu known as the "zebu Gobra".

1) Mineral Deficiencies

Mineral deficiencies and their pathological complications constitute the most serious obstacle to growth and to improvement of the herds living in the Senegalese sahel. Research in progress on this area leads to:

- recommendation of a method of mineral supplementation for the herds.
- determination of the nature of deficiencies apparently involving elements other than phosphorous.
- research studying the mineral composition of the hair as a sign of the calcium and phosphate metabolism, other than phosphoremia and calcemia.

a/ Pre-extension studies of mineral supplementation in the deficient areas.

Various solutions have been proposed: the addition of soluble phosphates for assimilation in the water at watering places; making available the breeders rock licks or powdered phosphates for addition to peanut cake. Financial considerations limit the widespread use methods of prophylaxis.

b/ Study of multiple deficiencies in certain livestock producing areas of Senegal.

Research now in progress intends to extend the investigations geographically that until now have been limited by the small number of bore-holes, and to determine the nature of other contingent deficiencies (Na, K, Fe, Cu, Zn, Mn, Mg, Mo, Co) to compare the results obtained in the Ferlo with those from the zone of highest rainfall (Soudanian or sub-guinean) free from deficiencies (Casamance).

The research programs are of the following types:

- biochemical, to analyze the blood of animals from the areas in question,
- chemical, through levels determined on a representative sample of the edible species of vegetation and on the drinking water.

c/ Calcium-phosphate metabolism and percentage of phosphate and calcium in the hair of tropical cattle

This program hearing completion has as its objective, to discover whether, in the tropical environment as in the temperate zones, there exists a significant relationship between the percentage of mineral elements in the hair and the mineral metabolism. If this yields positive results, the observation of the herds in the deficient areas will be greatly facilitated.

Moreover, this method will clarify the effect of mineral supplementation.

2) Study of Nutritional Problems

The preceding discussion has not taken into account the importance of nutritional problems in different types of husbandry.

For transhumance, the difficulties and their solutions are essentially in the area of agrostology. Important work has been done on the composition of the grassland types and to determine the nutritive value for each type by stocking-rate studies. Substituting a rational method of animal production for the traditional methods leading to better use of the grasslands is necessary for their

protection and eventual improvement.

The recently developed methods of production which involve ranching, milk production, or draft animals, it is most important to continue basic nutritional studies taking into account the probable physiological characteristics of local cattle, as well as the particular nature of feed available for their use.

Programs at the Laboratory of Dakar in this area are:

1) for the first time, determination of nutritive value of the feedstuffs and ration compilation, taking into account digestibility coefficients obtained by experimentation.

2) then, determination of the needs of the animals. This research necessitates study of the methods of utilization of cellulose, glucosides, nitrogen, etc. by the animal.

3) study of the method of supplementation of the main types of available fodder.

3) Selection of the zebu Gobra

The work undertaken at the Center for Zootechnical Research at Dara has a two-fold plan for the zebu Gobra; selection of animals, valuable breeding stock, for distribution among the farmers, and along with a correct level of nutrition, in order to bring out the potentialities of the stock.

Cross-breeding at the station of the Pakistani zebu with the zebu Gobra gives the latter the milk-producing genes which it lacks.

RESEARCH ORGANIZATIONS IN ANIMAL PRODUCTION AND HEALTH IN SENEGAL

IEMVT

SUMMARY

The objectives of the Government of Senegal in the field of animal production are defined in its national plan of development thus:

- to increase and improve livestock;
- to satisfy the needs of rural and urban populations for meat and milk products;
- to supply agriculture with the necessary draft animals for its expansion and particularly the extension of animal traction in cultivation;
- to promote rational exploitation of the products of animal husbandry and to encourage the exportation of fresh and canned meat.

In order to accomplish these objectives, the following research programs in the area of animal production and health are pursued:

1 - Intensification of the campaign against the diseases which constitute a constant danger to the herds and decrease their economic value,

2 - Biological and physiological study of the animal in its subtropical environment,

3 - Improvement of the rural environment,

4 - Improvement of the cattle herds by selection and cross-breeding to increase meat and milk production,

5 - Study of maintenance requirements of the animals in the farming system.

Research on animal production and veterinary medicine is based in two institutions:

- the National Laboratory of Animal Husbandry and Veterinary Research at Dakar-Hann;

- the Center for Zoological Research at Dara, comprised of two divisions: one largely devoted to research, the other to production and extension.

These are the two national institutions of research under the auspices of the Ministry of Rural Economy in Senegal. By virtue of agreements of cooperation made between France and Senegal, they are administrated by the Institute of Animal Husbandry and Veterinary Medicine of the Tropical Countries (I.E.M.V.T.) which is located in Maisons-Alfort (Val de Marne) and insures execution of the programs of research at these two institutions.

A - National Laboratory of Animal Husbandry and Veterinary Research at Dakar-Hann

This institution, of federal nature from its inception in 1950, became a Senegalese institution in 1960. Its administration is entrusted to the Institute of Animal Husbandry and Veterinary Medicine of the Tropical Countries which set up regional management to ensure administration and coordination.

The responsibility of the Laboratory is two-fold:

- manufacture of vaccines and biological preparations, and diagnostic services. By 1966, this manufacture had reached 17,000,000 doses of different vaccines intended for various States of West Africa.

- research in the fields of pathology, physiology, food and nutrition, and agrostology.

The Laboratory extends over six hectares and consists of the following offices:

Management - administrative and library services
Virology
Bacteriology and Histopathology
Avian pathology
Physiopathology - Biochemistry and food chemistry
Parasitology (Helminthology, Entomology, Protozoology)
Agrostology, Zootechnology

Beyond that, the Laboratory operates numerous experimental facilities for breeding of laboratory animals and auxiliary services (workshops, garages, etc.) and an experimental farm 38 kilometers from Dakar.

The personnel numbers 20 research scientists, specialist veterinarians, pharmacists, chemists and graduate scientists, and 120 technicians and junior staff.

B - Center for Zootechnical Research at Dara-Djoloff

This institution, whose research section is under the management of I.E.M.V.T., is responsible for all problems of selection and cross-breeding of local breeds to improve their meat and milk production.

It is directed by a veterinary trained zootechnologist. Its personnel is composed of technicians, assistants, and production personnel.

CURRENT RESEARCH PROGRAMS

Established at the request of the Government of Senegal, the programs are reviewed and endorsed by the Committee on Scientific and Technical Research of Senegal in the framework of the national development plan.

I - Dakar-Hann Laboratory

1 - Virology

a - Rinderpest

- Improvement of rapid diagnostic methods to make their use more practical
- Improvement of methods of vaccination for better manufacture and conservation of the vaccines
- Verification of immunity
- Decontamination of infested meat for exportation

b - Pest of small ruminants

- Study of the susceptibility of the small ruminants
- Study of physicochemical and biological properties of the virus

c - African Horse Sickness

- Development and manufacture of a large amount of live vaccine by tissue culture and of inactive vaccine
- Study of existing diagnostic techniques and development of new methods
- Study of the biology of the virus and research on serological types existing in Senegal

d - Pneumopathologies of the small ruminants

Insufficient work has been done in Senegal. These diseases have been diagnosed. Consequently, research concerning them is necessary because of lack of information on their economic effect and their importance to Senegal.

2 - Bacteriology

a - Bovine pleuropneumonia (CBPP)

- Development of a lyophilized mixed CBPP-rinderpest vaccine and verification of the vaccine's immunization effectiveness against CBPP by the method of testing with cannulaed cattle
- Research and verification of the value of diagnostic methods

b - Streptothricosis

- Studies to isolate the causal agent
- Factors involved in desensitization
- Study of three new treatments or prophylactic methods

c - Brucellosis

- Improvement of diagnostic methods and manufacture of vaccines

d - Botulism

- Preparation of botulism antitoxin
- Research on the circulatory toxins and their effects

e - Tuberculosis and nocardiosis of cattle

- Research into various diagnostic methods
- Isolation and experimentation with cultures
- Studies with experimental reproduction of the disease

f - Avian pathology

- Improvement of diagnostic and vaccination methods for bacillary white diarrhea, salmonellosis, fowl typhoid, etc.

g - Analysis, diagnostic study, and control of foodstuffs

3 - Parasitology

a - Helminthology

- A chart outlining the principal helminth diseases in Senegal
- Epidemiological investigation, study of life-cycles and intermediary hosts and a control of these afflictions
- Distomatosis, bilharzia, trichinosis, ocular filariasis

b - Cattle rickettsia

- Research in its etiology, treatment and prophylaxis

c - Piroplasmosis and anaplasmosis

- Treatment, prevention and atiopathogenisis

d - Trypanosomiasis and glossina

- Epizootology of trypanosomiasis and distribution of glossina
- Study of insecticide and biological treatments
- System classification and biology of the trypanosomas

e - Coccidiosis of the large and small ruminants

- Epizootology, treatment and prophylaxis

4 - Physiology, physiopathology, biochemistry

This research relates to the study of the animal in its tropical environment.

a - Metabolism of the water in cattle

- Influence of climatic and genetic factors on the distribution of water in the organism

- Study of the influence of dehydration and time of watering on the behavior of the animals

b - Feed and cattle nutrition

- Determination of the chemical and biological value of the available pasturage in Senegal and its capacity for fulfilling the animal's requirements
- Study of its utilization by the animal
- Establishment of dietary supplements to assure the primary services of the animal; meat, milk, and work

c - Study of multiple deficiencies

- Study of the elements in multiple deficiencies responsible for the observed nutritional syndromes
- Establishment of mineral supplements to cure these disorders
- Study and evaluation of phosphate and calcium metabolism

d - Aflatoxin

- Study of the toxicity of aflatoxin and its effect on the various animal products

5 - Agrostology

a - Charting the grasslands in Senegal

- Study and inventory of the grasslands in the various regions of Senegal: work accomplished by agreements

b - Management and improvement of natural grassland

- Research into the best method of exploitation of natural grassland for study of the influence of yield, crop rotation, mowing, and bush fires
- Study of improvement through introduction of perennial plant species
- Studies of forage crop production

c - Study of the dietary value of local feedstuffs

This study should result in the establishment of balanced diets, adapted to the various animal uses, using local feedstuffs.

- Study of the digestibility of both natural and cultivated hay and straw
- Digestibility of the products and by-products of food and industrial crop production
- Establishment and experimentation with rations.

II - Center for Zootechnical Research at Dara

1 - Improvement of meat production : selection of the Zebu Gobra

- Study with crossing and yield in the zabu gobra
- Continuing selection for improvement of its slaughtering qualities
- Distribution of improved C.R.Z. stock with registration of the offspring

2 - Improvement of milk production

- Development by cross-breeding of stock suitably adapted to Senegal with good milk production
- Cross-breeding the native gobra with imported breads, such as those from Pakistan (Red Sindhi and Sahiwal) and Brazil (Guzara)
- Studies of cross-breeding, and of product increase due to cross-breeding after one generation
- Research into the generation giving the best results
- Extension

3 - Improvement of horses

- Improvement of the local horse by artificial insemination with imported strains
- Development of dilution media with good viability and ready use of fertile sperm

4 - Brown Maradi Goats

- Establishment of large center for production of goats with a high percentage of Maradi blood
- Definition of the best method of cross-breeding and the amount of Maradi blood compatible with local conditions in order to preserve the improved quality of the hides

5 - Study of the use of by-products of food production in the diet of the cattle under extensive systems and in the combination of arable and livestock farming

POSSIBLE EXTENSIONS OF THE PROGRAMS

The financing of the research programs in the two institutions is equally shared, under general research agreements, by the governments of Senegal and France. Defrayment of the cost of special equipment is provided by special loans.

The annual increase of these loans corresponding to tax on annual growth allowed by the financial organizations is approximately 6%, sometimes hampering the extension and augmentation of research programs. The programs elaborated in the quadrennial plan are reviewed annually, according to the results obtained during the preceding year in the various areas of research.

If it is possible to pursue and study certain research areas in depth, it is often difficult to enlarge and introduce new subjects, very often of a regional nature. Foreign aid is solicited, and these programs are carried out outside the agreements.

Among the new undertakings and extensions of existing research programs in Senegal's Second National Development Plan in annual production and health, certain studies have been completed or are in course of completion, such as a study on the occurence and distribution of rinderpest virus in slaughtered animals. Others, on the other hand, have been discontinued due to lack of funds; the delay increases in proportion to the size of the estimates. This is the case for:

- microbiology

Bovine pleuropneumonia : new methods of identifying chronic animal carriers and recently infected animals, choice of a vaccine and methods of prophylaxis.

- virology

Research using tissue culture methods to broaden knowledge and improve vaccine production.

- parasitology

Cattle thelaziosis or ocular filariosis : newly discovered parasitic diseases with great economic effect (10 to 20% mortality in the young animals), study on the nature and biology of its vectors in general and of means of prophylaxis : intermediary hosts, biology of the larva, evolutionary cycle, decontamination and prophylaxis of the disease.

- physiology and physiopathology

Study of the behavior of imported strains of high meat and milk producing cattle in the tropics with a view to cross-breeding with local cattle

Calcium and metabolism using radio-isotopes

Study of multiple deficiencies of the sahel and Sudano-sahel regions (extension into other areas of studies made in Senegal, in the Ferlo).

- agrostology

Extending the mapping of natural grassland throughout Senegal

Studies in depth and of broad scope of the nutritive value of the various tropical products and by-products capable of introduction into the animal's diet.

- breeding and improvement

Programs introducing new high producing breeds and the study of their behavior in cooperation with the physiological service.

Extension of conclusions and methods of selection derived from research, which would necessitate additional funds and personnel.

Development and extension of the research center at Kolda, homologous with the center at Dara, but devoted to study and improvement of the N'Dama cattle.

In the framework of the program for development of milk production in Senegal, the establishment of an experimental facility for intensive production.

In large part, these subjects of research are of general interest, especially in the area of pathology. To cite them:

Rinderpest
Bovine pleuropneumonia
Streptothricosis
Pest of the small ruminants
African horse sickness
Deficiency diseases in the sahelian zones
Studies on the metabolism of water and on the digestibility of fodder by tropical cattle
Helminth diseases

Research projects of local interest are the following:

Botulism
Interotoxemia
Tsetse flies and trypanosomiasis in Senegal
Listing and improvement of grasslands
Selection of the zabu gobra and improved cross-bred stock

Research programs for registration and improvement of the herds in Senegal, listed by discipline and order of importance, should be comprised of:

Pathology

a - Bovine pleuropneumonia (CBPP) - Studies on diagnostic methods and research for stable vaccine.

b - Rinderpest - Pursuit of research in improvement of vaccination methods (stability of vaciines) and research on the preparation of a mixed lyophilized vaccine against rinderpest and CBPP

c - Pest of small ruminants and allied diseases

d - Streptothricosis

e - Control of trypanosomiasis

f - Ocular filariosis of cattle - epidemiology and prophylaxis

Physiopathology and Nutrition

Study of nutritional problems in the sahelian zone. Calcium and phosphate metabolism in tropical cattle

Breeding and Meat Production

Improvement of the slaughter quality of the local breed by selection and cross-breeding;
Widening observations and conclusions in the animal producing areas;
Extension of these methods.

Milk Production

Improvement by selection and cross-breeding of the zebu gobra with humpless N'Dama cattle.

Introduction of species with better production, maintained as pure stock in favorable zones. Studies of acclimatization and nutrition, using locally available agricultural by-products in an experimental milk farm.

Agrostology - Nutrition

Pursuit of studies on the nutritional value of tropical products and by-products in the diet of the animal and formulation of rations.

Extension throughout Senegal of charting of the grassland to ensure its conservation, improvement, and especially, in the near future, better utilization.

STUDY AND SELECTION OF THE SENEGALESE FULANI ZEBU CATTLE (GOBRA)

J.P. Denis,
Zootechnical Research Center, Dara Djoloff

J. Valenza,
I.E.M.V.T., Dakar

SUMMARY

At the Zootechnical Research Center at Djoloff, located at the Sudano-sahel zone, the research program comprises:

- selection of the Fulani zebu 'Gobra" for its slaughtering characteristics

- cross-breeding of the Gobra zebu with the imported zebu (from Pakistan and Guzera) to develop milk-giving properties.

The extensive system of animal production in the forested zone is deliberately applied at the station with the adult animals. Only the young receive, until weaning, an occasional dietary supplement. This method enables conservation of the hardiness of the animals in the course of the selection, and of the precise criteria of selection in local conditions.

Annual variation in rainfall, concentrated during three months of the year, brings with it qualitative and quantitative variation in pasturage, which is essentially composed of annual species.

The Center devotes itself to isolating and improving the slaughtering qualities of certain stock for distribution. A herd of animals selected from the stock at the center is branded. Weights and measurements are made systematically and compared at intervals. The following characteristic ages are recorded: birth, ten weeks, 6, 12, 18 and 24 months.

The following results are documented:

I PERFORMANCES

I - 1: With the total group of animals

I - 1/1 - Birth weight has been recorded: from 1952 to 1962, the average weight of males was 19.99 ± 3.4. Since then there has been an increase:

20.99 ± 2.7 in 1963/64
24.16 ± 3.4 in 1965/66
26.91 ± 4.42 in 1967

The same increase is observed in females:

19.26 ± 2.71 in 1962
25.13 ± 5.95 in 1967.

The differences in weights are significant.

I - 1/2 - At ten weeks, and for the same years, the weights have not varied significantly, and the average is:

54.96 ± 11.3 for males
53.46 ± 8.9 for females

In contrast, for calves--born from selected cows--the weight at ten weeks is significantly different:

61.16 ± 9.48 for males
57.70 ± 10.35 for females

I - 1/3 - Since 1963, there has been an increase in the weights at six months:

For males: 94.6 ± 21.6 (1962)
and 99.8 ± 21.7 (1967)

For females 89.77 ± 24.0 (1962)
and 95.42 ± 14.2 (1967)

In 1962, weights of calves born from selected cows were:

125.40 ± 22.80 for the males and
117.47 ± 19.89 for the females

This was possible due to intensive dietary supplementation enabling realization of the animals' potential.

I - 1/4 - The weights at 12 months have increased since 1963 from:

122.80 ± 28.9 to 135.60 ± 30.5 for males and
115.48 ± 25 to 118.30 ± 20.80 for females.

I - 2 : <u>With the selected herd</u>

The selected herd is composed of:

- Cows chosen for:
  - -weight of their calves at 10 weeks and 6 months, above average, giving an idea of their lactation performance,
  - -butchering confirmation, and
  - -reproductive ability.

- Bulls chosen for:
  - -pedigree
  - -growth
  - -physical characteristics
  - -progeny testing

The cattle have been selected since 1956. The weights of the progeny have been the following:

	Birth		10 weeks		6 months		12 months	
Males	23.25	4.37	61.16	9.48	106.16	12.75	142.44	25.85
Females	22.28	4.10	57.70	10.35	98.38	19.34	132.32	20.13

I - 3: Individual Performances

The following data gives an idea of the quality of the Gobra zebus.

	Birth	10 weeks	6 months	12 months	18 mon.	24 months
Males	26	64	123	258	328	391
Females	22	64	130	156	218	254

II - RESEARCH ON CRITERIA OF MASS SELECTION

The criteria of selection applied by C.R.Z. at Dara should be implementable in the field. It essentially depends on study on weight of the animals at characteristic ages.

In the absence of scales, the study of various correlation between body measurements can give an approximation of the weight.

II - 1: Correlation of weight with chest circumference

There seems to be a positive and significant correlation at the selected areas, principally at 12 months ($r = 0.745$ for the males, $d_o = 133$).

II - 2: Correlation of weight at different areas

There is a positive and significant correlation essentially between the following ages: birth, 10 weeks; birth, 12 months; 10 weeks, 6 months; 6 months, 12 months.

III - INFLUENCE OF SEASON

The average weight at different ages is influenced by season. Weights at birth, 10 weeks and 6 months are significantly greater at the beginning of the dry season. At 12 months, the weight is superior during the first quarter.

These results point to the possibility of a season of ascendancy during the first four months of the year.

IV - CONCLUSIONS

These observations taken together should enable broad guidelines of selection to be established which are practical in the rural environment for the zebu Gobra in Senegal.

ANIMAL PRODUCTION ON PALM PLANTATIONS

P. Boyé, IRHO

SUMMARY

Animal production on palm plantations constitutes an interesting speculation in terms of agricultural, economic and social planing.

This report describes a herd of cattle on the Grand-Drewin plantation and describes the animal raising conditions there. This herd consists of purebred animals from the lagoons; it suffers from inbreeding but confirms the good rural characteristics of this race and its inbreeding adaptation to pasture under palm trees.

The profits from the sale of meat and milk and the production of ferilizer largely cover the expenditures involved.

This experiment confirms the importance of animal production in palm plantations and the large-scale development which can be achieved here within the framework of the oil palm plan which is now being implemented in Ivory Coast.

Animal production on palm plantations is a rather interesting speculation in agricultural, economic, and social terms.

Palm growing areas are not major livestock zones; meat production should be developed there but many factors must be taken into consideration if the herd of animals is to be managed with success.

Taking as an example the herd on the Grand-Drewin (Ivory Coast) experimental plantation, this operation illustrates the importance of this subsidiary activity, and may be used to describe the major factors.

The herd on the Grand-Drewin plantation is not a recent development; the plantation had about a score of animals in 1924, and at that time, this was the only herd in the region. Over the past 10 years, it has grown considerably.

The current cattle herd is composed of small-sized animals belonging to the so-called Lagoon breed; the hide is spotty black or spotty red.

The herd was expanded without any introduction of new blood, an something which of course does involve a number of inconveniences.

This Lagoon breed, which is strictly confined to the Lower Coast, combines great hardiness with rather insignificant milk output. It seems

rather well adapted to the palm plantation and to the shade which the trees provide; this is not true of the savannah breeds which prefer the open areas that get plenty of sunshine, particularly along the roadsides.

These animals have an average weight of about 130 kg, from which an average of 75 kg of meat, or 57%, can be obtained.

Growth

Tables I and II, show the development of the herd and its makeup between June 1961 and December 1966, as well as the vital statistics and data (births, deaths, and sales) over these 6 years.

TABLE I
COMPOSITION OF CATTLE HERD

Dates	Adults		Heifers	Yealing Bulls or Bullocks	Calves		Total
	♂	♀			♂	♀	
June '61	3	62	18	18	11	22	134
June '62	2	77	22	25	24	35	185
June '63	3	95	56	38	24	22	238
April '64	5	96	41	12	53	54	261
August '65	5	144	55	27	50	30	311
December '66	5	157	30	64	54	30	340

TABLE II
ANNUAL DATA

Year	Births	Deaths	Sales	Number of Animals at the end of the year
1961	64	5	11	163
1962	56	6	17	199
1963	96	19	24	252
1964	81	25	24	284
1965	91	8	25	342
1966	80	13	69	340
6 Years	468	76	170	

These two tables and the comparisons which can be made with them give a picture of the situation of this herd and its development.

Two remarks should be made: 1965 and 1966, the number of births was no longer related to the number of females of calving age. Apart from any occasional errors and on the basis of regular checks, this drop in the birth rate thus could come only from the herd itself since the increase took place when the herd was completely free and no abortions in the course of gestation were observed; the cause must therefore be found in a sterility factor due to excessive inbreeding.

In order to increase this growth rate, it would be necessary to obtain two or three breeding bulls coming from a very distant herd; but there is a great risk in the possibility of introducing brucellosis, which might cause heavy losses.

Although the breeding bulls themselves might not be sick, they might in effect be carriers of the disease and transmit it to the herd. This is the problem which has so far prevented introduction of breeding animals.

It is however certain that the renewal of the blood would also improve the development of the animals which is currently slowed down as a result of inbreeding.

It might be possible to obtain improvement by introducing Baoulé or N'Damas breeding bulls -- a rather interesting solution because there is a possibility of finding some very good looking beasts in the livestock service; this, however, would reduce the herd's natural resistance to trypanosomiasis.

Tables I and II likewise show the rather high mortality in 1963 and 1964; this was due to a shortage of straw during the rainy seasons of those two years; this produced a bad state of health which was particularly harmful to the young animals.

Losses due to mortality were 3% in 1961 and 1962, 7.5% in 1963, 8.7% in 1964, 2.3% in 1965, and 3.8% in 1966.

A number of animals died due to accidents (they choked on mango, development of tetanus due to cassava, highway accidents, or bunches of coconuts dropping on them from the tree tops.).

The sales figures in Table II pertain only to male animals between the ages of 2 and 2 1/2, earmarked for the slaughter house, except for in 1966, during which 40 heifers had to be given up in order to keep the herd at a level compatible with the existing support facilities and the pasture available during the rainy season.

We must point out that there was no increase in the weight with age like the drop in fertility, this may be a sign of degeneration due to inbreeding.

Conditions at this Ranch

The plantation has two cow sheds; the older one is near the refinery. Constructed of bricks and cement, with a concrete floor; it is 24 m long and 6 m wide. The height under the roof, in the middle of the building, is 3 m. At the end, there is a manure pit with a small liquid manure basin.

Ventilation is very good since the structure is open along the two long sides and at one end.

Water is supplied to a trough which the animals use only during the day.

This cow shed shelters an average of about 100 animals. A two-room concrete structure is connected to the shed, for the herdsmen.

A new cow shed was built in 1963 in the center of the plantation; it is surrounded by an enclosure which contains a 1/4 ha cattle pen. This building is 20 m x 7 m, with a concrete floor; the water is brought in each week by a tank truck. Plans call for the construction of a water of clear water just a short distance away (500 m); this source, however, does not offer much water during the dry season.

This facility currently has a small two-room house for the herdsmen. A pen was built in 1965 in one of the corners of the enclosure for the young bullocks and the yearling-calves which cannot be sheltered in the cow shed during the night; the surface is 130 square meters; plans call for this enclosure to be covered shortly. At the end of 1967, this second cow accommodated 236 animals.

There are five herdsmen; they are generally Fulanis. They milk the animals every morning and they take care of them; then they take the animals to the various sections of the plantation and they are also responsible for replacing the litter straw. Theoretically, they work every day of the month; in fact, those who are not assigned to taking the herd to the fields put in only 4 hours per day. These people are very hard to replace and they are very independent; but they are also very much attached to the herd and look after the animals to the best of their ability.

The straw supply and the removal of the manure are handled by teams from the plantation.

Health Checks and Surveillance

The head of cattle are counted every month and the ear of each calf newly born in the month is properly marked, with numbered plastic tags.

Every 5 or 6 months, depending on the season -- except of course when it rains -- the animals are branded on the thigh; these brands

remain quite visible in most cases; each animal is carried on a register and crossed off when it dies or is sold. Checkups are made regularly.

The Sassandra Animal Health Service regularly vaccinates the animals and the location along the seashore, with Lagoon breeds, means that there is very little mortality in adult animals, this is particularly true since 1966, when certain areas were planted to grass (panicum); as a result, the ranch now has the raw material necessary for keeping the cow sheds clean.

Fodder and Litter

Animal production at Grand-Drewin is typically extensive and the fodder for the animals is limited to what they can find on the palm plantation or in the young plots under a legume cover crop; the animals generally are driven out around 0930 and they come back to the pen around 1700 hours.

The herd moves rather wide and far over the plantation and covers 7-8 km each day, particularly at the end of the dry season, when fodder becomes rare as a result of the extreme drought. In this connection, it should be pointed out that Grand-Drewin is in a rather special micro-climate which is not representative of the southern part of Ivory Coast; the dry seasons here are long and very pronounced.

The grass which the animals consume during the wet season should not reveal deficiencies because the herd at that time is in a rather satisfactory condition and the meat is fat enough.

Two types of pastures are used here:

(a) Newly-grown pastures on natural palm plantation soil, of rather mediocre quality, if we judge this by the movement of the animals in search of grass that suits them, particularly the moment the dry season begins:

(b) the leguminous cover crop, in the young plantation area, consists of Centrosema and Pueraria.

This cover crop retreats very quickly at Grand-Drewin because the dry seasons are too long there.

In the most recent replantation areas, the cattle are able to find an abundance of high-quality nourishment.

The herds begin to damage the young palm trees the moment the drought becomes worse because these animals, especially the ones, have a tendency to eat the outside leaves of the plants.

At present, the development of the herd is actually limited by the amount of grazing available during the months between January and April.

When the quality and the quantity of the pastures decrease, the animals are given a supplementary fodder supply in the form of wheat bran mash.

Because the source of supply in this case is rather far away, the price of this flour is rather high, and furthermore, we do not know its real food value because the bran is mixed in with by-products.

The quantity consumed here is rather small, compared to the number of head of cattle. It is very difficult to say whether abundant supplementary nourishment would have any worthwhile economic effect on cattle as thrifty as this particular breed.

Per-Hectare Stocking Rate

According to the Animal Production Service, we should reckon on one 200-kg animal for every 2 hectare of palm plantation, which for the animals at Grand-Drewin, would be one animal per hectare or perhaps 1.3 hectares.

This evaluation however is quite theoretical; during the rainy season and during the 2 months afterward (from May to August and October to December), one Lagoon-breed animal, without any supplementary rations, can be supported on about 1.2 hectares, the situation is not the same during the dry season, when the animals have to look for fodder. 2.5 Hectares per animal should be allowed for grazing which also will have to be supplemented.

In regions where the rainfall volume is more normal, 75 kg/ha can be allowed without risk, or two Lagoon-breed animals on an area of three hectares.

In the new plantations, the optimum operation would be to the herd for 15 days in each block of 100 hectares, which has been rolled a month previously; indeed, it was found that the animals quite voluntarily seek out the rolled areas, where the shoots are rich in digestible water.

Straw and Litter

Since 1962, "Panicum maximum" (Guinea grass) has been grown there on a field kindly donated by the Gagnoa agricultural farm.

The area currently cultivated is about 6 hectares. This grass grows vigorously; the area was cross-plowed with the Rom-Plow and then the seeds were planted 30 cm apart, on lines 1 m apart. Weeding is necessary every 1 month or one and a half month after the seedlings have been planted, as well as one fast annual passage, if there is any woody regrowth.

These crops are fertilized with a nitrogen fertilizer (ammonium sulfate or urea). In 1965, the figure was 30 units of nitrogen per hectare and 50 units of nitrogen in 1966. These levels are rather low for a crop that is as productive as this. Depending upon the rainfall, we can cut the grass here three or four times a year, with a tractor drawn 1.80 m reaper.

This straw makes excellent litter. Moreover, the animals eat a by no means negligible quantity of it.

When there is no straw, coarse litter (ferns, gorse, etc.) is collected from the lowland. The quality of manure obtained from this low-quality vegetation is not as worthwhile as that from grass straw.

The animals are stabled freely at night. The litter is removed only eve. three to six months, depending upon the need.

It is difficult to evaluate the quantity of manure which could possibly be produced here. This quantity is above all limited by the available straw.

Well-decomposed manure is of good quality. It is used for replantations and for the dwarf coconut palms in the nurseries.

Milk

There is no control over the production per animal in lactation. Only a portion of the milk of each animal is taken in the morning because the calves would otherwise not have any nourishment.

The milk is placed in 2-liter enamelled pails; the milk is immediately filtered through a special cellulose filter. It is kept in 10-liter aluminum cans, in which it is delivered to customers after a second filtration.

The material is washed with Teepol or a similar product with bactericidal action which is not harmful to man.

Table III gives the monthly milk output.

Table III MILK DRAWN IN 1965 AND 1966

Month	1965	1966
January	1,105	954
February	866	866
March	741	966
April	701	807
May	916	901
June	753	538
July	473	515
August	506	635
September	455	650
October	725	831
November	844	874
December	877	893
	8,962	9,440

Economic Aspects

The approximate expenditure and income figures for this operation are:

Annual Expenditures

(a) Litter Crops

Planting of 5 ha panicum, 150,000 per 3 years	50,000 Fr.
Five clippings of panicum and straw recovery	150,000 "
Fertilizer	50,000 "
Distribution of fertilizer and loading on trucks	30,000 "
For 400 tons of fertilizer	280,000 "

(1 ha of panicum gives 80 tons of green manure or 80 tons of fertilizer.

(b)	Care of animals; 2 cow sheds . 5 cowherds	370,000 Fr.
(c)	Flour milling	170,000 "
(d)	Milking and health care	30,000 "
(e)	Cow shed maintenance	50,000 "
(f)	Cow shed depreciation	100,000 "
	Total Expenditures	1,000,000 Fr.

Annual Revenues

(a) Increase in herd: With a herd of 350 animals, we can figure on a sale of 70 animals; this figure is easy to achieve when the cow sheds are clean and when the animals are properly tagged.

	Value of increase (minimum)	900,000 Fr.
b)	Value of milk (8,500 liters)	480,000 Fr.
(c)	Value of fertilizer (400 t at 500 fr)	200,000 Fr.
		1,580,000 Fr.

Even if the fertilizer has a very low value, it can still be said that animal husbandry here represents a profitable supplementary activity.

CONCLUSION

The Grand-Drewin herd constitutes a subsidiary activity which is quite worthwhile in spite of the relatively extensive character of the livestock production.

The number of animals had to be restricted to 350 due to the existing support facilities and the pasture available; however, the construction of a third stable, in a new sector, should make it possible to increase the herd by about a hundred animals.

In spite of a high degree of inbreeding, this Lagoon-breed herd is very hardy and quite well adpated to pastures on palm plantations.

This possibility of diversification in the operations of a palm plantation is very important within the framework of the palm tree planning for the Ivory Coast; the newly planted areas will make it possible to develop animal husbandry throughout the entire forest zone -- a zone in which the meat supply is particularly scarce.

ANIMAL PRODUCTION AND HEALTH

Max Diaw, O.C.A.M.

In order to improve our livestock herds in quality and increase their numbers, once having decided to overcome known shortcomings, certain measures must be put into effect urgently. These include:

1) continuation of rinderpest control campaigns;
2) irradication of bovine pleuropneumonia;
3) organization of research and vaccine manufacture;
4) promulgation of animal health laws;
5) establishment of sanitary cordons.

Continuation of rinderpest control campaigns

Since cattle calve every 5 or 6 months, the calves must be vaccinated for two consecutive years, thus affording protection of all the livestock in certain regions obtaining success in complete irradication.

Irradication of bovine pleuropneumonia

Experts of both the Food and Agriculture Organisation of the United Nations (FAO) and the Office International des Epizootiques (OIE) at Khartoum have in their report advocated experimentation to judge the comparative value of pleuropneumonia control vaccines, in order to outline an action policy. Francophone countries of Western and Central Africa are primarily concerned about this problem. It therefore appears essential that there be selected without delay appropriate tests of one or more vaccines to determine their immunisation value and safety for cattle in these countries. Resolutions along these lines have been taken at intergovernmental veterinary meetings (in Chad, Cameroun and in the Republique Centrale Africaine, at Bangui on 4 April 1967) or at international meetings (OIE). It should be remembered that member countries may avail themselves of the services of four laboratories: Dakar, Fort-Lamey, Niamey Tananarive, and of animal production centres: Bouaké, Bouar (R.C.A.), Dakar (Senegal), two in Madagascar, Wakwa (Cameroun).

At the Secretariat of O.C.A.M., with the collaboration of the Institut d'Elevage et de Médecine Vétérinaire Tropicale (IEMVT), two files on this subject have been compiled. One provides information on the comparative value of present-day antipleuropneumonia vaccines. As a follow-up to the Khartoum conference in February 1967 (FAO and OIE), the value of the leading vaccines of today should be determined in order to select the one which will be used for mass vaccination on a regional scale, or even for the entire continent of Africa.

The other project calls for the study of the pest complex of small ruminants, an endemic infection, the main symptom of which is high temperature followed by diarrhea, death occuring within a few days after the first clinical symptoms.

Promulgation of animal health laws

In order to organize international trade, the OIE, to which most African countries and Madagascar belong, has placed on the agenda of its last general sessions the study of standardization of health regulations on international trade in animals and animal products.

Attention should be drawn to the OIE meeting where animal health laws and regulations framed and recommended by that agency will be up for approval and implementation.

It should furthermore be noted that O.C.A.M. member countries intend to create sanitary cordons, to give their national animal production services adequate authority and means to ensure proper animal inspection.

GENERAL DISEASE PREVENTION IN AFRICAN LIVESTOCK--CURRENT VETERINARY RESEARCH PROBLEMS

J. Orue, IEMVT, Dakar

SUMMARY

The organization of contagious disease prevention in Africa must take into account an extremely complex pathology as well as factors related to management, the climate, malnutrition, and insufficient equipment.

A systematic organization and inter-governmental agreements determine the principles of disease prevention. Under current conditions, these are difficult to apply. Only preventive medicine which relates to infectious diseas[illegible] actually able to assure protection of animals. It remains for the coun[illegible]es to set up organized immunization campaigns through the animal health service which puts into general practice the results acquired in the laboratories.

However, insufficient means make impossible, in general, assurance of the possible technical control of disease, and prophylaxis and treatment of parasitic and nutritional diseases are incapable, also for this reason, of realization. International technical assistance would be able to supply its indispensable help.

Research should be pursued or undertaken in order to resolve the immediate problems which impede livestock development.

These involve the following diseases:

Rinderpest

- improvement of the heat-stability resistance of virus vaccines,
- development of an inactive vaccine to enable exportation of animals or carcasses originating from uninfected or quarantined areas,
- research on the possibilities of contamination of the cattle by the pest virus of small ruminants and on possible methods of avoidance.

Contagious Bovine Pleuropneumonia

- improvement of diagnostic techniques to assure finding the chronic carriers;
- improvement of actual vaccination techniques and choice of a vaccine to fulfill the guaranties of efficacy making possible the organization of inter-government immunization campaigns.

This program outlines the recommendations of the last meeting of FAO experts held in February 1967 at Khartoum.

Parasitic Diseases

Destruction of the molluscs, intermediary hosts of distomiasis and schistosomiasis, as well as glossina (carriers of Trypanosoma brucei), in well-defined areas which are favorable to animal husbandry, is possible and has been the object of experiments of predistribution, but studies on the diseases caused by nematodes and trematodes should be pursued, particularly on ocular filiariasis of Thelazia.

Research on trypanosomiasis should be continued:

- on trypanocides of low toxicity,
- on immunology,
- in widespread use of methods of resistance by the application of radiobiological techniques through releasing sterilized males in areas infested with tsetse flies.

Nutritional Diseases

Rural water supplies result in the settling of herds. It modifies the ecology of the sahelian countries and causes the appearance or increase of deficiency diseases. The consequences on the health of the herd and on its increase, however difficult to understand, should be brought to a minimum and necessitate investigation, studies of the pasture, the soil, and the water, and on the deficiencies of trace elements.

* * *

General Considerations

Disease prevention in the African animal is subject to a variety of influences having to do both with a particular set of pathological conditions and conditions of husbandry, the climate, malnutrition and lack of equipment in specific areas.

Indeed, in the tropical and subtropical zones this pathology presents a greater diversity than in the temperate and favorable zones, like Madagascar, due to their privileged geographical position. For the most part the endemic diseases in these countries are superimposed on microbial, viral, and parasitic diseases characteristic to each country and found more widely spread still in hot, humid areas than in hot, dry areas. Even more, the appearance of new diseases is anticipated in the near future, an inevitable consequence of marketing and trade or from subsequently developed susceptibility, whether it be from genetic improvement or from poorly-suited or richer diet.

There are other elements which render difficult the application of classical methods of prophylaxis. They occur both with favorable climatic conditions in the appearance and spread of diseases, and in ecological and social influences.

In addition, it is a fallacy to assume that the great health problems have been resolved in Africa, and that it is possible to move immediately into the second stage of planning for the economic development.

In these countries, prophylaxis of infectious diseases follows the same rigorous rules of application as in other continents. There thus must be hygienic or medical laws passed, anticipated by resolutions adopted by governments. Often inter-governmental agreements can be implemented in regional plans. But it is always of a collective type of prophylaxis which should be adapted to specific local conditions.

The existence of herds from grouped, more or less cooperative and settled villages makes application less difficult in the agricultural or agro-pastoral environment; and, in general, the services of technical offices are helped by an adequate infrastructure.

It is not the same for the sahelian regions of extensive husbandry, a strictly pastoral situation. Control of animal diseases clashes with material difficulties. These are largely due to the environment, to transhumant husbandry on a large scale, and isolation of the herdsmen, who very often reject the methods of prophylaxis, wishing to avoid efforts for which he does not understand the need. The operations of prophylaxis should thus be based on his education and on the development of a field team of sufficient size. The associations and cooperatives of breeders which have been created or are in the process of organization should provide important assistance in this development.

Whatever happens, and in spite of progress made, it appears that certain factors very often render the rules of hygienic prophylaxis inapplicable under existing conditions, so that medical prophylaxis, developed through campaigns of organized vaccinations by the livestock service, is essential for protection of the animal.

Current Basis for Medical Prophylaxis in Africa

The responsibility for prophylaxis rests with the laboratories, which have had since their creation the goal of satisfying requirements for biological products; the directions of research have evolved in the course of developments of this activity.

During the last twenty years, a cooperative infrastructure of a regional nature has been established. This has led to the foundation of important research centers and to the manufacture of biological products at Dakar in Sénégal, at Vom in Nigeria, at Farcha-Fort-Lamy in Chad, at Tananarive in Madagascar, and at Muguga in Kenya. Most of them,

such as the Laboratory at Dakar, are responsible for all the needs of their region's veterinary research. They embrace all disciplines which are concerned with the protection and improvements of the herds.

This important infrastructure has been completed on the one hand for the national laboratories designed especially for diagnosis or manufacture of certain vaccines, and on the other, for specialized centers involved with such precise studies as, for example, the research centers on trypanosomiasis.

The results obtained are important. From study of the epizootology of diseases and their pathogenisis, effective and safe vaccines have been developed from research into the real needs of the herds.

Microbial diseases such as bacterial anthrax, symptomatic anthrax, and hemorrhagic septicemia which occur episodically and whose spread is limited by their very nature are effectively controlled by known methods which it is not necessary to describe.

It is in the area of microbial or viral diseases that results acquired by research have been most remarkable. Thanks to the infrastructure which has been established to put into practice use of specially studied biological products, new vaccination methods have been used on a wide scale for a number of years; these have become ever more adapted for use in tropical countries.

Only insufficiency of personnel and material resources has restricted the achievement of total control of these diseases. Nevertheless, the success achieved by the joint campaign against rinderpest sufficiently demonstrates the possibilities. It would be desirable to anticipate similar joint efforts with the same resources, which are technically possible and in the general recognized interest. Bovine pleuropneumonia is the most urgent of these.

It is also for financial reasons that control of parasitic and nutritional diseases which are primary causes of mortality of young animals and the poor profit from the herds is still to be undertaken. The organization and realization of prophylactic campaigns agains such diseases as schistosomiasis and trypanosomiasis seems perfectly justifiable for economic and social reasons. Unfortunately achievement of these efforts can not be anticipated other than in the context of coordinated international assistance.

Current Problems Posed by Prophylaxis of Diseases of Livestock

For the good of the areas, tropical animal pathology poses problems which necessitate continuing present studies, or new applied research or basic research programs.

Of most urgent concern are those diseases which constantly endanger the livestock, causing serious losses, and thus retard development, improvement of animal production, and marketing of animal products.

These include:

- virus diseases: rinderpest; pest and pneumopathias of small ruminants;
- bacterial diseases: pleuropneumonia; nocardiosis; streptothricosis;
- parasitic diseases: trypanosomiasis; ocular filariosis of cattle;
- nutritional diseases.

1. Virus diseases

Rinderpest

There are two distinct problems concerning this disease: one relating to the improvement of heat tolerance of virus vaccines, the other, to their use in quarantine zones or those not yet infected.

Progress realized in the manufacture of biological products has progressively facilitated the use of vaccines which have become more and more effective and well-suited: formaldehyde vaccines, capripestic virus vaccines, lapinized, and finally vaccine from tissue culture which is now in general use. The efficacy of virus vaccines from tissue cultures evidently depends partly on the conditions of their manufacture which must be standardized and partly on keeping them at low temperatures until their use. This condition can only be achieved in the tropical environment by the expensive establishment of a network of cold storage.

In order to avoid the reduction in immunological qualities of the antiplague virus vaccines and the consequent expense of recommencing the vaccination campaigns, the heat stability of the vaccines must be investigated.

The conservation measures adopted after the joint campaign should gradually eradicate rinderpest and creation of disease-free areas. However, the exportation of animals, living or dead, which have been immunized by attenuated live or even modified virus vaccines is not permitted by international law. Consequently, to lift this ban, an inactive vaccine of satisfactory effective duration must be developed. Indeed, recent experiments have demonstrated that cattle immunized with such a vaccine and then subjected to infection no longer harbored the virus 25 days after its introduction into the animal.

Pest of small ruminants

This disease has been observed for some time in West Africa. It is responsible for many deaths. The Offices of Virology of the Laboratory at Dakar have studied it. It resembles a rinderpest virus adapted to the small ruminants. The question arises of whether the virus is capable of regaining its virulence under certain conditions and contaminating cattle in areas free from rinderpest. If this hypothesis proves correct, vaccination of small ruminants will be indispensable both to reduce losses resulting from this disease and to minimize the risk of contamination of cattle herds.

2. Microbial diseases

Contagious bovine pleuropneumonia

This disease is actually one of the most serious menaces to African stock due to the losses it entails and the impediments it causes to marketing and development of draft animals.

Despite great progress, some gaps of knowledge remain to be filled. These include:

i) diagnostic methods, applicable only in the laboratory by experienced technicians. They are not yet able to identify chronic carriers causing continuous contagion.

ii) the vaccines: killed vaccines are ineffective or else the difficulties of their manufacture prevent their mass use under existing conditions.

Vaccine cultures prepared from unstable strains are weakened by successive application and by rapid aging. Their limited period of preservation and delays in using them strictly reduce the possibility of their use and well explain their failure. In short, the vaccination strains used in West Africa should correspond to the varying sensitivity of the cattle species (whether zebu or N'Dama) in order to avoid extensive reactions. However, lyophilization improves preservation and makes possible manufacture of vaccines from strains of established effectiveness. These methods of manufacture make possible the planning of organization of wide-scale annual campaigns of vaccination which ought to be renewed every 5 years in order to eliminate chronic carriers. However, in the context of practical application, knowledge on the subject must be broadened to include:

- the choice of a vaccine strain which will respond to existing conditions with safety and efficacy;
- the detection of chronic carriers.

Streptothricosis

Despite important work accomplished in the laboratories of Africa, the means of prophylaxis against this disease remain exceedingly uncertain. Dermatophilus congolensis is responsible for many losses and constitutes an obstacle to animal traction in certain tropical areas.

The hematophagic stinging insects which exist in areas of humidity represent a factor in the appearance of this disease whose etiology remains unknown, while immunization has yielded no results.

Research programs currently in progress in Francophone Africa are concerned with etiology, prophylaxis and treatment.

Brucellosis

This is a problem of regional interest in certain countries of Africa. In the agro-pastoral areas of Sénégal, where old investigations revealed its existance, the toll of infestation reached 60% of the herd. However, the resultant economic importance cannot be measured precisely on account of the conditions of husbandry and the indifference of the breeders. It is important to determine its actual extent in order to recommend proper prophylactic action and practicable vaccination with either strain B-19 or killed vaccine of type 45/20. Application of hygienic prophylaxis rules with regard to existing conditions of traditional husbandry seems difficult.

3. Parasitic Diseases

These diseases constitute one of the most serious pathological agents. Their incidence, as catastrophic in their effects as those of the microbial and viral diseases, is not any the less widespread. They are particularly rampant in the hot, humid climates due to conditions which support their incidence and propagation.

Some of them have been thoroughly studied by research teams at the research centers, but putting into effect measures for their control which are immediately practical for mass use remains yet to be done.

Efforts can be cited which are leading to the eradication of areas of concentration of distomatosis and schistosomiasis by destruction of the intermediary host, the mollusc vector. The efficacy of these methods has been demonstrated by pre-extension trials in Sénégal and Upper Casamance.

Similarly, certain areas infested with glossina, carriers of sleeping sickness of man and the animal trypanosomiasis T. vivax, have been treated and rid of insect vectors to a manageable extent by spraying with long-lasting insecticide.

Diseases of trematodes and nematodes

When the conditions for satisfactory prophylaxis against certain diseases caused by trematodes and nematodes have been determined, these diseases must be made the subject of complementary studies so that recommendations for campaigns, which are effective and adapted to local conditions, can be made.

These diseases include those of the nematodes such as Thelaziosis in Thelazia, the helminthiases of the nematodes (anguillulosis, trichostrongylosis, cooperiosis) and the cestodes (moneziosis). Research conducted on epidemiology and with practical applications should be [illegible]ted to assure the protection of herds under extensive management whic[illegible] subjected to the climate and environment.

These diseases are at their peak in the southern and Soudan sahelian zones. Investigations in Sénégal are planned to define exactly the specific nature of the responsible helminths, their life-cycles, and their type of propagation in the natural environment.

However, the most urgent study concerns thelaziosis. In fact, recent investigations have shown the existence of many organisms of unilateral or bilateral opaque keratistis living in the humid areas, and the cause for a relatively high mortality rate of 10 to 15% of the total livestock. It involves the ocular filariosis Thelazia localized either in the conjunctiva or cornea, or in the anterior chamber of the eye.

In Sénégal the vectors are the Muscidae.

Consequently, research should be conducted to:

- determine the host vector and the intermediary host;
- study the life cycle of the nematode parasite;
- study the biology of the intermediary host;
- develop campaigns or prophylactic measures.

Animal trypanosomiases

These have been the subject of numerous research investigations and despite progress achieved over the last fifty years, they constitute a major epizooty difficult to overcome. Eradication can reasonably be foreseen of virus diseases such as rinderpest. With the trypanosomiases, however, there is no hope yet of eliminating their pernicious effect on tropical livestock, as the flagellates transmit themselves differently and exhibit differing responses to medical treatments.

Very complex research should be brought to bear from the diverse disciplines of biology and pathology, agronomy, biochemistry, and pharmacology.

In the area of prophylaxis alone, the control of animal trypanosomiases necessitates:

- destruction of the tsetse flies in the areas infested and more or less favorable to husbandry
- treatment of sick animals or carriers of the trypanosomes
- the protection of the healthy animals
- the conversion from extensive transhumant husbandry to intensive husbandry in the fly-free areas.

These plans are complementary but are capable of implementation only in geographically isolated areas, which are incidentally less susceptible to reinfection, due to obvious economic constraints.

These difficulties make the need for continued research obvious, which should be organized around:

- research on trypanocides as effective but with lower toxicity than those discovered at the present time (suraminate of anthrycide; suraminate of prothidium; suraminate of metamidium);
- research on the nature of the immunity which apparently occurs in specific cattle species;
- the elaboration of new means of control by the application of radio-biological techniques. This method is based on biological competition by releasing sterile males in zones infested with tsetse flies.

4. Nutritional Diseases

These have come more and more to the attention of pathologists in West Africa following observations made in the sahelian zone of Sénégal, as being a grave concern in regard to the animal, caused essentially by a hypophosphorosis associated with C beta botulism.

The symptoms are identical with those described about 1920 in South Africa by Theiler, a disease he called "Lamsieke." Analogous disorders are encountered in Australia, New Zealand, and Louisiana.

The recent appearance of this disease, principally due to aphosphorosis and botulism, is linked to a change of the techniques of husbandry. It results from digging deep water-holes in this area. In facilitating supplying water to the herds and, at the same time, reducing the magnitude of migration, it brings about some settling of the herds with consequent over-grazing of vegetation. The animal is thus deprived of nutritional elements supplied before in the course of its wanderings, as well as the occasional rock-licks.

The losses caused by these epizooties are very difficult to evaluate, but evidence is that they are very great. The largest mortality is reported at the end of the dry season. More than that, the mineral deficiencies which are the determinate cause for the deaths, also constitute one of the primary limiting factors to the productivity of the herds, in that they are responsible for lowering of the birth rate, minimizing of breeding, and a reduction in the production of meat and milk.

A program of studies has been elaborated. It is comprised of research work in the laboratory on the etiology of observed deficiency diseases, their complications, and the bacteriology of germs at the source of the toxemia.

Another part of the program will be carried out in the field; it will undertake a general investigation on the composition of the herds and their development.

Complementary studies will be undertaken and conducted on analysis of the pasturage, the soil, and the water of the water-holes.

Vaccination currently has been undertaken against botulism, but the establishment of mineral elements which would necessitate large investments has not yet been realized.

* * *

This is a brief exposition of the current problems encountered in relation to animal health and development of livestock production in the countries of Africa south of the Sahara.

They will be resolved only by collaboration between the research and extension organizations, coordination between research scientists of the various disciplines and controlled implementation of the results.

ANIMAL TRYPANOSOMIASIS

J. Itard, I.E.M.V.T.

SUMMARY

In order to develop livestock production in the endemic zones where animal trypanosomiasis is present, it is necessary to have as complete knowledge as possible about the distribution of the species of Glossina causing the disease and their biology. This knowledge would then make it possible to develop eradication methods.

The governments in the endemic zone requested the I.E.M.V.T. scientists to carry on this type of research.

Maps of the distribution of glossina in different areas were published.

The biology of these insects was studied in the field and in the laboratory, and breeding of these insects for observation was undertaken.

Thus, eradication programs using classical methods were able to be put underway. Biological control methods are being studied and an eradication project through sterile males was set up.

Serology of bovine races tolerant to trypanosomiasis is being studied. This research may be used for the serological protection of animals that are sensitive to the disease.

The chemotherapy and the chemoprophylaxis of domestic anamals has been perfectly codified in terms of local conditions and objectives to be attained.

Research is now oriented towards control of the vector and towards the serology and immunology of the trypanosomes.

INTRODUCTION

The governments of the countries situated in the endemic glossina zone have taken up the problem of the development of livestock production on their territory.

This problem can be met with in several ways: a map showing the distribution of the tse-tse fly can be drawn up for each country, and then the proper eradication methods, either chemical or biological, decided upon. Finally, measures can be taken to populate the area with trypanotolerant cattle.

Many countries have appealed to the I.E.M.V.T. scientists to develop research programs to define the options necessary for developing livestock production in the face of this problem.

Maps showing the distribution of the tse-tse were drawn up for the following areas:

Central African Republic (1963)
Chad (1966)
Ethiopia (1966)
Sénégal (1967)
Cameroon, Garoua Region (1967)
Togo, Savannah Region (1967)

As for the more precise problem of the control of the glossina, this can only be done through a precise knowledge of their biology.

Research has been carried on in the field and in laboratories. Glossina have been bred in climatically controlled rooms at the I.E.M.V.T. central laboratory and at research centers.

This research has made possible a program for the eradication of glossina in regions of Logone Birni (Chad-Cameroon) and in the Central African Republic (Nié Valley, Topia Valley). The insecticide used was dieldrin in a 2% solution, sprayed on the forest floor and up to a height of two meters, after the infested forest was isolated by encircling it with a cleared area. In the Topia Region, the use of insecticides on 250 kilometers of forest made it possible to recuperate 45,000 hectares of grazing. An analagous project is being studied at present in Bambari (Central African Republic). Treating 1100 kilometers of forest will make it possible to use an additional 80,000 hectares of grazing.

Biological methods of controlling the tse-tse fly are also being studied at the central laboratory. Breeding was done in large quantities and studies of the effect of ionizing radiations were made possible. In this way, a project for sterilizing the males was perfected and submitted for the approval of the FED. This project, which includes a comparative study of the two methods of treatment, will make it possible to determine all the conditions necessary for widespread application and will make it possible to determine the economic components. It will be carried on in the Central African Republic, near Bangui, on approximately 20 kilometers of forest infested with glossina fuscipes fuscipes.

Bovine sensitivity to the trypanosomiosis infection is highly variable according to species. In order to study this sensitivity, research has been done on the hemoglobin structure of zebus and taurines. A comparative study of the serum proteins of taurines and zebus has shown that although the albumin/globulin proportion is almost identical, the percent of β-globin is much higher among taurines. This research will hopefully make it possible to explain the low receptivity of some

bovines and will lead to the development of serological protection for domestic animals.

Research has been done on trypanocides and proplylactics at the research centers of Bouar and Fort-Lamy, making it possible to codify the utilization of these chemical in terms of local conditions and the desired objective.

Research is currently being oriented in two priority directions:

1) Control of the vector, primarily through sterilization of the males;
2) Serology and immunology of animal trypanosomes.

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PROGRESS AND OUTLOOK FOR THE RINDERPEST AND PLEUROPNEUMONIA PROGRAMS IN AFRICA SOUTH OF THE SAHARA

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SUMMARY

Rinderpest is an epizooty which exists in many areas of the world ravaging livestock and limiting the development of animal production.

Campaigns to stamp out the disease were impossible for many years because no vaccine existed that was stable, easy to use, and guaranteed lasting immunity.

This type of vaccine has now been developed and has made possible a "Joint Campaign Against Rinderpest" which began in 1962 and has been successfully carried out in West Africa.

But the eradication will only be complete if the countries follow up their Joint Campaign by using conserving measures for a few years, that have been developed on an international level and proved effective.

Contagious bovine pleuropneumonia (CBPP) is more difficult to eradicate than rinderpest.

The main reason is that it has been impossible to perfect one vaccine. There are many variations of the disease that are known as causal agents of the disease; on the other hand, vaccines have been developed successfully against one variation or another of the disease and can be used simultaneously with those against rinderpest.

Thus, a campaign for the eradication of CBPP can be envisaged shortly, based on the campaign against rinderpest; the campaign must be accompanied by sanitation measures that are already known.

Whether one is dealing with rinderpest or with CBPP, international control is needed during the vaccination phase and later during the follow-up phase.

A. RINDERPEST

1. Definition and history

Rinderpest is generally seen as a serious disease, causing high fever, highly contagious, almost always fatal, and attacks mostly large livestock.

It is a very old disease, and has been known to man since ancient times.

In 810 Charlemagne brought it to France, and that same year cases were also reported in Great Britain.

The ravages caused by this disease was one of the direct causes of the creation of the first Veterinary School in the world, in Lyon, France in 1762, and one of the reasons for creating a Veterinary Service Division attached to the Departments of Agriculture of modern nations.

Western Europe has been freed from this epizooty for a long time, but one cannot say the same thing about Africa.

On the African Continent, rinderpest was first noted by Lugard in 1893, who stated that it had attacked East Africa, at a place facing Aden, and had probably come from Arabia or India. Numerous cases of it were reported long before that in Egypt.

Three years after Lugard's comments, massive livestock and wild-animal deaths were reported as far as the Zambesi River, and shortly after the plague spread to the southern tip of the Continent. It was then estimated that the number of dead bovines in South Africa alone was two and one half million. which did not include the wild animals that died from it also.

But as of 1903, rinderpest had run its course in South Africa, and although some wild animals, carriers of the virus, may have migrated, it never bothered South Africa again.

On the other hand, the disease remained in West Africa and East Africa with varying degrees of virulence.

During the first sixty years of this century, numerous efforts were made to control rinderpest, and they were only moderately successful. These efforts were usually undertaken locally in the territories of a colony or state, with absolutely no cooperation or coordination with the neighboring state or territory, whereas the boundaries between nations are not respected by the livestock breeders nor by the animals.

In 1940 through 1942, a common effort was undertaken against rinderpest in Nyassaland, Rhodesia, and the South African Union. This effort effectively eliminated the disease to the South of the Dar-es-Salam railroad line at Kigoma, and since then it has never reappeared in the countries listed above.

2. Vaccinations

During the same sixty years, great advances were made in control methods and ways of fighting epizooties, a direct result of the improvement in the effectiveness of vaccines in laboratories.

A few years ago, these vaccines were not foolproof, were difficult to use in the jungle, and were generally onerous to produce. Since then, by 1928, the first vaccination experiments were done with reaction vaccines

on goats (capripestic vaccine). This vaccine was gradually improved as to quality and sureness and is still used today in certain areas and for certain breeds of bovines. In a few of these zones, and taking into consideration the climate and maintenance of livestock, postvaccine deaths have been reported on the order of 2-3%.

About twenty years ago, a lapinized vaccine was perfected, and it has the advantage of being usable on animals that are too sensitive to the capripestic one.

This vaccine is nevertheless very fragile, delicate to use in the bush and requires large quantities of rabbits in the laboratories.

Finally, the best and most recent weapon against rinderpest has been the tissue culture vaccine, which was perfected in the last decade in East Africa, and is widely used in all of Black Africa.

This vaccine fulfills all requirements in the field, in that it is relatively easy to use, confers stable and durable immunity, and usually covers the duration of the economic life of the bovine. This immunity is conferred without provoking any reaction in the animal, even the young, and there is no post-vaccinal mortality.

3. Eradication campaign on a Continental level

Linked with this vaccine, and at the same time, the possibilities for carrying out an eradication program encompassing the entire African Continent was immediately envisaged. It led the IBAH (Interafrican Bureau of Animal Health) to hold a Conference at Kano (Nigeria) in 1961; this conference was attended by the Cameroons, Niger, Nigeria and Chad as well as several international organizations. The decision was made to launch an anti-rinderpest campaign on a regional level (river States of lake Chad area) and it was to be led by an inter-African coordination organization.

a) Phase 1.

This operation was known from then on as the Joint Campaign against Rinderpest (code name: JP.15), and began in 1962 under the aegis of the CCTA, the organization which in 1965 merged with the Scientific Technical and Research Commission of the OAU. At that time the activity in the field and the administration of the program entrusted to us as International Coordinators and members of the Commission cited above.

This inter-African operation showed signs of being successful from the first, both vis-a-vis the livestock-breeders and vis-a-vis the successful results obtained. These results are condensed in the table 1 that is attached to this document, and shows a spectacular decline in the incidence of rinderpest outbreaks and the number of animals dying from the disease; this was done during a campaign which lasted from 1962-1965 in the countries mentioned above.

b) Phase II.

The success of Phase I from its first years of operation incited the STRC/OAU and the International Foreign Aid Organizations (especially US Agency for International Development and the European Development Fund/FED) to undertake Phase II as of 1964, which overlapped with Phase I by one year so that there would be no breaking of continuity in the activity undertaken.

The program thus took on a Continental amplitude, because Phase II covered the countries mentioned above as well as Nigeria-West, West Niger, East Mali, Upper Volta, Northeast Ivory Coast, Ghana, Togo and Dahomey.

c) Phase III.

Phase II brought the same good results as the preceding one, and in 1966 Phase III was begun, covering all the African countries in the West to the Atlantic. (West Mali, Northwest Ivory Coast, Mauritania, Senegal, Gambia, Guinea, Sierra Leone, and Liberia). This phase is currently going on and it should last three years like the preceding ones.

The statistics on the vaccinations given are summarized in the tables 2 and 3 which are attached to this document.

As an annex to this Phase, complimentary operations were undertaken in Chad, covering that portion of its territory which extends between the 20° longitude and the frontiers of the Sudan, in order to connect this operation with other operations planned in this country in the near future.

d) Extension to East Africa

At a Conference held at Addis Ababa in June 1965, under the auspices of the STRC/OAU, many countries of East Africa expressed the wish that the Campaign be extended to their territories; these countries were: Ethiopia, Somalia, Sudan, Tanzania, and Uganda.

From that time, though, in spite of much activity and several meetings, nothing has been done along those lines to date. It is to be hoped that it will nevertheless begin in October, 1968, so that they can be coordinated with the activity going on in Chad as we mentioned above.

This is important because there are still outbreaks of rinderpest that have recently been reported in Sudan, Ethiopia, Somalia, and North Kenya.

The risk is that reinfection can occur in the areas that have been cleaned from the areas that have not been cleaned up as yet (that is, the disease might spread from East Africa to West Africa).

4. Progress in Rinderpest Control

We have said that during this Joint Campaign Against Rinderpest we used a capripestic vaccine at first, then progressively and almost exclusively turned to the tissue culture vaccine, as the latter is perfectly adapted to the needs of the area and accepted by the livestock breeders.

Livestock protected by this last vaccine has been tested subsequently and were shown to be fully immune.

Progress in protection of livestock against rinderpest has thus been constant and more and more complete (during the last decade). The activity undertaken by the Joint Campaign has been shown to be the most effective ever undertaken against this disease. If not the only operation of this type, it is surely the only one undertaken on a continental scale, as it has called upon and still does, the cooperation of 16 African states under the aegis of the STRC/OAU, with the appreciated help of the Foreign Aid Organizations.

5. Future Outlook

The future of further campaigns to be undertaken against rinderpest rest upon two basic points:

a) The extension of the Joint Campaign to all the countries of East Africa up to Tanzania, the entire tropical livestock-breeding zone which extends from Dakar to the West to Mogadiscio in the East. This entire zone must be covered by J.P.15 before one can safely say that bovine plague has been completely eradicated.

b) "Conservatory measures" must be undertaken by each country involved at the end of each Phase.

As far as these two points are concerned, we can hope for the future, because it is highly possible that the Eastern Campaign will begin in October 1968, and most of the countries that have already participated in Phases I and II have agreed to apply (and already do so) conservatory measures.

Conservatory measures

These were defined in an Interstate agreement, at the conference marking the end of Phase I, in May 1965 at Vom (Nigeria). Here is how it reads:

"Each country agrees:

1 - to vaccinate with a recognized rinderpest vaccine the annual calf-drop at least once per year in two successive years. The animals will be marked with the clover-leaf ear-punch so that any animal over two years old will have two such ear-marks.

2 - to vaccinate and ear-punch all animals detected without clover-leaf punches.

3 - to keep neighboring countries informed of the state of affairs in respect of Rinderpest through the Liaison officers, and by means of annual scheduled meetings convened by STRC. In particular, each country will notify all concerned by the most rapid means possible of any outbreaks of Rinderpest, stating the number of animals involved and geographical grid location of the outbreak.

4 - in the case of an outbreak of Rinderpest, to implement the accepted Control measures as quickly as possible and under professional veterinary supervision. It is essential to verify by a recognized laboratory technique etiology of the infection. Recognized control measures would include strict quarantine of all infected herds and in-contacts, slaughter of all infected animals within a radius of 10 miles and payment of compensation for animals slaughtered.

5 - to have veterinary authorities maintain strict surveillance over the movements of migratory and trade cattle which shall be furnished with valid vaccination certificates.

6 - to provide adequate legislation to permit the undertaking of the requirements of paragraphs 1 to 5 above.

7 - These measures will be subject to annual review."

The above was also accepted by the states that participated in Phase II, at the Terminal Conference at Dakar (Senegal) in June 1967, and was subsequently included in extenso in the financing agreements relative to Phase III as basic conditions to be accepted by countries wishing to participate in Phase III.

Apparently these measures have been strictly applied in the Zones covered by Phase I, and they are being applied in the areas where Phase II just terminated.

International Control

It would nevertheless be necessary to have these measures controled by an international organization to make sure that they are fulfilled according to international standards and by qualified veterinarians.

We know that many countries are lacking this type of personnel and will lack them for many years to come.

It is not within our scope to control the application of the conservatory measures, as our task ends at the end of the phase for each area. That is why, since the control is necessary, we have proposed that it should be put in the hands of the IBAH (Interafrican Animal Health Bureau). Unfortunately, up to now, this organization has limited its activity to collecting reports and information furnished by each country, because of lack of funds.

Small outbreaks of disease, of which some have been confirmed as being rinderpest, have been reported in the countries where the campaign is over, although these cases are few and isolated. This is inevitable (animals that escaped vaccination, contact with wild animals, etc.) and does not surprise the professionals. Conservatory measures should contribute towards definitively wiping out the final traces of this disease.

This confirms that an international control is indispensable after the Joint Campaign has finished its task.

Conclusions

In conclusion, the outlook for the control and eradication of rinderpest in intertropical Africa is very good, but the danger will only be permanently wiped out if:

a) the present operation known as Joint Campaign continues to operate with the help of the International Organizations, the countries involved and the livestock breeders.

b) if it is extended to the rest of the intertropical zone, that is to say to the countries of East Africa up to the "Tanzania barrier."

c) if the conservatory measures are completely and sincerely applied by all the countries at the end of each phase, including the "stamping out" measures done by the Veterinarians and controled by an international organization.

B. PLEUROPNEUMONIA

1. Definition and History

At the same time as rinderpest is disappearing, pleuropneumonia , on the other hand, is increasing to alarming proportions in almost the entire geographic zone that we are concerned with in this paper.

This disease was first reported in Germany in 1693, but disappeared from Europe at the beginning of this century; it was first commented upon in South Africa in 1854, but disappeared there after 1916. At present it exists in almost all of the livestock-breeding countries of the intertropical zone of Africa and also exists in Australia, the USSR, Central Asia and India.

It persists in Australia in spite of the fact that country undertook vast vaccination campaigns and in spite of the excellence of Australia's Veterinary Services, but it exists only at isolated places over a limited area.

This disease is highly contagious, and is seen in severe forms, mildly severe forms and as a chronic disease; this last type greatly contributes to the persistance of the disease, because livestock that has

a chronic case can be a possible source of infection for others, even though the animal may be considered clinically as cured.

Thus pleuropneumonia is a much more insidious contagious disease than rinderpest.

2. Progress achieved in the control of pleuropneumonia

Progress in the control of pleuropneumonia has been very variable.

In Europe, for example, the disease was eradicated thanks to administrative action and not because of vaccination, that is to say it was eradicated by a program of systematic slaughter of the infected animals.

Vaccines:

One of the main problems in the control of pleuropneumonia has been the fact that up to now we have not had one universally accepted vaccine, easily usable in the field and having durable immunological qualities such as the tissue culture vaccine against rinderpest, for example.

Research is going on at present in laboratories and in the field, and vaccines that are improved and confer a reasonable period of immunity will shortly be forthcoming; it is certain that researchers are working as fast as possible to meet the general demand and hope to produce one or several vaccines that are effective against pleuropneumonia.

There has not been up to now spectacular progress in vaccination on a wide scale against pleuropneumonia as there has been against rinderpest.

Nevertheless, recent work in East Africa has shown that the situation could be at least partially improved by using the vaccines and equipment that are available at present. The authors of the research have shown that if the animal is vaccinated against pleuropneumonia with vaccines manufactured from T1 strain at the same time as it is vaccinated against rinderpest with a tissue culture vaccine, a sufficient number of antibodies against both diseases are produced.

This was discussed by a panel of experts that met at Khartoum in February 1967, and it opened the way for thinking in terms of using the Joint Campaign against rinderpest and vaccinating the animals against pleuropneumonia at the same time.

At the same time, in the last eighteen months, some experiments have been carried on in Chad and they are already using, with our approval, the Joint Campaign against rinderpest for vaccinating the animals against both diseases at the same time. Contrary to what was done in East Africa, we have been using a mixed rinderpest pleuropneumonia vaccine (KH3 J strain), administered to the animal in one injection. The results are satisfactory, the immunity against pleuropneumonia is good, because there

has been a marked decline in the incidence of this disease in the last eighteen months. It is still a bit early to draw firm conclusions from these experiments, but it was worthwhile to mention them here.

Because of the nature of the disease, it could be possible in many countries to vaccinate only animals in certain prescribed zones, as opposed to what is needed against rinderpest, but this could only be done if the operation were carefully carried out by qualified veterinarians.

It should be recalled that all vaccinations should be done obligatorially with quarantine measures and "stamping out" measures where the disease has already struck.

3. Outlook for the future

The future outlook for the eradication of pleuropneumonia is better than it formerly appeared, although it is less bright than the outlook for eradication of rinderpest.

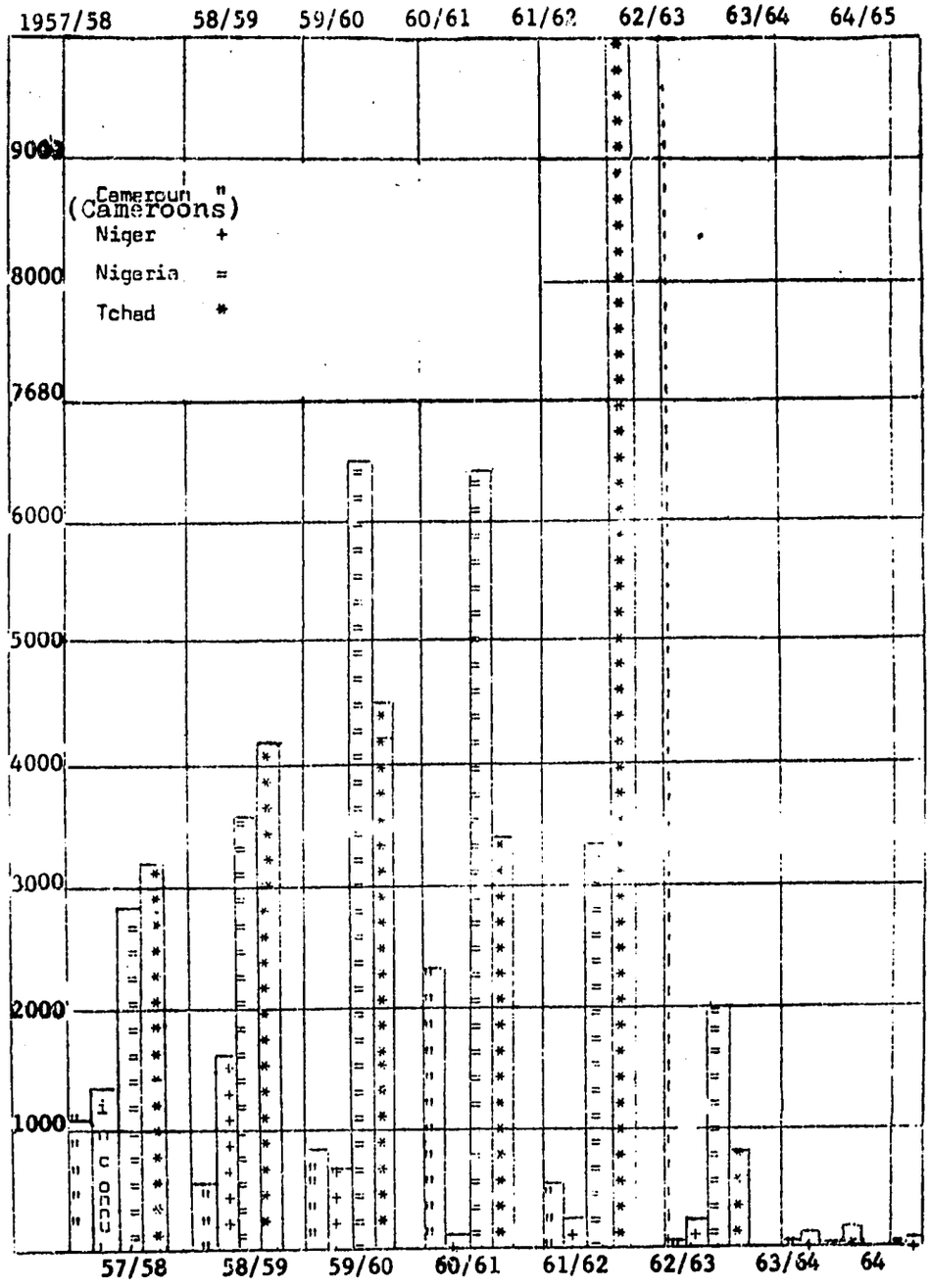
If vaccination is accompanied by a strict sanitary policy (quarantine, slaughter, payment of indemnities for slaughtered animals) we believe that there is a very good chance that it could be eradicated.

But at any rate, and our experience with rinderpest shows this clearly, there is no chance of eradicating pleuropneumonia if it is not attacked jointly on a regional and even continental basis in Africa.

The African countries must show the solidarity and make the decision for such activity, analogous to the activity being carried on at present against rinderpest; this alone will resolve the problem. These same countries must study how this can be done, how it can be financed, and they must seek the help of international organizations, if need be.

Table 1

Number of cattle dying from rinderpest in the operational zone of the Joint Campaign (Phase I)



2/63 Beginning of Joint Campaign

Table 2

Table of Vaccinations (Phase I)

Countries	Estimated no. of livestock	Vaccinations 62/63	Vaccinations 63/64	Vaccinations 64/65	Totals
	588,700	665,504	736,328	674,409	2,076,241
NIGER/EST	1,735,000	1,841,070	1,820,739	2,155,629	5,817,438
NIGERIA	4,050,000	4,787,083	5,975,976	6,219,559	16,982,618
CHAD	2,500,000	2,485,871	2,709,275	2,677,658	7,872,804
Totals	8,843,700	9,779,528	11,242,318	11,727,255	32,749,101

Table 3

Table of Vaccinations (Phase II)

Countries	Estimated no. of livestock	Vaccinations 64/65	Vaccinations 65/66	Vaccinations 66/67	Totals
Ivory Coast (East)	50,000	44,696	43,369	55,900	143,965
DAHOMEY	350,000	263,020	324,678	363,865	951,563
GHANA	400,000	305,997	355,512	391,118	1,052,627
Upper Volta	2,400,000	1,830,275	2,301,970	2,359,200	6,491,445
MALI/EST	3,406,000	1,859,101	3,426,587	3,292,733	8,578,421
NIGER West	2,150,000	2,054,289	2,141,858	2,186,894	6,383,041
NIGERIA S/West	150,000	329,580	164,543	142,568	636,691
TOGO	160,000	---	59,663	46,451	106,114
Totals	9,066,000	6,686,958	8,818,180	8,838,729	24,343,867

CURRENT PROBLEMS OF BACTERIAL DISEASES IN WEST AFRICA

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SUMMARY

Contagious bovine pleuropneumonia is a disease of considerable economic importance. The losses for which it is responsible are higher mortality and morbidity rates and retardation of marketing of the animals and of development of draft animals.

Great progress has been made during the past year in knowledge about the disease; nevertheless numerous problems have still to be solved.

Various forms of serology have been applied to the investigation of the disease and its chronic carriers, with variable results.

The causal agent Mycoplasma mycoides has been the subject of many studies. Research carried out into its biology has established which media favor dense culture development in which the microorganisms can survive for a sufficient length of time. Recently documented improvements in this field of inquiry are directly responsible for the increase of antigenic qualities of the vaccines.

The actual structure of the microorganism is known only incompletely with the isolation of a protein group. This is true likewise for the isolation of the endotoxin. The eventual role that this substance will play in relation to the pathogen is not yet clear.

Knowledge about the pathogen and its etiopathogenesis has been greatly increased. Experimental reproduction of the disease no longer causes difficulty, and this provides invaluable tests for immunity.

However, these are works connected with immunization of animals and provision of effective vaccines which have been subjected to a great deal of research. In effect, with the conditions prevailing in tropical Africa, hygienic prophylaxis in unattainable and intensive vaccination is the only realistic precaution.

Killed vaccines have been shown to be ineffective or too difficult to prepare under current conditions.

The problem of live vaccines is complicated by the poor antigenic qualities of M. mycoides, the instability of the herds and the different sensitivies presented by the cattle herd. The use of lyophilized products has considerably improved the duration of conservation.

Currently, many vaccinated herds (attenuated live vaccines, or avirulent) have already served in programs of systematic vaccination on the

African continent. There only remains selection of the most appropriate vaccine ultimately for use in inter-governmental vaccionation campaigns.

INTRODUCTION

While certain microbial diseases such as hemorrhagic septicemia, bacterial anthrax, symptomatic anthrax, salmonellosis, etc. do not have grave economic repercussions, due to the efficacy of the measures of medical prophylaxis used upon their discovery, this is not true with various other infections. Among these, of primary importance is contagious bovine pleuropneumonia, and following that, streptothricosis and nocardiosis.

CONTAGIOUS BOVINE PLEUROPNEUMONIA

Though great progress has been accomplished over the preceding years in knowledge about this disease, there remain without question numerous points to clarify.

Various serological methods (slide agglutination and in tubes, indirect hemagglutination, indirect agglutination with latex particles, gel diffusion precipitin test, precipitation, complement fixation in different forms, all recent allergies) have been applied in diagnosis of the diseases and in detection of the chronic carriers with variable success. Slide agglutination in particular gives rise to false positive reactions and variation of the complement does not detect all the animals which exhibit lesions.

The techniques of fluorescent antibodies is considered more as an immunological method than as a diagnostic technique.

Concerning the causal agent, Mycoplasma mycoides, its biology and nutritive requirements have been thoroughly studied and culture media developed to give dense cultures and sufficiently long survival of the microorganism.

Fundamental analysis in regard to immunization is incomplete. While the isolation of the lipopolyoside fraction and the galactan has been achieved, the protein elements have not. The role of these fractions in the development of various antibodies remains to be determined.

Evidence for the existence of an endotoxin seems apparent, but its isolation has not yet been achieved. Even the part played by this substance in the pathogenic capabilities of Mycoplasma mycoides remains unknown.

Anitgenic analysis of samples and the eventual establishment of a system of classification based on biochemical criteria should be made the object of a specialized study.

The areas of pathogenisis and etiopathogenisis have been generally examined. Even so, experimental reproduction of the disease must be accomplished in the near future.

Most of the work has concerned development of good and effective vaccines. The reason for this is that, under existing conditions in tropical Africa, hygienic prophylaxis is unrealizable in practice, except in rare and very localized cases. In the face of these difficulties, vaccination is necessary. It is logical to suppose that only recourse to medical prophylaxis for a long enough period of time over extended areas, will enable the disease to be eradicated entirely or for all practical purposes. This should be undertaken by a joint intergovernmental campaign.

Killed vaccines are either ineffective or their preparation is beyond current techniques (vaccine killed with Freud's antigen and auxiliary oil).

The problem of live vaccines is made a difficulty by the poor antigenic qualities of Mycoplasma mycoides and by the instability of the preparations in which strength decreases with time gradually and in proportion to their use. The differences of susceptibility of the cattle species (zebus or taurins) makes vaccination ineffective or of varying effectiveness. The use of lyophilized preparations has considerably improved the length of stability.

Currently, the Laboratory at Dakar dispenses a certain number of vaccination stocks for Mycoplasma mycoides which can be classed in order of increasing strength: KH_3J (totally avirulent), strain T_1 and strain DK (isolated and attenuated at Dakar, which keeps some of its strength).

The antipleuropneumonia vaccines can be introduced in two forms:

-- liquid vaccines: in sealed ampouls or vials with limited stability for several weeks (strains KH_3J, T_1 and DK).

-- lyophilized vaccines: in penicillin type vials, that can be kept in a refrigerator for more than a year.

Lyphilization is able to be used with either a broth culture of the stock vaccine with an appropriate diluent (KH_3J, T_1 and DK), or with Mycoplasma cultured in eggs (egg vaccine T_3).

On account of the difficulties of preservation, a massive and extensive campaign of vaccination will be able to use only lyophilized products. Use of the egg vaccine for large prophylactic programs seem difficult, if only because of the difficult techniques of its manufacture.

Practically, then, the only vaccine envisaged for use is the lyophilized broth culture under conditions that the number of live bacteria per dose is stable (10^8 per ml).

Determination of which vaccine stock should be used in West Africa remains to be decided. According to experience acquired by the Laboratory at Dakar, the strain DK and the egg vaccine T3 are too virulent for the susceptible species (taurins). Also, whether it is possible to retain the use of attenuated stock of strains KH3J and T_1 must be determined.

A program has been drawn up with the expectation of outside financial aid. It is concerned with two important areas:

(1) Experimental study of the comparative immunity conferred by lyophilized vaccines of the strains KH3J and T_1. This recommendation was recorded at the Conference of Specialists on Bovine pleuropneumonia held at Khartoum in February 1967.

(2) The means necessary to manufacture annually approximately 3,000,000 doses of vaccine, designed for a campaign of immunization in the countries of West Africa.

In sum, our knowledge in regard to bovine pleuropneumonia must be improved in the following areas:

-- serological detection of chronic carriers;

-- the antigenic constitution, isolation of the protein fraction and of the endotoxin;

-- immunization.

STREPTOTHRICOSIS

The scientific data that we possess on streptothricosis is relatively abundant; on the other hand, our means for control of this disease, which causes great economic losses, are practically nonexistant.

Bacteriological study of the causal agent Dermatophilus congolensis in its various manifestation has been made by several authors. Evidence of the antigenic capacity of the microorganism has been shown by various immunological reactions (slide agglutination, passive hemagglutination, interfacial precipitation in a liquid medium, gel diffusion precipitin, complement fixation, immunofluorescence).

Experimental reproduction of the disease in laboratory animals, as well as histological study of the lesions, has been made the subject of many studies.

The climatological conditions favorable to the appearance of the disease have been delineated precisely, but although it is known that ticks and the hematophagic insects play a certain part in streptothricosis, its etiopathology remains uncertain.

The means for controlling this disease are practically nonexistant. Experimental vaccination with a killed vaccine in oil have yielded no worthwhile results. In chemotherapy to date use of quaternary ammonium has only yielded inconclusive results. Antibiotics, apart from the combination of a very high fresh dose of penicillin with dihydrostreptomycine, have not provided radical solutions. Only repeated de-ticking, spraying or bathing with acaricides and solutions of quaternary ammonium compounds, exhibits definite prophylactic action.

In sum, research on streptothricosis should be conducted in the areas of:

-- etiopathogenisis,

-- prophylaxis,

-- treatment.

BOVINE NOCARDIOSIS (BOVINE FARCY)

Bovine nocardiosis is not of as great importance as the two previously described diseases, for this disease is both less extensive and causes fewer deaths among the animals. Apart from the cutaneous form, the lesions are most often discovered (and can be confused with those of tuberculosis) upon examination of the carcasses, and the economic losses which have been recorded are those that the slaughter inspector has examined.

The knowledge that we possess on this bovine farcy is very fragmentary and the means against it nonexistant.

Investigations on the presence and incidence of bovine nocardiosis have been carried out in various countries: Senegal, Chad, Sudan and Somalia.

The pathogenic agent, Nocardia farcinica, has been the subject of various studies. The systematic position of the microorganism is still under discussion, and its antigenic structure is poorly known; does it exist as a single species or in varieties?

Investigations to be completed are entirely in areas of pathogenisis, etiopathogenisis and experimental reproduction of the disease. The physiology and immunology for N. farcinica are unknown. Consequently, we do not know whether there is toxinogenesis and production of allergens, with the possibility of using an allergic reaction for detection of infected and sick animals.

The confusion with tuberculosis, by cross-reaction, is a known danger but it has not been defined by specific tests. Is the discovery of a "farcinin" a possibility ? So many points remain to be clarified.

Finally, measures of prophylaxis and treatment are totally nonexistant.

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CURRENT PROBLEMS OF BACTERIAL DISEASES IN WEST AFRICA

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SUMMARY

The virus diseases depleting the herds in the countries of West Africa are not numerous, but extremely important because of the resultant economic loss to these countries. The most important of these diseases have been for some time the object of a program of prophylaxis, but continued extension of the regions of animal husbandry and insufficient personnel responsible for controlling the diseases have made them difficult to contain. These diseases are enumerated:

Rinderpest

Since 1962, the countries which practice animal husbandry in the border areas have undertaken a combined campaign of vaccination and introduction of Joint Program No. 15. Its realization is due to financial aid from F.E.D. and U.S.A.I.D. and to the use of effective capripestic and lapinized and tissue culture vaccines. The manufacture of these vaccines in numerous laboratories makes their standardization necessary; moreover, the tissue culture vaccine whose use is now general, would be better with increased heat resistance.

The success of the joint campaign should result in control of rinderpest and allow large-scale meat production from the Sahelian countries. For the first time, exportation of sanitary meat would be possible, beginning with the disease-free areas. Preservation by refrigeration is not in all cases the best method; heat is the surest method.

Creation of disease-free areas poses a certain number of problems to resolve:

- setting of times during which rinderpest should not be observed in these areas;
- vaccination of animals in these areas with a good inactive vaccine;
- the necessity of vaccinating small ruminants living in this area which harbor in their serum antibodies neutralizing the virus, carriers of concealed disease;
- the existence of wild ruminants capable of harboring the plague virus.

Foot and Mouth Disease

This was found endemic in West Africa as a benign disease showing the low resistance of the cattle. However, an upsurge of the disease is anticipated with improvement of animal husbandry.

Mucosal disease in cattle

A disease little known in West Africa due to its clinical resemblance to rinderpest, it could become important with the disappearnce of that disease. It thus appears necessary to study susceptibility of the livestock and preparation of a vaccine.

Disease complex in small ruminants

In this group distinction must be made between the pest of the small ruminants, which is found on the Ivory Coast and in Dahomey and for which a vaccine has been developed, and the pneumopathologies of the small ruminants, for which etiology and epidemiology are under investigation.

African swine fever

This constitutes a major obstacle to the development of swine husbandry, notably in Senegal.

INTRODUCTION

The virus diseases which are afflicting livestock in the countries of West Africa are not numerous but extremely important due to the resultant economic losses for these countries. The most widespread of these diseases have been for some time the object of a program of prophylaxis, not so much from the medical standpoint as that of hygiene. But due to the extension of the areas of husbandry and the lack of personnel for its control, these programs are managed with difficulty. Among these diseases are found rinderpest and pest of small ruminants. Other viral organisms are known, such as those for hoof-and-mouth disease and disease of the mucous membranes, but these do not yet have the pathological importance of the preceding which stems from the method of husbandry in West Africa and the low resistance of the herds; they at first can cause confusion to the person unfamiliar with them, in their similarity to the better-known diseases.

RINDERPEST

Since 1926, the livestock-producing countries in the sahelian zone have undertaken a joint campaign of vaccination which moved from east to west. This campaign, arranged under Joint Program No. 15, began in Chad and is currently in Senegal; it has been made possible by financial aid from the European Community and the United States and has resulted in actual control of rinderpest. Its success is due to the use of vast material means and vaccines that are effective, capripestic, lapinized, and prepared from tissue cultures using the kidneys of cattle embryos. This last vaccine is now generally used because of its immunological qualities, its ease of preparation in large quantities and its total safety with even most susceptible stock. Prepared at first only in a few Centers, the tissue culture vaccine is now made in numerous National

Laboratories. Under these conditions, in order to preserve all its qualities, it will be necessary to set standards for methods of manufacture and control, and to establish minimum requirements, failing which, the virus vaccine will be rejected. In this arrangement, several large centers will be responsible for the control of vaccines manufactured in a given area.

The use of this tissue culture vaccine is still rather expensive, not because of the cost of manufacture which is fairly low, but because of the necessity to preserve and transport it under refrigeration. This necessity imposes or will impose higher expenses for preservation methods, which will become the responsibility of the governments of the countries after the current joint campaign. To alleviate this expense, research is being conducted in the laboratories of I.E.M.V.T. to increase the thermo-resistance of the virus, notably by adding to the vaccine certain mineral salts (1966).

The success of the joint campaign should result in effective control of rinderpest. This fact is of great economic importance to marketing of meats originating from the sahelian zone, since the importing countries refuse to accept animals or meat coming from countries where the disease occurs in the endemic state or even meat from areas yet untouched but where medical prophylaxis uses even an attenuated live virus.

In response to such exigencies, two series of measures must be planned, the first based on treatment of suspect meat which is only a palliative; the second, on creation of disease-free zones where the animals will be immunized only by an inactive vaccine. This last is a logical measure to follow the joint campaign.

The treatment of infected meat has been and is the object of research conducted in the laboratories of I.E.M.V.T., where research was undertaken under the aegis of O.I.E. with financial aid from the European Common Market.

First experiments had to do with studying the persistence of the virus in refrigerated meat coming from susceptible and vaccinated animals. The results obtained have demonstrated that, first, preservation in cold cars for 8 days before maturation was not sufficient to inactivate this virus in meat coming from infected animals; and, secondly, that vaccination with inactive or living vaccine could not ensure in all cases destruction of the disease in meat from vaccinated animals which were later infected.

Another study has been made to examine the results of decontamination of infected meat by heat (1967). It appears that purification can be obtained with pieces of meat of from 4 to 5 kg, which are wrapped in a double plastic envelope and plunged into a water-bath of 80° C, reaching 60° C. in the center of the pieces. A complementary technological study has shown that the meat keeps all the necessary qualities for preparation of canned beef.

One last point must be clarified, in regard to the multiplication of aerobic and anaerobic bacteria during heating. A recent study (1968) has shown that, for meat handled hygienically, the aerobic bacteria diminish while the anaerobic are slightly multiplied at the surface of the places but at a rate perfectly compatible with the demands of dietary hygiene.

The creation of disease-free zones is the ideal solution and the one which is essential to the success of marketing of meats originating in West Africa. If the results of the joint campaign support the practicability of this plan, its plan of implementation presents a certain number of problems:

1) To fulfill the requirements of the consumer countries, rinderpest must not have been observed in these areas for definite periods of time, ranging from 6 months to a year.

2) The animals introduced in this zone must be free from all living plague virus, pathogenic or not, and must be vaccinated with an inactive vaccine and remain under quarantine. In regard to the last point, there is evidence (1968) that cattle immunized with inactive vaccine, manufactured from spleen and ganglion pulp, and subsequently infected deliberately, are free of the virus 25 days after its introduction. This study must be resumed using inactive vaccine manufactured from tissue culture. To be effective, the vaccine should contain the maximum of viral particles. Studies are already underway in this direction, attempting to increase tissue culture yield by the use of hypotonic environment, tensio-active agents and proteolytic enzymes.

3) Epidemiological investigation made with small ruminants in Senegal (1968) reveal the presence of antibodies neutralizing the plague virus in their serum in proportions of 50% in the endemic zone and 15 to 20% in zones untouched by the disease. Are these antibodies evidence of a modified virus infection adapted to the small ruminants, such as the pest of small ruminants (PPR) virus? Are these viruses capable of recovering their original virulence and being spread by the small ruminants in the disease-free zone? This point will be studied in ecologically similar zones and if the results are identical, vaccination of the small ruminants in the disease-free zones will become a necessity.

4) The wild ruminants are also able to harbor the virus, so that their presence poses another problem in creation of disease-free zones, but not so serious as that with the small ruminants due to the disappearance of wildlife in West Africa.

In conclusion, it can be said that rinderpest is presently on the wane in West Africa following the joint campaign of vaccination, whose results should be supported by strict application of conservatory measures. To enable meat to be marketed in countried free from rinderpest under existing conditions, it is necessary either to decontaminate the meat, only a palliative method, or to create disease-free zones

under quarantine, which is desirable but which must take into account existing ecological problems and will necessitate a rigid prophylaxis centered around the use of an inactive vaccine, complemented by quarantine measures.

FOOT-AND-MOUTH DISEASE

A universal virosis, foot-and-mouth, is also found in West Africa, particularly in Upper Volta where it is endemic in a benign form, rapidly followed by recovery of health and with very little effect on the economic potential of livestock. In some countries it has been on the increase for several years. Is the benign aspect of the disease due to the fact that the types of virus found in Africa have reduced pathogenicity or to resistance of Africa cattle? Is it necessary to list the types of virus existing in West Africa in anticipation of an upsurge of the disease due to improvement of cattle husbandry?

DISEASES OF THE MUCOUS MEMBRANES

Still infrequently found in West Africa, mucosal diseases of cattle, similar in symptoms to rinderpest, may become more widely spread at the conclusion of the joint campaign. This being the case in Central Africa (1967) where numerous apparent failures of immunization led to a suspicion of its existence, the disease was confirmed by isolation of the virus in the Laboratory at Fort-Lamy (1967). Though epizootologically zebu cattle are resistant, taurine cattle are not, particularly N'Damas.

The attention of the animal health services must thus be focused on the possibility of its existence and the necessity, in cases where apparent failures of vaccination are observed with the vaccinated cattle, of reconsidering previous deductions in the laboratory with a view toward a different diagnosis. This research must of necessity be concluded by a serological investigation to determine the sensitivity of cattle to this disease, in regions where it has been identified.

In case this disease does appear on the increase, it will become essential to plan the manufacture of a living vaccine from the attenuated stock C 24 V.

PEST COMPLEX OF SMALL RUMINANTS

Numerous cases of resurgence of mortality of small ruminants are frequently observed during the cold or rainy season. The breeders or even uninformed professionals often attribute these losses to pest of small ruminants (PPR). In fact, under this name are grouped various disorders whose symptomatology is alike and whose diagnostic differences can be established by an elaborate post-mortem examination conducted by laboratory tests. Very often, at least in Senegal, pneumopathologies are involved whose etiology has yet to be determined.

PPR exists on the Ivory Coast and in Dahomey where it was recorded in 1942.

This was discovered from research made at Dakar (1956, 1962, 1967) to be a plague virus adapted to small ruminants. It was responsible for many losses in Senegal between 1956 and 1962. Since that time, it is no longer found in this country. Is its disappearance due to a new modification of the virus which is no longer contracted by small ruminants or has it become a hidden disease for which evidence can be found in the presence of neutralizing antibodies in the serum of these animals (1968)? These facts together tend to prove that in natural conditions the virus is capable of undergoing mutation in the form of an attenuation; there seems no evidence that an inverse mutation is not possible.

Depending on the results of this investigation, it will be desirable to continue research on PPR, especially in the countries where it is still in evidence, the Ivory Coast and Dahomey. Notably, a serological investigation must be made in these countries to discover the exact sensitivity of the small ruminants to the virus and if necessary to procede with a campaign of vaccination of these animals. The vaccine has been developed; there only remains to demonstrate its effectiveness on a wide scale.

There is a second point that remains to be clarified: the etiology and epidemiology of the pneumopathologies of small ruminants.

In West Africa, these animals are afflicted during the cool season with pulmonary infections (pneumonia, bronchopneumonia and pleuropneumonia) which are the causes for a large mortality rate in certain years. Since the etiology of these pneumopathologies was unknown until the present time, their prophylaxis has been impossible, causing harmful economic losses. Consequently, a research program has been outlined concerning the following areas:

Etiological research

Identification tests, from conclusions formerly drawn in the infected areas, of the pathogenic agent responsible for these disorders, with particular emphasis on the part played by rickettsia and the large pneumotropic viruses in the etiology of these diseases.

Epidemiological research

These must enumerate the areas afflicted by the diseases, in order to determine their extent and severity. The research to find the etiological agent having been successful, these investigations will be supported by serological investigations.

Control methods

Knowledge of the responsible microorganisms for these infections will eventually enable laboratory research to decide upon the most effective prophylactic and therapeutic means.

AFRICAN SWINE FEVER

This disease had decimated the extensive swine production in Senegal between 1959 and 1960; it continued endemically until 1964. Since that time, the disappearance of the large herds has eliminated the disease. The present infrastructure of the laboratory at Dakar is not able to plan research on this disease, especially as large teams, mostly in East Africa and Spain, devote all their time to their regions. It is nonetheless essential, in the course of rebuilding the swine industry, to take its existence into account and devote part of current and future research programs to the control of this disease.

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VETERINARY RESEARCH IN AFRICA AND PROPHYLAXIS AGAINST CONTAGIOUS DISEASES OF LIVESTOCK

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SUMMARY

Prophylaxis against contagious diseases of livestock was from the beginning the main function of the first livestock Services in all the West and Central African Francophone countries. Veterinary research was organized very quickly; today it is carried out in a series of laboratories, the management and scientific direction of the majority of which has been entrusted to IEMVT.

The amount of acquired information is imposing; in the area of practical application, the research comprises mainly use of very elaborate diagnostic techniques, and particularly the production of a series of vaccines of a high technical quality. Numerous viral and bacterial diseases have been combatted for many years with vaccines which are second to none compared with those used in the developed countries of North America and Europe.

Briefly, the African countries have already at their disposal the effective means to control the important classical diseases which constitute one of the principal obstacles to the development of economic livestock production. In such a sphere as this, priority ought therefore to be given not to research itself, which goes ahead at its own pace, but to its application in the field. Priority research is research into effective-means of disseminating prophylactic methods, organization of vaccination campaigns, education of livestock herders, rational utilization of vaccines, training of informed technical personnel.

The systematic application of the programs of prophylaxis proposed today in connection with the major contagious diseases (rinderpest, bovine pleuropneumonia, anthrax, pasteurellosis, botulism, etc..) would already enable a great step forward to be taken.

Particular mention should first be made of the zoonoses, diseases common to man and animals (rabies, Q-fever, arboviruses, brucellosis, tuberculosis) control of which should be undertaken with the collaboration of the medical health services.

Secondly the serious epizootic diseases (particularly viral) should be mentioned. The African countries are a permanent reservoir of these, which prevent trade with the disease-free countries; the best examples are rinderpest (affecting meat exportation), African horse sickness and swine fever.

* * * *

It is now many decades since veterinary research was first carried out in Francophone countries in Africa. It began by numerous observations of all kinds, ethnological investigations, epizoological reports, various collections (anatomical specimens, parasites, insects, photographs, etc) which the French veterinarians, who were either military or officials of the livestock Services, accumulated patiently and often meticulously during their African trips. An immense mass of documents exists, always insufficiently exploited.

However this was not official research, organized and oriented by defined programs and entrusted to workers who were always provided with adequate basic knowledge necessary for the effectiveness of this research. This organization only came into existence with the construction and operation of the principal veterinary laboratories: Dakar-Hann in 1953; Fort-Lamy - Farcha in 1953; Tananarive in 1955. Other, more recent centers where research has not yet become the major activity, will not be considered, although their production of vaccines is already very important.

The amount of acquired knowledge about contagious diseases of livestock is imposing, particularly regarding their medical prophylaxis and their epizootiology; one has only to refer to the already long list of annual reports of these laboratories to see the lines followed and to understand that the African countries possess in these centers very important research instruments.

Since today Africa would like agricultural research (in the broadest sense) to be, first of all, only a means to the development of her economy, it is useful to mention here that veterinary research from its beginnings to the present time, has always been oriented towards applied areas, thus neglecting - to the great regret of some - its fundamental side.

The medical prophylaxis of the contagious diseases of livestock is linked to problems of vaccine preparation and the numbers cited in the following table show to what level production has been raised in these three laboratories in 1967:

Production of the Veterinary Research Laboratories of Dakar, Fort-Lamy and Tananarive in 1967

Rinderpest vaccine (tissue culture)	8,215,000
Rinderpest vaccine (others)	2,435,000
Bovine pleuropneumonia vaccine (egg)	1,173,000
Bovine pleuropneumonia vaccine (liquid medium)	3,965,000
Bacterial anthrax vaccine	6,385,000
Symptomatic vaccine	2,572,000
Bovine pasteurellosis vaccine	1,178,000
Poultry disease vaccines:	
- Newcastle disease	2,539 000
- fowl-pox	900,000
- pasteurellosis	2,453,000
- fowl typhoid	228,000

If one considers that these vaccines are for the most part the result of many years of research, one can thus measure in a concrete way the range of work carried out for the control of infectious diseases. It remains to be emphasized that these vaccines are of a high technological level perfectly comparable to those used in countries at a high level of development (Europe, U.S., etc..). It is enough to think that the Chad zebras, for example, can undergo vaccination against rinderpest through an injection of attenuated living virus, obtained by tissue culture and perfectly preserved by lyophylization. This example, taken from many others, shows that the means are available to control and eradicate the principal infectious diseases which were always obstacles to the increase or yield of the herds.

Since this Conference has for its principal objective to define the research priorities for economic development of the African countries, it appears to veterinary microbiologists that the only priority to establish is that of the application in the field of modern methods of prophylaxis. It would be ridiculous to maintain that veterinary research is ended and that the infectious diseases of livestock have surrendered their ultimate secrets; it would be equally ridiculous to recognize that all the benefits of this research is lost if the extension of the methods developed is insufficient or impossible.

It is clear that without new research the systematic appplication alone of programs of prophylaxis propssed today regarding the main contagious diseases,(rinderpest, bovine pleuropneumonia, anthrax, pasteurellosis, botulism, etc..) would already enable a great step forward to be taken.

Priority research is thus that of effective means of diffusion of methods of prophylaxis, organization of vaccination campaigns, education of herders, training of informed technical personnel, rational utilization of vaccines.

Two areas of pathology merit particular attention:

1. zoonoses, diseases common to mean and animals (rabies, fevers, arboviruses, brucellosis, tuberculosis) against which control should be undertaken with the collaboration of the medical health Services;

2. certain serious epizootic diseases, particularly viral diseases, of which the African countries are a permanent reservoir, and which prevent trade with disease-free countries - rinderpest and African horse sickness. The repercussions of this pathology on the economic sphere are more evident here.

MINERAL DEFICIENCIES

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SUMMARY

Mineral deficiencies are a serious problem of livestock in the Sahelian zone. In these areas, in effect, the conditions of the natural environment and in particular the improvishment or mineral imbalance of the soils have repercussions on the composition of the fodder and on the health of the animals which consume it.

The animals develop an adaptation which tends to conceal the deficiency but affects productivity. This condition, even latently developed, is thus held responsible in part for the lack of early development, the low level of milk production, and for the prevalence of disease in young animals.

In addition to these factors limiting production there is the serious animal disease rampant in the Senegalese Ferlo provides a perfect illustration of the danger for extensive animal husbandry arising from mineral deficiencies.

GENERAL DISCUSSION

The various animal species, because of their physiological and biochemical pecularities, make different use of the food available to them. Consequently, the nutritional problems presented by each species is of a highly specific nature.

In the areas of tropical husbandry, the ruminants (cattle, sheep, goats) now constitute, in number and economic value, the most important livestock. Thus it is their problems which will be discussed here.

Two types of nutrients should exist in an animal's diet. The first provides energy for the functioning of vital mechanisms, the second, the body-building elements including nitrogen and the mineral salts. As a result of the enlarged development of the digestive tract and the microbial symbiosis found there, the ruminant's energy supply is always satisfied in the natural state. The tomach structure also demands little as regards the type of nitrogen ingested for, unlike the monogastric animal, the ruminant can utilize inorganic nitrogen.

On the other hand, as regards mineral metabolism, cattle are as demanding as other species. Deficiency or imbalance in these materials seriously affects their health and especially their productivity. As a result, mineral deficiencies constitute a serious nutritional problem

in tropical animal production.

A. Conditions leading to mineral deficiencies

Deficiencies in the mineral elements are an important aspect in the pathology of animal production in tropical areas. Their appearance and subsequent increase evolve from a number of factors among which can be cited: the climate and the soils, frequent mineral imbalance in feed stuffs, changing livestock management techniques, and the necessity of increasing production.

1. The climate and the soils

In the tropical areas where extensive husbandry is practiced, the interdependence of the soil, the vegetation, and the animals is still more limited than in the temperate zone. An imbalance of the soil was fatal consequences on the animal through the intermediary of edible vegetation.

Generally, analyses conducted on the African soils in rural areas have revealed great dearth of nutrients. The level of nitrogen and organic matter is low, and the mineral supplies are not much greater. This deficiency is especially ture for phosphorus generally, found in small quantities or in a form incapable of utilization due to the laterization of the soil.

This condition is brought about essentially by a set of climatic conditions which, combining rainfall and great heat at certain times, favor the decomposition of rocks. The soluble minerals are then rapidly released and leached deep into the ground because of the absence of impermeable bedrock near the surface.

The nature of the soils in the tropical agricultural area thus contributes to the appearance of mineral deficiencies in animals.

2. The imbalance of mineral supplies

The mineral elements, in particular phosphorus and calcium, which are supplied in the food should meet two conditions:

first, minimum requirements: second, a definite balance between the elements, which varies according to species.

The specific requirements of cattle for phosphorus are well known For this species, the ration between Ca/P sholld be 0.75 to 12. (Ferrando).

Numerous analyses carried out on grass samples from tropical areas do not, in general, fulfill either of these two requirements. During the long dry season, it has been discovered that the diet does not contain the minimum phosphate requirement and that the Ca/P ration

exceeds 10. These two conditions thus predispose the animals to disorders of calcium and phosphate metabolism.

However, the metabolic problems in regard to mineral salts are not limited to the presence and balance in the diet of the macro-elements such as calcium, phosphorous, sodium, and potassium. More and more, nutritionists are putting emphasis on the role in the diet of trace elements whose action is principally catalytic. The trace elements, principally copper, cobalt, manganese, zinc, flourine, and selenium, in excess produce disorders and if deficient, specific syndromes, a certain number of which have already been identified. It is possible that in explaining nutritional disorders a deficiency of a single element should no longer be referred to, but a "polydeficiency" in which the trace elements play an important part must now be discussed.

3. Changing livestock husbandry techniques

In the tropical agricultural areas in the past, the techniques used in husbandry were primarily of great migrations of the herds, which provided them with pasturage varying from the plateaus to the river valleys.

The availability of pumps, wells and dams has made possible the settling of herds around permanent water locations, so that periodic migrations are no longer necessary.

On the other hand, the increase in cultivated land and the profit incentive have caused the rural populations with proper social and economic progress to support this settling.

This sedentarization of herders leads to a number of consequences.

First of all and throughout the year, there occurs an intensive concentration of animals on the same ground and the same pasturage, causing more or less severe "overuse" of the land.

The animals are no longer able, as in the past, to find and store the indispensable nutrient elements as they moved from place to place.

The appearance of deficiencies is thus, in many cases, the price of sedentarization.

The livestock of the tropical zone is reputed to be of generally low productivity. The mineral deficiency or near-deficiency by which it is threatened is one reason for this condition.

What happens, in effect, is that the animal reduces its output as much as possible in such a way as to maintain the integrity of the organism. This economy exhibits itself in reduced size, reduced fertility,

reduced weight of the young, and poor milk production.

In the light of the animal's adaptation to the environment, the mineral deficiencies are largely concealed. On the other hand, efforts to increase the production of the herds will reveal the deficiencies more visibly and necessitate counter-measures.

B. Symptoms of mineral deficiencies

The disorders resulting from mineral deficiencies will be dealt with in a general way, taking as an example phosphorus, which seems to be one of the elements most frequently lacking.

This nutritional deficiency is manifested by a series of more or less acute disorders.

With the affected herds their frequently present abnormal feeding habits, a depraved appetite which drives the animal to search for organic waste of all sorts with a predilection for the remains of dead animals. The syndrome, known as pica, generally results from a poly-deficiency of many elements or mineral trace elements in which the deficiency of phosphorus plays a primary part.

Pica is often characterized by an obsession which reduces the animal's appetite for normal food and is reduced to a low state of maintenance. The most serious and frequent complication is botulism, an often fatal toxemia, which the animals contract from ingestion of the organic wastes and putrefaction infected Clostridium botulinum. It is the prevalence of this disease which has attracted the attention of specialists in Africa to mineral deficiencies.

At this most acute stage, skeletal disorders are encountered. In fact, the animals draw essential phosphorus from their reserves, stored primarily in the bones. This results in osteomalacia, causing great fragility of the bones and frequent fractures.

The reproductive ability of the animals is also affected. Frigidity can occur with the males as with the females, causing intervals between gestations or infertility. The young are born in a state of deficiency and are then susceptible to all the microbial or parasitic diseases, as the milk production of the deficient females is very poor.

In sum, mineral deficiencies play an essential part in the economic production of livestock. They measureably reduce meat and milk production, as well as being prone to serious secondary diseases. These two factors reduce the normal growth of the herds.

C. Frequency of mineral deficiencies

Mineral deficiencies are not a new pathological phenomenon for Africa or the world. Since 1920, Theiler and his collaborators have been

b) two etiological factors are at the root of its appearance:

- a nutritional disorder causing pica and osteophagy due to a polydeficiency in which the element phosphorus plays an important part,
- a botulinic toxemia contracted by the animals from ingestion of dead waste contaminated with Clostridium botulinum.

Hypophosphorus plasma was discovered in the affected area after an extensive biochemical investigation. Isolation of the microorganism and its toxin were accomplished subsequently.

The disease is combatted, at the present time, by distribution of mineral supplement and by vaccination of the herds with botulism anti-toxin C.

The conditions for the appearance of this disease in Senegal seem linked to a recent development of husbandry techniques. It happens that the fact of the establishment of deep water-holes, which greatly improve water conditions, cause the breeders in the Ferlo to reduce the extent of their migrations and to become settled in the aeea served by various watering-places.

The animals thus consume insufficient forage during the whole dry season, while in the past, due to the disappearance of water in the Ferlo, they migrated toward the banks of the Senegal River or those of the Lake of Guiers.

CONCLUSIONS

Mineral deficiencies constitute a definite pathological hazard for herds in the tropical zone. Their already established existence in certain areas leads to widespread complications such as botulism. But even in the latent state, they contribute to the low productivity of the herds often acutely.

Any improvement in production in these areas thus depends on the exact identification of the nature of the deficiencies followed by supplementation of the diet with the missing elements.

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BIOCHEMICAL PRIORITIES IN AFRICAN AGRICULTURAL RESEARCH

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SUMMARY

Within the framework of the programs defined by the governments and in order to resolve the particularly difficult problems that the African farmer faces, the following biochemical research has been given absolutely top priority among our present and future research programs. The goals to be pursued point to this priority.

1. aflatoxin, levels and simplified detection
2. biochemical constituents of the blood of African bovines
3. hemoglobin groups
4. biochemical studies of trypanotolerance
5. chemical composition of microorganisms

Among the disciplines that are engaged in research in order to solve the problems facing African agriculture, very little is done in the field of biochemistry. And yet, when one knows about the efficiency of biochemical methods, it seems that their use should be increased as one of the priorities for solving the problems we are facing.

1. Aflatoxin

The importance of peanuts for the African economy has led to the search for a rapid and simple method of estimation for aflatoxin which would make it possible for a non-specialized laboratory to develop chromatography with elementary equipment and easy methods.

2. Biochemical constituents of African bovine blood

Research on the health of livestock is sufficiently well-advanced that lack of knowledge and information on the biochemical properties of bovines' blood is an obstacle to maintaining the animal in good health.

Many diagnosed problems could be treated at the herd level by simple chemical treatment, if the physiological dose of the required step is sufficiently well-known for the breed or the region.

Setting up biochemical racial tables would be an important step in rational livestock breeding (5).

3. Hemoglobin groups

The importance of biochemical criteria for zootechnology and genetics need not be emphasized further. In fact, the simple factor

of hemoglobin in heredity is very interesting to know. Large systematic inquiries must be made to establish groups according to races in order to know these beyond their phenotypes.(5)

4. Biochemical studies of trypanotolerance

Trypanotolerance remains a real enigma and is very irritating in that discoveries on this subject would make it possible to greatly extend livestock production in zones that are greatly affected by the disease.

This vast problem can be approached from various aspects and the biochemical facets of the problem are not the least important, in terms of the information they can provide on the subject.

One working hypothesis makes it possible to investigate one of the probable causes in hemoglobin composition. Thus, the hemoglobin of trypanotolerant and trypanosensitive animals must be examined.(5)

5. Chemical composition of microorganisms

In order to constantly improve vaccines, it is necessary to obtain particularly selected antigens in order to produce the greatest amount possible of very protective antibodies.

This selection is partially operated through biochemical research of the bacterial constituents which are the most antigenic followed by their isolation and then simple preparation. (1)

Thus biochemistry can bring hope to the solution of certain problems of African agriculture if priority is given to certain subjects that we have briefly outlined here, namely aflatoxin, the biochemical components of bovine blood, trypanotolerance and the study of antigenic constituents of microorganisms.

INTRODUCTION

In Africa, one must first develop animal proteins in order to improve the level of nutrition and develop the economy.

All tools must be used to resolve the problems; biochemistry is one of those tools and it has two advantages and one relative disadvantage.

Among the advantages let us note its particularly wide effectiveness and the rapidity with which it obtains first results. The disadvantage is the high cost of the necessary infrastructures. However, this cost is only high on the surface and is lessened or removed when thought of in terms of the gains and savings obtained after the research is applied.

Thus the first objective would be to introduce the intensive use of biochemistry in African agricultural research.

This priority seems particularly well-illustrated by the research pursued by the IEMVT laboratories, in close collaboration with our colleagues in the field.

1. Aflatoxin

This is a very important problem for livestock production and agriculture in general as peanuts are an important crop for many African countries. Studying the metabllisms of A. flavus makes it possible to find out very precisely the conditions under which the toxins develop. It is particularly fruitful to be able to recognize and rapidly and simply estimate the amounts of B_1 aflatoxin.

Without underestimating the importance of the other five toxins, on a practical level, a rapid estimation of B_1 aflatoxin can improve utilization conditions of the raw material by closely surveying the evolution of the contamination. It has been demonstrated (2,3,5) that if thin layer chromatographic support film of determined quality were available to laboratories, it would be possible, with simple equipment (rubber stoppers, tweezers, etc.) to get an approximate estimate of aflatoxin B_1, particularly using pure commercial toxin..

Among research priorities to be followed through as soon as possible, it would be worthwhile to study the metabolism of A. flavus to discover the constituents which end up as toxins.

2. Composition of the blood of African Bovines

As progress is gradually made in maintenance of health, the importance of knowledge about the biological constituents of the animals increases. It is essential therefore to systematically gather these facts on clearly defined ethnic groups.

This type of knowledge is still fragmentary and acquiring these facts will be a long and tedious process. The IEMVT research workers apply immunoelectrophoresis methods to the study of serum proteins. Other constituents are studied and estimated such as: bilirubin, cholesterol, biological active phosphate, etc. as well as various physical properties such as osmotic pressure, etc. (4)

3. Hemoglobin groups

These blood proteins can be given a place apart, not only because of their biological importance, but also because their quality makes it possible to define ethnic groups on a scientific basis. One can put all bovine hemoglobins actually known into four large groups and their

combinations. Perhaps further study of these proteins will show, as for man, that there is a whole series of sub-groups, not important as to numbers of individuals belonging to them, but very important for studying the associated biological properties.

This work will involve investigations over a very long period of time, because the value of the results obtained in great measure depends on the number of individuals examined. Through this biological property we have a way to define the African races better and a key to studying their optimum crossbreeding.

4. Biochemical study of trypanotolerance

There are some problems, which, if solved, would lead to spectacular progress. One of these is trypanotolerance. This tolerance is linked to certain well-known races and must depend on a combination of biological properties of which we are still ignorant.

Knowledge of these properties and the mechanism by which they lead to tolerance to the parasite would open immense possibilities for livestock production in areas that have been ill-favored until now. Research in this area is urgently needed and it is through analogy with humans that a way to solve this problem has been sought by the IEMVT.

It is truly remarkable that humans with drepanocytosis show a particular tolerance against malaria. It has been shown that this tolerance is due to the presence of a special hemoglobin, the S hemoglobin which through its biological properties keeps the parasite from developing in the blood. And yet it only differs from the A hemoglobin by the presence of a neutral valine in its two β polypeptide chains in position 6 instead of a glutamic acid residue negatively charged.

It thus seems logical to look for resaons for trypanololerance through comparative studies of resistant and sensitive animal hemoglobin. This type of research should be worthwhile even if the mechanism is different among bovines.

5. Chemical composition of micro-organisms

The chemical analysis of bacterial antigens promises to be quite fruitful from a practical point of view.

Knowledge of antigens bears on all areas of microbiology, the preparation of more effective vaccines, better and more rapid diagnostic methods, studies during epidemics and so on.

But it is in immunology that incidence is greatest and would justify the creation of a new branch, immunochemistry.

Biochemistry could bring to the very diverse areas of African agriculture the scientific region, required by its methods.

From the brief enumeration here of a few of its areas of application one can easily see the economic importance of the research currently being carried on. Not only can rapid results be obtained in precise areas but also long-term results can be hoped for that can transform livestock production and other agricultural activities.

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MAKING AGRICULTURAL RESEARCH RELEVANT TO AFRICAN FARMERS

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SUMMARY

Agricultural research must be largely oriented to the requirements of the small family farm which is characteristic of African agriculture. Research should not be understood simply as the technical and scientific work carried out on agricultural experiment stations. It must be more broadly conceived as including all types of studies and investigations that produce innovations which farmers will consider feasible and rewarding. It must be concerned with all the factors, socio-economic as well as technical, which condition the receptivity to change at the farm level.

On agricultural stations research must depart from a knowledge of the farmer's whole farming pattern and of the rationale of prevailing methods of cropping and animal husbandry. Single innovations which appear worthwhile by themselves may become unprofitable or impractical when their repercussions on the entire farm are taken into account.

Research should not be concerned exclusively with increasing the yield of crops or livestock per unit of area. It should recognize that most farmers in Africa, particularly those in the savannah areas, consider labor their principal constraint and are therefore primarily interested in maximizing their returns to labor rather than to land. It is important therefore to devote more study to the labor implications of possible agricultural improvements - to determine how the farm family uses its available labor resources over the entire season and where the bottlenecks are; and to estimate to what extent and when a proposed innovation is likely to require additional labor.

Labor bottlenecks may be widened by judicious introduction of machinery drawn by animals or by tractors. African agriculture is greatly under-equipped. Unfortunately, however, there are still only a relatively few cases where tractors have proved successful, and even the adoption of animal traction has been confined to certain areas. Mechanization, particularly with the tractor, is difficult because it usually entails a rather thorough revolution in farming methods and practices, including the adoption of changes in land tenure and new means of maintaining soil fertility and the replacement of extensive with intensive methods of cultivation. Much more work must be done to devise implements and machinery suitable to African conditions; and every major research station should carry on such work, adapting it to the problems encountered in the area it serves. Systematic efforts should also be made to analyze the many experiences with the use of various types of machinery and to disseminate the results of such analyses so that costly mistakes will not be repeated.

Many innovations have not been accepted by the farmer in the past because the nature and amount of incentives required to bring about their adoption have not been adequately appreciated. More socio-economic studies are needed to throw light on all the factors conditioning response to change in the societies of which farmers are part. These are important also for determining the best way of organizing agricultural extension work in various societies. Particularly when we are dealing with situations where there has as yet been little change we must be sure to study in advance such relevant social factors as the kinship organization and the associated network of obligations, the identity of the people who wield authority and those who may be potential leaders in effecting change, the system of land tenure and inheritance, the degree of exposure of the society to stimulating outside contacts through labor migration, trade and education, and others of this type. Sociological investigations should, of course, not be content to describe a society at any one point of time but should rather single out and assess both the factors which are making for change and those which still tend to impede progress.

Adequate preliminary studies can bring about much more intelligently devised methods for improving agriculture. They will not, however, ensure absolute success. There must always be a certain amount of trial and error. Under such conditions it is especially important to have periodic surveys to check the effectiveness of agricultural improvement or development programs. Too often there has been a tendency to continue with the same program without evaluating the results. It is only through farm economic surveys that we can determine what problems are being encountered at the farm level and how we can devise innovations that will take these problems more effectively into account.

INTRODUCTION

Before launching on a discussion of the subject which has been assigned to me I would like to define two terms - namely "agricultural research," and "African farmers."

In using the words "agricultural research" I do not want to confine them to research conducted on agricultural experiment stations. The work on such stations may be characterized as primarily technical and scientific in character. It is concerned with testing new crops, developing new varieties or improving livestock breeds, devising methods of treating diseases and pests, analyzing soils and the possibility of their improvement, assessing water requirements, improving methods of cultivation and the like. The focus of this research is largely on raising and conserving yields per unit of land area. There is usually some concern with the economies of research solutions in the sense that attempts are made to relate the cash cost of inputs to the cash value of the increased output that is said to be possible. In some, but by no means the majority of, cases an agricultural station may also undertake some applied research in the rural milieu outside the station in order to ascertain to what extent the cost:benefit ratio of innovations may need to be modified under actual farming conditions.

However important this type of research may be, its scope is not sufficient to determine whether innovations will really be adopted in practice - that is, whether they take into account the needs and capabilities of farmers for whom they are intended. Thus agricultural research must be broadened to cover the study of all the factors which condition the farmer's acceptance of change. One of these factors relates to the feasibility of proposed changes. Does the farmer command the additional inputs of labor and other factors of production that are required; and if he cannot, can the government take the necessary action to put them at his disposal? A second factor relates to the profitability of the proposed innovation. In the eyes of the farmer will the benefits be sufficient considering the costs of the extra labor and other inputs involved, the troublesome nature of the adjustments of his working habits and the degree of risk inherent in the supposed benefits? A third and final factor relates to the proper approach that must be used to persuade the farmer living within a certain social framework to try whatever is judged by others to be to his advantage. Here it is above all a question of determining the methods of agricultural extension work that are likely to be best suited to the structure of the society of which the farmer is a part. A knowledge of the last two factors depends above all on the adequacy of economic and sociological research.

I now come to the definition of "African farmers." Characteristically these are men and women who farm small family holdings. Except in still limited areas where there have been increasing population pressures on available land, the size of the holding is circumscribed in part by the fact that the need for land is still primarily governed by subsistence requirements and in part by the limited equipment available to the farmer. The first of these has tended in many areas to become a less important governing factor as profitable opportunities for growing cash crops have opened up. The second, however, remains a serious constraint. Over much of Africa the hoe and the

axe remain the only tools available to the farmer; and the improved equipment of the farmer in a manner that will prove economic is one of the central problems of African agriculture.

The family holding must be further characterized. In the majority of cases it is not a single production unit. Normally the man in the family is responsible for the portion devoted to cash crops, while the woman or women are charged with the cultivation of subsistence crops.

There are, of course, deviations from this pattern. Here and there, particularly in East Africa and in Rhodesia, large individual African farms exist. There are state and cooperative farms and privately-owned plantations. But for the most part these do not play a major role. The area in plantations, for example, is unlikely to be extended except perhaps in the form of so-called nuclear plantations with associated outgrowers consisting of small farmers who deliver their crops such as sugar cane, palm fruit and rubber to central processing facilities located on the plantation which itself produces the minimum crop necessary to make the processing plant economic. In that case, however, the problem is still to give the small African farmer the means and incentive to contribute the supplemental output.

Need for Knowledge of Prevailing Farming Patterns and Constraints

A study of selected experiences with agricultural development in tropical Africa which I directed for the World Bank has convinced me that one of the major causes of failure in the past has been the inadequate attention paid to the contraints of African farming and to the types and magnitudes of incentives required to bring about change. 1/

The first prerequisite of successful development is an adequate knowledge of the prevailing farming patterns and methods of production. Efforts to introduce innovations are likely to fail unless one knows why farmers adhere to certain practices, in what respect the innovations will modify the farming pattern and what difficulties the necessary modifications are likely to cause the farmer. One must know, for example, why farmers sow a crop at a particular time, especially when the date of sowing practised does not maximize the yield per unit of area. Similarly, if one wants to introduce an improved variety of a cash crop which should only be grown in pure stand, it is useful to know the implications for the farmer and his wife who have previously grown this crop mixed with others.

In recent times much more study has been devoted to the study of indigenous farming systems. 2/ Traditional African farming is no longer always dismissed as primitive and unworthy of consideration. There is a greater appreciation of the fact that the farmer, within the limits of his experience, makes a fairly rational use of the resources available and often displays a good practical knowledge of ecology. Yet the need for a more systematic collection and analysis of information on prevailing farming patterns still exists. Such surveys must not be purely descriptive, but must try to understand the rationale of given cropping patterns and methods of crop and animal husbandry. Information of this sort can be invaluable to both research and extension workers in enabling them to understand situations with which they must deal and which they are seeking to modify. It should form part of the teaching material in all agricultural schools and colleges.

I do not wish to suggest, of course, that all improvements in farming involve profound changes in existing systems. Some may involve little or no change. An improved variety may be substituted for another, or spraying may be introduced with minimal disturbance to the pattern of production. Perennial crops such as coffee and cocoa may simply be "added" without involving changes in established farming activities. Yet even in such cases experience in West Africa indicates that farmers often do not adopt the improved practices that are essential for high yields because these involve them in certain changes in utilizing their labor which they do not find advantageous. When new annual crops such as cotton are introduced these usually do have more far-reaching implications for existing cropping patterns because they raise problems of devising new crop rotations and of reconciling the competition of cash and subsistence crops for the available farm labor during the planting season. The most profound transformations are usually involved in the introduction of mechanization or irrigation, for these nearly always necessitate the replacement of extensive by intensive methods of production, the re-allocation or re-grouping of land, the adoption of new methods of increasing and maintaining soil fertility and the acceptance of a generally more disciplined form of agriculture.

The Labor Constraint

In this connection the need for a much better knowledge of the labor constraint in African agriculture must be particularly emphasized. Inadequate appreciation of this constraint has caused the rejection of many innovations. Again and again efforts to get farmers to increase their yields by timely sowing of a particular crop have failed because farmers have considered that they simply did not have the labor to do so at the recommended time. The most conspicuous example of this sort has been the failure in large part to bring about earlier sowing of cotton. Changes in practices which required greater inputs of labor per unit of area, such as tie-ridging of cotton land in Tanzania or improvements in coffee and cocoa husbandry in the Ivory Coast, have often failed because farmers considered with some justification that they could increase their output with less expenditure of labor by putting new land under crops and retaining their more extensive methods of cultivation. Irrigation schemes such as the Office du Niger in Mali have failed to recognize their full potential because it was not sufficiently appreciated that a high density of settlement was necessary to produce the intensive system of agriculture that the high capital investment in the irrigation network appeared to require. Attempts to introduce the transplanting of rice on this scheme quickly proved unsuccessful simply because there was not enough labor available and farmers accordingly found that the continuation of the old method of growing rice by direct sowing yielded a better return for their efforts. On the other hand, the transplanting of rice was successfully introduced on the Mwea-Tebere irrigation scheme in Kenya because the comparatively dense population in nearby areas made it possible to achieve a greater density of settlement and to procure supplemental paid labor for transplanting.

I am inclined to believe that research stations have often been too much preoccupied with increasing the yield of crops per unit of area and to work on one crop in isolation from another. Farmers on the other hand are primarily concerned with maximizing their returns to labor rather than land, and they frequently continue to consider labor their limiting factor even when land is becoming progressively scarcer. Moreover, farmers may be less interested in the yield of a single crop than in the aggregate return from all the activities on the amount of farm land they can manage to utilize

within the limits of available labor supply. They may find that their interest in security and the total return for their efforts are best served by sowing their food crops at optimum dates and planting their cash crops at a later time even though this practice may not optimize the yields of cash crops according to the findings on research stations.

In orienting their work research stations should therefore take fully into account the factors which in the eyes of farmers govern output. This may necessitate more emphasis on subsistence crops. Given the fact that the total amount of land which the farmer can cultivate with the labor supply available is limited, the possibility of growing cash crops in addition to subsistence crops is in many cases restricted. Additional labor and land could be released for cash crops if improved varieties of food crops could be developed and grown with less labor and on a smaller area of land. Another way of recognizing the labor constraint would be to look at the cropping system as a whole and to devise improvements which would relieve labor bottlenecks, enable the farmer to utilize available labor over a longer period and thus obtain a greater aggregate return. For example, where a farmer grows sorghum or millet and cotton, it would be desirable to develop a combination of varieties and planting sequences that would make better use of the farmer's labor. I do not know what the potentialities of plant breeders are, but I wonder whether in such a case it would not be possible to develop a shorter-maturing sorghum or millet that could be planted after cotton or alternatively to concentrate on developing a cotton variety which would give the best return when planted after sorghum or millet.

If existing farm labor constraints are to be respected two conditions must be met. The research stations must work out the labor implications of any improvements in crops and crop husbandry they have worked out for possible adoption by farmers; and there must be sample surveys to determine the labor supply available and how and to what extent this supply is actually used for various tasks during different parts of the cropping season.

Neither of these conditions is easy to meet. Research stations, using different methods of cultivation and employing paid labor under more or less close supervision, will have some difficulty in working out the amount of labor the African farmer will need to effect particular improvements. They will need to simulate the actual methods used in African farming or induce some African farmers to test the proposed improvement or practice and thus measure the labor inputs. The measurement of farm labor availability and employment also poses problems which, however, are not so great as to make the exercise valueless.

Any studies of labor availability must take into account the supply both from within the farm family and from outside sources. As already indicated, it cannot be assumed that family labor represents a single pool on which one can draw to carry out uniformly all tasks on the family holding. There still tends to be a division of labor responsibilities between men and women even though this may have become less sharp on those farms which produce a growing proportion of their output for the market. Account must also be taken of the considerable amount of work which women must devote to non-farm activities including domestic tasks, the fetching of fuel and water, and marketing.

Another factor affecting the availability of labor may be the incidence of sickness. On this subject little research has yet been done. In various areas, however, one often gets the impression that labor inputs may

be seriously curtailed by such diseases or infections as Guinea worm, bilharzia and malaria. At critical times, particularly during the transition from the dry to the rainy season, various types of fevers may incapacitate one or more members of the family just at the critical time when land must be prepared and crops planted. Wherever there is prima facie evidence that this is the case it would certainly be desirable to study closely the relationship of health to labor inputs and determine to what extent measures to improve public health should be an integral part of any agricultural development program.

The availability of outside labor for employment on the farm may be critically important in coping with seasonal labor peaks such as planting, weeding and harvesting. In many areas the only labor available outside the immediate family is that furnished in the form of communal work groups usually based on ties of kinship, age or neighborhoods. Since they are usually based on reciprocity, they theoretically provide no net supplement to family labor; yet in practice they may do so by raising the efficiency of labor or extending the number of hours that people are willing to work. Over much of Africa, however, the use of hired labor has become a practice on farms producing largely for the market. In some cases this hired labor may come from the same tribe to which the employing family belongs; and the tabus against the employment of fellow tribesmen which have prevailed in some areas have gradually disappeared, particularly where, as in the Central Province of Kenya, land has been scarce and unequally divided and there accordingly has been a pressing need for the poorly endowed farmers to seek employment with the more prosperous ones. The most important source of workers, however, has been migrant labor from other tribes and other areas. The development of the large Gezira scheme in the Sudan, for example, would hardly have been conceivable had it not been for its ability to attract labor for sowing and weeding and, especially, for the picking of cotton, from the poorer regions of Sudan and and even from northeastern Nigeria, the Central African Republic and the Chad. Similarly, the expansion of cocoa and Robusta coffee in the Ivory Coast and of cocoa in Nigeria and Ghana owes much to the availability of labor migrants from the northern parts of these countries as well as from the Upper Volta and the southern part of Mali.

In assessing the feasibility of certain innovations in farming which depend on the ability to hire outside labor, two factors must be taken into account. First of all one must make sure that there are reservoirs from which such labor can in principle be drawn. Secondly, one must determine whether the increase in farm cash income which the proposed innovation is likely to generate will be sufficient not only to warrant the payment of wages high enough to attract labor but also to leave the farmer with a net income that will appeal to him as an adequate incentive. It is significant that the crops which have been grown with substantial amounts of paid labor - coffee, cocoa and irrigated long-staple cotton - have all been highly profitable in relation to other alternatives open to the growers and have therefore made possible the payment of wages to labor migrants which were in turn considerably higher than the incomes which such migrants could obtain in their native regions.

The Problem of Equipment

It is equally important to consider to what extent actual or potential labor bottlenecks can be relieved through the use of appropriate implements and machinery. Within the scope of a brief paper it is impossible to give an adequate appreciation of both the potentialities and the problems of introducing animal-drawn and tractor-drawn implements. In the study which I directed for

the World Bank we tried to sum up the conclusions which might be tentatively drawn from the many experiences with the employment of various types of machinery in tropical Africa. 3/ Although some progress has been made, particularly in the introduction of animal traction, it is obvious that there are still many unresolved problems in devising types of equipment that would be both effective and economic. I have already alluded to the fact that the economic use of tractors in particular usually entails a far-going revolution in farming methods which is by no means easy to effect. To some extent this is also true where animal-drawn implements are to be introduced. Experience also emphasizes the importance of making sure that the use of machinery to widen one bottleneck does not aggravate other bottlenecks such as weeding and harvesting with which machinery so far has not generally been able to cope effectively. On a cotton growing scheme in Tanzania where land preparation and spraying had been mechanized I noted, for example, a tendency to assign each participating farm family a cotton plot larger than this family could be expected to pick effectively with the labor available. Toward the end of last year I also visited a number of mechanized group farms in Uganda. These consisted of grouped individual holdings on which tractors were used under centralized management to do the plowing and sowing for both cotton and food crops. Weeding and harvesting were the responsibility of the participating farm families. On one of these group farms the use of tractors had apparently been successful in removing a key bottleneck. With the help of such tractors food crops were sown first, and when the farmers were busy harvesting their food crops the tractors were at work preparing the land for, and sowing, cotton. The farmers were thus able to harvest their food crops before it became necessary to weed cotton. Yet on another group farm farther to the north where the growing season was somewhat shorter, there was apparently considerable difficulty in achieving a proper timing of agricultural operations. There cotton had become badly infested with weeds because the farmers were still gathering their food crops when the weeding of cotton became necessary.

A considerable amount of useful work has been done in developing and testing implements and machinery on agricultural research stations and at a limited number of implement centers. Attention should also be drawn to various pilot projects, usually involving the introduction of animal-drawn equipment, undertaken by a number of French organizations engaged in extension work in Africa. There have also, of course, been many experiences with the employment of tractors on a large scale which have in most cases proved costly, albeit potentially instructive, failures.

In the future there is great need for more comprehensive and better-directed efforts to devise ways and means of meeting the equipment requirements of African agriculture. I would like to see all major agricultural research stations, except for those specializing in a single crop, devote some work to this subject, relating it to the practical problems encountered by farmers in the area which each of them serves. More attention, however, should probably be devoted to the multiplication of well-designed pilot projects which would test the technical suitability and the economies of various types of machinery on African farms. I would emphasize the pilot nature of such schemes, for far too much money has been wasted in the past on ill-conceived and untested large-scale projects. However, whatever the nature or the scale of the scheme, it is vitally important that there be more systematic evaluation of past and current experiences with the introduction of machinery. Failures to make such evaluations and disseminate the results of past experience have no doubt contributed to the constant repetition of costly mistakes. In this connection I have suggested that serious consideration be given to the possibility of creating, within FAO or ECA, an international center specially concerned with

the problem of agricultural equipment in Africa. Such a center might collect, analyze and disseminate all relevant information on experiences with various types of traction and equipment under different conditions. On the basis of this analysis, it would also recommend and sponsor further experimental and developmental work to devise improved types of implements and machinery. This task of evaluating, testing and developing equipment should not, however, be the exclusive province of the agricultural engineer. Practical agriculturists and economists must be associated with it if the end product is to conform to the practical requirements of the farmer and meet the test of economic soundness.

Identification of Labor Bottlenecks

I would now like to return to the question of identifying actual labor bottlenecks encountered on the farm. What is required is a time profile of the utilization of farm labor over an entire season. Information on the existing pattern of labor inputs can only be obtained by sample surveys covering the time devoted to agricultural and non-agricultural activities alike and distinguishing between the work of men and women. There have been an increasing number of such surveys, but much more work needs to be done in this field. The necessary data must be obtained basically from periodic interviews with farmers. Since we must rely on their own subjective testimony, the information may not be objectively accurate. However, this is not a very serious handicap, since we are in any event primarily interested in the farmer's own appreciation of his bottlenecks. If he thinks that at any given time in the agricultural season his family is already excessively burdened with work, it is unlikely that he will take very kindly to innovations that will increase the workload at that time.

Care must be taken in interpreting the results. The labor profile which emerges may itself already reflect a tendency by the farm family to extend certain farming operations over a longer time than what would be the optimum if there were no labor shortage. Experience with surveys that have already been conducted shows that the use of resources and the resulting output is likely to vary widely within the sample. In such cases attention must be paid to the frequency distribution within the sample and to the reasons for differences in performances among farm families. In any society some people will obviously work harder and more effectively than others. Probably only a minority will work extremely hard, just as only a small number may be extremely lazy. In the practical work of promoting agricultural development it should be recognized that the greater number of people are likely to fall between these extremes and that efforts to improve their output will have to proceed, at least initially, within the limits set by their existing capacity to work.

The Determination of Necessary Incentives

In most cases the amount of labor that a farmer and his family will be willing to undertake is to some degree flexible. Even at peak labor requirements the farm family may be induced to work still harder. The critical question is the type and extent of inducements needed to bring forth the extra effort. At this juncture it is well to examine how much we know about the broader problem of the nature and amount of return which any group of farmers is likely to want as compensation for their own labor and the cost of any additional cash inputs.

We do know that farmers are interested in the reliability as well as the amount of return they may get from any innovation. People who live near the bare subsistence level and have little cash income are disinclined to take risks and are not interested in any improvement which promises them greater returns over an average number of years without giving them an assured return each year. For example, they do not generally want to pay cash for fertilizer when experience shows that fertilizer in some years will give them little or no increase in output out of which their cash outlay can be met.

I suspect that underestimation of the level of incentives required has often prevented the acceptance of innovations. h/ It may be significant at any rate that in the past the greatest progress has been made in the adoption of tree crops such as coffee, cocoa and tea which were extremely profitable in relation to any alternative opportunities for earning cash income. Similarly, there is considerable empirical evidence that the adoption of new crops has been particularly rapid when prices of these crops were rising.

Presumably the kind of incentive required is closely geared to the extra effort or trouble involved for the farm family and the level of income it has already attained. The type as well as the amount of extra effort demanded may be important. There is reason to believe that incentives must be greater when farmers have to make rather fundamental changes in their working habits, when they are expected, for example, to conform to a high degree of labor discipline as may be the case on a managed irrigation or mechanized farming scheme. It cannot always be assumed that farmers who have already experienced a considerable rise in income will necessarily take advantage of any opportunity to increase it further. They may do so only if the return for their extra effort significantly exceeds the average return they are already obtaining for the labor they have been putting into their farms. In any event they may be expected to weigh, consciously or subconsciously, the advantages of additional income against the disadvantages of losing time for leisure, or as social anthropologists often express it, of time devoted to social activities.

In considering the whole problem of the adequacy of incentives, I believe we are still working too much on the basis of impressions and untested hypotheses. How much for example, do we really know about the reality of "target income" concepts in various societies and their impact on incentives? How much do we know about responses of farmers to price changes? Last year in Uganda a Bank Mission appraising the country's five-year plan had to determine the possibility of attaining a certain cotton production target in the light, among other things, of a recent government measure which had slashed the farm price of cotton by one third. In recent years there had been a considerable expansion of cotton output. It proved virtually impossible, however, to get an accurate idea of the factors that had contributed to this increase in production - to what extent many farmers had recently started growing this crop or in what degree already existing growers had expanded their acreage or raised their yields. It was equally difficult to determine the effect of the reduction in prices. Would farmers who had long been growing cotton and had presumably become accustomed to a certain level of cash income from this crop strive even to raise their output in order to maintain their cash income? Would they be more disposed or less disposed to try and raise their net yields through spraying and the use of fertilizers? As for the unknown numbers of farmers who might have been growing cotton for only a few years, would they be sufficiently discouraged by the price cut to abandon the crop? The Mission could obtain no really reliable answers to these questions.

The Need for Socio-Economic Studies

In determining the adequacy of incentives or the general receptivity to innovations one must never lose sight of the fact that the customs, values and institutions of the society to which the farmer belongs may greatly influence the responses one is likely to get. All those concerned with stimulating agricultural progress must have a proper understanding of the rural societies within which development is taking place or is being initiated. The need for careful study of the factors that are pertinent to development in each society will, of course, vary. It will be of little importance where kinship and other social bonds have been greatly loosened and the interests of the individual and the nuclear family are the paramount factors governing responses. Conversely, it will be specially important where the society is highly structured and hierarchic, kinship ties are still strong and the standards of value and behavior are largely determined by the community and its authorities. Preliminary sociological or socio-economic studies are particularly necessary when one deals with a traditional society which has as yet experienced very little change.

However, great care must be taken in planning sociological investigations. If sociologists are to be employed, one must be sure to select those who are interested in, and are capable of, analyzing social change. A static description of society is useless. One must determine in what ways the society is already evolving, what factors are favorable or unfavorable to innovation and in what ways change may be accelerated. It is important that the agriculturist, economist and sociologist agree on the terms of reference for any such study. Otherwise the result may be simply a catalogue of customs, practices and institutions which, however, fascinating, may not throw much light on the feasibility of various means of modifying agriculture.

Within the scope of a brief paper it is possible to give only a brief and illustrative indication of some of the aspects of any society which are particularly relevant. The nature and strength of kinship groups or lineages and the network of social obligations to which they give rise have an important bearing on incentives. Practices governing land tenure may affect not only incentives but also the feasibility of re-allocating or re-grouping land to facilitate the introduction of new methods of cultivation. The duration and extent of stimulating contacts with the outside world through labor migration, trade and education will influence income aspirations and the receptivity to innovation. The division of tasks and the distribution of income among men and women within the family will affect the degree of identity of interest in the adoption of agricultural improvements. Wherever considerable livestock are kept, it is obviously important to determine attitudes toward cattle - whether they are or can become a source of regular income or whether they are to be considered wholly or primarily as a source of subsistence, a means of cultivation, a form of insurance or a method of cementing social ties or consummating marriages.

As I have earlier indicated, a socio-economic study may be needed not only to get a better understanding of all the factors governing receptivity to change and of the required incentives, but also to devise the proper methods of broaching proposed innovations to the members of a society. Except in areas where considerable agricultural progress has been achieved and people have acquired confidence in the government, one must be prepared to counter considerable distrust and skepticism. One must identify the persons who effectively wield authority and whose collaboration must be obtained or whose

potential opposition must at least be overcome. One must determine whether one can work with individual farmers or only with groups. If it appears possible to work with individuals, it is desirable to find out whether there are persons who by virtue of education or outside experiences are likely to be more receptive than others. If some form of group action is indicated, it is necessary to determine on what basis the group should be organized and who should be the leader. Kinship may in certain cases be the right basis for organizing groups, but in other cases kinship groups may be so rent by internal strife that they are an unsuitable vehicle for constructive effort. Similarly, while it may be necessary to get the consent of a traditional village chief for any agricultural extension work in the village, he may not himself have sufficient interest in innovation to lead a group effort to introduce changes in agriculture. 5/

Even though careful preparatory studies are undertaken before launching campaigns to improve agriculture, one can often not be sure in advance that any proposed measures will prove feasible and profitable in the eyes of farmers. One must inevitably proceed to some extent by trial and error. This leads me to make one final observation. It is important to have periodic evaluations to determine what is really being accomplished at the farm level. Today much attention is being paid to planning, including planning for agriculture. Comparatively little effort, however, is devoted to assessing the effectiveness of the specific measures taken to achieve plan objectives. Even where there are no agricultural development plans as such, agricultural extension programs are often pursued indefinitely without really finding out specifically what obstacles are being encountered in persuading farmers to adopt the recommended measures. Here and there farm economic surveys have been undertaken and have thrown some useful light on the degree of acceptance of innovations. 6/ But they have not been on an adequate scale or sufficiently far-reaching. One cannot assume that an increase in output necessarily reflects the effectiveness of agricultural extension efforts. Experience indicates that such increases are often unrelated to the recommendations that are being made by the extension workers. Sample surveys are needed to determine the extent of acceptance of specific recommendations and the specific causes of failure to secure adoption. Where, as is often the case, some members of the community are adopting recommended new crops or practices but others have failed to do so, it is important to discover the reasons for this difference. Only on the basis of such evaluations can one determine what changes may be necessary in extension methods, what additional services may have to be provided to overcome certain difficulties of application, and to what extent the research on agricultural stations may have to be reoriented to take into account problems encountered at the farm level.

Notes

1/ John C. de Wilde et al., Experiences with Agricultural Development in Tropical Africa (Vol. I, The Synthesis; Vol. II, The Case Studies; the Johns Hopkins Press, Baltimore, 1967.)

2/ See, for example, William E. Allan, The African Husbandman (New York, Barnes & Noble, Inc., 1965).

3/ See Chapter 6, "Implements and Machinery", in de Wilde et al., Experiences with Agricultural Development in Tropical Africa, cited.

4/ Prof. Schultz has particularly criticized the failure to develop, on a sufficient scale, new agricultural inputs which are really rewarding to the farmer. See Theo. W. Schultz, "Economic Growth from Traditional Agriculture", in A. H. Moseman, ed., Agricultural Sciences for the Developing Countries (Publication No. 76 of the American Association for the Advancement of Science, Washington 1964).

5/ Two agricultural extension schemes - one in the Bokoro region of the Chad and the other in the central region of Upper Volta - illustrate the importance of prior sociological investigations before effective groups for initiating agricultural innovation can be organized. See Chapters 3 and 4 of Section II, Volume II, of de Wilde et al., Experiences with Agricultural Development in Tropical Africa, cited; also "l'observation sociologique et psychosociologique dans les opérations de modernisation rurale" (mimeographed paper presented to a symposium at the Bureau pour le Développement de la Production Agricole, Sept. 1-2, 1966.)

6/ Notable in this respect are a series of farm economic surveys carried out by the Farm Economics Survey Unit of the Ministry of Economic Planning and Development in Kenya.

ECONOMIC RESEARCH FOR AFRICAN AGRICULTURAL DEVELOPMENT

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Summary

Science and technology or "modern inputs" (fertilizer, improved seeds) have played a critical role in the few less developed nations that have harnessed their agricultural sector as an effective instrument of overall national economic development. However, the "modern input" approach to agricultural development is a vast oversimplification of the requirements for developing a modern agricultural sector in a typical African nation. In most cases "modern inputs" would be virtual failures if complementary investments had not already been made or were concurrently made in irrigation, credit, feeder roads, pest control, etc. Likewise, investments in irrigation, feeder roads, etc., will be likely to yield low rates of return in investment unless appropriate high yielding plant varieties, etc. are adopted by farmers. As a result, any discussion of economic research priorities for agricultural development in Africa must recognize the interdependence between investments within the agricultural sector.

The interdependence between the industrial and agricultural sectors in the development process is also stressed in this paper. Agricultural development in African nations is not a process independent from the rest of the economy. In fact, enlightened general economic policies such as trade, taxation, manpower, education, and pricing policies, etc., may be as important in determining the pace of agricultural development as policies for land consolidation, cooperatives, marketing or the introduction of modern inputs. Therefore, economic research for agricultural development must be concerned with macro relationships of the agricultural sector to the industrial sector, international trade policies, international lending requirements and international commodity arrangements (such as the International Coffee Agreement). Also, economic research must devote considerable attention to policies and innovations necessary to induce the non-agricultural sector in supplying inputs to the agricultural sector.

We move from macro to micro level research and emphasize that economic research for agricultural development must evolve from the agricultural strategy of a particular African nation. A strategy for rural development involves more than slogans such as import substitution, balanced growth, unbalanced growth, etc.; these

concepts are not operational concepts for planners. The profitability of investment in agricultural production, marketing, and processing or import substitution is an operational concept which should play a central role in developing an agricultural strategy for a particular nation. Therefore, an important aspect of economic research involves the collection of basic micro data on the profitability or rates of return on investments by farmers in food crops, livestock export crops, etc. We indicated that effective agricultural planning cannot proceed unless substantially more attention is devoted to micro studies of the profitability of investment in agriculture.

We conclude this paper by pointing up some priority research topics which should be pursued by agricultural economists in African nations. Special emphasis is devoted to macro economic research--pricing policies, trade projections, etc.--necessary for effective agricultural sector planning. Likewise, we emphasize how the decentralized nature of decision making in African agriculture requires micro studies to be developed to meet the needs of rural change agents and farmers within the context of marked differences in soils, rainfall, transportation and social and cultural parameters. Finally we note that considerable research needs to be done on methods to strengthen effective demand in African nations (via income redistribution) as many of the agricultural problems will not be solved with expanded food production.

I. INTRODUCTION

Only a few less developed countries (LDC's) have been able to harness their agricultural sector as an effective instrument of rapid economic and social development. Mexico, Taiwan, Israel, and recently Pakistan are a few LDC's which have achieved rapid rates of growth of agricultural output in recent years.

As we analyze these "success stories" we detect a common theme--science and changing technology--has played a strategic role in the expansion of agricultural output. For example, at the beginning of the UN Development Decade in 1960, Pakistan was considered a country of little promise for rapid rural change. However, the importation of Mexican semi-dwarf wheat varieties and International Rice Research Institute (The Philippines) rice varieties coupled with a backlog of irrigation infrastructure, rapid expansion of tubewells, and effective fertilizer policies, etc. all contributed to a dramatic increase in food grain yields and enabled Pakistan to surpass its Second Plan targets. Likewise, Taiwan's recent rapid development has been aided by irrigation development beginning in the 1900's, the development of the Taichung #65 rice variety in 1926 following twenty years of research on 1,300 native rice varieties, and subsequent research into fertilizer use (15). Turning to Mexico, you are well aware that

Mexico's economic development spurt in the 1950's and the 1960's has been significantly aided by biological breakthroughs, especially new wheat and maize varieties which have been developed since the 1940's (34). In sum, science and technology have been of strategic importance in the rural transformation of Taiwan, Pakistan, and Mexico. However, the widespread agreement about the critical role of science and technology or "modern inputs" in transforming agriculture has led to an oversimplification of the agricultural development process in the LDC's. We only need to recall that large investments in irrigation in Pakistan over many decades complemented the introduction of Mexican dwarf wheat varieties in West Pakistan in the mid 1960's. Investments in irrigation in Taiwan beginning in the early 1900's provided water for the new high yielding rice varieties that were developed in the 1920's. Instead of suggesting that modern inputs are the key to agricultural development, we need to recognize that complementary investments in irrigation, feeder roads, pest control, etc. are essential for high returns on investments in modern inputs such as the IRR-8 rice variety. Likewise, investments in feeder roads, irrigation, etc. will likely yield low returns on investments unless investments are also made to develop new plant varieties which are responsive to fertilizer, irrigation, etc. (16). As a result, the complementary nature of investment activities should be brought to the forefront of our discussion of agricultural research priorities in the context of agricultural development in African nations. With this in mind let us turn to a discussion of generalizations about the development process of advanced nations for African nations.

II. INTERDEPENDENCE BETWEEN INDUSTRIAL AND AGRICULTURAL DEVELOPMENT

Three important generalizations for LDC's can be drawn from an analysis of the growth process of presently advanced nations. First, in the early stages of industrialization of a typical less developed nation the absolute number of people employed in the agricultural sector will almost certainly <u>increase</u> for a period of several decades, level off and then decline slowly over time. The relative percentage of people employed in agriculture will likely decline slowly--in 25-50 years--in countries where 50-75 per cent of the population are in agriculture and where population is growing at 2-3 per cent per year. Why is this so? The slowness of the relative decline in the percentage of people employed in agriculture is attributed to population growth of 2-3 per cent per year and to the inability of the nonfarm sector to grow and create new jobs by much more than 3-4 per cent per year. African development plans which focus on rapidly reducing the percentage of people in agriculture and achieving a take-off within one or two plan periods are completely unrealistic. The growth of the agricultural sector is intimately connected with the growth of the industrial sector. The inability of the industrial sector to expand employment by more than 3-4 per cent per year has a decisive influence on maintaining a high percentage of people employed in agriculture for

several generations. This means that there is little reason to expect the percentage of people in African agriculture to decline in the early stages of industrialization (5). The implication of this analysis is that agriculture will be the self-employment sector in African nations for a long period of time and imagination policy measures will be necessary to utilize underemployed labor in periods other than the planting, weeding and harvesting peak periods.

The second generalization about the growth processes of advanced nations concerns food requirements. Food requirements are influenced by two primary forces---rates of growth of population and income. With population in Africa now growing at 2-3 per cent per annum and income by one per cent (as projected in many African Plans) food output will have to expand at the rate of 3-4 per cent per year unless food is imported, or inflationary pressures are allowed to come into play. The critical point, however, is the need to assess on a country by country basis the relative priorities that should be devoted to staple food crop expansion relative to investments in (a) export crop expansion, (b) import substitution crops (kenaf, cotton), and (c) "superior foods" such as poultry. In India and Pakistan, planners have no choice but to devote major administrative and financial resources to expanded food production. However, in some African nations investment in food production may be given second or third priority to the expansion of export crops, import substitution crops, etc. as a recent CSNRD report recommends for Nigeria (3). In summary some planners become overly imbued with food shortages in India and Pakistan and conclude that African nations also need to import surplus foods from high income nations or retrench export crop production and expand food production. It is dangerous to say the least to think that the number one agricultural problem in African nations is the need to expand food production. Many"marketing problems" in Africa are the result of inadequate effective demand and not food marketing problems per se.

The third generalization about the development process of advanced nations concerns the key role of the nonfarm sector in providing fertilizer, insecticides and pesticides, etc. to farmers. It is now being recognized that nonfarm inputs are a sine qua non for expanding commodity output as a nation exhausts its frontier of arable land and moves into intensive production. Agricultural development strategies for typical African countries must devote attention to pricing, taxation, and trade policies in order to create incentives for investment to be made in generating nonfarm inputs--particularly fertilizer--for the agricultural sector.

These three generalizations about the development process of advanced nations illustrate that industrialization and agricultural development are not substitutes for each other but are mutually supporting. This discussion also illustrates that agricultural development is not a process independent from the rest of the economy and that enlightened public policy in the nonagricultural sector will play a critical role in the expansion of agricultural output (23, 24).

Unfortunately many agricultural workers advocate replacing marketing boards with cooperatives, reducing taxes on farmers, etc. as if expanded agricultural output and income were the sole objective of agricultural development. Agricultural development must be analyzed in relationship to the overall goal of economic and social change of the entire nation.

III. RECENT TRENDS IN AFRICAN ECONOMIC DEVELOPMENT: IMPLICATIONS FOR ECONOMIC AND AGRICULTURAL RESEARCH

Economic Man in Africa

As a starting point in a discussion of several major African economic development problems, we note that an increasing number of empirical studies document the rapid response of small African farmers to economic incentives. Recent studies by Jones (21), Hill (10), and Low (24), all demonstrate that concepts of "target income," backward bending supply curves of labor, etc. should be substantially discounted in discussions of African economic development. As a result the cultural and sociological barriers to change that once featured so prominently in the African development literature now appear to be less important than previous imagined. Therefore, a starting point in our analysis of economic research for African agricultural development is that given economic incentives, the African producer will respond in much the same way the Mexican, Japanese, or Pakistani farmers have responded. This evidence does not mean that there is no need for "change agents" in rural Africa. However, it does suggest that *if* "change agents" (extension, voluntary agencies) have profitable innovations to offer farmers then African farmers will adopt them in much the same manner as farmers in other continents.

Ubiquity of Planning

In contrast to Latin America where economic planning is tolerated and rarely ever assigned a strategic role in the development process, African nations are generally pursuing planning as an accepted instrument of rapid economic and social change. To be sure, African development plans have frequently been (1) overconcerned with the public sector, (2) composed of shopping lists of individual investment projects, and (3) stressed achievement in terms of the expenditure of government funds rather than with the development of policies which will call forth the private investment of farmers and traders. Nevertheless, one is impressed with the ubiquity of planning in Africa and with the improvement in planning within the past ten years. As a result, economic research for agricultural development in Africa should be guided to a considerable degree by the *needs of planners*. Although agricultural research cannot be undertaken to satisfy the immediate needs of planners, there is an urgent need for planners to express their needs when technical agricultural research programmes are reviewed each year.

External Aid for Agriculture

During the past ten years many African countries have shifted attention from infrastructure to directly productive investments, which, hopefully, would be financed to a considerable degree by external loans and grants. However, external lending agencies have experienced great difficulties and delays in shifting their lending policies from infrastructure and technical assistance to directly productive investments. External lending agencies such as The World Bank, USAID, etc. are unclear as to whether they should support directly productive investments in agriculture in Africa through a program or a project approach. In addition, feasibility studies for agricultural investment projects are usually starved for funds and skilled manpower. The time gap between the initiation of a feasibility study and the granting of the loan for agricultural projects is three to five years. For the above reasons, more economic research should be devoted to computing pay-offs on potential investments in agriculture.

Manpower Problems

Manpower problems in the agricultural sector fall into two categories in African nations: (1) shortage of high level manpower for agricultural research, extension and administration of agricultural programs, and (2) surplus of unskilled farm labor, including underemployment and seasonal unemployment. Manpower planning in many African nations has been misguided by focusing on urban manpower requirements and then sending signals to universities to educate manpower for industrial-urban occupations. However, it is now being recognized that the modern industrial sector can absorb only a small percentage of newcomers to the total labor force. Fortunately, Professor Harbison from Princeton University and UNESCO experts are focusing on high level manpower requirements for rural modernization. The second manpower problem--rural underemployment--is far more complex and difficult to solve than the first. Economic policies--eg., marketing board pricing policies--which are pursued by some African nations are offsetting biological breakthroughs and thereby restricting investment and labor absorption in agriculture. Economic research for agricultural development should concentrate on developing highly profitable investments in agriculture which will create the demand for labor.

Needs of Farmers and Rural Change Agents

We have already commented on the ubiquity of planning in African nations. Now it is appropriate to comment on a major bottleneck in planning--the implementation of agricultural development programs. Although economists often discuss the wisdom of balanced growth, it is obvious that a lack of administrative capacity, financial resources, feasibility studies, etc. forces most African nations to concentrate on a few major agricultural schemes which can be described as a process of selective growth. As a result the "change agents" (extension

agents, rural development officers, credit and cooperative officers) who are responsible for implementing agricultural development schemes require assistance from economic researchers in the identification of these selective growth crops and schemes and in the computation of gross profits or rates of return to farmers. It is not an overstatement, however, to say that many "change agents" in African nations are"telling" farmers to adopt many farm practices without elementary knowledge on the profitability of these innovations or the profitability of alternative crops or practices. Therefore, the research should examine the needs of farmers, suggest solutions, and feed these solutions both to the farmers via change agents.

On the Profitability of Technical Agricultural Research at the Farm Level

As we pointed out in the introduction to this paper rural modernization requires enlightened public policy on matters such as trade, rural taxation and pricing policies for inputs, and farm products, etc. in order to guide and stimulate the rapid introduction of high pay-off investments in agriculture. However, technical agricultural researchers in many cases are located in government commodity research stations where emphasis in research is often placed on maximum physical yields per acre rather than on the profitability of investment. Social science research is usually given a footnote position in technical agricultural research stations in African nations. However, effective agricultural research in the context of economic development requires close cooperation and teamwork between agricultural economists, farm management researchers and technical agricultural scientists. In order to guide their research, technical agricultural researchers need information on prospective world market trends, economics of local processing of raw materials and the economics of new varieties, and inputs such as fertilizer at the farm level. Economists, agricultural economists and farm management personnel can cooperate with technical agricultural researchers in supplying these data. On the other hand, planners need information from technical agricultural researchers on prospective biological breakthroughs such as high protein legumes, new varieties of crops and new crops such as citrus, sugar, kenaf, etc. Planners also need to have an assessment of soil types, rainfall patterns and the technical dimensions of selective mechanization of production and farm processing. The important point of this discussion is that economics of technical agricultural research should be developed in close cooperation between agricultural economists and technical agricultural researchers.

On the basis of this discussion of current problems in African agricultural development we conclude that economic research for African agricultural development should be guided to a considerable extent to serve the needs of:

a) farmers
b) economic planners
c) technical agricultural researchers, and
d) rural change agents (extension, co-op workers, voluntary agencies).

IV. SOME ELEMENTS OF AGRICULTURAL DEVELOPMENT STRATEGY FOR AFRICAN NATIONS

Before we can suggest how to design economic research for agricultural development to meet the needs of farmers, planners, technical agricultural researchers and rural change agents, it is essential to recognize that agricultural research priorities should be closely tied to an overall strategy of agricultural development on a nation by nation basis.[1]

Selective Growth

An important element in African agricultural development strategy is the concept of "selective growth." Since administrative, financial and organizational skills are usually severely limited, planning which emphasizes balanced growth of the agricultural sector is unrealistic in most African nations. Instead "selective growth" which focuses on introducing a new maize variety, a fertilizer subsidy scheme for groundnut farmers, or a small holder tea scheme are examples of limited projects which can be undertaken at any one time by the typical African nation. Therefore, research attention should be directed, in my judgment, to the identification of significant "single trait"[2] innovations which can increase yields by 50 to 100 per cent and can be grafted on to the present farming systems and adopted in selected areas of the country.

Skipping Preconditions and Growth Stages

African nations have a range of technological options which were unavailable to advanced nations in their early stages of industrialization in the 19th century. Also, foreign aid, prospects of effective low cost population control programs, and improved protein content of cereal grains, etc. suggest that African nations should not be preoccupied with following the growth stages of presently advanced nations. The relevant question to ask is in what ways and means can an African nation substitute for certain growth stages or preconditions to development.

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[1]For an example of this approach see Glenn L. Johnson (18, 19).

[2]This terminology is used by W. O. Jones of Stanford University to describe innovations--such as improved tobacco seed--which can be offered to farmers without requiring the simultaneous introduction of other new inputs and greatly improved managerial skills.

Export Crop Expansion

African nations generally are land surplus economies and are a generation away from the pressing food-population problems now being encountered by India and Pakistan. For these reasons many African nations can continue to devote considerable attention to selective export crop expansion consistent with overall world demand projections. However, the recent demand projection by the FAO and Goreux indicate that the prospects for the LDC's agricultural trade with the developed nations are indeed gloomy largely because of the combination of four main factors in the developed nations:

> "Slackening in the rate of population growth,
>
> Per caput consumption getting close to saturation for sugar, oils and fats and tropical beverages,
>
> Increasing substitution of agricultural raw materials by synthetics,
>
> Continued tendency for food output to increase faster than demand" (12).

The severe limitations of expanding LDC agricultural exports to high income countries offer two implications for economic research for agricultural development. First, considerable attention should be directed to prospects for increasing agricultural trade in processed and manufactured goods such as meat and textiles between African nations.

Second, African economists should step up their market intelligence analysis in the same way that Taiwanese have within the past few years used market analysis to capture new world markets--such as mushrooms, canned pineapple, etc. However, market analysis of developed nations requires clsoe cooperation between technical agricultural researchers and economists in Ministries of Agriculture, Commerce, Trade and Industries.

Processing in Africa

The ECA, FAO and other organizations have suggested that local food and raw material processing be greatly accelerated in Africa. This general observation is sound for long run planning but recent empirical studies have indicated that there is a general phenomenon of overinvestment in processing in some African nations--particularly when the investment is government managed. For example, in 1966 the Asustuare and Komenda sugar mills in Ghana are reported to have operated at 2.5 per cent and 20 per cent of capacity, respectively. Also, in Nigeria a government oil palm processing plant which was installed in the middle 1950's is still not being utilized. In short, although there are good prospects for selective investments in expanding processing of agricultural raw materials, the record to date suggests

that a monolithic import substitution strategy may create unexpected problems of underutilization of processing plants. Import substitution is a well accepted strategy of development but it is "not an operational concept for development policy." (35) The operational concept is profitability and the profitability of expanded agricultural processing in African nations is what should be uppermost in the minds of planners.

Food Crop Expansion and the Lack of Effective Demand

There is some misunderstanding about the economic dimensions of food problems in Africa. The one area of implicit agreement seems to be that every African nation should push rapidly towards self-sufficiency in food production even though food crop production has expanded almost automatically as export crops have expanded in many African nations (6, 13). Nevertheless, increasing food imports in some countries and increasing rates of growth of population require that food crop research and food production should be accelerated in most African nations. However, we should keep in mind that there are major demand constraints (lack of purchasing power) on the expansion of food production (3). Moreover, we should keep in mind that demand expansion cannot be solved in isolation from the general process of raising per capita incomes through economic development which, in many African nations, will mean through industrial export crop expansion (3). For these and other reasons self-sufficiency in food production cannot be justified on economic grounds in many African nations. Rather, food, export crop, population and nutrition policies should be developed for each nation. In some cases African nations can become food exporters (eg., Kenya's recent maize exports) while in others economic criteria will suggest that nations should expand export crop earnings and continue to import some food such as wheat, milk.

We can summarize this section by noting the urgent need for individual African nations to develop agricultural strategies which are consistent with the economic and political realities of their nation rather than pursuing monolithic self-sufficiency of food production (such as the folly of producing wheat in Northern Nigeria) policies.

In summary, agricultural research priorities cannot be determined in isolation from the agricultural development strategies for a particular nation. Teamwork is essential--planners and technical agricultural researchers--to develop realistic agricultural development strategies and agricultural research priorities on a nation by nation basis. Unfortunately many planners do not understand the relevance of maintaining close liaison with technical agriculturalists and vice versa. Hopefully, the Abidjan conference will help overcome some of these compartmentalizations.

V. ECONOMIC RESEARCH PRIORITIES

We shall now make a few observations on some general research problem areas and then conclude with some specific research priorities. The first general comment is that there is a large amount of agricultural economics research on Africa underway in Africa, Europe and in North America (7, 27, 28). However, in many cases, this research is not relevant to the needs of farmers, planners, technical agricultural researchers or "change agents," in Africa. In addition, agricultural economists should be aware that a large amount of relevant research on African agricultural development is undertaken by geographers and anthropologists and only rarely utilized by planners because geographers and anthropologists are usually on the fringe of the process of planning and implementing agricultural development. Geographers and anthropologists, however, can be helpful to planners, technical agricultural researchers and to change agents because they can increase our understanding of systems of farming, the diffusion of innovations, etc. The next general point concerns the need for economic studies which go beyond national boundaries and focus on problems in major ecological zones. La Anyane's study of the oil palm industry is one example of this type of research (22). Also Saylor's recent study of "Obstacles to Investment in Plantations in West Africa" is another example of research which has immediate policy implications for six to eight countries in West Africa (32). Another general research topic which can be useful to a number of African nations is world demand projections for major export crops. Another type of general research concerns problems of external financing of agricultural development. Although several agencies such as CDI, USAID and the IBRD are devoting some attention to this problem, there is a need for comprehensive and continuous analysis of the problems involved in extending aid for <u>directly productive investment</u> in African agriculture.

The final point concerns the important and time consuming process of improving basic estimates of crop and livestock production, production inputs and farm prices. Although it will take decades to improve the basic estimates of the agricultural sector, there is a need for agricultural economists and planners to undertake specialized research to find methods of improving the continuous reporting of production and marketing data. Although these continuous estimates can best be generated by government, it should be recognized that economic researchers in universities can assist government in the gradual improvement of survey design and data analysis.

We shall close by listing some research studies which, in my judgment, are of priority for many African nations:

<u>First Priority Research Topics</u>

1. Taxation and incentives in African agriculture with special emphasis on alternatives to export crop taxation.

2. Effective demand and agricultural planning with special emphasis on methods of redistributing income to expand effective urban and rural demand for agricultural products.

3. Economic, sociological and political aspects of alternative techniques of designing agricultural production units.

4. Pricing policies for (a) agricultural inputs, (b) agricultural products and (c) consumer goods for farmers.

5. Farm level profitability of presently available technology from agricultural research stations.

6. Technical, economic and sociological aspects of irrigating rice in selected West African countries.

7. Overcoming labor constraints during peak periods: engineering and economic problems associated with expanded use of bullock power in farming.

Second Priority Research Topics

1. Population projections, migration estimates and attitudes to family planning.

2. Constraints on food crop expansion--(a) environmental (tsetse fly), (b) cultural and (c) credit and (d) lack of managerial skills.

3. Demand projections for African agricultural (food and export) products within (a) Africa, (b) Western European markets and (c) emerging markets in Japan, Eastern Europe, etc.

4. Case studies of successful and unsuccessful approaches to implementing agricultural schemes.

5. Techniques of utilizing underemployed labor during off-season periods.

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ECONOMIC AND TECHNICAL CO-ORDINATION IN AGRICULTURAL DEVELOPMENT: THE CASE FOR OPERATIONAL RESEARCH

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SUMMARY

The strategy of the Development Plans of many African countries correctly recognises the importance of a rapid improvement in the productivity of the agricultural sector in the short run if a sustained increase in standards of living is to occur. The choice of a promising development strategy does not guarantee this, however. The selection and implementation on the ground of programs and projects giving a high ratio of benefits to costs is where success or failure is really determined.

The responsibility for implementation of crucial public sector programs is commonly entrusted to civil servants with a technical and applied science training, whilst national level plans are drawn up by general economists. It is argued that a hiatus often exists between these two groups, neither of which benefits fully from the other groups specialist knowledge and techniques. Fuller and more accurate data about the problems and potentials of the rural sector is required by planners. On the other hand, there is a need for micro-economic analysis to be extended into the "grass-roots" level of program and project implementation to assist in appraising alternative uses of scarce resources and raising their net contribution to national income.

Practical ways of achieving fuller co-ordination between the economic and technical approaches to agricultural development are required. Possibilities for this are discussed in relation to the following areas of agricultural development activity:

1. Agricultural Development Planning.
2. Agricultural Extension and Credit Programs
3. Implementation of Schemes and Projects.
4. Agricultural Price and Marketing Policy.
5. Agricultural Research.
6. Agricultural Education.

The quest for improved performance on the ground is seen to require various types of inter-disciplinary operational research which are concerned, *inter alia*, to improve the supply of planning data, evaluate

existing schemes and projects, devise improved farming systems, pinpoint agricultural research priorities and appropriate research methods, follow up the products of agricultural training courses, etc. A spirit of enquiry and flexibility towards traditional methods and organisations is seen to be required if the changes necessary for improved performance are to take place.

INTRODUCTION

In the majority of African countries, both the present importance of the agricultural sector in the economy and the crucial role it must play in the future process of development have become widely recognized. The several drawbacks of heavy reliance on a forced industrialisation program (such as the limited size of the protected domestic market and the problem of foreign exchange to pay for increased capital goods imports) have also been widely realized, sometimes through costly experience. Many of the current Development Plans in Tropical Africa, therefore, recognize the critical importance of the rapid and widespread modernization of agriculture in order to provide the impetus for the later structural transformation of the economy. However, the choice of a promising development strategy does not ensure the successful attainment of a Plan's objectives. This will be dependent especially upon the final selection of projects and programs, the suitability for growth of the institutional framework and the nature of the implementation process on the ground.

Commonly in Africa the bulk of the agricultural program is executed by the public sector within traditional civil service structures. The heavy weight of responsibility for successful implementation has been laid upon a body of civil service executives who are by training and experience field agriculturists or applied agricultural scientists. Clearly, however, the process of devising and rapidly implementing large development programs requires techniques and knowledge outside the normal frame of reference of either bureaucratic procedures or biological processes. This situation explains, on the one hand, the interest in some countries in adopting quasi-commercial forms of organization within the public sector, and on the other, the increasing emphasis placed on the social sciences - especially economics and latterly sociology and administration - in training the agriculturist and the more applied agricultural scientist.

These developments are symtomatic of a desire to bring economic criteria and commercial procedures to operate increasingly within the agricultural development program. Typically, however, African countries are still reliant upon traditional types of bureaucratic structure staffed by mainly technically or scientifically trained personnel to carry through these programs. It is in this structure that less progress seems to have been made in achieving full co-ordination between economic and technical knowledge in an operationally productive manner. By and large, the traditional systems of agricultural administration

continue to operate within their own mileu of technical agricultural criteria plus bureaucratic caution. Both the very recentness with which development planning has arrived in Africa and the emphasis on macro-economic procedures for making the major investment decisions for the agricultural sector has meant that the role of economic analysis in the day-to-day development process is not understood very clearly within the technical agricultural cadres. As a result, economists working in the agricultural sector may be regarded with suspicion or viewed as fashionable irrelevancies to the real task of replacing one blade of grass with two.

It is the major thesis of this paper that improved performance in implementing agricultural development program will depend in many cases on the further penetration of economic thinking, whether done by economists or agriculturists into the grass-roots levels of development. In other words, the hiatus generalized above between the technical, biological or mechanical approach to agriculture, at the field level, and a macro-economic approach, at the sectoral planning level, leads often to inefficiency, error and waste. This is so for two main reasons. Firstly, it is the distinctive emphasis of economic analysis to appraise the range of alternatives open in any resource allocation decision. This applies equally at the micro-level - at the farm, district or research station level - as at the macro-level - the major investment project, commodity price fixing or inter-sectoral capital and manpower allocation kinds of decision. Where decisions are made in ignorance of the "opportunity costs" - the flow of net benefits from alternative uses of the same resources - the chances of less efficient choices are increased. Secondly, informed choices between alternatives must depend on the accuracy and comprehensiveness of available physical and financial data. Economic planners and project or business managers (including farmers) will tend to ignore certain possibilities, or make wrong inferences about them, if a flow of appropriate data is not being provided from both operational and experimental levels of agriculture.

This implies the necessity of an awareness by agriculturalists of the process and requirements of both economic planning and commercially viable operations. Co-ordination involving a two-way flow of information is therefore necessary to avoid inefficiency arising from these causes. This in turn requires institutional and methodological innovation which is itself a field for research and experimentation of an operational kind. This type of research may embrace formal "operations research" techniques and efficiency principles from business or public administration, such as critical path programming. However, it is typified mainly by a basic concern with the question of cost-effectiveness on the ground and a receptiveness to innovation in the task of implementing and if necessary modifying, development decisions taken at a higher planning level. The discernment of many beneficial improvements may require little more than the willingness to consider changes in structure or method, without the need to apply the latest techniques of formal operations research. This kind of often informal research is envisaged as the final stage beyond applied research; it is concerned with finding

optimum ways of appying the results of applied research.

In this paper the major possibilities of economic and technical co-ordination in agriculture are reviewed, looking firstly at the main phases of agricultural development from the initial planning through to the actual implementation of the plans (sections 2, 3 and 4). Secondly, the infrastructure of agricultural markets and prices, research and education, which are vital to the success of agricultural improvement policies, are also looked at from the same viewpoint (section 5, 6 and 7). A similar approach is followed in each section; first the aims of policy are indicated, then the respective contributions of economic analysis and agriculture technology are outlined and finally specific suggestions are made concerning areas for operational research and "on the job" innovation.

1. Co-ordination in Agricultural Development Planning

Planning involves the formulation of strategies designed to achieve the highest possible rate of economic growth within the framework of national resource and policy constraints.

Comprehensive economic planning is concerned not merely with ranking viable projects in each sector of the economy; particular attention must be given to the inter-relationships between the different sectors of the economy, and the implications of total activity in terms of such national aggregates as Government revenue, the balance of payments, manpower supplies and employment. Planning must identify, and far as possible prescribe remedies for, the major constraints to economic growth whilst it should also ensure that the resulting improved production potential yields the maximum quantities of desired goods and services. The plan should be consistent in the sense that the total demand from all projects in the plan for one resource e.g. University graduates, will not exceed the supply, and that bottlenecks will not develop because of failure to expand one sector to supply another.

Planning should incorporate a continuous process of reviewing development opportunities and experience. For example, the present Uganda Five-Year Plan 1966-71 is the first stage of a long-term perspective plan aimed at doubling the monetary income per capita by 1981. Projects and targets contained in the Plan will be modified during the plan period to adapt to changing circumstances which were not forseen in the original plan; such flexibility is crucial to optimum resource use.

National Plans are usually drawn up by central planners with the risk of overlooking the differing potentials and problems of the various regions. The current plans in East Africa, for example, are noteably deficient in spelling out the regional implications of national aggregate targets in terms of employment and incomes. The dangers resulting from the high level of aggregation in a National Plan are particularly great in the agricultural sector as problems and possibilities vary

greatly according to the ecological and social characteristics of an area. Clearly, knowledge and understanding of potentials and constraints operating at district and even at farm level are essential to planning effective agricultural development programs. Ignorance of local conditions could lead either to the exclusion of desirable projects or the inclusion of those which are unlikely to succeed.

The necessity of economic and technical co-ordination in the planning process is illustrated here by a specific agricultural project, that of cocoa development in Uganda. Expansion of the cocoa acreage in Uganda poses many many questions of a biological, technical and economic nature. Perhaps the most critical question concerns the price at which additional cocoa production could be sold. Before marketing economists can answer this, it is necessary to estimate the possible levels of cocoa production and the quality of the product which could be attained in Uganda. The amount of "ecologically-suitable" land would roughly determine the possible maximum cocoa acreage; estimates of likely yields must then be made. Information on the varieties which can be grown and the processing difficulties which might be encountered are necessary to estimate the likely quality of the processed product.

Marketing is only one aspect causing difficulties in planning such a scheme; the production estimates also depend on a range of other variables. A policy must be formulated on the type of production organization to be promoted. Governmental, quasi-governmental or private estates could be promoted; major emphasis might be given to small-farm production or some combination of approaches might be chosen. Some measure of profitability under each system must be calculated if the rate of future expansion is to be gauged. This will be even more important if small-farm production is encouraged, as the state can only influence the rate of acreage expansion indirectly, by price manipulation, subsidies and credit, when production decisions are taken independently by thousands of small farmers. The provision of resources and incentives, such as seedlings, credit and extension advice must be carefully worked out. Estimates of the inputs, and therefore of the costs and returns which growers might expect, can be based on data supplied by experimental workers, by modifying results from other countries with relevant experience and by collecting field performance data during the initial phases. The attractiveness of cocoa to farmers also depends on the possible alternative uses for their limited land, labor and capital. A detailed knowledge of the economics of competing enterprises must therefore be obtained, as an understanding of this "opportunity cost" aspect of peasant farming is required before farming system changes can be forecast. Profitability will also be influenced by the successful application of improved husbandry methods, such as nursery and planting techniques which enable earlier harvests and by the adoption of fertilizer regimes which would improve yield levels. Some indication of the degree of the risk attached to cocoa production should be gathered from inspection of time-series data on the incidence of pest and disease attacks; price uncertainty can be arrived at by market

analysis. If the crop happens to be risky, the innovators will not be copies by other farmers unless profits are very attrative in comparison with alternative products.

This whole array of information is necessary to make a reasonably rational decision concerning cocoa expansion. If a positive conclusion is reached in the initial appraisal, the annual rate of expansion must be determined in advance in order to phase the provision of funds for processing and storage facilities, nurseries, continuing cocoa research and extra personnel. It is not surprising, therefore, that in this particular case the Uganda planners decided that there were too many gaps in the available data to arrive at a worthwhile evaluation of the project. Other projects were not even considered as planners felt that there was not enough information currently available to test their feasibility. It is clear that opportunities for profitable investment can easily be sacrificed unless a comprehensive body of relevent economic and technical data is built up, and research resources may have to be used to assemble this information if it does not already exist. This implies that Ministries of Planning may have to play a greater and more detailed role in determing agricultural research programs.

With many different agricultural projects competing for inclusion in the Plan, it is necessary to rank them in order of profitability. If enough information is available, the technique of benefit:cost analysis can be used to calculate the worthwhileness of each possible investment. Physical and financial data and the pattern in which they occur over time must be fed into the calculations. This demands accurate knowledge of yields, disease control measures, fertilizer responses and other production functions, as well as the desired staffing levels, cost of processing equipment etc. The planning economist will use this technical data to compute the direct costs and benefits of the scheme. Some direct costs and benefits such as the equity of the resulting pattern of income distribution, the value of social facilities provided as a result of a project, etc. are intangible and cannot be handled mathematically. If the planners are given this non-quantifiable information, however, it can be discussed qualitatively in the project description and this may influence the final decision. More sophisticated planning procedures also consider the secondary or indirect project costs and benefits. Further information is then required on such aspects as costs of transport and processing and the multiplier effects of the extra spending power generated as a result of the scheme. Other criteria may also influence the ranking of a project. These include the likely expenditures in terms of foreign exchange, demand for and supply of skilled manpower, ability to absorb unskilled labor, the pattern of government revenue feedback from the project etc.

The reliability of the final plan mainly depends on the quality of the data fed into it. It is clearly important, therefore, that the collection of information for future agricultural planning should be given careful thought and organized so that the questions inevitably

raised by the planners can be satisfactorily answered. This implies the focussing of attention on a wide-ranging program of forward-looking interdisciplinary research. Apart from the type of information considered above, this would embrace also the effects of current agricultural production and marketing policies and the extent to which the fiscal and land tenure systems assist or hinder agricultural development. It seems particularly important that economists, field agriculturalists and research scientists should combine to discuss research and data collection programs which are necessary at the district and regional levels. This might require the formation of standing committees, the appointment of regional economists and a systematic program to periodically evaluate the experience of different schemes and policies in each region of the country.

2. Co-ordination in Agricultural Extension and Credit Programs

Agricultural Extension can be viewed as a process whereby capital and management skill are injected into, usually, small-scale agricultural businesses. The main objective of extension work is to induce agricultural development by persuading farmers of the benefits of innovation and improved efficiency; administration and legal control should ideally be a relatively minor feature of extension work. Successful extension pre-supposes (i) a mutual trust and respect between advisor and farmer (ii) the competence of the advisor in appraising improved techniques and crops (iii) his farm business and (iv) his understanding of the social environment within which the advice is given and production changes are made. The last three attributes assume an awareness of the applied social sciences in an agricultural context.

One of the economists' potential contributions to extension programs is to indicate remedies for the constraints which limit farm output. This approach may be applied either in depth to individual farms, or to test in general the validity of current extension policy in a relatively homogeneous farming area and to suggest modifications to that policy. With the general agricultural manpower shortage in Africa the latter approach is likely to give a higher ratio of benefits to costs. This is the farm-level equivalent of the planning approach which was discussed at the macro-level in the previous section. In a similar way, a comprehensive plan is required rather than the piecemeal crop-by-crop approach which characterizes much of the present extension work in Africa. Such farm plans should, as far as possible, make use of relevant technical data on advanced husbandry methods which can improve farm productivity from existing farm resources. They must also consider ways of expanding existing resources and raising productivity by purchases of suitable inputs such as better tools and other mechanical aids, better seeds, fertilizers and sprays; or even by the hire of labor at periods of peak labor demand. The farm management economist, whose specialism is the design of such viable farm-level plans, must also have an understanding of the complex network of

socio-economic factors which may limit farm improvement; without this knowledge technical innovations will often fail. It is therefore necessary to possess information concerning the local land tenure system, attitudes to risk and uncertainty, the range of farmers' objectives, seasonal cash profiles, traditional demands on farmers' time and other information of several kinds.

Research station reports, farm management surveys, farmers' own opinions and field work of a sociological nature can all provide valuable sources of information for the farm planner. On the other hand, farm accounts which play a valuable part in enabling farm advisors to devise suitable farm plans in developed countries are rarely available in Africa. The farm management economist must utilize a whole spectrum of knowledge embracing both technical and economic aspects. Economics without husbandry will certainly lead to decisions which are equally inapplicable as those arrived at by using husbandry data without economic analysis.

Given adequate data there is a range of analytical and planning techniques available for improving the individual farm business. Budgeting methods are suitable for testing small ad hoc adjustments, whilst program planning and linear programming methods can deal with more complex changes in the farming system. These latter techniques can maximize total farm returns from available resources and automatically take into account the opportunity cost problem which arise when many products are competing to use the farmer's limited productive resources. For perennial crops, calculations of profitability are more difficult because costs are incurred over a different period of time from that in which revenues are received. If data on the time pattern of inputs and outputs are available, however, discounted cash-flow analysis, which is rather similar in method to benefit: cost techniques, may be used.

Another economic concept which must be considered when framing farm advice is that of the least-cost combination of factors at given levels of output. Many advisers are tempted to recommend the most modern buildings and equipment but usually these have been designed in the context of the high labor costs which typify the developed countries. Although these methods may be sound on institutional farms and research stations paying high legal minimum wage rates, on the peasant farm they may be substituting high cost, capital-intensive methods for cheaper labor-intensive ones. Alternative capital investment strategies need more careful appraisal than is usually the case in African agriculture at present.

The extension worker should ideally be many things at once, a husbandry expert acquainted with the latest technical developments, a farm management specialist able to identify production bottlenecks on each farm and to suggest realistic plans to overcome them, and a personnel relation-cum-advertising man able to sell his ideas to the farmers. Large new agricultural credit programs involving credit

appraisal and supervision put additional work on the extension worker and require a sound grasp of farm management economics. In practice one finds a lack of detailed knowledge of farm level problems and a widespread shortage of extension personnel trained in the farm management approach to agricultural extension work. This would seem to imply that the few farm management economists there are on the continent should be fully utilized in (a) providing data relevant to practical farm-level advisory work, (b) testing the validity of current extension policies and (c) interpreting the significance of new farm survey and experimental data to the extension personnel at the regional and district levels. Further, there is widespread need for an integrated socio-economic-technical approach to agricultural problems which would seem able to secure gradual farm improvement where currently extension workers are making no progress. Finally, refresher courses for extension staff would not only keep them abreast of the latest technical developments but should also include training in the management economics approach to farm advisory work, based upon operational research in previous extension programs.

3. Co-ordination in the Implementation of Schemes and Projects:

Government agricultural schemes usually play a major role in agricultural development in Africa. The importance of adopting an integrated economic and technical approach to secure their efficient implementation is correspondingly important. Inefficiency on a public project is likely to jeopardize other schemes either by absorbing more resources than budgeted for, at the expense of development elsewhere, or by failing to generate finance required for new projects.

To take one example of the complexities of scheme planning and execution, the Government tractor hire service in Uganda assumed an increasing demand for hired mechanical cultivation services from an increasing number of farmers so that a pre-determined expansion in tractor numbers could be efficiently utilized. This demand for tractors is affected by the hire rates charged and the economic advantages to the individual farmer accruing from their use. Hire rates can be varied over a wide range; a lower rate generating higher useage but running the risk of not covering the total costs of the mechanization program. The actual choice of tractor hire rates is a rather complicated problem because this "price elasticity of demand" for tractor services will probably differ for different types of tractor operation and in different parts of the country. For financial reasons the government will wish to cover its own costs in order to avoid diverting funds from other projects in the Development Plan. Even if it is possible to break-even in this way, the real benefits of the mechanization scheme is another question altogether. It is in fact measured by the net increase in the value of agricultural production directly resulting from the use of the tractor hire service. Clearly, a low hire charge involving a subsidy from public revenue may be justified if the use of tractors causes a net increase in production of

significantly greater value than the subsidy. However, this resultant net increase is very difficult to estimate as it depends on the uses to which the tractors are put. To the extent that they boost yields by enabling earlier planting, or they enable farmers to increase their total crop acreage then there could be a direct net benefit accuring to the tractor hire service (as long as costs are covered by increased output). If, on the other hand, tractor cultivations are substituted for labor and result only in increased leisure or reduced employment, the scheme is wasting scarce resources irrespective of whether the operations are covered by hire charges or not.

The evaluation of the tractor hire service is therefore not the straight forward balancing of costs and hire revenue which is sometimes assumed, but consists of a detailed analysis of the real costs and ensuing benefits; this requires a thorough knowledge of farmers' reactions to mechanization. Additional technical data and costs, therefore, must be gathered to answer these kinds of questions in order to determine either the feasibility of newly proposed schemes or the viability of those which have been started but which have still not been satisfactorily evaluated.

It has been increasingly recognized that a more careful technically and economically co-ordinated planning approach would help to improve the effectiveness of such projects.[1] This would usually consist of:

(i) The pre-investment survey, which would use what data was already available. For example, keeping to the tractor hire service by way of illustration, the effect on yield of planting date, the necessary cultivations to prepare a seedbed, the structure of the typical farm business and the effect of mechanization on this structure, etc.

(ii) Experiments and surveys to provide answers to questions on which information was not available e.g. new tillage techniques, crop varieties suitable for mechanization, etc.

(iii) Pilot schemes can them be organized to test conclusions under field conditions at a fraction of the cost necessitated by the full scale operation. These pilot stages should indicate any remaining technical difficulties which must be solved and should give an estimate of economic viability. It should be possible to scrap or defer the project at this stage, if the pilot stage results indicate this.

(iv) Full-scale development should follow a successful pilot stage; this may embrace further technical and socio-economic problems requiring solution.

(v) Co-operation in keeping detailed records of both physical and financial inputs and outputs once the scheme is underway will ensure that future schemes are planned more efficiently.

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[1]See K.D.S. Baldwin, The Niger Agricultural Project, Chapter IV, The Lessons of Mokwa.

Phases (i) - (iii) constitute applied research activity, whilst research continues as an important component in phases (iv) and (v).

4. Co-ordination in Price and Marketing Policy

This area of agricultural policy is concerned with (a) the effects of price on the allocation of agricultural resources (b) with the storage, processing, distribution and sale of agricultural products and (c); with the creation or discovery of increased internal and external market outlets. The first aspect, price policy, obviously includes the selection of price levels for those products the prices of which are directly controlled by the government. It may also involve decisions concerning the degree of price fluctuation which is tolerable for those agricultural products whose prices are indirectly influences by the state. Determination of the most suitable price policies depends upon correct analysis of the market structure and an understanding of the probable repercussions of various types of policies. A successful overall policy must aim at:

(i) the stimulation of surplus agricultural production for the market,
(ii) the adjustment of quality and quantity to increase export revenues,
(iii) the assurance of an adequate flow of low-cost food supplies to rapidly expanding urban population,
(iv) encouraging the continuous re-allocation of productive resources to those products for which there is the prospect of higher prices and away from those whose price level is falling, bearing in mind always the possibility of low-cost expansion based on cheap resources and/or simple technical innovations.

In this area it is quite common for economic considerations to take second place, e.g. to fiscal policy where the export taxes may significantly reduce the farm-level incentive to grow those crops in return for a small direct contribution to government revenues.[1] Taxes on those consumption goods required by low-income groups, such as cloth, sugar, etc., also have repercussions on agricultural production because they reduce the real value of farmers' cash incomes thereby also weakening the incentive to produce, whilst they also limit cash savings available for farm investment.

Very little knowledge has been accumulated on these issues in Africa; one's general impression is of widespread tax discrimination against export crops and in favor of domestic activities on grounds of administrative convenience and of ignorance of the effects of these policies.

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[1]Information needed to assess the wisdom of this kind of policy includes the price elasticity of supply of the export crop in question, the cross-elasticities with other products and the effect on government revenue of a given increase in producers' incomes.

A second main area for agricultural marketing research is the analysis of factors influencing the size of the marketing margin. The role of marketing co-operatives, for example, is of growing importance but recent exposures of the inefficiences of certain Unions in Tanzania, Kenya and Uganda underline the emergence of adverse factors in this privileged sector. There seems to be a strong case, in these circumstances, to strenthen competitive pressures to squeeze existing margins rather than to continue to a policy of protecting co-operatives. In other instances, powerful private or quasi-governmental companies may, with or without statutory assistance in the form of exclusive licenses, tariff protection, etc., establish a monopolistic position in the domestic market. This may result in large book profits (although not in every case). Nevertheless it runs the risk that policies maximizing the benefits to the nation as a whole - reducing marketing costs and expanding the market by reducing retail prices - will not be implemented very vigorously, to say the least. Clearly, careful analysis of the effects of monopoly creation, and their duration, is highly desirable in many cases if growth-reducing investment is not to occur.

A third area of agricultural marketing policy is that of price manipulation and stabilization. To provide an example, recent experiments with legal minimum crop prices in Uganda have resulted in some unintended side effects, although one should not be too surprised that in some instances arbitrarily chosen prices, which ignore transport costs and seasonal demand and supply conditions, will lead to situations where produce traders refuse to pay the minimum price, leading to the disappearance of the market for the "favored" crop altogether. Obviously there are circumstances where government intervention in the marketing process is desirable but often actual cases have been unimpressive from the viewpoint of economic efficiency. There is a great need for investigations into the potential role of different storage strategies and selling methods. The provision of "market outlook" information, which could help farmers to plan their own marketing and production policies, is generally at a primitive stage reflecting the paucity of acreage, production and market quantity data.

Agricultural marketing, as we have describe it, may seem to be dominated by the agricultural marketing economist but in fact he is very dependent on technical knowledge in a major part of his work. The economist must co-ordinate closely with agricultural staff concerned with the expansion of agricultural production as their efforts should be guided into those products suggested by anticipated future market situations. Market intelligence concerning potential crops is clearly of the utmost value in conjunction with rapid and flexible crop expansion programs. Once detailed market information is collected it could be an important contribution of agricultural research to produce varities possessing those characteristics in greatest demand and to evolve impoved husbandry, storage and handling methods which would ensure satisfactory quality.

A further area for practical co-operation, which involves the medical profession, sociologists, community development workers, agricultural extension staff, agricultural scientists, and marketing economists, is that of combating malnutrition. A multi-disciplinary approach to the problem is in fact being followed experimentally in Uganda where adequate low-cost supplies of plant proteins must be stimulated in order to counter protein deficiency in children. A connected problem is the need for further research into farm-level storage of food crops where a large percentage of harvested output is destroyed by pests. The solution to this waste of food lies in the development of efficient and cheap insecticides, better food stores, pest resistant plant varieties and perhaps changes in crop rotations.

International commodity policy is an area in which objective economic appraisal is essential. In East Africa there appears to be a strong case for the secondment of marketing economists from the Ministries of Planning to the Marketing Boards, or alternatively, for specialist sections to be created within the Ministries of Planning. The importance of export crops to African economies emphasizes the importance of maximum marketing efficiency. In practice, quantity and price decisions may be made by semi-autonomous Marketing Boards with reference only to the narrow interests of a group of producers, and without reference to the similar decision of other Marketing Boards. Both an awareness of the national implications of their policies and the provision of co-ordinating machinery are necessary in some cases. The case for such machinery is even stronger in the case of inter-national trade within a Common Market, where unco-ordinated decisions may frustrate the potential advantages.[1]

5. Co-ordination in Agricultural Research

Research is, of course, a vital part of the agricultural infrastructure as it offers the means of producing greater quantities and better qualities of agricultural produce from existing resources. It is usually regarded as being pursued only on research stations or experimental farms. Although this does comprise a major part of current research programs, this could be more widely supplemented by research of other types. Farm management surveys, demographic social and nutritional investigations and follow-up research on the effects of extension work and other policies should all be utilized to provide the data for the formulation of successive agricultural improvement policies, including future agricultural research programs.

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[1]See e.g., D.G.R. Belshaw, Agricultural Production and Trade in the East African Common Market, Chap. VI in C. Leys and P. Robson, (eds.) Federation in East Africa, Oxford University Press, 1965.

When planning the agricultural research program three main questions must be answered:

1. What proportion of the total available national resources should be allocated to agricultural research?
2. What fields of research and which particular research projects should command the major share of current research expenditure?
3. What is the optimum design, scale and cost of individual research projects?

The total share of national resources allocated to agricultural research may be decided by general economists who may be unaware of its potential contribution to the development effort. This situation is aggravated if research scientists are unable to justify their projects in economic terms; this may be because they are out of touch with farm-level agricultural problems. At [illegible] most research results which are readily available to field work[illegible] and research scientists is of the research-station type.

Priorities in research are difficult to outline as the very nature of research frequently precludes the direct measurement of benefits flowing from it. It is safe to say, however, that few developing countries can afford the luxury of a research program which is not primarily oriented to answer the direct needs of the agricultural industry. As the agriculture of most of Africa is comprised of a multitude of small farms, research should, of course, be mainly geared to solving problems arising under these particular conditions. The applicability of research results is likely to depend, therefore, on the accuracy of the state of knowledge concerning the problems and constraints in small scale, poor resource conditions. This usually implies that research station results must be valid under non-research station conditions; this is frequently not the case in practice.[1]

The design of research projects can only be thoroughly discussed by taking a range of specific projects, but there are some general considerations of an economic nature which should be taken into account when planning agricultural experiments. The emphasis on returns to land e.g. return per acre, tends to overlook the fact that in many parts of Africa the seasonal availability of family labor is often a more limiting factor than land. Reliance on technical measurements such as yield per acre, gallons per cow, tractor hours per operation etc. may lead to a striving for technical optima to the detriment of net economic

[1]This and subsequent points have been discussed in more detail in D.G.R. Belshaw and M. Hall, The Analysis and Use of Agricultural Experimental Data, Zeits. fur. ausl. Landwirtschaft, 1965 (in German with English summary); also in D.G.R. Belshaw and D.M. Etherington (eds.) The Analysis and Use of Agricultural Survey Data, East African Publishing House, Nairobi (in press).

returns. What is important to a farmer is the net return available for consumption from his productive resources. This is not necessarily maximized by the achievement of high yield levels as the process of reaching these levels can absorb too many resources and reduce net returns. Many research projects indicating the possibility of high productivity levels have incurred a high price in terms of labor and other inputs. Frequently the farmer cannot afford to duplicate these production conditions. The fact that crop harvesting is scrupulously carried out on research stations results in the gathering of every part of the crop. This biological yield may not be achieved under farm conditions where, after a certain point, the cost of continued harvesting in terms of labor diverted from other uses is greater than the value of the extra output which would be added.

Agronomic experiments on a single crop may lead to rotational problems being overlooked. Recommendations tied to one crop only have rarely considered the repercussions on other crops resulting from the diversion of scarce resources such as seasonal labor. The risks involved in the adoption of improved techniques should be stated by including co-efficients of variation when results are tabulated. If the margin of profitability is likely to be relatively small, recommendations should preferably be delayed until experiments have been carried out over a reasonable range of weather conditions, ecological zones, etc. On the other hand, where the crop or husbandry innovation is clearly advantageous, advice of a general and tentative nature should be issued before the final data on statistical significance becomes available, so as to allow the more progressive farmers to give the new development a practical field trial. An example of different attitudes by governments to innovation can be quoted from East Africa, where Kenya African farmers had been using phosphatic fertilizers manufactured in Uganda for four years before the Uganda farmers were themselves encouraged to try them out. Greater rapidity in the dissemination of research results would seem possible if the extension and research workers focussed on the probability of improving farm incomes, rather than on the accuracy of physical output predictions.

The farm management economist should acquaint the research scientist with farm resource situations and co-operate with him in the design of both research programs and where appropriate, of the actual experiments. The increasing interest on the part of research workers in carrying out farm-level trials is a welcome development which will bring the researcher, extension personnel and farm management economists on the same ground and should facilitate co-ordination in moulding research priorities and methods to meet observed needs. Once the machinery of co-ordination has been devised, the process of initial education can be greatly accelerated. Farm economists can introduce scientific research workers to relevant economic concepts and conversely, economists can be appriased of the state of current scientific research. Probably, full co-ordination would require the appointment of full-time agricultural economists to the staff of the major research stations.

The ideal relationship between agronomic research and the farm has been described in the following terms:[1]

> "The framework for carrying on fertilizer research, particularly that to be used in farm decision-making, appears to be on the verge of rapid change. Acceptance of the concept of the farm production unit in terms of the economists' model of a "firm" gives a new perspective to the role of physical research. Recommendations on all production practices and enterprises must fit together in the economic sense if the farm is to maximize returns. The farm operator, not the production specialist or economist, should make the choice of the types and combination or production factors or practices to be employed, as well as the types and amounts of products to be produced. He must make these selections in terms of his capital, ability to stand risks and the family's goals as a consuming unit. The production specialist or the economist cannot supply a single "best answer to a production program if the farm is considered a firm-house-household combination. The farmer must be given data from which to fashion a plan to fit his own particular circmmstances."

In our view this framework provides the most realistic and penetrating basis for programs of induced technical and economic change for Africa's agriculture. Management-based, project-oriented agronomic or husbandry research programs which include a phase of full field trials, would appear to be able to make significant progress where the traditional research station experiment may be relevant only in its own limited environment.

6. Co-ordination in Agricultural Education

Agricultural education is another important pillar of the agricultural infrastructure. It must cater for a wide range of students from illiterate farmers to agricultural post-graduate students. Courses may be full-time and last for several years or may be only one day courses and this divergence in educational standards and the length of the educative process is reflected in the wide diversity of training institutions which it is not necessary to describe here.

One definition of education is "preparation for future life", and it is important for students of agriculture at all levels to be conversant with the reality of farming and rural life in their own country. This seems obvious but students seem often unaware that agricultural development not only involves the production of crops and animals but is also essentially concerned with maintaining and raising the standard of

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[1] E.C. Baum, E.O. Heady and J. Blackmore, Methodological Procedures in the Economic Analysis of Fertilizer Use Data, Iowa, 1956, p.218.

living for those engaged in farming. This implies that technical and scientific knowledge should be supplemented by economic and sociological considerations. The agriculturalist with training in economic analysis should be constantly attempting to assess the costs and returns involved in any decision. This approach may also be useful to peasant farmers, if explained simply, as even though many farm inputs such as family labor cannot be given a money value, they do have alternative uses. Farmers are, of course, aware of this, but formal teaching of this opportunity-cost concept will help the farmer in consciously planning and distribution of his resources in more optimal patterns and, perhaps more important, it will enable a duologue to take place between the advisor or teacher and the farmer within the context of farm-level decision-making, i.e. the area of most immediate concern to the individual farmer.

At the professional level of training, the same education precepts imply that since graduates will be in administrative charge of the agriculture of whole districts, they must at least be able to participate in the economic planning process at this level. In order to do this, they must have an appreciation of planning techniques, a knowledge of what data is required in planning and the ability to make simple first approximations to project appraisals. They must also be aware of the infrastructure within which the plan has to be worked out and should therefore receive instruction in the social aspects of rural development, agricultural marketing structures, project implementation and other areas which are important in achieving development on the ground.

An appreciation of the national importance and development role of agriculture would also improve the motivation of the students and some lectures covering this aspect are very useful at all levels. It is particularly important that management data and analysis should be closely integrated with crop and animal husbandry teaching (under the general head, for example, of crop and animal production) so as to produce extension workers able to think in terms of the farm business rather than in purely technical terms.

Clearly, for these aims to be achieved further co-ordination is required, in this case amongst the specialist teachers and syllabus planners. Impetus for re-thinking and re-designing syllabi can come from follow-up surveys of past students. This kind of operational research would appear to be high priority at all levels of agricultural educational institutions.

Within the largest sector of the educational system - primary and secondary schools - there is an increasing realization of the relevance of rural science and agricultural studies to pupils who must perforce earn their living in the rural sector. Here is a policy area embracing incomes and employment, manpower, agricultural projects, land tenure and credit and educational syllabi which is of the greatest magnitude

and importance for many African countries. It seems capable of solution only by a vigorous multi-disciplinary approach incorporating operational research and organizational innovation on several fronts simultaneously.[1]

7. Conclusions and Policy Implications

The discussion in this paper has been set out at length in an attempt to communicate across the disciplinary barrier between economics and the natural sciences. We have tried to indicate the role that applied economic analysis, in particular, is playing and can increasingly play in achieving effective implementation of the crucial agricultural development programs. To be effective, this role should be played in full co-operation with other approaches, especially those derived from agricultural technology and applied science which provide the previous professional training of the greatest proportion of executives finally responsible for implementation on the ground.

A number of suggestions were made for improving economic and technical co-ordination of this kind. The main points arising from the discussion and analysis were as follows:

1. Economists are essentially involved with assembling information to improve decision-making processes at all levels of the economy. The collection of input-output data is only one facet of their work. Such information when combined with technical and scientific data provides the raw material for agricultural planning.
2. The example of the proposed cocoa expansion scheme was taken to indicate the frequent existence of numerous gaps in the information required to plan agricultural projects. Collection of information for future agricultural programs should attempt to anticipate the questions which will be asked by the planners. Economists, field agriculturalists and research scientists should combine to discuss research and data collection programs which are necessary at the district and regional levels.
3. Regional economists should be appointed to evaluate the experience of different schemes and policies in each region of a country.

The economist can help the extension specialist by indicating remedies for the constraints which limit farm output. Given the current shortage of farm economists and extension personnel with adequate training these plans would be most valuable if applied to groups of similar farms rather than to individual farms.

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[1]For discussion at the policy level see J.J. Sheffield (ed.) Education, Employment and Rural Development, East African Publishing House, 1967.

4. Comprehensive farm plans are likely to be more effective than the piecemeal crop-by-crop approach which characterizes current agricul ture extension work. This whole-farm approach necessitates an understanding of the range of available husbandry techniques and a detailed knowledge of the socio-economic structure at the farm and rural community level.

6. Given again the scarcity of adequate extension personnel the existing farm management economists should concentrate on (a) providing data relevant to farm advisory work (b) testing the validity of current extension policies and (c) interpreting the significance of new farm survey and experimental data to extension personnel.

7. A technically and economically co-ordinated approach is needed to help improve the implementation of government projects. This approach would include initial data collection from all possible sources; and experiments and surveys to be followed by a pilot scheme. The full scale project would only be inaugurated after these steps had been satisfactorily completed.

8. The repercussions of macro-economic policies and institutional structures on agricultural production incentives should be examined by the collection of evidence at the grass-roots.

9. Although the benefits of research are often long-term and difficult to quantify some attempt should be made to rank research projects in order of desirability by using a benefit:cost approach. This would require intensive co-operation between scientists and economists but because of generally restricted research budgets, it is imperative to formulate a policy which ensures that the most rewarding projects are chosen.

10. Research design should be project-oriented so that all aspects of a particular improvement campaing are satisfactorily cover, e.g. the engineering and economic aspects of pest control spraying programs may be neglected, whilst the point of diminishing returns is passed on the entomological and biochemical aspects of research.

11. District-level agricultural development reviews on a multi-dis disciplinary basis might be the type of research which gives the biggest return in terms of realistic appraisal of the effectiveness of current programs and alternative lines of approach.

12. Research station results must be interpreted very carefully because of the differing resource situations found at the peasant farm level; economists could be usefully integrated into research station establishments. As an additional role they would facilitate the interchange of information between extension officers and research scientists.

13. Agricultural education must be adjusted to the type of work the

student will eventually carry out. It is desirable that management concepts should be taught at all levels to provide a framework for effectively using the variety of scientific and technical data which has been taught.

Given the scarcity of applied economists working in African rural development programes today, the choice as to how to use them is itself an economic allocation problem of some difficulty and, one which does not admit to easy generalization. Their effectiveness can be increased, however, by spreading their distinctive concepts and techniques through inter-disciplinary problem-solving research teams. A strong case can be made for using such teams on the operational problems of implementing agricultural development programs and projects.

ECONOMICS OF PRODUCTION AND MARKETING

Max Diaw

INTRODUCTION

1. Food Crops (millet, sorghum, cowpeas, plantain, rice, etc.)

Research on food crops requires simultaneous action on three fronts: a) agronomic, b) economic, c) psycho-sociological.

In face of the necessity of providing daily food supplies for populations growing at tremendous speed or whose nutritional status one wishes to improve, agronomic research on food crops is essential. It should cover, improvement of quality and increasing of yields (varietal selection, controlled water use, application of fertilizers and pesticides, introduction of simple tools, especially, if it is the man and no longer the women only who will be farming, improving cultivation techniques.

As regards economic research, this should cover channelling of food supplies to ensure nationwide distribution (depending on the season, communication and transport facilities available or to be created, domestic commercial channels, new markets or expansion of old markets, etc.). Where surpluses occur, the problem of how to use them arises, whether by processing or export or trading for other foods.

From the psycho-sociological standpoint, research should embrace present consumption and dietary patterns (customs, taboos, etc) and be conducted with the aim of ensuring permanent success of health and nutrition education campaigns, particularly with respect to new dietary habits that one wished to inculcate.

Research in OCAM countries along these lines

2. Cash crops (coffee, cocoa, peanuts, oil palm, bananas, citrus fruits, pineapples, rice, cotton, etc.)

It is by no means too early for the OCAM countries to undertake surveys and research work throwing light on all their economic problems in relation to their export crops (world situation; projections on consumption, price trends, transport charges, quotas; joint market for several countries; new outlets) with a view to determining what measures should be taken and organizational tactics.

Such research can effectively help each and every country in gaining a relatively accurate appraisal of its own situation as regards export crops.

3. Marketing Structures

Marketing structures for agricultural commodities differ widely from one country to another and producer prices vary depending on economic and even political circumstances.

Theoretically consumer prices depend first on costs of production (soil fertility, average crop yields, climatic conditions) and secondly, on the interplay of supply and demand on various home markets, for commodities consumed in the producer and adjacent countries, or on the world market in the case of export crops.

In practice it is often extremely difficult to take all these points into account especially for export crops - coffee, cocoa, cotton, pepper, vanilla, peanuts and so on. Falls in quotations for these commodities on the world market can bring about serious financial crises.

In order that producers may not have to sell at ludicrously low unremunerative prices, certain governments have established commodity price stablization funds or price subsidies with a view to evening out the demand and falls in world market prices. However, such measures are merely palliative and in most cases cannot ensure producers higher prices as a result of which their standards of living could be raised.

Usually official prices set by ministerial decree are published in the official gazettes. However for commodities consumed locally, such as maize, millet, sorghum, cassava, paddy, etc, only very small portions of the total crops are actually traded at these prices, since very frequently growers do not market their crops through official channels but sell directly to the public at the "going price" - which is extremely variable and can sometimes be even three or four times higher than the official price! This is the reason we recommend marketing surveys covering price data so that prices may be stabilized and more efficient, new marketing channels organized.

INTENSIVE AGRICULTURAL SYSTEMS

F. Bour, Director General, IRAT

SUMMARY

This paper defines the objectives for the agricultural development of the Third World countries, which up to now have basically peasant (micro-exploitations) agricultural farming systems. The principal objective should be improving the income of the farmers.

Next a whole series of problems are examined briefly and it is pointed out that these problems should be looked into both individually and in combination at the farm level.

These problems are agricultural, but also socio-economic in nature.

The author feels that agricultural research, that has the objective of devining intensive agriculture, should be undertaken according to the following five principles:

- research which does not provide results capable of extension on a large scale throughout an entire region is of little significance;

- compartmented research which can not be practically applied to the farms in a determined zone does not fulfill its purpose;

- research must take psychological factors into consideration in the choice of solutions to a problem to discern which solutions have a chance of being successfully applied;

- extension systems must be studied alongside of agricultural research to give research its true significance by changing the customs and practices of farmers in an entire region;

- primary research need not be complete before undertaking "operational" research which can be begun as soon as sufficient knowledge and information on zones situated within other regions with similar ecological characteristics is available.

The author cites figures on the size and average yield of farms in tropical and equatorial Africa, and describes two examples (Senegal and Madagascar) of integrated agricultural development projects that were very successful.

The paper includes four statistical tables and has two addenda with details on the two projects cited as examples.

In the countries of the Third World, where the agricultural structure is primarily "peasant": that is to say, it is a micro-exploitation system, a primary objective for agricultural development must be improving incomes of the farmers.

On the production level, this means that an increase in the profit made by each farm, through the labor spent on the farmland.

Thus a whole series of problems arise which must be examined both specifically and in combination at the farm level. Some of these problems are:

- improvement of varieties
- introduction of new crops for diversification, which in turn is often governed by commercial considerations
- improvement of soil fertility through the use of mineral fertilizers, and through working the soil (problems using mechanization and draft animals)
- introducing livestock production into the agricultural pattern
- crop rotation: fallow periods; introduction of clover, alfalfa, etc.
- crop protection
- conserving stocks.

To these agricultural problems can be added socio-economic ones:

- collective organization of heavy work: cooperatives
- organization of burying necessary supplies or selling the products
- problem of cooperatives and agricultural credit
- problem of technical training of farmers: extension and rural organization.

Thus a group of problems are stated that are generally dealt with independently by various scientific organizations, technical services, or establishments or agencies that specialize in development.

It is well to remember that research that would give results unsuitable for extension on a large scale for a widespread region would not be worth very much.

Yet, too often research does not take into consideration the need to judiciously combine the different elements in order to set up an extrapolable model. Too often, research is carried out on a restricted level, on one particular aspect, and then a report is published dealing with the conditions under which the results can be usefully combined with other factors in order to make a region go from the traditional phase to a progressive one in which there is intensification of agriculture.

It is good to keep in mind that piecemeal work, which cannot be practically applied to a determined and specified zone, will not be very worthwhile.

It is also necessary to remember that research must keep in mind psychological factors when choosing and working on solutions, in order to select solutions that have a chance of being applied.

It is absolutely necessary that an extension system be studied along with and parallel to the research endeavor so that the research can ultimately lead to the transformation of the habits and working habits of farmers in an entire region.

That is why we found it necessary to systematically set up close working ties with organizations and agencies specially entrusted with agricultural development and extension. From the exchange and confrontation of ideas a method of activity developed which helped us to orient our research.

At the risk of belaboring a point, we feel that it is necessary to emphasize the interdependence between the various factors enunciated above and to indicate that in actuality, the different problems analyzed in a study of the natural conditions of agriculture, should end up in defining research programs.

Nevertheless, we must make the point that this category of research, which is indispensable to any regional program, proceeds from a particular starting point, and does not mean that classical primary research should not be done for tackling typically agronomical problems such as:

- varietal improvement;
- mineral fertilization and working the soil;
- crop protection.

But it is ne ecessary to wait until these primary types of research are finished bef one starts the "operational" type research; these can be begun as soon as one has sufficient knowledge of zones in other regions with similar ecological characteristics.

Production research of the type that we are attempting to define here should include the following:

- optimal utilization of the natural conditions as well as the material and intellectual resources available, this to be done as quickly as possible and for as many of the people in the zone under consideration as possible;
- a schema of progressive improvement so that a traditional unproductive agricultural system can become an intensive one, progressively eliminating the shifting nature of the cultivation;
- definitions of the different levels of progress so that each can be reached by most of the farmers without costing an effort out of proportion with the increased wealth that they will obtain.

All these considerations seem to me to be the real purpose of research and absolutely necessary before a development task is undertaken.

If one considers the fact that in tropical and equatorial Africa most of the agriculture is farmed in a traditional manner, as is shown by the figures following, and if one observes that most of the farms give very poor yields, then it becomes apparent that the problem under consideration here is applicable to nine out of ten development projects. Improving the methods of approach to these problems and their solution is in itself a major task.

Average Size of Farms
(Land under cultivation--in hectares)

Senegal	3 to 4
Ivory Coast	4 to 5
Togo	2 to 3
Central Africa	2
Brazzaville-Congo	1
Madagascar	1 to 2

Average Yield per Farm (kgs/ha)

	Sorghum	Maize	Cassava	Rice (Paddy)	Peanuts	Cotton (seed)	Coffee (beans)	Cocoa (dry beans)
Senegal	490	850	4570		885			
Mali	660	780		830	660	350		
Niger	500	600	7920	1340	810	430		
Ivory Coast	575	690	5200		580	250	420	370
Togo	400	575	10,660	880	500	140	480	430
R.C.A.	600	400	3270	780	810	240	520	
Malagasy Republic		1100	6000	700* 2200*	1000	1400	300	600

* dry
** irrigated
(These figures are the overall averages for all farms, both the traditional ones and those at other levels of development.)

Before we go into the various aspects of this operational agro-economic research, we feel that it would be interesting to examine the steps that were taken in preparing development projects in two regions of Francophone Africa, each one encompassing an area of about one million inhabitants. We will deal with what is known as the Senegalese peanut basin (four million hectares in the Thies-Diourbel-Kaolack triangle) and the High Plateau regions of Madagascar, where primarily rice is grown.

I. SENEGAL

In the first case, on geographic area of about four million hectares, five years ago the situation was as follows:

- 750,000 hectares of peanuts, 600,000 of millet
  average peanut yield: 910 kilograms
  average millet yield: 460 kilograms
  fertilizer consumption: little for peanuts, practically none for millet
  animal traction used on 50% of peanut farms

The Senegalese Government decided to intensify the production of peanuts and millet of this region.

Research, which went on before the decision was made, had done the following:

- defined varieties with high productivity, adapted to the different zones of the region (a function of the varying rainfall)
- perfected cultivation techniques (dates for seeding, spacing, density, etc.)
- defined fertilization formulas
- showed the importance of upkeep.

The Senegalese Government, in a first stage, decided to popularize these themes systematically so that they would be applied, in four years time, by 70% of the farmers. To do this, an organization which specializes in agricultural extension (SATEC), with the help of the research institutions and under their control, was entrusted with systematically organizing this extension.

Four years later, a great deal of men, materials and so on, were put to work. The tables below indicate input and the results:

People put to work

		1966 Campaign	1967 Campaign
Senegalese Extension Agents		675	695
Technicians:	Senegalese	16	24
	European	41	35
Engineers:	Senegalese	1	1
	European	15	15

Results

	1963		1966		1967	
	No.	%*	No.	%	No.	%
Sowing machines	65,000	50	108,000	80	124,000	95
Hoes	20,000	15	53,500	33	80,350	55
Plows	2,400	1.5	6,100	7	14,800	17
Fertilizer:						
Peanuts	18,700	16	35,200	29	44,250	37
Millet	2,300	2.5	10,560	8	11,116	10.4

* of optimum peanuts + millet

These figures allow us to say that, barring a climatic catastrophe, an increase of 25% on the average of the productivity of fields planted in peanuts should be achieved by the end of this year.

During this first phase, the Senegalese Government decided to work on a second phase whose technical goals are a major step towards intensifying and "sedentarizing" agriculture and creating at the same time an integration of crop and livestock production.

These goals, assigned to research and the development agencies, are as follows:

- intervention of "heavy" themes: major projects, intensive mineral fertilizers;
- reduction in the time land is allowed to lie fallow; attempt to progressively replace this by planting fodder crops, clover, alfalfa and the like, especially in rainy zones;
- integration of livestock production (draft and small animals) with crop production.

The economic goal to be attained in five years is as follows:

- increase the productivity of peanuts an additional 15%;
- increase productivity of millet 25%;
- increase the quantity of meat and milk produced by 10,000 tons and begin a significant operation for producing and collecting milk.

II. MADAGASCAR (High Plateaus, region with an altitude of between 1200 and 1500 meters)

In most of the zone, only the bottoms of valleys are cultivated in rice. Rainfall is from 1200 to 1500 millimeters. Each farm is about 0.65 hectares; each has an average yield of less than two tons.

The peasants are good farmers and take excellent care of their paddies, using what little manure they can find on their nurseries, but no mineral fertilizers. The micro-hydraulic system, which is often imperfect, does not regularly nor surely control the water. The hills, which make up 9/10 of the surface are hardly ever planted upon except in the naturally extremely rich, volcanic regions.

The determination of the Malagasy Government to develop this region included the following goals:

- increasing rice productivity: increase yield on 50% or 60% of the farms, or a 30% net average increase, through improving fertility;
- improvement of cultivation techniques;
- organization of crop protection;
- organization of agricultural credit and supplies.

At the same time:

- projects to utilize land with hills of less than a 12% slope and reconstruct the fertility of the soil (which has been washed away in many cases) through working the soil and mineral fertilizers;
- development of a rotation system which would permit diversification of crops and maintenance of the organic fertility of the soil;
- organization of animal traction (and mechanization).

Here too, research institutes and development agencies were invited to collaborate in defining the methods and in launching primary and combined research in order to find farming models suitable for extension.

Without waiting for the research to be finished, extension was begun with the simplest themes concerning rice production, such as improvement of nurseries, improvement of cultivation techniques, use of mineral fertilizers, improved weeding techniques, and how to combat cercospora.

This operation was decided upon eighteen months ago, and at the present time employs the following task force:

- in research ..... two expatriate engineers[1]
- in the extension program.....30 expatriate engineers
  more than 200 engineers and local agents
  nearly 500 extension agents in th field

These two operations are so large that they have economic and human significance. Both of these development plans are built on a close collaboration between agronomical research and the socio-economic development agency, which, parallel to the research studies how to develop certain aspects in order to meet the psycho-economic problems as effectively as possible.

These different problems are what we are going to examine now, keeping in mind that it is through seeing contradictory examinations of a problem and their interaction that one can find a workable schema.

1. On the High Plateaus, the OPR has eight researchers and three "rice technicians" on loan from IRAM.

ROLE OF AGRICULTURAL RESEARCH IN THE DEVELOPMENT OF AN INTENSIVE FARMING SYSTEM FOR SENEGAL*

P. Silvestre, Chief Research Engineer, IRAT

SUMMARY

The various orientations and results of research on crops in Senegal (exclusive of irrigated crops) are discussed.

This research was begun before the last war, first with peanuts (for economic reasons) and later with cereals. The results made it possible to define simple improved practices (fertilizers, varieties, farming techniques) which could easily be taught to the peasants and did not require any modification in their basic agricultural system, which could remain itinerant.

Since 1950, research on soil fertility has shown that real improvement in soil fertility is obtainable only within the framework of a sedentary agricultural system with mechanization (animal-drawn plows).

New research problems were then created requiring studies on agricultural equipment, developing new and more productive varieties better adapted to the new conditions, the problems of crop rotation and fodder-crops, and the introduction of new crops.

From the results obtained, farming techniques were defined.

Finally, the importance of communication between researchers and extension agents was pointed out, in encouraging the farmers to accept new techniques which will greatly change their traditional habits and patterns.

* * * * * *

Senegalese agriculture, for the most part, is still in a primitive stage today; it is often itinerant, the soil is exploited and not cared for; land cultivated per worker is low; there is no integration of crop and livestock production which are in most cases in the hands of different ethnic groups.

The causes for this state of things are numerous; they are generally economic and social in nature; lack of capital, social traditionalism, inadequate means of diffusion in the rural environment, the customary system of land tenure which hinders private ownership and restricts investment in land.

These factors, which oppose agricultural development, were only

* F. Bour, "Definition of Intensive Agriculure"

recently lessened or eliminated through improved credit, a vigorous rural action program, and a land-tenure law.

The purpose of this paper is to show the successive orientation of the agricultural research involved in this development, the results obtained, the outlook for intensification of the farming system, and, in the face of this new framework, what are the new problems that research has to face.

We will only look here at the research concerned with dry-land farming which makes up 9[illegible]% of gross rural production.

Most of it is peanuts, approximately 1,000,000 hectares, and 900,000 tons, and food crops, approximately 1,000,000 hectares, including 500,000 tons of cereals, millet and sorghum.

1. Early orientation of agronomic research - Improvement without radically modifying the cropping system.

The research was begun at the CRA in Bambey well before World War II.

At that time, research was primarily on peanuts, especially selection of improved varieties.

The reason for the choice of this priority was the economic importance of this crop for Senegal; selection was emphasized because it was believed that improved varieties would be the easiest improvement to introduce to the rural areas.

Rapidly, and especially after the war, while research was continued on selection of varieties, other research programs were developed:

-on cultivation techniques;

-on phytosanitary protection of seeds and seedlings;

-on fertilization.

Parallel research was undertaken on sorghum and millet.

At the same time, research was carried out on agricultural implements.

It should be pointed out that the research, very sketchily outlined below, was into improving yield of the main types grown, the various types being compared one to the other so that improvement factors could be given to the rural milieu without changing the traditional cultivation pattern radically and so that the agricultural system could remain partially itinerant.

Thus, for example, mineral fertilizers that were proposed for

extension purposes in this context were of such a type as to be profitable at very low levels for the one crop for which they were developed.

The results of this research were:

- a map of the ecological adaptation of the selected varieties of peanuts;

- a map of appropriate mineral fertilizers developed for peanuts and definition of a polyvalent formula for cereals;

- the definition of best cultivation practice for peanuts and cereals (disinfection of the seed, density and proper time of seeding, techniques for caring for the crops, etc.) and definition of proper agricultural tools for carrying out these methods, such as horse- or ass-drawn plows, etc.

One could safely say that the introduction of these improved methods into the rural environment could increase yields under conditions at Bambey from 900 to 1700-1800 kilograms per hectare for peanuts and from 500 to 900 kilograms per hectare for cereals.

These results have, since 1964, led to the extension of the findings and their introduction as a result of the development of an efficient extension framework into the rural communities in almost the entire peanut-growing area.

2. Research towards intensifying the cultivation system

While the research described above was going on around 1950, the Centre de Recherches Agronomique (CRA) of Bambey began a series of projects oriented towards the intensification of the farming system.

First this type of research concentrated on soil fertility.

The soil of Senegal, as is generally the case in Africa, is low in phosphate.

Senegal has access to tricalcium phosphate which is insoluble but cheap

Research for correcting this main mineral lack in the soil showed that this made a good depth fertilizer in large doses, especially in the areas that had a sufficient rainfall.

Research also showed that:

- these phosphates did become soluble in areas that had enough rainfall, provided that the phosphate was put deep into the soil ahead of time, with enough green matter;

- that a vast improvement was thus obtained, that the main soil

deficiency was done away with or greatly corrected, that it enriched the soil in organic matter, allowed for economic utilization of much higher levels of other elements, predominantly nitrogen for cereals and potassium for peanuts, than the annual fertilizers developed for an agricultural system that would remain itinerant in nature.

In the light of this, other research had to be undertaken.

Draft animals are necessary for getting the fertilizer deep into the soil until motorization is possible. Studies were thus undertaken on the equipment to be used, the labor input involved, care of the animals as well as feeding them, with natural fodder (planting fallow fields with fodder crops) or specially grown crops, or harvest by-products.

Results showed that wich such a cultivation system, peanut yields could reach 2000 kilograms per hectare and cereal yields could be brought up to 1500 kg/ha and that it is possible in this manner not only to feed the working animals, but also to feed a small herd for profit.

The development of such a farming system, which can be extended as of now in the more favorable regions, presents still other research problems which are now being studied in Senegal.

Selected cereals which did not give very satisfactory results within a framework of low soil fertility can now be studied more intensely for genetic improvement.

Fodder crops, techniques for improving natural pasture, temporary grassland, annual fodder crops and their production techniques (hay, silage) are all being studied now.

The high fertility levels make it possible to look forward to intentifying production; more demanding species than those that have been grown traditionally are being studied systematically (in certain areas maize is being substituted for the classical cereals, cotton, soy beans, etc.)

3. Problems of applying the results obtained to the rural environment: The example of Sine Saloum

3.1. Defining the type of farming system

Results obtained through research on the production level and the labor requirements for the various seasons and different crops on the basis of improved agricultural tools, available forage, etc. have made it possible to define for a typical family the maximum possible farm size, with optimum user of manpower, optimum profit, and optimum use of agricultural equipment without encountering bottlenecks.

This type of farming will permit the generous feeding of a pair of draft bullocks leaving a larger or smaller excess of feed depending on the type included in the crop rotation (fallow or annual crop) and the additional forage available (natural grassland). On the other hand the minimum size of a farm can be determined in terms of the return from a pair of draft bullocks and the associated implements as well as the discounted available feedstuff. The limits thus defined permit a choice of farming system for purposes of extension.

3.2 Scientific Farming Methods

Technical areas suitable for extension are:

- Soil Management - the shortness of the rainy season in Senegal and the necessity for seeding peanuts and millet early mean that it is only possible to plow and work the soil at the end of the rainy season (this work involves plowing-in green matter deep into the soil after harvest, fallow grassland or harvest of annual fodder crop).

- Preparing the soil at the beginning of the rainy season is only possible for sorghum.

- Crop husbandry - crops must be cared for early and carefully.

- Fertilization - correcting phosphorus deficiency can be done by applying 500 kilograms per hectare of tricalcium phosphate, set deep into the soil after plowing (at the end of the rainy season) and the "annual mineral supplements are calculated to ensure a balanced mineral content."

- Rotation - it comprises one or more years of fallow planted with fodder-crops which can be replaced partially or totally by an annual fodder crop and a legume-cereal-legume series.

  The legume is generally the peanut, but can be the cow pea (Vigna spp.); the cereal is millet or sorghum.

The main extension topics should be supplemented with general information on far management - cutting permanent access roads to the fields, hedge enclosures, for example; planting trees around the land under rotation cultivation as protection against animals - trees for firewood on areas where crops cannot be grown, fruit trees in areas with enough moisture.

3.3 Progressive Application of Scientific Farming Methods

The fixation and intensification of shifting cultivation, use of bullocks as draft animals, the need to manage and feed animals, use of new agricultural implements, all constitute great changes in the traditional way of life of the peasant farmers.

Thus in the eyes of the extension agent, it seems practically impossible to teach all the improved methods simultaneously to the farmers, whereas for the research worker it seems risky to separate them, inasmuch as each improvement is most successful when applied simultaneously with the others.

At this stage, communication between research and extension personnel is indispensable.

In the example selected, as a result of this communication, the intensification of the farming system was organized in three stages.

Extension must concentrate on farmers who have already applied the simple improvements enumerated at the beginning of this paper and who are thus already familiar with good agricultural practices and aware of the need for agricultural progress.

The three stages are as follows:

a) Utilization of bullocks for traction, and making the farmer aware of the value of this technique

-use of wagons for transportation;

-plowing of fallow land;

-use of animals for various phases of planting and harvest

Farmers will be made familiar during this phase on how to care for the animals (building shelters) and feed them (supplying feed supplements, making hay from natural vegetation, etc.).

b) Development of a system of crop rotation

Whereas the first stage could be applied to an agricultural system which was still partially shifting, the second stage is for sedentary agriculture.

It is characterized by applying fertilizer deep into the soil. This is progressive in itself as it is applied each year to soil lying fallow.

Improving the draft animals will be continued.

c) Complete integration of livestock into the farming system

At the end of the last rotation, where marked improvements in soil quality and so on will hopefully be gained, fallow fields which in the preceding stage might still have been used as part of an itinerant pattern are now used part of a sedentary pattern.

This stage is one of the rational use of fallow land (improvement, fertilization, enrichment of species used) and one of putting fields to temporary pasture or planting them in annual fodder crops.

This stage opens the door to sedentary economic livestock production.

3.4 Application to the Sine Saloum Region

Sine Saloum, in the peanut basin of Senegal, is the most favorable zone for such a modification of the agricultural system, for both ecological and social reasons.

At the present time, it is impossible to organize profitable sedentary livestock production on a large scale, for economic reasons.

The crop rotation chosen, therefore, for three years of cultivation, has only one year of fallow pasture.

It is foreseen that of the 52,000 farms that exist at present, within five years:

- 8,000 of them will use bullock plowing and heavy equipment;
- 31,000 can reach the stage of improved farming with light equipment and simple improvement techniques;
- 13,000 will remain in the traditional, extensive agricultural system.

RURAL DEVELOPMENT ON THE HIGH PLATEAUS OF MADAGASCAR*

R. Chabrolin, Research Engineer, IRAT

SUMMARY

The High Plateaus of Madagascar, which are densely populated (35.4 inhabitants per square kilometer) have little cultivable land because of the rugged terrain. Only 5% of the total land surface is under cultivation, half being devoted to rice fields, the rest being hilly land with mediocre soil fertility.

Annual income is very low, about 35,000 FMG+ per year for a five-person family. More than half of this income comes from rice production, largely consumed locally.

The population is increasing rapidly, at a rate of about 2.5 to 3% per year.

It is thus absolutely indispensable to increase the productivity of the farmers and the land, as there is only limited room for expanding the area cultivated, and at great cost.

Extension programs are aiming at raising rice yields per hectare from less than 2 tons per hectare to 3.5 or 4 tons per hectare, through teaching the peasants about the use of fertilizers, improved varieties, and improved techniques.

The problem of developing the hilly lands is being studied primarily from the standpoint of fertilization.

It is hoped that net agricultural revenue would double as a result of the application of this research, from 15,000 to 30,000 FMG per hectare per year.

Nevertheless, this improvement, which is low in absolute terms, poses a certain number of agricultural and socio-economic problems which have not as yet been resolved.

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* Prepared as a supplement to the paper by F. Bour, "Definition of Intensive Agriculture."

\+ The Malagasy franc as of July 1, 1968, is approximately 248 FMG to the U.S. dollar.

1. Agricultural characteristics of the region-its originality

1.1 Population. Occupying 6.3% of the surface of Madagascar (38,000 square kilometers out of 600,000), the central zone of the Plateaus has 28% of the rural population of the Island (1,350,000 inhabitants out of 4,750,000).

The population density is 35.5 rural inhabitants per square kilometer (the population density for the Island as a whole is 7.6 per square kilometer). It is thus in this area that the problems of demographic pressures are the greatest.

1.2 Tillable land. The land is very rugged. Land with a slope of less than 15° is only one-fifth of the total surface.

Nine-tenths of the land is very low in fertility, suffers intense erosion, and is covered with grassy steppes, mainly aristida; this land is used as grazing for a very extensive type of livestock raising. In addition it is swept by periodical brush fires that accelerate the biological deterioration of the soil.

Only 5% of the land is under cultivation. More than half of this is devoted to rice-fields; in the plains these fields are sometimes quite extensive; in the valleys they are narrow and divided.

The other crops (maize, cassava, beans, peanuts, etc.) are grown on the hills (tanety) which are allowed to lie fallow for varying lengths of time. Productivity for these crops is low because of the poor fertility of the soil of these hills.

1.3 Agriculture. It is essentially family-type farming, an average group being five persons, cultivating 6500 sq. m. of rice fields with a yield of 2.5 tons of paddy per hectare and 6500 sq. m. of various other crops.

The family income is on the order of 35,000 FMG per year, which is similar to the annual family income in the other regions of Madagascar. But the portion of this revenue attributable to rice production is much higher here than in the rest of the Island: 50% as against an average of 26.5%.

1.4 Development trends. The rural population is increasing at a rate of 2.5 to 3% per annum. The possible extension of the tillable and irrigated rice-field area is very limited (scarcely 1% of the land surface) and it is very costly at that (300,000 FMG per hectare).

2. Problems posed by the intensification of the cultivation system

This intensification is absolutely necessary if one considers the population increases on the one hand and the present income levels on the other, which are already quite low.

How can intensification be accomplished?

2.1 Increased rice production. Results already gained through research make it possible to look forward to vast improvement in yield to 3.5 to 4 tons per hectare.

This is the objective of the programs now being carried out on the High Plateaus - one project (IMERINA) financed by the Fonds d'Aide et de Cooperation (FAC - France), and the other by the Fonds Européen de Développement (FED).

These projects are aimed at teaching the people about progress in agricultural methods and so on and are based on proven research by the Institut de Recherches Agronomiques de Madagascar (IRAM).

2.1.1. Improvement of farming practices (improved rice-cultivation methods)

The extension program tries to teach the peasants to follow certain simple rules:

- to follow an optimum cropping timetable, defined in terms of the local micro-climates;
- to prepare the nurseries, fertilize, seed and irrigate them correctly;
- this makes for young, vigorous plants that can be planted in a line;
- experience has shown the optimum spacing so that hoeing can be done most effectively, with a rotary hoe.

2.1.2. Dissemination of better varieties. Selected and improved rice must be substituted for the local, heterogenous varieties, as these are more productive and of better quality.

According to the research of IRAM, the following have been recommended:

- the Rojofotsy 1285 for the Tananarive region;
- Ali Combo for the Antisirabe region and the West Finanarantsoa zone;
- Ambalalava for the Ambositra region;
- Latsika and the 1300xLatsika hybrids for the cold zones and the high altitude regions.

2.1.3. Improved irrigation. Most of the rice fields already have water systems, either put in by the farmers themselves or by the Government. But the upkeep of these canal systems is not always adequate: badly-cleaned canals, partitions in bad shape, missing or blocked sluices, etc.

Besides this, the distribution of the water among the various users is not regulated. It is used in a haphazard way and there is a good deal of waste as a result.

The projects in this area are attempting to organize this

domain, and make the users take care of the facilities. Besides this, there are other sources of water supply on the High Plateaus that could easily be utilized and are not at the present time.

Those in charge of the project are to detect the small possible improvements in the use of water and they are to suggest the solutions. The main technical solutions are: dams, on rocky soils particularly; canals, draining sub-surface water; reservoirs; local and temporary lifting of the water level with a plastic tank; mobile motopumps on wheelbarrows; pump with fixed screw.

If irrigation and control of water supply is widespread, dry periods will be avoided during the growing season, which are very bad if prolonged. Transplants will then be possible on the optimum date. Double cultivation will become possible in the milder zones, as well as interseason cultivation, especially of forage crops.

2.1.4. Development of the use of draft animals. Animals have already been used for plowing to some extent in the High Plateaus along with manual labor and a system whereby the beasts trample the rice fields. Use of animals must be made more general because, as it is faster, it allows cultivation to be undertaken at the optimum time.

Beyond this, rational production of livestock gives a useful by-product, manure, which is indispensable to the regeneration of the fertility of the soil of the hills.

The development of widespread livestock production requires research in the following: materials necessary; the animals (husbandry, health, etc.); credit mechanisms, which must take the debt capacity of the farmers into consideration.

2.1.5. Mineral Fertilizers. After the first stages toward intensification, as defined above, are achieved it will be possible to expect the mineral fertilizers used on the rice fields to give another boost to the productivity.

The soils of the High Plateaus are often lacking in phosphorus and potassium. It is know also that nitrogen is the mainstay of cereal fertilizer. The work of the IRAM makes it possible as of now to distribute widely an NPK 30-62-45 fertilizer which improves yield on the order of 40%.

Other studies of the use of fertilizer for improving soil are under way. They allow us to hope for vast improvement in yield (yields of more than 10 tons per hectare have been registered in some trials).

2.1.6. Double Cropping. Application of the foregoing themes and especially improved control of water supply make it possible to envisage, in the milder climatic zones, double cropping of rice.

Research must be carried out to this end on the following: the careful choice of varieties with short growth cycles; studies of cropping timetables; fertilizers; studies of rice diseases.

Double cropping ends the break in the biological cycle of parasites and there is therefore a rick of dangerously increasing the numbers of insect pests.

Double cropping may also involve inter-season fodder crops, thus allowing livestock production.

It therefore seems that improved rice production is possible.

Extension programs have the objective of 40% improvement in yield in the next five years, which would result in an average annual yield of 3.5 tons per hectare.

2.2 Development of the hills. Nevertheless, this increase in rice production does not appear to be sufficient in the long term and it is now essential to consider the development of the ferrallitic soils of the lower hillsides. Soils where the slope is greater than 15% would require major anti-erosion control which is probably too costly. For the moment reforestation to improve the quality of these soils in a limited fashion is the most that could be done.

2.2.1. General characteristics of these hills and plateaus (tanety). Their altitude varies between 700 and 2000 meters and their main characteristics are as follows:

- humid tropical climate or tropical high altitude climate;
- annual rainfall equal to or greater than 1000 mm/yr;
- ferrallitic soil, zonal, showing strong signs of weathering;
- poor and very old rocks: gneiss, migmatites; intrusive or more recent granites; basalt and intrusive volcanic rocks of Ankarata and Itasy.

Erosion of all types is found in this area, as there is a more or less "open" grassland of very low nutritive value.

2.3. Problems involved in cultivating the hills. In the last ten years an increasing amount of cultivation has been occurring in this area.

Although this is obviously a result of the demographic pressure, only mediocre results have been obtained to date because of the extremely poor quality of the soil and the lack of fertilizer.

The possibility of providing a large enough quantity of litter or humus is unlikely, straw being used to feed the animals and the aristida areas giving sparse vegetation, difficult to gather, and with a particularly slow decomposition time.

The factor limiting the extension of cultivation is thus very clear; it is the lack of fertility of the soil. It can only be partially corrected by the classical manner known to the farmers, manure, which is not sufficiently abundant and too difficult to produce in sufficient quantities. Other types of natural fertilizers, if used alone, do not give satisfying results either.

2.3.1. Research on the fertilization of the tanety (hills). In 1961 IRAM started an extensive trial (16 test areas in the provinces of Tananarive and Fianarantsoa), to find out if it would be possible to regenerate this soil with mineral fertilizers. In 1963 tests for mineral deficiencies were begun using potted material. As early as 1964 establishment of response-curve type trials in the field provided a greatly increased determination of fertilizer requirements.

The test plant most commonly used, in the interests of homogeneity, is maize. It is a plant that is very demanding where soil fertility is concerned, and is therefore a good choice for the experimenter. However, its low selling price (of the order of 10 FMG per kilo) deprives it of much interest in the economics of mineral fertilization in terms of cash return. Fortunately, other experiments were run, on a smaller scale, on potatoes, sweet potatoes, peanuts, cassava and tobacco. The following equivalents can thus be derived: a return of 2.5 to 3 tons per hectare of maize is equal to: 10 to 15 tons per hectare of potatoes; 1 to 1.2 tons per hectare of beans; 0.7 to 0.18 tons per hectare of commercial tobacco.

To progressively improve the fertility of the soils on the areas tested as a whole, the following combination of techniques were used:

- correct working of the soil: plowing at 20-25 centimeters, correct care for the crops: hoeing, ridging, etc.
- annual utilization of 10 tons per hectare of natural fertilizer. This is considered the outside limit for the farmers. During the first year, the following fertilizer is added as well: 150 kilograms per hectare of bicalcium phosphate (57 units of P_2O_5; 100 kilograms per hectare of potassium chloride (60 units of K_2O); plus in some cases, 500 kilograms per hectare of Dolomie.

The second year, the phospho-potassium contributions were renewed and nitrogen was added; 200 kilograms per hectare of ammonium sulphate or 40 units of nitrogen, spread out thinly. As a matter of fact, the lack of nitrogen was very apparent when the manure was used and scarcely corrected at all by the use of manure alone.

The necessary fertilizer can thus be calculated (excluding manure which cannot really be given a price) at 23,300 FMG per hectare.

This type of fertilization made it possible to record yields of 2 tons per hectare with maize while control crops without the same fertilization had none at all or very poor yields.

Yields of 13 tons per hectare of potatoes, 4.5 tons per hectare of peanuts, 1.5 tons per hectare for beans were obtained from tanety soils.

Research is continuing and will certainly come up with figures for the optimum corrective fertilizers for this soil - it has serious deficiencies and correcting these would lead to tremendous gains in productivity.

It is thus possible to expect that within a few years, rational mineral fertilization will greatly increase the revenue per hectare. First estimates predict that it will double, gross revenue going from 17,000 to 50,000 FMG per hectare and net revenue going from 15,000 to 30,000 FMG per hectare.

2.3.2. Complementary research. Nevertheless, all the problems of developing the tanety are not resolved. Among the most serious are:

2.3.2.1. Agronomical problems:

Study of crop rotation. Choice of plants to cultivate. This must above all allow for the quick amortization of corrective fertilizers. If the fertilizer used makes it possible to preserve intact the fertility capital attained (that is not amortized in the real sense of the word), it is nevertheless evident that the financial amortization of the corresponding expense cannot be spread out over too long a period of time.

- Study of fertilizers in relation to needs of plants grown in crop rotation.
- Study of cultivation methods and optimum growing periods for each of these plants.
- Study of the necessary agricultural materials.
- Study of the program of improvement and use of tanety land, as a function of the cost that it implies and the available means. Development of an agronomical model.

2.3.2.2. Socio-Economic Problems:

Credit and debt capacity of the farmers; economic study of the profitability of corrective fertilizers; fertilizer subsidy; study of markets for the various crops possible for planting on the hills; evaluation of the balance sheet for the use of the tanety (hills), and the cost it entails and profit to be derived, within the framework of the national economy.

SOCIOLOGICAL ASPECTS OF DEVELOPING INTENSIVE FARMING SYSTEMS. METHODOLOGY AND FRAMEWORK FOR INDEPTH STUDIES OF CONDITIONS OF RURAL DEVELOPMENT

H. Lefebure, IRAT
R. Rege, SATEC

SUMMARY

It is generally said that the sociological aspects of agricultural development are always paramount and that the limiting factors, the curbs and constraints on this development are man, as though man were the only real obstacle to the techniques and ideas of progress.

The present predicament of research is largely due to the wide gap between what research is trying to propose and what men of the soil can receive or be willing to accept.

The farmers judge all techniques in relation to the advantages or disadvantages. They are never passive, indifferent objects of the fate that is assigned or promised to them.

Also technical solutions developed through research are rarely received in their original form. Sometimes they are refused or rejected at first sight. Often they are contested by the very person who is responsible for their introduction, the extension agent.

It is necessary to ask why this is, and on this theme, three topics for reflection are proposed:

1. The relationship of the agriculturalist to the concrete reality of the farmer's world.

Is the research worker really concerned with the rural world, which may appear completely anachronistic when compared to the spectrum of available technical methods?

It is essential that researchers recognize their permanent and special responsibility where the peasants are concerned.

Agricultural research runs the risk of being sterile if it is not enlightened at the same time through association with the farm environment.

2. Technicians like systems and systematic thinking. It is very tempting to try to rebuild the world into a rational, schematic framework and ask men to fit themselves into it.

There is danger in perfectionism, because rural man instinctively resists external things. The vocation of researchers is certainly to pave the way for the future and to orient and signpost the route. But the wisdom of the researcher also aims at concrete solutions, immediately applicable, designed for men as they are.

A method must be defined for resolving the contradiction between the demands of the present and the systems of the future.

3. The extension agent is a man dealing in realities. His goal is to increase agricultural production in such proportions as to rapidly be economically significant at the level of the country or region under consideration.

Within this perspective, a dialogue between research workers and extension agents is absolutely imperative for developing studies in depth, which take all factors into consideration.

A method must be found by which research becomes more closely involved in the actual development activity than through the usual methods of integrated experimental development zones and pilot schemes.

INTRODUCTION

It has been said and written many times that the sociological aspects are always an essential part of development. This concept is a commonplace among specialists.

Emphasis is placed on limiting factors, impediments and constraints due to man, as if man were in the last analysis the only real obstacle to methods and ideas of progress. The current predicament of research is largely due to the wide gap which exists between the solutions offered and what man can recieve or is willing to accept.

Man judges all methods in relation to their advantage or disadvantage to him. He is never a passive object, indifferent to the fate which is assigned or promised to him. He wants to know if a particular method is his ally or his enemy, in accordance with his own definitions; in the end, man is far more demanding than one might suppose. Technical solutions arrived at through research are rarely received in their original form with all their constitutent elements. Sometimes, they are turned down at first sight. In the first place moreover, they may be contested by the very person responsible for their introduction, the extension agent.

We must ask ourselves why this is so. Why are they turned down, distorted? Why are there such ill-explored conflicts between research workers, extension workers and those concrete men who are the farmers everywhere?

Judging the pros and cons is beyond the scope of this presentation; however, three different topics will be examined around the same theme:

- the extension workers faced with the reality of the farmer's problems;
- the dangers of a systematic approach; and
- the need and the form of the dialogue.

I

Too often, research remains a closed world. In the last analysis, the research worker is alone; working as he does for the long term, he has no doubts either of his mission nor of his permanent place.

The objective is the development of intensive farming systems which are adapted to the local conditions and can be extrapolated.

Research must be truly concerned with man, who is one element among others of what we have agreed to call a "starting situation", which might seem deeply anachronistic when compared with the already available technology.

Research workers must feel a special and permanent responsibility to the communities of a rural world marking time.

In fact, all research, however remote it may appear to be from everyday life, has a temporal and human significance. However, all agricultural research runs the risk of sterility if not enlightened at the same time by an intimate knowledge of the environment.

Established in a particular area, among people belonging to a particular community, a research organization must explore in detail such matters as language, way of life, farming habits, beliefs, motivations.

II

Technological thinking likes a systematic approach. It classifies, arranges in a certain order and invents articulations. For the research worker, this concern for clarity is a necessity.

However, temptation is great to reconstruct a world based on reason-induced schemes and to invite men to subscribe to the promises of intelligence. Danger results from perfectionism, since rural man holds out instinctively against external contributions.

The development and dissemination of more extensive cultivation models require an extremely open approach in which, in necessary association with one another, both the research and the extension worker cannot appear merely as the bearers of a new world. True, they are the agents of progress and, consequently, the ferments of evolution. But their contribution, essentially technical in nature, must be adjustable in relation to non-technical requirements.

If an agent of progress behaves as a mere provider of technological recipes, he would run the risk of failure, because the suggested solutions inevitably imply a change in mental habits which are quite often the reflection of the will, conscious or otherwise, of the community.

For example, a traditional crop is to a large extent part and parcel of the value system of the rural population. This is particularly true of food crops, where in most cases, suggestions of new cropping systems involve, as an essential element, an upheaval of varying magnitude.

Resistance becomes more pronounced when a method is presented as part of a comprehensive coherent system which is to replace another system deemed obsolete by the planners.

Experience shows that an outside initiative, which is not felt as a need, or is not sufficiently understood or brutally threatens community organization is met with distrust and increases reliance on traditional values.

Therefore, development action is not possible if the agents of progress do not display a certain amount of modesty and recognize that:

- successes or failure of a particular method is partly beyond their sphere of action, being dependent as it is on the relationship between the authorities and the population;

- the methods suggested are not the starting point of a revolutionary reorganization of the recipient community. Such method must be redefined in relation to the rural environment in which they are to be used.

We must guard against a messianic approach to development. We always come back to the observation that farmers base their judgments on the results and not on principles or formalized thinking. Research workers have the task of preparing for the future, guiding and opening the way. Yet, in his wisdom, the research worker aims also at finding immediately usable solutions, geared to man as he is now. A methodology must be found to smooth out this discrepancy between the requirements of today and the systems of tomorrow.

III

The extension worker lives in the present. His objective is to increase agricultural production to such an extent that this increase would quickly have an economic significance for the area or the country concerned.

This concern for immediate efficiency can be questioned, as it is, in fact, by those who believe that a more selective, and therefore more educational, approach is necessary.

Yet, for any action to have an economic significance, to bring an economically felt solution to the main current problems in the developing countries, it is necessary to "stir up" millions of people short of the

implementation of a policy of large public works which is, it is known, fraught with difficulties and disadvantages. The problem is posed in terms of mass strategy: how to pass a series of improved agricultural practices on to a rural world organized along the lines of customs, most of them having a limiting character? Is communication possible under such conditions?

In the beginning, the extension worker is not primarily interested in the future of man - what Father Lebret has called the "being more" of man - but in people as production agents. They have to bw won over: the initial concern should therefore be to create a collective reflex of involvement.

In order to achieve a measure of success, it is necessary to find a useful motivation - useful to the extension worker - and to select in the first instance technical themes which can be dealt with as slogans: training before education.

Research must take these facts into account for the orientation of its action and the finding of the solutions which it must devise.

* * *

Confrontation of research and extension workers is therefore an absolute necessity, but this indispensable dialogue cannot take the form of a mere exchange of information. In any event, research needs to supplement the analytical data obtained on small plots or in laboratories either in an experiment station or through a series of experiments conducted at various locations, with full scale tests in the field.

Such tests, which serve as confirmation and, sometimes, as demonstration, include among their purposes:

- an evalutaion of the extent of depreciation resulting from the transposition from experimental conditions under strict control to the physical, economic and human environment of actual application;

- an integrated study of the factors of rural development, in other words an appreciation of the value of the management systems suggested and a realization of the various problems raised by their implementation.

This full scale action seems to offer a meeting ground for research workers and for the authorities responsible for development activities.

Various formulas and various structures may be used for this purpose:

1. An experimental area of integrated development, covering a sufficient number of farms, under strong leadership and under the joint supervision of both research and development agencies. Such a system, which would probably yield quick and interesting results, has the disadvantage of creating in fact very artificial conditions. On the other hand, it requires

large investments.

2. A pilot-farm operated by technicians who influence the farmers, with a considerable loss of initiative for the latter. In a way, the disadvantages are similar to those mentioned under (1) above.

3. A more flexible organization involving the frank inclusion of research among development activities, for example through the establishment of a link between its local branches and the extension agents and through direct contacts with some farmers on previously prepared farms (SOMALAC area in Madagascar, estates in Dahomey, model farms in the peanut basin of Senegal).

The latter formula seems to offer the best possibility of clearly establishing a common responsibility and the requirement of a continuing contact with farmers.

ROLE OF AGRICULTURAL RESEARCH IN DEVELOPING INTENSIVE FARMING SYSTEMS

Proposed Outline for Discussions

IRAT

SUMMARY

This paper defines the purpose of the forthcoming discussions as being the study of "the methods and means producing a synthesis of agricultural, economic and social elements involved in the development of suitable extensible farming systems."

The paper refers basically to peasant family-type agriculture.

First, the basic situation will be analyzed, taking into consideration the limiting factors and constraints on development, to determine the objectives to be attained.

Then, the nature and purpose of the agricultural research involved with the intensification of agricultural systems will be analyzed.

This research will particularly deal with;

- the fertility of the soil
- crops and crop-rotations
- studies of labor input
- the integration of crop and animal production
- the mechanization of agriculture
- rational utilization of water resources
- pest control.

Even though they are not really within the realm of agronomic research, the socio-economic and human problems will have to be analyzed, as their solution, which is linked to the establishment of extension programs and adequate leadership, conditions the effective application of the research and therefore affects its orientation from the outset.

Lastly, in the final phase, a synthesis will be made of the preceding facts in order to develop a methodology for in-depth studies, making controlled observation of the results obtained possible by integrating the various basic factors of rural development.

1. Definition and Framework of the Subject Matter

The importance of a discussion on the development of farming systems lies in the possibility which this offers for examining one of the

critical areas of agricultural research where underdeveloped countries are concerned and would be a step towards solving these countries' agricultural problems.

The following discussion does not pretend to solve all the various problems posed, especially since these vary with each country. Moreover, some of these problems will be examined in a different light when other agenda items are being considered.

We are dealing here with methods and means for producing a synthesis of agricultural, economic and social factors involved in the development of appropriate farming systems.

* * *

A farming system is here defined as the combination of crops and animals, factors and means of production (land, labor, capital, equipment, etc.) in the hands of a farmer of particular defined ability and behavior.

We will refer particularly to peasant, family-type agriculture rather than industrial agriculture, and more particularly, to the development, with the help of agricultural research, of "appropriate models" which can be adapted, with certain modifications if necessary, and multiplied under certain specified conditions.

In the majority of cases, the object of agricultural development is to provide the rural populations with more intensive methods of production, and here we are trying to show the important part that research should play in this process of changing over to more intensive farming systems.

We will relate these considerations either to research topics conceived in terms of a future integration of the farming structure, or to the study of the various formulas for the integration of the different aspects of production.

The nature of these concerns places them at the crossroads of pure and applied research. Thus in this context, socio-economic considerations and knowledge of human behavior assume extreme importance.

2. Analysis of the Basic Situation: Limiting Factors and Constraints on Development, Determining Objectives

The first step towards developing conditions for farmers to engage in more intensive systems of production, is to define precisely the existing situation.

One must:

- detect and measure, by an agro-economic study of the environment, the limiting factors: certain systems of crop production, methods and practices must be eliminated as slowing down development; other

non-modifiable drawbacks must also be defined, such as climate, nature of the soil, lack of capital, etc.;

- study the possibilities for removing or attentuating factors restricting development (introducing draft animals to increase productivity, irrigation to reduce moisture deficiency);

- define certain factors that must be taken into consideration when designing methods (food production by the farmer, conservation, full employment of available manpower, etc.).

Agricultural research can and should be involved at this stage as well as the previous one. Undoubtedly some of the elements mentioned above do not respond to research, but must nevertheless be taken into consideration in defining research priorities (economic and social environment).

* * *

Shifting cultivation, which is a widespread phenomenon in Africa to this day because of the sparse population and the absence of private property, is the corollary of very extensive farming systems of low efficiency. Intensification of this kind of farming will require its stabilization which then permits cultivation of crops in rational rotation systems.

Within the framework of sedentary agriculture, one can set objectives at various levels of intensification corresponding to more or less complex combinations of the factors and production techniques. Numerous, mainly economic factors, can enter into the process of determining the correct formulas:

- equipment possibilities linked to the credit and debt capacities of the farmer;
- relative price of fertilizers and crops;
- cost of manpower, etc.

* * *

Experience has shown that the limiting factors and constraints on development which it is possible to alter are:

- the fertility of the soil;
- the limited work capacity of the farmers;
- limited water supply;
- loss of crop production through pests;
- the problem of inadequate professional infrastructure;
- human problems: receptivity of the farmers, transfer of technical knowledge, economic organization.

To these different factors will be added the complex process of

developing, on the basis of agronomic techniques, appropriate combinations of crops corresponding to the geographic, economic and social conditions of the area it is proposed to develop.

It should be noted that the priorities among these different factors are defined in terms of the precise study of the existing conditions and the stages envisaged in the development of more intensive systems. However, these factors are linked interdependently and through very specific interactions.

3. Agricultural Research Linked to Intensification of Farming Systems

Research into the development of intensive farming systems has the objective of comparing with the necessary experimental rigor the various possible techniques and combinations of techniques.

A. Fertility

Developing new diversified crops and varieties with a high level of productivity necessitates improving the fertility level of the soil. Basic and deficiency-correcting fertilizers must be developed and the organic matter of the soil improved. Through rotation and so on, an improved soil profile should be progressively obtained with better economy of water and which will help the root development of the crops chosen for cultivation.

Fertilization within the framework of crop rotation is a rather controversial aspect that has not been carefully studied as yet where the use of fertilizers is concerned:

- the residual effects of fertilizers should be measured and determination made of the modifications required to bring optimal fertilization to a crop in light of these residual effects;

- the problem of the cumulative effects of fertilizer on a continuous crop (irrigated rice, for example) should be investigated;

- distribution of fertilizer in crop rotation should be studied in relation to the needs of the different crops;

- minerals removed by the crops should be measured in relation to fertilizer use;

- the problem of maintaining the natural or acquired fertility of soils is linked both to studies of soil erosion and to those of fertilization and crop rotation.

B. Crops and Rotation

- identification of crops adapted to natural conditions, as a means of eventually raising the level of fertility;

- search for crops that, within the framework of a barter economy, maintain an appropriate equilibrium between food crops and cash crops (either food or industrial) and also, as much as possible, assure employment during the dry season;

- eventually, it is to be hoped that within the farming system there could be rotation of annual crops with perennial crops.

- Research into Optimum Crops Successions

There is no point in perfecting experimentally over-rigid crop rotations. The worth of such complex experimentation is debatable: the crops must be adapted to economic evolution (food and monetary needs of the farmer, markets, options taken by national planning etc.).

- Crop Rotation, on the other hand, must follow certain agronomic criteria: influence of different plants, fallow periods, fields allowed to go to pasture or not, on the production of the next crops; length of vegetative cycles and production as a function of the date of seeding.

- Research must be undertaken to reduce to a minimum the length of unproductive fallow, and to ascertain whether continuous cultivation is foreseeable.

Development of crop timetables in terms of vegetative cycles and labor input.

C. Studies of Labor Input

If the choice of crops depends on the cropping timetable, the demands of the crops can be inversely determined by a critical study of bottlenecks in labor input which must be clarified

- to insure the necessary cultivations are carried out at the right time, and

- if necessary, modify these operations to a certain extent.

At any rate human productivity must be increased to a maximum, either through better tools and equipment, or by substituting for the human element other sources of energy, such as animals or machines.

D. Integration of Crop and Animal Production

In order to develop complete and coherent cultivation systems, the period of time that a field is allowed to lie fallow must be reduced without lowering soil fertility. This entails the practice of improved fallow and the profitability of pasture - in which case it an be incorporated into the rotation - and in any event the integration of animal and crop production.

The development of animal traction is a first step in this integration. The use of draft animals can be achieved without causing more complex problems to the farmer than the provision of forage.

The development of draft animals does cause some general problems which should be carefully studied and made more systematic.

These problems are:

The Animal: Its utilization: work capacity of the beast in terms of the nature of the soil, the type of work and the type of equipment to be used; study of labor input; production of manure; feeds and housing; training and feeding the animal.

Fodder: By-products of harvest; quantitative and qualitative value; optimal utilization by the animal; fallow periods and their improvement; forage crops; planting and cultivation techniques within framework of different agricultural systems.

Agricultural production: Resources; livestock necessary in terms of the agricultural resources, the local conditions and the production systems.

Transition to Economic Livestock Production: At present as a result of the traditional extensive methods of animal husbandry in Africa, development of intensive animal production poses particularly economic problems. The first steps indicated would appear to be small-scale livestock production, with production and fattening of range-bred calves.

E. Agricultural Mechanization

The problem is not one of a systematic study and critique of new materials that might be used in African farming, but of the mode of intervention of the machine and the characteristics of the materials and machines capable of carrying out the main planting and post-planting operations envisaged by the agronomist.

These studies should be undertaken in terms of the two basic options of mechanization:

- animal traction is more attainable and at present should be the most carefully looked into;

- motorization is a possibility which, although even better known because it is technically easier, is less feasible for the moment - this is due to financial factors, to the inadequacy of the technical infrastructure and to the lack of technical training of the farmers. It should, nevertheless, not be overlooked by agricultural research workers.

For each of these two aspects, beyond a study of the relation between

machine and the agricultural environment, the definition and adaptation of equipment to the different systems and situations, studies should also be made relating to:

- the socio-economic involvement of mechanization in the proposed environment;

- the place of the machine in production: nature and type of equipment according to the different systems and agricultural structures.

- the qualitative and quantitative needs of production.

F. Rational Utilization of Water Resources

As the availability of water is often limited and badly distributed in time and space, water is in many situations an obstacle to the development of rural areas.

The studies envisaged in this chapter are the necessary complement of an inventory of water resources and studies relating to putting these resources to proper use, either by broad, overall projects or by small more individual projects.

The rational utilization of water must be developed both from an economic and from an agronomic point of view.

Moisture Requirements of Crops

- consumption through evapotranspiration;

- effect of deficits on yield;

- economic study of the increase in gross production and net revenue resulting from irrigation.

Diversification of Crops - Varietal Adaptations

- determination of species capable of giving the best returns;

- study of cultivation techniques adapted to climate and soil conditions and availability of water.

Irrigation Methods and their Parameters

- comparative studies of methods of irrigation best adapted to the soil, climate, proposed crops and the technical skill of the farmers;

- identification of factors governing water-use at the plot level (ration utilization and uniform distribution of water.

G. Pest Control

Parasites and diseases are factors limiting productivity that are not always studied in this light.

One can foresee that they will become more important as yield increases, as agriculture develops; new varieties of crops (from diversification) may be found to have less resistance to ecological conditions than the traditional crops; improved varieties are often more sensitive; parasites (particularly nematodes) may be a problem in crop rotation.

4. Socio-economic and Human Problems - Organizational Framework and Extension Economic Factors

In order to compare correctly the diverse production systems that are possible it is necessary to make the following analyses on each:

- the costs of production; research must try to reduce them;

- unit yield;

- value of products obtained (improvement of quality: possibility for processing at the farm level; study of markets for orienting choice of crops).

Although they are not, strictly speaking, objects of development activity, the socio-economic and human aspects are nevertheless essential. The knowledge about these aspects and development of solutions appropriate to them is a prerequisite of effectively applying established methods in addition to economic and technical viability. These problems are not directly the province of agricultural research.

Socio-economic Problems

- organization of means of supplying the farmers;
- organization of marketing the harvests;
- pricing problems;
- elementary processing of the crops.

Human Problems

- traditional structures;
- land tenure and ownership;
- orientation of motivations and training.

5. Methodology Study Structure - Integration of Factors of Rural Development

The elementary results obtained by research in each specific area must be tested in depth and in combination under the ecological, economic and social conditions that will ultimately prevail.

From these studies information will be gained on:

- possible increases in yield in relation to consumption;

- adaptation of preconceived techniques to the limitations of that environment;

- possible reorientation of research;

- possibility of integrating various levels of technical solutions to a greater or lesser extent at the farm level.

Such in depth studies, which must be carried out under farm conditions, can be organized more or less along the following lines:

- various types of farming representatives of a homogenous zone, taken as a whole and supervised jointly by research and development organizations;

- setting up of a "test-farm" where the farmer would be closely or broadly supervised by research and development technicians, thereby losing a great part of his initiative;

- direct integration of research in the development activity, through, for example, liaison by extension agents regarding its applications in the different areas, and through direct contact with some farmers.

FARMING SYSTEMS IN AFRICA
MANAGEMENT OF CROPS, SOILS AND WATER: MECHANIZATION

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SUMMARY

Africa's greatest asset for agricultural production is a tropical climate with a twelve-month growing season. Much of her present agriculture is characterized by islands of cash crops, grown largely for export, surrounded by larger areas used for food production, largely by primitive shifting cultivation.

To ensure a more dependable supply of better quality tropical crops for their home market, the former colonial powers established several research stations, usually devoted to a single crop, to provide the scientific and technical information needed. As a result, this sector of African agriculture was soon raised to a higher level.

Most of these stations devoted but little attention to the improvement of native food crops; and as a result, this sector remains more primitive. It is important that this be changed. But it is not yet clear what form the new system should take. There is some sentiment and experimentation favoring small mixed farming units, on which the production of annual food crops and perennial tree crops for export are integrated. There are sound arguments for such an integration. High priority should be given to research on this problem.

There are large areas of land in the river valleys and deltas which are not yet very productive. These areas usually have the most fertile soils and the most dependable water supplies, and have great agricultural potential. If provided with adequate water control-irrigation during the dry periods and drainage of harmful surpluses during the wet periods - these areas seem to be well suited for the production of wet land rice.

Yields of rough rice, comparable to those obtained in Taiwan - 3000 to 10,000 kg/ha - have been obtained in hundreds of experiments in 15 different African countries by teams of rice production specialists from Taiwan. These yields were obtained by the laborious paddy culture of Asia. More modern, less laborious, mechanized methods should be developed for Africa.

In addition to one or two high yielding crops of rice, many Taiwan farmers are growing one or two other crops on the same land each year. As in our experiments in the Philippines on multiple

cropping with rice, efforts should be made in Africa to develop similar systems of multiple cropping which can be mechanized. There seems to be no reason why research by a team of agronomists and agricultural engineers could not pave the way for such a development in a few years at a modest cost.

These proposals as a whole should ensure Africans of an abundant food supply for a long time.

INTRODUCTION

To one accustomed to the agriculture of up-state New York, with a latitude about 20° north of the Tropic of Cancer, the tropics seem to have many advantages. Winter never comes in the tropics. Instead of growing hedged in between the last killing frost in May and the first killing frost in late September, the growing season is 12 months long. Even this fact does not reflect these advantages fully. In New York, temperatures after the last killing frost in the spring and long before the first killing frost in the fall are suboptimum for many crops which require a fairly definite number of "degree days" to mature. For example, Golden Cross Bantam sweet corn requires about 80-85 days to reach the "eating stage" in New York. In the Philippines, it is ready to harvest in 60-65 days, a saving of 20 days, time enough to grow a third of a second crop.

Even this does not reflect the full advantage of a tropical climate in food production. The period of availability for consumption for many fresh vegetables is 12 months. In up-state New York, it is seldom more than 2 months. Since we like to eat vegetables throughout the year, we are obliged to:

1. Preserve the summer grown crop for winter consumption by canning, freezing or drying.

2. Ship in supplies from distant places like Florida, California or Mexico in refrigerated cars.

3. Create a tropical environment by enclosing a small area with glass or clear plastic and heating it artificially.

Each technique is more expensive than the preceding one and the last is prohibitive in cost except for a few luxury crops.

Yet, paradoxical as it may seem, the countries of Northern Europe and of North America are among those with plenty of food for their own people and often a sizable amount of surplus for export; while most of the tropical countries, with their year long season, have a much higher proportion of undernourished or malnourished people, and are commonly referred to these days as underdeveloped.

Why these wide differences? The year-long growing season appears to be a major advantage. The total rainfall pattern of Africa, south of the Sahara, while far from ideal, in many places is reasonably good. The distribution

through the year is frequently uneven with one, and in places two, rainy seasons separated by one or two dry seasons. Many perennial plants, especially trees, are able to survive and even grow during the dry season, but the more shallow rooted annual crops require supplemental water supplies to do their best. But the rainy seasons supply large surpluses which find their way into huge rivers which often pass through land scorched with drought on their way to the sea. The mighty Congo has a rather even flow throughout the year because one part of her drainage basin has a rainy season while another part has a dry season. The waters of the Congo as it falls down on the sea is one of the most majestic sights I have ever seen and the electric power potential is probably the largest on any river in the world. It is capable of supplying the water and the power to move water on a large scale.

In my country, states like California and Florida, although only subtropical, are playing a steadily increasing role in our agriculture in recent years. It was not always so. What would the agriculture of these two states be today were it not for a very large investment in technology? What could Florida produce on her poor sandy soil without the liberal use of commercial fertilizer and what could California produce if she did not exploit her deeply buried water resources or import water from other sources, often hundreds of miles away. The water resources of most of Africa south of the Sahara are much more abundant than in some of the most productive valleys of California and the soil resources of most African countries have more natural fertility than the sandy soils of much of Florida. I realize that there are other differences of significance. But are these deficiencies so great that they cannot be economically corrected by modern scientific research and technology? Many of the problems are large and complex. They cannot all be tackled at once. With limited resources of scientific manpower and of capital for development the question for most African countries is where to start and how. As I understand it these are the questions we are assembled to discuss.

Each country must start with what she has and gradually shape it into what its people want. The simplest and easiest problem should, in general be tackled first. As these are solved, the more difficult should be dealt with in the order of their complexity and of their importance to the country.

Two widely different types of farming occur in much of Africa: (1) shifting cultivation, which provides little more than subsistence for those practicing it and (2) cash crop production largely for the export market. In many countries there is dissatisfaction with both of these as they have existed in the past. There are, however, differences of opinion about the changes needed.

Shifting Cultivation

It is widely agreed that the age-old system of shifting cultivation, practiced to some extent in most tropical countries, must eventually go. It is estimated that 30% of the world's exploitable soils are now under shifting

cultivation, but it supports less than 10% of its people. Africa is said to have the largest area under shifting cultivation of any of the continents. It is also the area which has been studied most. Unfortunately, these studies have not yet revealed a promising substitute for this "slash and burn" technique. Its importance to our subject justifies further attention.

Shifting cultivation is usually practiced on upland, forested areas on soils with rather low to moderate reserves of fertility. The first step is to select a suitable area in the forest, often an acre or less. The trees and bushes are slashed down with a bolo or axe and allowed to dry out during the dry season. Toward the end of the dry season the slashed material is ignited; the leaves, smaller branches and some of the undecomposed leaf litter is burned. The humidified layer on the surface is not burned except locally, where the fire is more intense and for a longer period. The larger logs and stumps are charred but not burned. Of course most of the nitrogen in the burned material is volatilized and only the ash remains. It is this ash, collected by roots going deep into the subsoil, which partially restores the fertility of the soil. At the beginning of the rainy season, seeds of the various crops are planted in holes made in the loose soil with a pointed stick. Weeds are not a serious problem the first year and ordinarily a fair crop is produced. Each successive year the yields decline a little, weeds become thicker and after a period of cultivation from 2-5 years, the area is abandoned, reseeded naturally from the surrounding forest and gradually a new bush is established. This is allowed to grow for 6-20 years depending on the soil and the density of the population. The cycle is then repeated. The practice is surprisingly similar in the different continental areas in spite of the probable independent origins.

The maximum population which the system can support for a long period is about 20 per square mile. If the population rises much above this level either the people must migrate or the fallow period must be shortened. If it is shortened very much it loses its effectiveness and the people are soon short of food.

The labor costs seem very heavy by western standards. Nye (1) cites studies by Conklin indicating that, in the Philippines, clearing and burning of virgin forests requires about 600 man hours per hectare. Guarding activities, protecting from rodents, monkeys and other animal pests, requires an additional 550 hours per hectare per year, a total of 1100 hours per hectare per year. These items are in addition to the normal cultural practices, seeding, weeding and harvesting by crude hand tools. We need to keep in mind, too, that even at these labor costs the job of clearing is only partial. The tree stumps and larger logs remain on the land. Mechanical cultivation would be impossible until these too are removed. In these days when wood is in such great industrial demand, for so many purposes, it seems a little extravagant to burn the forest cover for its ash. Cannot modern science and industry find a far cheaper way to supply the 500-1000 pounds of ash per acre (largely calcium, magnesium, and potassium oxides) which is made available each cycle? If planted to the proper species of trees, would not the wood produced in

20 years of tropical growth be worth more than its ashes? Besides the leaves and twigs would be left on the soil in a lumbering operation. If these were mechanically macerated, a mulch containing the nitrogen now lost in the burning process and a high proportion of the ash produced in the burning process would be left on the soil as a protective cover through which plantings could be made.

Belgian scientists at their wonderful research station at Yangambi, in the Congo, developed the ingenious coridor system which is a sophisticated modification of the "bush fallow" system. While it has many advantages I doubt if it is yet the complete answer needed to solve this world wide problem.

Shifting agriculture, at best, is a primitive form of subsistence farming. It yields its practitioners nothing more than a bare subsistence. They live outside the rest of the national economy, occupy much of the country's land and squander much of its forest resources. Science must find a way to bring these farmers into the modern world, and the land they are farming into a more efficient, permanent agriculture or into better forests or other needed tree crops.

Export Crops

The European colonial powers in Africa were interested in more dependable sources of many tropical crops needed to supply the increasing demands of their home markets. The existing native agriculture could not supply these needs. Research stations, usually working on a single crop, were set up to find ways of improving the quality and economy of production of these various crops: oil palm, cocoa, coffee, tea, rubber, etc. These stations were, as a whole, remarkably successful. Islands of the various plantation crops developed on the better soils surrounding the different stations. Much excellent research was done. As a result we know much more about the production of cash crops for the export than about the production of basic food crops of the native population. Both types of agricultural production-food crops and export crops-will be needed in increasing quantities in the future. Since independence, there have been many changes in the management and research on most plantations. But the need for continuing improvement remains.

It seems probable that the scope of activities of many of the special export crop research stations will be broadened to include more work on the more important local food crops. There may be some changes in the structure of the farms with more diversification and the production of food crops on the same farms that produce crops for export.

Rice

In addition to these changes in the older traditional forms of farming there is interest in exploring the possibility of introducing new crops. While rice has been grown on a small scale for a long time in Africa, there is considerable interest in expanding its production. In the past, yields have been low and quality poor. Results obtained in the last few years on demonstration farms, established by Chinese Rice Production teams, sent out by the government of Taiwan as a part of their foreign aid programs, show, rather conclusively, that yields of rice comparable with those obtained in Taiwan can be obtained in many African countries by using the same varieties of rice and the same cultural practices. In countries where native farmers are getting average yields from 500 to 2000 kg/ha., these teams have been getting from 4000 to 9000 kg/ha. The teams have worked in Cameroon, Gabon, Zambia, Ivory Coast, Liberia, Libya, Malawi, Niger, Ruanda, Senegal, Sierra Leone, Chad, Togo, Upper Volta, and Saudi Arabia. These results were obtained with several of the excellent standard varieties grown in Taiwan. A few new varieties of rice developed in the last two years at the International Rice Research Institute, in the Philippines, have been tried extensively throughout the tropical rice belt of Asia. One of these, known officially as IR-8, and dubbed unofficially as the "miracle rice," has, in many places, out-yielded all older varieties by 1000 to 2000 kg/ha. There is good reason for thinking it will do equally well in many places in Africa with the same management. (See Figure 1)

Most of the rice in monsoon Asia is grown by the transplanting-paddy system. It evolved through the centuries as an adjustment made by farmers to the peculiarities of the rainfall distribution. But few crops could be grown on the more fertile river flood plain and delta soils during the rainy season. During this season the rainfall is often 10 to 20 inches per month. Some rain falls nearly every day for weeks. Under these circumstances the soil seldom gets dry enough to cultivate in the conventional way. Many grassy weeds thrive under these conditions. Farmers learned that they could plow these heavy soils more easily when they were saturated with water and that soils saturated with water never get too wet to cultivate.

By developing a system based on the use of puddled soils, rains seldom interfered with farm operations. The farmer could plow, harrow, transplant, cultivate and weed his crop immediately after or even during torrential downpours of rain. This system of rice farming supports some of the densest populations on earth. For tropical Asia, this average is over 180 people per square mile. The more intensive areas, the Tonkin Delta of Indo-China, for example, supports a population of 1400 per square mile, which is almost 80 times the average for the shifting cultivation areas of Africa.

There are large areas of alluvial soils in the river valleys and deltas of Africa. These are level and better supplied with both fertility and water than the upland soils. A high proportion of the soils are probably suited to rice culture. But what form should this rice culture take? Should

it be patterned after the labor intensive paddy system of Asia described above, or, after the highly mechanized systems used in the United States and Australia, or should some compromise between these two extremes be evolved?

The farmer practising shifting agriculture in Africa and the paddy rice farmer in Asia are very far apart in the amount of food they produce per acre of land used in their respective systems. But both systems have very high labor requirements and both harvest very small areas each year, usually 1 to 3 acres. As a result the total production per man is very low in both areas and of course incomes are correspondingly low, too low, in fact, to support a satisfactory standard of living. Both are regarded as peasant types of agriculture, a form which all countries should strive to replace with something better.

The mechanized rice farmers in the United States and Australia on the other hand, farm hundreds, even up to thousands of acres of rice, seed with airplanes and harvest with huge combines. Such farmers make very large investments in equipment in order to save high cost labor. Studies in Japan indicate that it takes 40 times as much labor to produce 100 kg. of rice in Japan as in the United States. Africa needs to develop some compromise between these two extremes.

Multiple Cropping with Rice

Taiwan has made more progress in improving her agriculture than most countries in southeast Asia. She has made great progress in developing her water resources and as a result has been able to use much of her agricultural land throughout the year. Her farmers commonly grow two crops of rice and two other crops on the same land each year. Each crop is heavily fertilized, carefully protected from pests and well watered. Improved high-yielding varieties of all crops are used. As a result, yields are high and the total annual production per farmer is high for such small farms which average only one hectare in six.

For the last three years we have been experimenting with multiple cropping systems involving rice at the International Rice Research Institute. Our goal is to keep the soil producing crops as many days in the year as possible and by techniques which will permit the mechanization of as many farm operations as possible. Most underdeveloped countries have 70-80 percent of their population on farms. This proportion is too high. In the United States 7% of our population on farms produces all the foods we need at home and large surpluses for export. As other countries industrialize and develop their public services, more people will be needed in the cities and farms will have to increase in size. Mechanization is the obvious answer. But the mechanization of many operations is difficult if they have to be performed in the mud of puddled soils. This has led us to question the necessity, even the advantages, of transplanting rice in puddled soils. The highly successful rice growing industries of the United States and Australia show that it is not necessary in order to get high yields. If soils are not puddled they can be drained more quickly and planted to other crops sooner after the crop is harvested.

Sorghum

We have been thrilled with the production we have been able to obtain from each hectare when we take maximum advantage of the twelve months growing season of the tropics. Yields of over 20 tons of cereal grain per hectare have been obtained in 12 months in one rotation which includes one crop of rice (5.0 tons) and 3 harvests of grain sorghum (16.5 tons, one from seed, the next two from ratoons). Total yield of grain per hectare - 20.5 tons per year.

Soybeans

The diets of many of the poorer people in underdeveloped countries are often very low in proteins. This is very serious in children and can injure their health and impair their mental development permanently. Most of these people cannot afford to buy much milk, meat, fish or other high quality animal products. Proteins of vegetable origin are usually much cheaper, but are often of much lower quality. Soybeans not only contain 35-40% protein, almost twice as much as other pulses, but the protein is of very high quality as well. It has been widely used by the Chinese, Japanese and Indonesian peoples for centuries. Many varieties grow well in the tropics. Yields equal to those in the Corn Belt of the United States have been consistently obtained in the Philippines. A few varieties, which are not strongly photoperiodic, can be grown satisfactorily throughout the year. The varieties we are using mature in 75-90 days in the tropics and can be used as either green or dry beans. Many people prefer to pick a part of their soybean crops while the beans are still green and eat them as a vegetable. It is easy for a farmer to grow enough soybeans, in this way, to meet the protein requirements of his family. Any surplus finds a ready market as dry beans.

Sweet Potato

The sweet potato is a very valuable crop for the humid tropics. It will produce about as many calories as any other crop. It can be grown at any time of the year. Some of the newer varieties, like the Julian developed at the Louisiana Agricultural Experiment Station, are an attractive reddish-orange color and contain 18 mg. of beta-carotene per 100 gms. They are superior to the ordinary potato nutritionally and practially free from fiber, have a good flavor and mature in about 90 days. They can be used in a number of ways. The tender tips of the vines can be cut off while the crop is immature and used like spinach. When harvested, the tops, which have a feeding value comparable with alfalfa, can be fed to livestock. The small and misshaped roots can also be used as feed for livestock. Much of the pork in Taiwan is produced largely with sweet potatoes. The roots are used as human food. A good crop will yield from 20-30 tons per hectare of roots and about an equal weight of tops, all in about 90 days. The roots can be stored for 1-2 months at ordinary tropical temperatures. It is easily propagated

from vine cuttings. Few crops can surpass it as a source of calories for the small farmer with a family of growing children. If grown on ridges it can tolerate wet soil conditions. By making a regular succession of plantings it can be made available throughout the year.

Sweet Corn and Corn

In many countries, golden ears of sweet corn of new improved varieties, are regarded among the most tasty products of field or home garden. It is easy to raise and reaches the "roasting ear" stage in the tropics in 50-70 days depending on the variety. It too, can be grown at any time of the year in the tropics. We ordinarily harvest from 40,000 to 45,000 ears per hectare. These sell for 2 or 3 cents (U.S.) each in the Philippines and bring in a gross income of about $1,000.00 per hectare in 60-70 days from planting. In addition, the green stalks are excellent feed for the livestock. Ordinary field corn should be substituted if the crop is to be used as dry grain.

Rotations

The crops described above are all being grown in rotation with wet land rice. The rice is grown by direct seeding like wheat, on beds of unpuddled soils, 1 meter wide, early in the rainy season. It is cultivated mechanically with some hand weeding. When about 30 days old the field is flooded and kept flooded until about two weeks before the rice is ready for harvest. As soon as the soil is dry enough after the rice is harvested, the land is prepared for planting to the next crops. The crops sequences for our two examples are:

(1)	Rice	→	Sorghum	→	Sorghum ratoon 1	→	Sorghum ratoon 2	→	Total Days
Days to harvest	110	+	85	+	80	+	80	=	355
(2)	Rice	→	Sw.Potatoes	→	Sw.corn	→	Soybeans		
Days to harvest	110	+	90	+	60-70	+	60-80	=	350

Rotation 1 should not be grown continuously on the same land but rotated with rotation 2 or one similar. The above schedule is a little tight. We need a high yielding 100-day variety of rice. If bad weather prevents immediate replanting it is sometimes necessary to omit one crop from one of the rotations. When this is necessary, we harvest only 7 crops in two years instead of 8.

These rotations are only two from the many which can be devised depending on location, market demand, etc.

Agronomists in the "one crop per year" belt of the temperate zone are accustomed to rate crops on their production per crop. In multiple cropping systems, in the tropics, we must learn to think in terms of production per day and then keep the land in production for as many days of the year as possible. We plan to make more detailed economic studies next year.

These studies were made with the food needs of the densely populated areas of southeast Asia in mind. Our objectives were to produce as much food and feed per hectare as is economically feasible and to give the small farmers, with only 2-10 hectares of land, a better income, and a better standard of living. Time and place will not permit a discussion of the contribution which livestock can and should make to this system.

Another objective was to find out how to minimize and mechanize as many of the operations involved in the production of these crops as possible. Human muscle, even at low wages is an expensive source of power. A cheaper source should be used whenever possible. We are finding it difficult to find on the market the exact types of equipment needed in our operations. But our experience to date indicates that much of the hand labor in use on small farms can be replaced by suitable designed machines. The labor thus freed can easily be absorbed at more productive jobs.

I can see no reason why the methods used and the results obtained in the Philippines should not be applicable to large areas in the tropics of Africa and South America as well as Asia. The main difference is that the population pressure is greater in Asia. The in-puts for such systems are; high grade varieties of all crops, water control at all times, with plenty for irrigation during the dry season and ample provision for drainage during the wet season. Fertilizers under these conditions can and must be used liberally. Insect pests, crop diseases and weeds must be controlled at all times. But the returns promise to be great enough to justify all the costs involved (Figure 1) Unit costs of production can be lowered because of the higher yields and the more efficient use of land, labor and equipment. The productivity of the land will be increased. Most important of all, the farmer will become more of a "master of his fate" instead of a helpless victim of circumstances beyond his control.

(1) Nye, P.H. and Greenwood., The Soil Under Shifting Agriculture. Tech. Comm. #51, 1960. Commonwealth Bureau of Soils, Harpenden, England.

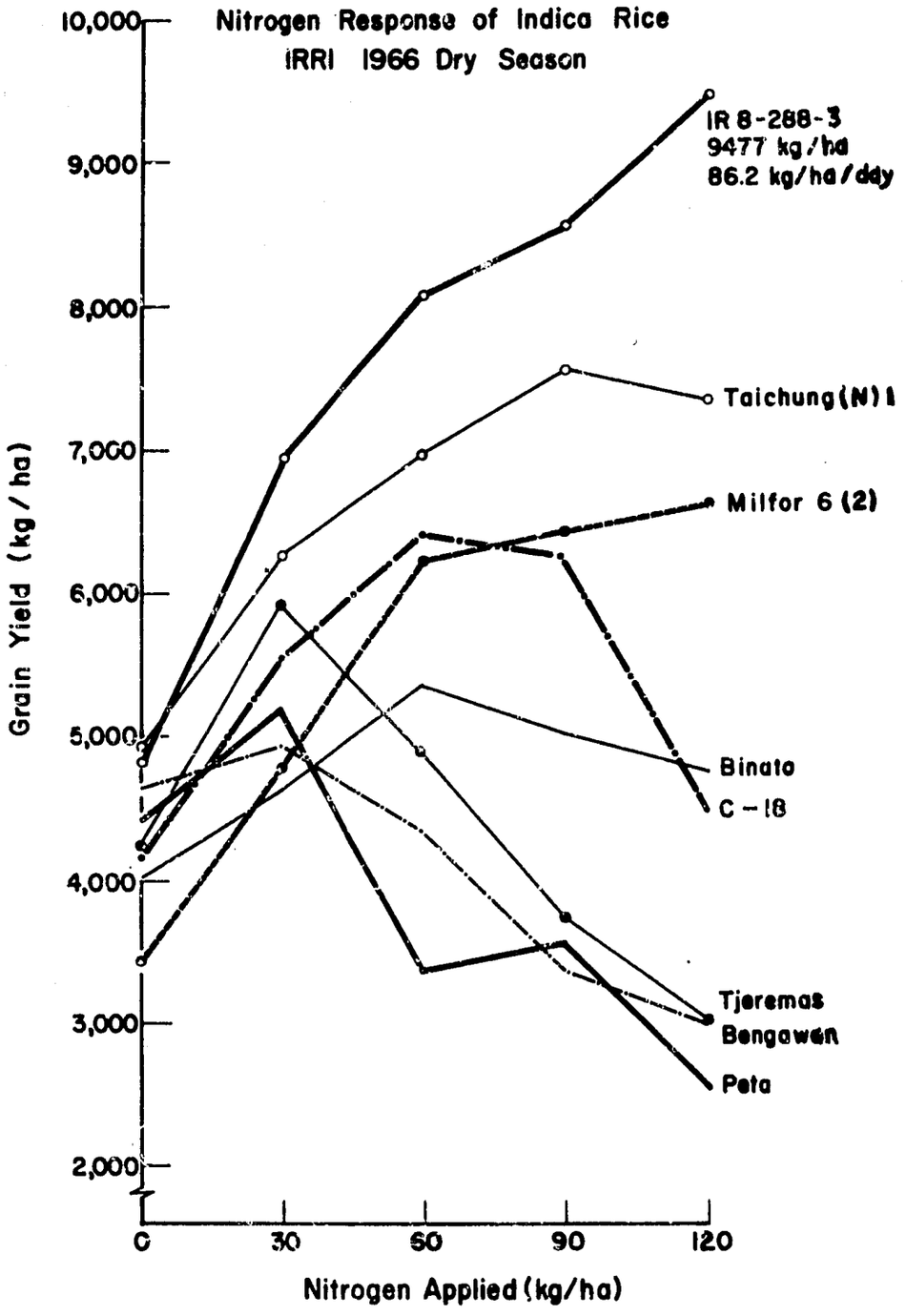

FIGURE 1. Responses of Different Varieties of Rice to Nitrogen Fertilization

STUDY OF LABOR INPUT IN TROPICAL AGRICULTURE

R. Chabrolin, IRAT

SUMMARY

In tropical countries, agricultural work is still done mostly by hand. The low productivity of manual labor as against mechanized labor restricts the amount of land which can be cultivated and sometimes prevents the introduction of profitable technical innovations. It is therefore important for tropical agronomists to know the work time or labor input corresponding to each operation and each crop in order to:

- evaluate the possibility of new operations;
- determine the cost of each operation in order to establish a valid comparison among the different possible agricultural systems;
- discover the bottlenecks existing in agricultural work and thus determine the priorities to be adopted for the introduction of agricultural machinery.

However, it is difficult to measure labor input correctly. The information obtainable from existing literature on the subject is not satisfactory. This is due to the fact that agricultural work is not homogenous and the different jobs are not well defined. The farm workers themselves are not homogenous. The units used are not satisfactory. Further, there are certain variables which must also be taken into consideration, such as travel time and rest time.

There is a great lack of precision in this field at the present time and our knowledge in this area, which is so essential for agricultural development, must be increased. The French Secretariat of State for Cooperation was aware of this need and asked the Bureau of Agricultural Production Development (BDPA) to prepare a study called: Rural Techniques in Africa: Labor Input, which draws on existing material (it has a bibliography of 484 books and articles) and suggests methodology for undertaking such studies on a rigorous quantitative basis.

* * * * *

Agriculture is now, and will undoubtedly be for a long time, the main productive activity in the developing tropical countries. Manual labor is still the main motive power for this activity and imposes upon it rather narrow limitations.

Several reasons, none of which is conclusive, explain this situation:

The cleavage between farmers and cattlemen, which is traditional in Africa and often of an ethnic origin, makes it difficult even now to find a real association between crop and animal production.

The harshness of the climate (arid during the long dry seasons) often forces the cattlemen to migrate over a relatively extensive area; this is different from the farmer, who is sedentary by nature, even if he practices so-called itinerant agriculture.

The presence of endemic cattle diseases, which have not as yet been brought under control (trypanosomiasis), makes it impossible for cattle breeding to exist in large areas of Guinean Africa, and makes it impossible to have animal-drawn plowing.

The low level of technological knowledge and skill of the people of these regions accounts for the scarcity and rudimentary nature of the traditional agricultural implements. The use of imported agricultural material is handicapped by a number of social, psychological, commercial and financial factors.

The frequently autarchic nature of production means that the farmers are usually lacking the financial means to secure the necessary equipment. Agricultural credit, which could help in solving this problem has only recently been introduced. Its effects, however, have been considerable and are bound to be even greater in future.

Finally, and it is important not to ignore this, the general discredit in which agriculture is held in Africa, has meant that the elite have diverted their imaginations and ingenuity away from agricultural problems in order to occupy themselves with more "noble" activities. There has been a relative stagnation of traditional agriculture.

As human motive power is weak and particularly poor in power yield, it is not surprising that one of the main bottlenecks of productivity in tropical agriculture is to be found in the amount and kind of power available for the execution of farming processes. This means that the amount of land farmed is limited in Africa, where there is an excess of land, one is surprised by the size of individual holdings, and the rudimentary nature of farming methods.

On the other hand, and this may seem paradoxical, under-employment, especially in agriculture, is mentioned as one of the consistent features of under-development.

The contradiction is only apparent and due to the fact that certain tasks, more demanding in labor, represent primary bottlenecks that limit in an absolute way the area worked by an individual or a family. There is, thus, clearly under-employment during the execution of the other work requiring less labor, and during the slack period imposed by the climate.

The above-mentioned considerations show how important it is, in order to make a valid assessment of the agricultural systems of these regions, to have as precise a knowledge as possible of the amount of work required by each crop, and even by each farming operation.

The notion of work time or labor input, however, is still too loose

to merit a definition: from a theoretical viewpoint one could say that labor input, for any given operation, is the actual time used by an average worker to perform that operation on the area unit. Thus the total labor input of a crop would be the sum of the labor input of the different operations required by that crop. We shall see, however, how illusory this is in reality.

In what way is the knowledge of labor input useful?

1. The foreign agronomist called upon to study the farming systems of African farmers, most of the time gets a very vivid but false first impression, namely, that these systems are so primitive and so near the picking and gathering stage, that it must be relatively easy, with just a little thinking and extra work on his part, to improve the farmers' productivity considerably. Any action based on so superficial an analysis has failed in the past. Obviously it will result in bitterness on the one hand, and indifference or resentment on the other.

It is true that African farming systems may seem improvised and inefficient, but they are the end result, as are those of all other countries, of extremely progressive and empirical experiments and adaptations between the desired result (subsistence of the individual and the group) and available means. It is true that these means seem to be underemployed and likely to be increased by the introduction of improved tools and materials and the utilization of new sources of power: animal traction and the industrial motor.

It is, however, obvious that the extra work required, either for intensifying a traditional crop (cleaning the fields of stumps, weeding, etc.) or for introducing new crops (most often industrial ones) must be put within the framework of the existing agricultural calendar.

If the new work required from the farmers coincides in time with the peak loads they had in traditional crops or in customary activities of importance (hunting, fishing, festivities, etc.) this will cause a disturbance which may well result in the rejection of the innovation (thus discrediting it for a long time). Again it may result in the neglect or abandonment of the traditional crop. The latter is true whenever the new crop presents a sufficiently attractive economic incentive, thus causing economic disturbances (as in the case of the peanut crop in Senegal), or if the pressure on the group is strong enough, the customary activities may become obsolete. One can then notice modifications in the psycho-sociological make-up of the group, which are not necessarily beneficial (loss of cohesion, rural instability, rapid urbanization and unemployment).

Because of this, anyone introducing new techniques into a rural environment must keep in mind at all times the actual distribution of everyone's activities; these have to be known and analyzed.

The new techniques must aim at reducing the work at peak times, when labor is scarce or time is short (sowing or harvesting), and conversely create occupations during the slack periods.

2. The precise knowledge of work time involved makes it possible to detect what we have called primary bottlenecks (farming activities that require the greatest amount of labor and thus limit the acreage that can be farmed).

It is then possible to foresee the introduction of agricultural mechanization or modern working methods, and establish the priorities needed to break these bottlenecks.

In the dry areas, for example, it is important that sowing be done as soon after the first rains as possible.

On the other hand the soil may be so compact that it cannot be worked until it is humid. Therefore, the time allowed for plowing is extremely short. The introduction of animal traction, or plowing with tractors, both of which are faster than hand labor, will therefore have priority in those areas.

In other areas it may be weeding of the crops that is the bottleneck (this is frequently the case in rice production). It would then be a question of looking for an improved tool (rotating hoe for rice field weeding) or for new methods of intervention, such as chemical herbicides.

In other cases, as when the rice field is used for two crops, it would be good to make the land available as soon as possible by accelerating the harvesting and threshing, which would require the popularization of certain tools such as sickles, carts, threshers, etc.

In order to orient the agronomic research required for the improvement of farming practices efficiently and in order to introduce efficient ways and means into the rural environment, it is necessary that the modern techniques put at the disposal of the farmers (machinery, products for protecting crops, etc.) reflect precisely the amount of work required for each particular farming operation.

3. The replacement of the traditional farming systems in Africa with more intensive systems based on other crops or on the improvement of the means of production, implies a choice among the various possible systems.

One of the essential elements for this choice is a comparison of the output/input ratio of these various systems.

Therefore, for each farming system a realistic value has to be assigned to each of the two terms of this ratio.

As for input, it is true that the value of the work (even if it is difficult, in the case of family labor, to determine the price of a day's work) plays a considerable role in it.

Independently from the price of labor, which will often be valued arbitrarily and based on non-agricultural criteria, it is essential to know the work time involved in the traditional system and in the more intensive

ones that are being proposed to replace the former.

The problem encountered is not only to know whether these systems are compatible with the labor available to the farmer, but also, and maybe more important, to measure the price at which these systems will pay for a day's work.

Thus a quick study of the farming of irrigated wheat in Northern Mali has led to the following conclusions:

Traditional farming, with hand irrigation (490 work days per hectare) gives a price of 90 Malian francs for a day's work.

Mechanical pumping, which would require an investment of 17,600 Malian francs per hectare, would bring down the number of work days required to 105 per hectare, thus enabling the farmers to quadruple the farmed area, and would bring the compensation for a day's work to 260 Malian francs with equa crop productivity. This operation would thus be extremely profitable, and the introduction of this new farming system would seem to be completely justified.

Only the accurate determination, through a survey of the worktime involved in irrigation, has made it possible to arrive at this conclusion. If the basis had been an old and inaccurate evaluation, that put this time at about fifty work days, the conclusions would have been exactly the opposite.

Difficulties in Determining Labor Input

We have seen how important determining labor input is. We must also know what are the difficulties likely to be involved.

1. Due to the heterogeneity of the African tropical agricultural environment similar tasks cannot be compared one with the other. If, for example, the expression "plowing" presents a rather clear idea in our minds, it is nevertheless true that there is a great difference between the superficial scratching done with the hoe (daba) by a sorghum farmer in the African Savannah and the deep digging done with the spade (angady) by a rice-farmer in the High Plains of Madagascar.

The texture and structure of the soil are extremely variable in different places and these variations have an obvious repercussion on the mechanical resistance of those soils, and therefore on the work time they require.

Rainfall, solar light, fertility, the duration of the fallow, all this affects the vigor and density of plants. Thus the farming operation called "weeding" is such only in qualitative terms, and the work time it requires may vary within a large range.

In the same way labor-time involved in harvesting one hectare depends

obviously on the size of the harvest. It would be foolish to measure or evaluate it without reference to the crop yield, which can easily vary in a proportion of one to five.

If we can examine things in detail we will see very soon that similar observations can be made on most of the farming operations.

Farming operations are often not well defined by the authors that discuss them. That is why the expression "plowing" may or may not include certain connected operations such as the clearing of brushwood and the harrowing. Harvesting may mean including transportation and/or threshing of the harvested products or not. The degree of perfection of operations such as harrowing, weeding, and hoeing can seldom be defined objectively.

2. To the heterogeneity of the environment we have to add that of the workers:

The work time of a healthy and strong adult cannot be compared to that of a youngster or a woman.

The work time during the cool season is different from that of the hot season.

The lack of food causes an important decrease in the productivity of the workers in the period between crops (from September to October).

Finally there is nothing in common, either from the point of view of intensity or time devoted between the work of a hired agricultural worker and that of an independent farmer, the first one working longer hours but with a lower output than the second.

3. There is another important element in determining the work time, but its importance is at times difficult to evaluate correctly. That element is the time spent by the workers in traveling between the house and the field.

In general the cultivated fields are far away from the villages, and the travel may be the opportunity to engage in extra activities (hunting, picking, visits and talks, etc.) which increase travel time. The same thing applies to the rest periods in the field.

Should these travel and rest times, which vary from one worker to another, be included in the work time as such? It would seem that the answer is yes, but they would then add their own variability, which does not make the matter easier.

4. The most frequent time unit used is the work day. It is a particularly inaccurate unit, although theoretically it is eight hours in length. Actually for a farmer the work day has a very variable length, depending both on the worker's personal capacity, and the urgency of the work to be done.

To measure the time by the hour would seem more satisfactory, but

except in some particular cases (running time of an engine, especially) the advantage in accuracy would require that the measurement be taken on a sampling basis large enough to include a sufficient number of individuals doing the same kind of work, and on a large enough sampling of identical tasks. Without even referring to the disturbances that these measurements and the intervention of an observer would create in the normal rate of work, id can easily be seen that this is not feasible in agriculture, due to the heterogeneous nature of the agricultural work, which differentiates it from industrial work.

5. If the time unit used is inaccurate, the extension unit, the hectare, can also be inaccurate.

The figures for work time that one can find in literature are the result, most of the time, of intuitive estimations rather than of strict measurements. It looks as if the observer has seldom bothered to take the geometrical measurement (takes a long time and is delicate operation) of the area of the field observed. The farmers themselves have a very vague idea of the area of their fields.

From what has been said previously about work time one would expect that it is only possible to have rough ideas of magnitudes rather than accurate values for the different characteristics of work distribution (intervals of variation, averages, variables, etc.), but even these rough ideas of magnitude, as can be found in the specialized literature, have to be used with caution due to the extent of their range of variation.

Thus in 1965, the French Secretariat of State for Cooperation, asked the Bureau for the Development of Agricultural Production to make a study of the existing documentation on labor input in rural environments, to determine the gaps and insufficiencies, and to try to define the methods and means to obtain a better knowledge on the subject.

The result has been an important work: "Rural Technique in Africa: Labor Input," which collects, it is true, invaluable data, but which on the whole is incoherent, because of all the ambiguities mentioned above. The documentation review is, however, comprehensive, including 484 titles of books, articles, etc. in the bibliography.

But if one admits that the knowledge of the distribution of the farmer's activities is useful for the sociologist as well as for the agronomist, that it is absolutely indispensable to determine whether a technical innovation or a more intensive farming system are compatible with the capabilities of the available labor, and if there is a real interest, one has also to admit the consequences: In order to be developed, tropical agriculture must be studied now in a decidely economic and quantitative framework. The time of "guestimates" is gone. It is now time to be rigorous, to measure and to use figures.

From this approach, the work of the B.D.P.A. mentioned above indicates an outline of a methodology to be used for a correct study of work time and labor input in a rural environment.

One would wish that this type of study included a great number of individual cases throughout the African continent, thus increasing our knowledge and the possibilities for a balanced development of the tropical countries through the rational intensification of their agriculture.

CROPS AND CROP ROTATION

P. Silvestre, IRAT

SUMMARY

The general principles are given which make it possible to orient agricultural research as a function of the need to make the primitive and itinerant African agricultural systems develop towards sedentary and intensive agricultural systems.

Because of demographic evolution, the traditional agricultural systems cause a lessening in soil fertility and in some cases lead to the elimination of demanding crops and their replacement by more resilient species.

The improvement of soil fertility requires investments which are not feasible under an itinerant agricultural system.

Research must be done on the following:

-fertility problems: organic matter, mineral fertilizers, allowing fields to lie fallow, etc ;

-on the agro-economical aspects of various crops to be used in crop rotation ;

-on agricultural systems; that is, the relation between exploitation means and methods available and possible crops.

INTRODUCTION

What type of crop rotation you are going to engage in is guided by agronomical considerations: that it is better not to plan the same crop on the same land for many years in succession but rather to alternate with crops that are sufficiently different as to their root systems (deep or superficial), their sensitivity to parasites (insects, cryptogams and especially nematodes), the cultivation techniques they require (weeders and non-weeders) and so on.

There are also economic considerations involved. These are the necessity for the farmer to produce a certain number of agricultural goods per year, to choose marketable crops, produce fodder and adapt to problems of cultivation that he may come up against.

The type of crop rotation that a farmer will choose and the types of crops that he will use for this purpose will be in effect a compromise between the economic and agronomic factors involved.

I. The Traditional African Farmer

Agricultural systems which develop after a nomadic hunting and gathering phase retain itinerant characteristics. The traditional African agricultural systems are often at this stage, and a certain equilibrium is obtained in that crops are grown on the same plot of land only after several years have elapsed. Abundant natural vegetation, usually in the form of shrubs and the like, can regenerate the organic components of the soil during that time and bring minerals that are deeply imbedded in the soil, up higher towards the surface. A rather satisfying fertility makes it possible to produce various different plant types, either by planting mixtures of crops or by planting them in succession.

Agricultural tools and machines make it possible to till larger surareas of land and also cause farmers to return more frequently to land that has been already cleared where the use of these tools is easier; that coupled with the introduction of new crops and the increase in the population have meant that the time when the land is allowed to lie fallow has been much shortened.

This evolution generally leads to a reduction in the fertility of the soil, a reduction in the number of types of crops grown, or even a disappearance of crops that need particular attention or very rich soil.

Such situations can be observed for instance in Senegal where in certain regions land is not allowed to lie fallow at all; the traditional cereals were produced less and less until they were finally replace altogether by the peanut which is far less demanding of the soil.

Another case can be seen in the overpopulated areas of the countries on the Bight of Benin, where cassava is now substituted for the traditional maize, which is also too demanding.

In the Mossi country of Upper Volta, the traditional agricultural system is that of a monoculture in sorghum, quasi-continuous, with a very low yield, and introducing any new crop would entail the problem of first raising the quality of the soil, and then substituting new crops on land that is already planted in sorghum.

II. Preconditions for Crop Diversification

Diversification of crops is closely tied with problems of fertility.

In areas where there is low population density, one can envisage introducing new crops without worrying about the problem of fertility, simply by extending the cultivated surfaces by introducing new crops. Nevertheless, this can be a dangerous oversimplification, and can cause some problems.

Even if very long periods of lying fallow are allowed the land, it seems natural that once plows or agricultural machines are used, the natural tendency is to keep returning to land that has already been planted,

so that very dense vegetation will not grow during the "rest" phase.

Besides this, the new crops will only be profitable if yields are sufficiently high, and high yields mean that a decent level of fertility must be maintained.

Finally, introducing new crops or new agricultural materials preclude the fact that they will be used in an efficient atmosphere and this means they are only justifiable when introduced in an area where the population is not too dispersed.

If we admit to the definition which says that output is more intensive where the value of production per unit of surface exploited is higher, then agronomical research will have to gear its solutions to making the farming more intensive, especially where soil is scarce or expensive, which is the case where there are many people per kilometer and where very expensive projects such as anti-soil erosion or irrigation, have been realized. In Africa, sometimes the mere fact that land has been cleared and burned would justify intensive farming.

In order the maintain intensive farming, the following must be done:

-unproductive surfaces must be done away with and/or kept to a minimum;
-high soil fertility must be created or maintained;
-species must be found that could give high yields in that specific area and which are certain to do well.

III. Researchers Face Problems when Making Decisions on Crop Rotation

3.1. Preliminary Problems

The immediately preceding paragraphs have shown that introducing new crops will not be successful unless techniques are applied at the same time to maintain or guarantee an adequate level of soil fertility.

Perfecting these techniques means that the following must be studied:

-the regenerating effect of letting land lie fallow;
-the effectiveness of mineral fertilizers;
-the possibilities for using manure.

3.1.1. Letting Land Lie Fallow

The value of letting land lie fallow for a brief or average period of time has been much praised.

The primitive method of allowing land to lie fallow for a long period of time has the unquestionable effect of bringing to the surface minerals that are deeply embedded in the soil, improving the humus

and it further undoubtedly substitutes slow-growing perennial plants (that can be easily cleared with one clearing and burning operation) for the very competitive annual plants. Allowing land to lie fallow for short or average periods of time has less clear-cut results.

One of the essential goals of research must be therefore to study this in detail, to determine whether this phase can be done away with entirely, and whether this same land can be changed over for example, to producing forage.

3.1.2. Mineral Fertilizers

African soils are very generally lacking in phosphorous, but lack of sulphur, potassium and, rarely, magnesium and calcium have also been observed in certain areas. Improving agriculture means that researchers must look into techniques for correcting this lack in the soil, find mineral fertilizers adequate for each crop and make sure that the proper mineral equilibrium is maintained through rotation.

3.1.3. Manure

In the majority of cases in Africa, livestock breeding and crop production are separate and even engaged in by different ethnic groups. The nomadic nature of livestock breeding makes it nearly impossible to obtain this type of manure. The well-established proof that manure is a good fertilizer means that researchers must look into the possibilities of how it is to be produced in tropical areas, and how these people can be taught to inter-relate livestock and crop production. There is also the problem of growing crops for animal fodder and the use of fields that are lying fallow for feeding livestock.

3.2. Studying the Possibilities

Economic studies allow us to orient the choice of crops as a function of ecology.

Agronomy must show for each crop chosen:

a. the most favorable agronomical techniques: growth cycle, date and mode of seeding, cultivation and harvesting, phyto-sanitary protection, specific fertilization, etc.;

b. yield that can be expected;

c. means of production needed and their cost (labor time involved, agricultural tools and materials, fertilizer, etc.).

The priority for these studies should be on the traditionally grown species and especially to the crops that African farmers are especially attached to; if yield can be increased for these crops on existing land, new land can be used for experimental crops.

Research in selection and genetic improvement plays an important part in this. These traditional species are often the result of natural selection that favored hardier types that could more easily adapt to mediocre means of production. The purpose of this research is thus, while preserving the qualities of these crops to which the people of the are are accustomed, to create, if need be, by introducing new genes, varieties with a high production potential. Such factors as resistance to parasites and disease, vegetative cycle in relation to needs, should be taken into consideration.

Similar research should be carried on in marketable species that have already been introduced.

For other species, before they are generally introduced, a study phase on their behavior is necessary.

A special place must be made for the study of forage-crops, in that these are related to other areas of research such as problems of fertility and those relating to the feeding of livestock.

All these studies should be undertaken under the optimum fertility conditions outlined above.

3.3 Agronomic Studies of Rotation

One could be tempted to compare experimentally various crop rotations previously defined. This would pose several problems: it would require complicated experimentation (because of the large number of things to be compared) and it would take a long time; a valid comparison of crop rotations of different lengths of time would require several dozen years. Besides, any given rotation might not be considered as an absolute because the economic criteria which govern the choice also might change over a period of time.

Thus, it is essentially a question of studying the effect of a certain crop in rotation with another specific crop.

Certain more fundamental types of research must also be undertaken before a particular crop cycle is chosen. This research entails:

-parasitism and its evolution: insects, cryptogams, nematodes, striga, etc.;
-the possibilities of increasing soil nitrogen through the cultivation of legumes;
-studies of the root systems of plants and their effect on the structure of the soil;
-studies of the effect of cultivation methods (plants requiring weeding, plants that require plowing beforehand, precocious plants allowing fall plowing, and so on).

3.4. Studies of Crops for Rotation

There is, of course, a close connection between the kind of

rotation and the crops to be chosen. Certain economic factors which affect the choice of crop will, of course, be taken into consideration when crops are chosen for research and study and a fortiori when crops are chosen to be studied in a combination for rotation purposes.

Other economic factors should nevertheless be taken into consideration by agronomists.

One of these problems is the choking that can occur if several species with the same requirements as to seeding time, care and harvest are grown together.

The existence of such a possibility poses another problem for the researcher. Either one must study agricultural tools and materials that are better adapted to cope with this, or varieties must be created that are more precocious or more retarded or varieties that will not suffer if they do not follow their optimum growth period.

3.5. Farming Systems

The system to be used can be defined after the economic factors have been studied and after results from agronomic research have been obtained as to improvement of traditional crops, adaptation of crops or new crops (including for fodder), and study of agricultural equipment and mechanization, both motorized and draft animal.

Nevertheless, the orientation of research in various domains cannot be clearly defined unless a model system of cultivation is decided upon beforehand and which the agronomic studies will seek to optimize.

Thus it would seem utopian, in view of the costs involved, the absence of a technical infrastructure and the lack of professional training of the farmers, to try to make African agriculture evolve towards a system of motorized, mechanical cultivation.

The models of farming systems which we will set up, at least for a transitory phase, shall be generally based on the use of animal traction, which is one reason why it is so important to study the feeding of livestock (through harvest by-products, fodder, etc.) their work possibilities and their improvement.

Besides, this orientation is justified as it constitutes a first step toward integrating animals and crops into the same system.

We have seen that in the present situation, these are disassociated: there is an extensive nomadic livestock breeding which produces meat cheaply so that it has created economic conditions which make it impossible to have the same production with sedentary livestock fed with agricultural products.

Nevertheless, there is no question that because of the leaning towards cereals of many of the African countries, livestock breeding is the most promising in the long-run.

The cultivation systems that the agronomists must pick out should thus be geared to this possibility.

Bovine animal traction is a first step along this road. It would allow a first intensification of the system of production and it would make these traditionally agricultural people become interested in the animal.

The second stage in this evolution could be, under certain favorable conditions, milk production or fattening of calves produced under the extensive system.

The last stage would be the production of meat. This pre-supposes, so that it would be profitable, that the standard of living of the African populations be dramatically improved.

Exports of meat can only be envisaged when the problem of rinderpest has been resolved, which will require veterinarian research.

"RESEARCH" (IN THE BROADEST SENSE) IN THE FIELD OF TROPICAL FARM MECHANIZATION (FRANCOPHONE COUNTRIES)

G. Labrousse, CEEMAT

SUMMARY

After outlining research in the field of mechanization in agriculture, as distinguished from purely agronomic research, and after recalling briefly the main reasons supporting this mechanization of agriculture, the author successively covers:

- the objectives, ways and means of this research;
- the achievements to-date;
- the priority problems to be studied.

The whole of the paper deals exclusively with Francophone countries of tropical Africa.

The final objective of research (taken in its broadest sense) in the field of agricultural mechanization is to be able to advise objectively and reliably the representatives of the interested parties, public agencies and private industrial and agricultural sectors, for successful and optimum implementation of the most suitable units of machinery (in every respect), to be used in a given project.

To this end, it is essential that, in addition to field studies and data gathering surveys, research specialists carry out research and development programs together with economic surveys, in close cooperation with manufacturers and users. It is also essential that suitable "facilities" both in men and machinery, be made available for the execution of the project.

Next, a number of successfully completed projects are mentioned in connection with Francophone tropical countries. In those states, before independence, the initial research was performed by the men in charge of agricultural stations, together with a number of plantation managers. Following the second world war, the French Government established a specialized agency designed to act as a technical adviser to both the Ministry involved and the many users in the field. Following independence, the various existing research institutions initiated research work on machinery; some were specially staffed and were officially sponsored, in accordance with a wide variety of laws and regulations.

To remedy inadequacies, one solution has been suggested: that of regional or multi-national centers.

The French Specialized Center was also provided with increased facilities in order to meet ever-increasing activities.

The major projects completed by these Agencies are summarized and the necessary coordination is emphasized for the purpose of expanding and facilitating the use of data made available.

In connection with research priorities in this field, specific aspects and the problems raised in the countries involved are first outlined. Then information is given on the surveys and studies to be carried out prior to any research project (development of procedures and trial equipment, survey of requirements in the field, of the procedures for optimum of equipment available). Then a brief listing of research topics is supplied, since the whole of the priority question cannot be covered for all Francophone nations.

Some examples are provided, in connection with:

- hand tools and implements;
- animal-powered machinery;
- power machinery and implements;
- required economic surveys;
- measures taken to promote extension.

Conclusions cover once again the significant role of agricultural mechanization in Africa, while emphasizing the social aspects of its introduction: it will participate in the other agricultural improvements and in the "liberation" of man. Therefore it is quite possible that this research shall usefully contribute to the promotion of the African farmer.

Many results have been achieved, but there remains a great deal of work to be done both by existing and future agencies and centers. The collection and dissemination of data available are not always adequately performed, and this is detrimental to a successful implementation of agricultural machinery in those states involved.

INTRODUCTION

In the eyes of some research workers, specialists in fundamental research and even in applied research, research on the mechanization of agriculture does not constitute a distinct discipline and there are very few who are aware of the necessary mechanical means, particularly concerning the application of the results of their work.

Agricultural research practically always leads to additional work for the farmer. Research on the mechanization of agriculture seeks to improve the equipment used by the farmer to deal with his agricultural work, to increase the productivity of his work, diminish his labor and consequently to make his lot less hard and encourage the establishment of more developed farms. All this ought to lead ultimately to an improvement in the farmer's standard of living.

This is what allows us to say that the agricultural machine is the symbol of agricultural progress.

Without covering in greater detail the reasons favoring the mechanization of agriculture it is proposed to examine successively:

- the objectives, ways and means of research in this field, also the possibilities which seem open;
- what has been achieved to date;
- the priority problems to be studied: these are numerous and often highly specific, and can only be covered by citing examples.

I. The objectives, ways and means.

A. The Objectives

The ultimate aim of research into agricultural mechanization is to be able to reliably advise the representatives of the interested professions, agricultural or industrial, leading to correct application of machines which are from all points of view the most suitable to the operations to be carried out.

However, naturally, this advice can have effects well beyond the production and application of machinery, and can have consequences for the "options" of the interested governments.

The world "research" as it is used here encompasses both true research, or basic research, the design of methods and materials, and experiments and trials. The latter are directly linked to other aspects of research, since the studies which consist of defining the methods, and production of equipment used to complete trials can lead to basic research and ideas about machinery, while the accumulation of results of trials can lead to general conclusions of an original nature.

From another aspect, research must have two parts: one is mechanical, (or technical), involving the creation or adapting or perfecting equipment designed to replace or improve manual labor, or other types of work already existing; the other is economic.

In this, which is secondary, the profitability compared with this or that possible choice amongst the previously designed implements will be studied in the given context.

B. Ways and means.

Agriculture studies, research and trials have above all the objective of advising the farmer on the application of methods and means tending to increase the quantity and improve the quality of farming products.

Progress obtained interests public authorities more or less directly, and they are often the official agencies responsible for carrying out the experimentation.

In the case of agricultural machinery, a third group is involved, the mechanical "profession." This is extremely important, since equipment manufacturers and salesmen have an immediate interest here. The former conduct studies and research to develop prototypes of implements suitable for the solution of the problems posed. They have to complete experiments in order to perfect the precursors of these implements and the economic use of the series which will follow. It should be noted that if, most of the time these machines serve the application of known techniques, they are occasionally at the root of the development of new techniques. This is why, furthermore, research on agricultural machinery cannot be dissociated from correctly labeled agronomic research.

In order that the purchase of new machines developed by the manufacturers shall not be a burden to the farmer, it must be known if these correspond to the real needs of the farmers, who must be informed without the involvement of the subjective elements.

This is why there must exist official agencies for studies, trials and specialized research whose purpose is to inform the representatives of the other official agencies who use the machines individually or as groups, and also the engineering profession as objectively and as completely as possible. This, then, involves information. But this would be of very limited value if it were not founded on documented studies or observations in the field. This is why research, experimentation, trials and economic studies are essential to these agencies, and must be, moreover, carried out in direct collaboration with the designers, manufacturers and users of the equipment.

Research must, in the first place, provide a description of what is expected of an agricultural implement, for each cultivation operation and also the characteristics of the environment or the products which are the object of the work done. In the very long term, it must provide new solutions to known problems, particularly involving equipment in which the profession is no longer interested.

In the course of trials one must eliminate, as far as is possible, all subjective elements of estimation which must appear, whatever the quality of the private experimenters, in the absence of rigorously defined implementation carried out under wholly known conditions. This requires the provision of numerical data on the equipment to the users, enabling them to make comparisons.

Experimentation is very large and highly practical. The equipment here is introduced into a variety of conditions which will be those under which it will function in practice. It is then submitted to quantitative observations and qualitative evaluation in a variety of places and over a period of time.

Trials and experimentation practically always lead to modifications in the equipment, whether the research is carried out under tropical conditions or different conditions.

Economic studies, finally, bear on the economic consequences of the introduction of the new equipment, or the modification of equipment, in the farms under consideration. On a higher level they provide elements of evaluation of an eventual policy of development of agricultural mechanization, in terms of the means available, the circumstances of time and place, and the desired results.

All these activities of the official research agencies require on the one hand specialized personnel, on the other, means to carry out the work.

The specialized personnel should have an agricultural training with basic economics, completed by some knowledge about machinery. Emphasis is placed on the requirement that it should not involve only practical mechanics. Similarly at the heart of an agricultural engineering research organization specializations are necessary according to whether its members are more particularly involved with trials, information or economic studies.

The information relates necessarily on specialized training, which is rather complex and extensive. This activity is relatively recent even in France.

The material means depend on funding provided by the government. Buildings and equipment for necessary trials can be very modest or, on the other hand, constitute a vast establishment, in the countries with advanced agriculture.

It is now proposed to examine what has been accomplished in research for the Francophone tropical countries to date. This will be covered in detail because of the importance which agricultural mechanization should have in these countries.

II. Accomplishments.

A. Before independence.

A number of users of agricultural machines did some experimenting with them, to see whether they were well suited to the particular working conditions in their situation.

In the Francophone tropical countries, particularly in Africa and Madagascar, one cay say it was the officers in charge of the official agricultural stations who carried out the first experiments with the object of improving working conditions in the operations for which they had responsibility. Thus various implements were introduced.

Indirectly, when the urgent problems were solved, for example the provision of selected seed to the farmers, they envisaged the possibility of using the same kind of equipment in local farms.

However, in connection with the latter, the process of introduction of machines was different, according to whether it involved more or less industrial types of plantations, with their particular technical and economic problems, or more the traditional styled systems.

In fact the managers of the plantations were often in the forefront of introductions of equipment, as a result of their practical experience. The traditional farmers, almost entirely ignorant of agricultural mechanization, will follow the advice of the extension services (which are in turn informed of results obtained on the research stations) and also various advisors wishing to help them to profit from the experiments on the plantations.

In practice, moreover, the machines were not manufactured locally, and the managers and advisors had only a superficial competence in this field. Also the experiments were done with equipment which unspecialized business firms imported into the regions, each of the people involved, at all levels, transposing most of the time what he remembered seeing in his own country.

It was left to the personal inclination of a number of workers who specialized themselves more or less and, little by little, contributed to the elaboration of the basic elements of utilization of the equipment of tropical agriculture. On the other hand in some areas a relatively large amount of cultivation, harvesting and processing equipment was installed.

Nevertheless it is generally accepted that it was not until the end of the second world war that mechanization developed further. At this period, the creation of the specialized research institutes to which were assigned the colonial research stations, complicated matters, since each oriented itself toward special problems when most of the machinery used, for working the soil or for crop protection, for example, is multi-purpose.

On the other hand, ways then were being sought to increase materially particular areas of tropical production and bring the benefits of motorization to the agriculture of the Francophone countries. From this came the establishment of "production operations," and a wide variety of legal arrangements and statutes. These also were obligated to conduct practical experiments on equipment, transposing techniques already used very often in comparable ecological regions. Unfortunately, as time was short, the necessary precautions for good adaptation to local conditions were not always taken.

In France itself, moreover, at the same period, the doctrine for agricultural mechanization had been little more worked out. Nor were

the agricultural specialists trained there in a more rational or systematic way.

In 1949 a specialized Central Service was created in the Direction de l'Agriculture de l'Élevage et des Forêts Outre-Mer. It had the role of advisor both for this Ministry and the Ministry of Planning, as well as users, most often in the administrative sector, and manufacturers. Its means were very limited.

Then a Committee for Overseas Agricultural Mechanization (CMAOM) was established in Paris, in 1953. Set up "with a view to guiding the study and development of agricultural implements adapted to guiding the working conditions in the tropics.." its secretariat undertook the tasks of documentation and information already begun and brought together the most important elements through field studies.

Nevertheless the evaluations carried out on the qualities of machinery used were only rarely supported by recourse to reliable experimental methods, and the results were rarely useable. However certain of the stations mentioned above created Divisions or Sections de Machinisme Agricole, always very modest, and various agricultural services established sectors or pilot schemes of motorized cultivation.

Faced with the impossibility of comparing the results from this variety of sources, the CMAOM prepared in cooperation with CRA (Bambey) the main station interested in these problems, a basic document identifying the problems to be tackled, the different categories of trials to carry out, the general procedure to follow, etc. This document was circulated to the main overseas experimental agencies and a certain number of cooperative experiments were carried out in collaboration with the manufacturers. Each provided its technical and financial share, responsibility for the preparation of the report of the results falling to CMOAM.

In this way many types of equipment were tested under local conditions, tractors, plows, sub-soilers, harvesters, grinders, etc.

B. After independence.

It was in 1962, with the creation of the Centre d'Etudes et d'Experimentation du Machinisme Agricole Tropicale (CEEMAT), endowed with more substantial means than were at the disposal of CMAOM, that a more rigid methodology was proposed to competent local stations, which in the meantime had become the agricultural services of foreign countries or dependant organizations working there under technical assistance agreements.

1. The activities of CEEMAT.

CEEMAT was established near the French national center (CNEEMA) in order to take advantage of all the assembled resources and

the results obtained. The French Center is oriented particularly to trials and research into motorization. It was not then a question of CEEMAT becoming involved in this area, other than for the use of facilities, and from the first its activities were oriented towards implements related to animal traction.

It undertook, in the first place, to facilitate standardization of methods and means.

General instructions on experimentation, bearing particularly on animal-drawn equipment used at the farm level, were prepared. At the same time specific instructions were laid down, parallel to the outlines of reports.

All this was tested out and organized during the trials conducted by CEEMAT in tropical conditions, on the stations, notably CRA of Bambey in Senegal, and then disseminated to stations or centers soliciting the technical support of CEEMAT. (These various documents have been collected in a "Handbook for the Research Worker..." published by the Secretariat of State for Foreign Affairs responsible for cooperation of the French Government.)

With regard to research on useful apparatus, investigations and trials conducted both at Anthony and Bambey, enabled various direct-reading or recording dynamometers to be provided, along with other equipment recommended for use by the experimenters at the local level.

Other similar work took place relating to motorized equipment, for crop protection, etc...

Without wishing to catalogue all the equipment involved in these trials, the following indicate a few of the more important trials:

- animal traction implements (plows, harrows, seeders, etc.), crop protection equipment (various crop sprayers), a "simplified" tractor of low power, were tested;
- a series of trials of motorized equipment was completed in an artificially created tropical atmosphere (complete tractors, or particular accessories);
- measurements of the effort developed and power output of animals was carried out overseas.

To conclude this brief review of the activities of CEEMAT it should be mentioned that it has trained numerous technicians specializing in agricultural mechanization and among them, particularly, the future overseas research engineers.

From an economic point of view CEEMAT collects basic data (times for cultivation and market prices) for a study of the operations in which mechanization in all its forms could be involved. It disseminated overseas various publications designed to facilitate economic studies of mechanization projects, in a variety of forms. Finally, it

carries out studies concerning the profitability of mechanized operations funded by credit from FAC, during missions carried out on behalf of a number of African governments.

2. The activities of the overseas governmental stations.

Practically all devote themselves to experimentation with machines, a little everywhere; this account is limited to a few examples.

a) Senegal.

The oldest, and the most important specialized section of an overseas station concerned with agricultural mechanization, is undoubtly the CRA of Bambey. From 1930 studies have been undertaken on equipment adapted to local production. The first animal-drawn single-seed single-row seeders were developed here for peanuts. In 1949 this Section was created to experiment with the equipment, inform the manufacturers of local crop needs, and guide them in the improvement of their equipment. In 1961 it became the Division of Agricultural Mechanization and Rural Engineering and provided with an increased budget. Its general program includes:

- studies on mechanization; problems raised by the introduction of the machine into African farming, oriented towards economic and social aspects, such as:

  1) methods of integrating the machine: individual equipment or cooperative use, animal power or motorization; farm structure;
  2) estimation of market prices of mechanized crops;
  3) determination of Senegal's needs, participation in programs which supply equipment;

- research and experimentation;

  1) tests of machinery, requested by manufacturers;
  2) construction of prototypes; problems no longer of interest to manufacturers through, for example, lack of markets or the development of new cultivation techniques;
  3) comparisons of methods of storage and preservation.

The volume of work undertaken by the Division, either itself or through its new regional outposts, is already very substantial. We will limit ourselves to indicating the main categories of equipment tested and for which reports have been prepared:

- tractors (wheeled, caterpillar or half-track) and cultivation implements (soil preparation, sowing machines, spreaders, harvesters and transport);
- animal powered cultivation implements: plows, seeders, peanut diggers, fertilizer spreaders, hoes; treadmill pump;

- equipment for processing the harvest on the farm: threshers, decorticators, winnowing-machines, mills.

Research projects have been undertaken or are in progress on:

- the design of working parts of implements;
- tractive power;
- plowing-in green manure;
- development of a standard measure of soil resistance;
- development of a rice seeder (construction of a prototype, modification of others).

New equipment has been developed and adaptations carried out:

- adaptation of animal drawn seeders for motorization;
- prototype pearl millet huller and combination machine for simultaneous soil preparation and seeding;
- adaptation of a multi-purpose cultivator for tilling three rows.

A Senegalese National Committee, which would be responsible for selecting the appropriate elements to facilitate directing and coordinating the mechanization of agriculture, has been in the process of being constituted for a number of years. In its absence the Division of Agricultural Engineering at Bambey is the competent organization for interpreting, using and disseminating the results of trials.

b) In Madagascar.

In Madagascar until 1964, many administrative organizations, or those belonging to the technical assistance institutes or societies, were involved in testing agricultural machinery. They carried out practical trials in various parts of the Island, according to their location. Some examples of trials recently carried out are:

- rural engineering: improvement of an animal-drawn roller, and a root-cutter - straw-cutter; development of a "Spanish"-type harrow and a rice transplanter;
- IRAM (Lac Alaotra and Marovoay);

  1) hand implements: development of a leveller, a plant carrying cultivator, a seeder for planting rice in muddy paddies; trials of weeders and Japanese mowing-machines, paddy translaters, etc.;
  2) animal traction: behavior trials (cultivator, peanut-digger, locally-made seeder, development of a roller-compacter;
  3) motorized equipment: behavior trials (tractors, rice harvester-threshers, binders) trials with sowing and hoeing paddy mechanically.

- IRCT: trials with a variety of motorized implements adapted to cotton cultivation and crop protection equipment;

- IFAC: trials with mechanical cultivators in banana plantations and crop protection equipment;
- BDPA: comparisons of equipment for the preparation of cassava; development of mechanized techniques (soil conservation);
- CDFT: tests of a sowing-machine for un-delinted cottonseed and crop protection equipment;
- SATEC: participation in the development and testing of a roller-compacter, rice-cultivators, and a manual rice harvester for one and two rows.

By itself, the Lac Alaotra station carried out work comprising technical and economic comparisons between similar kinds of equipment, when the other organizations most often undertook simple visual evaluations during their experiments or demonstrations.

The complexity and confusion as regards the trials in Madagascar were not due to the involvement of many organizations, but to the fact that they were carried out in isolation, in the absence of well-defined standards. The coordination and centralization of the results obtained, necessary for the elaboration of a synthesis regarding suitable equipment to be adapted to the conditions characteristic of the country, was lacking.

To remedy this, the Malagasy government created a **National Committee for Agricultural Mechanization,** and a **National** Center for Studies and Trials of Agricultural Mechanization (27 October 1964).

The Committee "defines the needs, orients the construction and importations, and follows the distribution and maintenance of the equipment," while the Center "carries out studies and trials, of imported equipment or equipment constructed locally; it contributes to the design of prototypes. In addition it gathers all information and documents from organization in Madagascar or foreign organizations, and works in liaison with them." The latter should serve as regional and specialized stations of the National Center.

The construction and equipping of this Center is practically complete and its first projects have begun, including trials with pedal-threshers, Japanese rice motocultivators, etc.

c) In the Ivory Coast.

In this country, experimentation and testing relating to agricultural mechanization have been conducted in a disperse fashion, either by stations directly under the Ministry of Agriculture or the specialized Agricultural Research Institutes, as well as on the governmental or quasi-governmental maintenance or production projects, and even in the private plantations. Following an old concerted action project undertaken by the Experimental Committee for the Mechanization of Crop Production (COMEX), particularly oriented towards satisfying the

needs of the industrial plantations, it is only recently that coordinated arrangements have been made.

A Consultative Committee of Agricultural Mechanization (COMACI) was established on 13 August 1966 by Presidential Decree. An official testing center is in course of being established in the form of a specialized mobile team provided with the necessary resources.

The former organization, of which the permanent secretariat is provided by an agency of the Ministry of Agriculture, has the essential objective of promoting the exchange of ideas between various entities involved in the development of mechanized agriculture. Practical trials in the field will continue to be carried out by the experimenters previously referred to particularly in the framework of the Agricultural Research Institutes, but with the support of the mobile team and under the control of the Committee. This will enable the suitability of the equipment to local conditions to be more critically assessed.

Among the first trials undertaken under the Committee's aegis are: with disc plows (motorized), sprayers and nematocide injectors, cutting bars, a variety of small rice-growing equipment, etc.

d) Other countries.

The three countries dealt with above are also those in which the "research" in agricultural mechanization has been, until now, the most advanced. They enable three main types of involvement by coordinated research in this field to be identified -

1. A division of a governmental organization, in which the management is further entrusted to a specialized Agricultural Research Institute, is responsible for carrying out such studies and gathering those carried out elsewhere, without the official reports explicitly stating this in detail.

2. A National Center for Studies and trials is officially assigned these projects under the direction of a National Committee of Agricultural Mechanization.

3. A Consultative Committee of Agricultural Mechanization specifies the general lines of governmental policy relating to the mechanization of agriculture and makes various experimenters responsible for carrying out practical trials, bringing to them the support of an official body.

The other countries, which attach importance to this question, have established (or foresee) a type of involvement of research on agricultural mechanization relating to one or other of these three types. These are:

- Cameroon; where a Federal Testing Center for Agricultural Equipment is being established;

- Niger: where a representative of French technical assistance carries out the work within the framework of the Union Nigerien de Credit et la Coopération (governmental organization);
- Upper Volta, where a research institute (IRAT) carries out tests on agricultural equipment, within the general framework of its research program, with the support of CEEMAT by virtue of a decision of an administrative service.

It should be mentioned that the Republics of Mali and the Congo envisage the creation of an official testing center, the former appearing more advanced towards this.

This brief survey enables some lessons to be learned:

- many studies, trials, experiments have already been carried out at the very least in some Francophone African countries. Unfortunately these works have not always been conducted according to the principles described and the standardized methods, and their results have only rarely been disseminated.

CEEMAT tries to fill its role of advisor in urging the governments to establish useful organization, and cooperating with the elaboration of the principles of their efforts. It places at the disposal of these organizations both apparatus and technical documentation concerning the methods of carrying out trials. However, it only becomes directly involved at the request of governments or official organizations.

- in some countries, it did not appear necessary to create an organization responsible for specialized research and the Ministry responsible did not consider the possibility of it because the problems to be solved were neither numerous not complex at the time, and because of the expense inherent in the installation and running of a testing center. It seemed appropriate, in this case, to project that the Center of another country, involved in a comparable ecological environment, could be made to serve as a multinational center, supported by secondary stations responsible for multilocal experimentation. This role was moreover the choice formerly of the CRA de Bambey whose efforts extended throughout the Sudano-Sahel region to the countries of ex-French West Africa.

III. The Priorities.

In our opinion, the absolute priority comes down to the need for governmental authorities to recognize that equipping the farmer is a problem of national interest. It is only then possible to define the priorities of research in the mechanization of agriculture. One supposes besides, that the competent organizations have been created to this end (National Committees and Testing Centers with their subsidiary stations).

Before attempting to define some particular priority problems, it seems appropriate to briefly emphasize some particular aspects of the

of the work required from these organizations, in the countries moving towards development.

A. Specific Aspects.

Their task is a multiple one: they should advise the government, the extension service and the users, as well as, naturally, the manufacturers. In these countries where "many things need to be done' a number of difficulties have to be resolved; we will return to these. To correctly fill their role as advisors, these organizations naturally have to carry out studies, research, trials.

In the countries where they exist, they are often given other responsibilities, training of extension agents, for example sometimes of users of equipment, when it is not farm mechanics. Often, in addition, they have to provide certain of the functions of the extension service, or of the "profession," in demonstrating impoements. Sometimes they are asked to study local possibilities for the construction of certain implements.

The difficulties are many: they comprise in the highest degree throughout the field, hand-tools and machinery, animal-powered and motorized implements, used from clearing the ground to the processing and storage of products. As a result of the large variety of equipment used, this implies the collection of extensive documentation, this also requires vast technical knowledge, more extensive work than for the organizations in temperate countries where, generally, motorization predominates.

The climatic conditions in which the equipment must operate (humidity, heat and dust) require special trials. The social conditions also pose special problems (ethnic differences and traditions).

Other difficulties include:

- the small number of references available in this field. With the exception of the trials mentioned before, the early work carried out by the EATU (East African Testing Unit) is all that exists for tropical Africa;
- the relative magnitude of the expenditure necessary for their running, over and above that implicit in their establishment;
- the remoteness of the manufacturers and a particular lack, nearly always, of local representatives.

In sum, these organizations, young for the most part and with limited resources at their disposal, must face numerous problems which they must nevertheless resolve with dispatch.

B. Brief accounts of priority problems.

It is not possible, within the scope of this paper, to review all the priority problems for all the Francophone African countries.

For that it would be necessary to describe the agriculture of each (climate, soils, food and industrial crops, types of farming...) the main lines of future planning, (priorities, production objectives, export targets...) the local infrastructure (communications, repair workshops, local mechanics...) etc. Indications of a very general nature, then, will only be provided, giving some examples of research problems in the sense we have defined.

a) Preliminary studies.

- testing methods;

The newly established organization should build up basic documentation. Beyond that concerning all the agricultural machinery of possible interest to the country, it should gather all reports dealing with methods of testing used elsewhere, as well as the various ways of expressing the results.

These technical documents should be generally subsequently suited to the particular conditions of the local agriculture.

- knowledge of requirements;

Before undertaking testing, it is necessary to have a complete understanding of the requirements of the local agriculture, with a view to proposing for it equipment which is suitable, technically (quality of the work performed), agronomically (soil protection) economically (investment and running costs) and even sociologically (ability of the users.)

- understanding of the methods of introduction and use of mechanization:

In the countries with which we are concerned, in practice there is no crop for which work with hand-tools can be completely eliminated. To define the framework in which implements can be introduced it is therefore necessary to study the various combinations of the <u>three types of introduction of mechanization</u>:

- animal-powered and manual cultivation;
- manual and motorized cultivation;
- motorized, animal-powered and manual cultivation.

It is also necessary to know the methods of use of mechanization; individual, small companies or communal use, through governmental or quasi-governmental organizations.

These preliminary studies of the general "framework" in which the machinery is placed or should be placed, are essential, as are also those of the changes which the use of the machinery will cause. In fact, the determination of appropriate equipment and the study of their output very often leads to a modification of the dimensions of the project and its nature.

b) The other problems.

The sum of information to be collected, before undertaking true research projects, is extensive and essential. This information must nevertheless be kept up-to-date because of the proliferation of new equipment, used for carrying out evolving farming techniques. Continual bibliographic work is necessary which can be only undertaken by competent personnel with specific responsibility for it.

With regard to research, it concerns at the same time manual implements, animal-powered cultivation and motorized machinery, in varying proportions according to the respective importance of each type of mechanization existing in the countries, or being introduced.

- hand-implements.

Hand-tools and implements can already bring a considerable improvement to the farmer's productivity. The double interest they present is that they do not require major modifications to his activities, nor expense far out of proportion to his means.

The range of traditional tools (locally-made or imported) is very wide, and allows the farmer to solve, one way or another, nearly all the problems of clearing land, cultivation and harvesting with which he is faced. Research remains to be done on the size and shape of the most suitable working parts for the work they provide the farmer, as well as the size and shape of the handles or shafts providing the least laborious working positions.

Other hand-implements are for sowing, tilling and protecting crops, as well as for harvesting and processing. Some orientation for research to be undertaken is:

1) for sowing-planting: development of small sowing machines which are sufficiently multi-purpose—transplanting rice, for example.
2) for crop protection (the principal problem, taking into account the losses due to numerous parasites of growing and harvested crops): adaptation of simple implements to the level of the users, holding and correctly dispensing the minimum of liquid carrier, study of the resistance of plastic parts to the products, to the climate, etc.
3) for the harvest: study of the work-area using sickles, scythes, for rice harvesting.
4) for the processing and storage of products: development of mills for millet, small "economical" silos for replacing traditional granaries, etc.

- animal traction power.

Animal traction, if it is not always a possible or desirable intermediate stage before the introduction of motorization, nevertheless presents a novel character in the countries to which it is introduced, and

many advantages. The development of its rational use requires numerous studies and research, among which may be mentioned, beyond the improvement of the draught animal:

- the creation of types of harness adapted to the build of the animals, and possibilities of local manufacture;
- determination of the power of the teams, since the choice of adapted implements (studies should always precede the introduction of the properly so-called implements) depends, to a very large extent, on the tractive effort available;
- research in the variety of available implements (either simple or multi-purpose) on those which best correspond to the main criteria (lightness, robustness, simplicity, low cost) facilitating their general use and, in a very general plan, study of the shape of working parts requiring the least tractive effort, experimentation with a view to reducing the number of tilling operations; adaptation of simple mowing-machines, of multi-purpose sowing-machines (dry and wet, on the flat and on ridges), traction implements for asses, peanut diggers for hard ground (baiboho) etc.

The resolution of the problems involved requires extensive research, testing and experimentation. In fact this category of "research" does not interest specialized workers in countries with developed agriculture and very little basic information exists: to all intents and purposes everything must be done and the field is extremely vast.

- motorized cultivation.

There is much information available in research centers studying the various problems of motorized cultivation. However a great deal of "adaptive" work remains to be done, which does not require special trials, to extrapolate the known results to the particular conditions of tropical countries.

Concerning <u>means of traction</u>, according to whether small or large-scale farming is involved, it is appropriate to find the most simple machinery (but which gives satisfaction all the same) for the farmer, and relatively complex machinery, with the principal improvements available on the market, for the second. This involves research on small adapted motorized implements, to powerful and improved tractors, via the "simplified" tractor of low power on intermediate farms or small-scale operators.

For the <u>accompanying equipment</u>, research must be carried out among the array of existing implements, beginning with those of general use and seeking adaptations to suit them to the tropical conditions. Then those of specific use for local crops, and there numerous adaptations are possible. Often the particular problems lead to a study of prototypes. As examples, we can cite the "distributors" of straw for crops grown under mulch, sprayers capable of reaching the foliage of high trees, a microapplicator for distributing fertilizer, localizing it in

the heart of plants for the industrial cultivation of pineapples, equipment to till cover crops in tree-crop plantations.

The harvesting of some tropical crops is far from being done mechanically, and leaves the way open for numerous research projects, even for sugar-cane and rice, without mentioning tree-crops such as coffee, cassava, sweet-potato...

The treatment and processing of products, whether for export or local consumption, also presents problems, among which may be mentioned the adaptation of tropical fruit graders, the design of equipment for processing cocoa or small portable rice-hullers and pearl millet threshers, etc.. As regards the storage of harvests, in some tropical hot and humid zones, apart from parasites, the results of numerous trials carried out in temperate conditions should be verified locally with the different products.

c) Economic studies

Research on agricultural machinery necessarily includes the study of economic aspects of their utilization and entails the necessary syntheses for the understanding of the agricultural situation.

These economic studies must enable a determination to be made of whether a machine, corresponding to the technical and agricultural "ideal", can be recommended to the farmer without its introduction into the system having disastrous economic consequences for him or for the country itself. In the developing countries, development is always affected by these problems of equipment.

- at the farmers level.

Each time a new item is to be introduced into the farming system or replacing an old one, the economic consequences must be foreseen. In fact this new equipment always replaces either:

1) a certain amount of animal traction
2) some hours working of less improved equipment
3) human effort, for wages or not, human effort and animal power, etc.

The factors involved must not be neglected, nor the possible consequences. These, in particularly extreme cases, could lead to a reorganization of the farming system, and to a modification of its extent of intensification.

It is appropriate then to study if this does not lead to an increase in costs (compared to the previous working costs of labor, animals or machinery) or if the costs would be greater, if the equipment provides sufficiently profitable increased production giving a better return than before.

Other aspects must not be neglected, for a probable result does not mean that the proposed operation is automatically possible. For example:

- the available financial resources of the farmer or his credit possibilities;
- the capacity of the farmer to adapt to the new working conditions created.

Conversely, the psychological outlook of the user of the new equipment must be taken into consideration. This could lead the farmer into acquiring it, even if its profitability is only just probable.

- for the country.

In the developing countries, the more or less general introduction of agricultural machinery involves expense which most frequently falls on the state (often external aid). Individual acquisition of this equipment is practically never within reach of the modest resources of the farmers.

Public authorities, which fund the provision of equipment in the farming systems or which provide the money, want the equipment to correspond to the real needs of the farmers, but also want to know the way in which the agreed financing will be the most profitable risk. In other words, it is necessary to indicate to them an order of priority, which itself affects the crops (developed with the help of the equipment) or the most favorable zones (because of the receptivity of the population, the ease of the work, of the infrastructure, etc.) and the probable consequences of the choice which can be made for the general economy of the country.

To contribute to uniting these elements the scientists of the specialized research organizations are led to carry out studies of the profitability both at the level of the farm and of the state itself.

d) Extension

A research project is not ended when the results are published and it opens the way to extension, there as elsewhere. If extension is not within the competence of the research organization, they must foresee the methods and requirements of extension, after having established the data to recommend. Furthermore, in many cases, they must also make up for certain deficiencies of the extension services.

It is their duty:

- to prepare and put at the disposal of the extension advisors special texts and materials; technical works for the advisors themselves, simplest pamphlets for the farmers, diverse teaching materials (wall-charts, slides, films, etc); basic educational documents.

- to train extension agents initially and through refresher courses selecting those who are specializing in agricultural mechanization.

The completion of these tasks cannot be improvised. The most simple pamphlets, for example, are often the most difficult to prepare. They cannot be done well except by specialized personnel.

CONCLUSION

In the countries of which we have spoken economic development must be assured, at least today, by an improvement in all the aspects of agricultural production. These factors are agronomic: selection, use of fertilizers, crop protection, cultivation methods..., and mechanical: use of machines to work better, more quickly, less laboriously.

Agricultural mechanization contributes to other agricultural progress and "liberates" man. His particular lot of "man of the earth" with the living conditions this implies—discomfort, laborious work, risky and often deceptive income—merits all that can be done to improve the conditions and make them approach those of other categories of worker.

We feel the priority objective is to make known the need to study the problems of mechanization of agriculture as the other different disciplines of agronomy or animal production have been studied. When this initial step has been generally accepted, we will be nearer making suitable working methods available to the farmer, enabling him to gain higher profits from his labor, with less hardship, opening the way for general prosperity. "Research" in agricultural mechanization can contribute, to a modest extent, to a real promotion of the African farmer.

This research is vast and presents many aspects. Its final objective is the use of equipment designed by specialists, which is why the first trials had always been carried out everywhere without the involvement of the specialized research institutes. Today, these organizations have been established to formulate critical appraisals and provide the objective advice required by the representatives of the three "parties" interested in the development of mechanized tropical agriculture. We have tried to show how the present situation has been achieved little by little.

However the creation of these organizations implies that qualified personnel and financial means are available. Funds are difficult to find, even if the governments recognize the need; there are never enough trained technicians.

Some of the countries have the advantage of grouping together to create a multinational organization, covering the same ecological zones. Being aware of the importance of studies on agricultural mechanization, the French Secretariat of State for Foreign Affairs responsible for cooperation contributes, in many ways, to work of this type in many African countries. It participates in the initial funding of the

specialized organizations, or places at the disposal of countries requesting it, the means to fund CEEMAT's activities, or it may even provide both.

The research areas for these organizations, both in existance and to be created, are numerous. Only a cursory view has been able to be given because of the specificity of the problems. The research topics, in the broadest sense, have already been carried out in some countries and the results put into practice, with profit, in the agricultural sector.

However, these results acquired can be used by others; it is therefore necessary that their centralization, their synthesis and dissemination be better assured in future.

Moreover the acquired results are only provisional. There are always requirements for new research, either because of the appearance of new cultivation techniques, or the proliferation of new implements, or because of the priority established in a development plan.

The task is thus difficult, critical work is indispensible; but is essential; are these not the two greatest stimulants for the research worker?

FARMING SYSTEMS IN AFRICA - MECHANIZATION OF AGRICULTURE

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SUMMARY

The factors responsible for success or failure of mechanization schemes are becoming well known, but a case continues to exist for further analysis and dissemination of information on the topic.

Technical progress has been encouraging at all levels of mechanization but many techniques and equipment need to be evaluated in the environment in which it is to be applied, calling for a simultaneous extension program in farming in general.

Opportunities for all levels of mechanization exist in virtually every country of Africa, but the less spectacular forms are often neglected in favor of the more spectacular, notably tractor mechanization.

Priorities suggested are: the establishment of an African centre for mechanization, investigations on ergonomics of land cultivations and aspects of labor intensive and fully mechanized harvesting and post harvesting processes, as well as mechanical additions to relieve the drudgeries of rural communities.

INTRODUCTION

The very considerable share of agricultural development funds that has been allocated in the last two decades to mechanization of African agriculture, reflects the high hopes placed by governments on this aspect, to accelerate the much needed agricultural revolution. At the same time, few mechanization schemes have fulfilled this promise, and although the factors limiting success are becoming known, there is a continuing need for further analysis and dissemination of information on the topic.

A recent I.B.R.D. report (1) has stressed this and is clearly illustrated by a resolution passed by the 5th meeting of the East African Specialist Committee on Agricultural Machinery (2).

> "Noting that the introduction of mechanization in East African agriculture and elsewhere in Africa has met with both success and failure, with as much as a tenfold variation in operational cost, the Committee recommends that the data on factors influencing both success and failure should be collected and analysed to form the basis for future mechanization schemes."

In the discussion preceeding the resolution, it was evident that the more overrriding factors were well known to the members of the Committee (most of whom had been engaged in African mechanization for some 20 years or more):

> "Mechanization should only be introduced where really feasible, notably where there is a tendency to business farming - where farmers have developed management standards and are able to cash in on what mechanization can offer. For large scale development to be successful and lasting, it must be closely controlled operationally, administratively and financially by a comprehensive development plan which has been logically built up through the skilled interpretation of scientific survey in all the disciplines involved. Tractors and machinery can be used effectively and economically in clearly defined production schemes where the operations are integrated into a controlled development plan. When, however, tractors and machinery are released in large

> numbers to work for an unknown number of farmers, on an unknown acreage of land of unassessed potential, the operation is in danger of becoming uneconomic. This kind of operation is not mechanization of agriculture but should be clearly recognized as a subsidized and doubtful service to peasant farmers."

> "The Masai wheat scheme has made money this year as a result of working to the available funds."

On purely technical matters, a further resolution by the East African Committee is of particular interest:

> "The Committee considers that adequate advances have been made in all aspects and levels of animal use and equipment and considers further that unless suitable priority be given to this subject, there would be little point in continuing research into the subject and therefore strongly recommends that a concentrated effort on extension, education and training be initiated by governments in this form of mechanization, in areas where it is feasible."

Similar views were expressed by the Committee on a number of other items of equipment and techniques. Stress was thus laid on the need of a simultaneous extension program to enable new equipment to be tried and evaluated in the "environment and conditions in which it is to be applied." (3). At the same time, a scheme was initiated for the standardization of recordings in order to facilitate subsequent evaluation and comparison.

It would seem clear that mechanization should not be considered in isolation, and its integration with "farming systems" in the current conference is therefore the more welcome.

The position in regard to large-scale mechanization:-

The outstanding examples of successful schemes are worthy of mention, as they highlight some of the underlying factors contributing to success.

The mechanized production of wheat in the highlands of Kenya and Tanzania are amongst the most successful. There is little doubt that the success of these ventures can largely be attributed to the fact that the crop lends itself to complete mechanization and no major bottlenecks exist in the mechanized production process. Also, the ready market for the crop and the perhaps, resultant, business mindedness of the farmers involved, must be major contributing factors to success.

Interestingly enough, whilst wheat production in these areas had initially been confined to individual farms, "able to raise the $4000 to $5000 outlay on equipment (1), the successful mechanized production

of wheat is now also extending to groups of smaller farmers, as illustrated earlier in the reference to the Masai wheat scheme.

One is led to believe that, providing conditions are right, tractor mechanization will succeed, whether operated privately by farmers on their own farms, or on a contract basis. This is further demonstrated by the varying degrees of success of the private African tractor contractor scheme in the Sudan Gezira, the Mweya-Tebera irrigation rice scheme in Kenya, the rainland sorghum production in the Sudan, and, to some extent, mechanized cotton production in Sukumaland of Tanzania.

The success of these schemes appears to be directly related to the amount of planning that has preceeded their introduction, and the provision of repair services and technical advice to the contractors. In all cases too, the crops involved are readily marketable and usually high priced. This latter factor does not always by itself make for success, as demonstrated by the relative failure of schemes involving identical crops in Sierra Leone, Mali, Nigeria and elsewhere.

In other words, it appears that if one link in the chain of requirements is defective, the whole scheme is in danger of being a failure and suggests the case for a pilot phase even when most of the major problems appear to be easily surmountable.

Past experience would seem to suggest too that government-run contract hire services are likely to show a loss primarily because of the inherently high overheads associated with government-run ventures. However, the operation of such a service may be justified initially for the purpose of stimulating interest, and testing beforehand the economic viability of a proposed program.

Technical progress has been largely due to the general improvement in the quality of agricultural equipment as compared to that of 20 years ago, the increasing attention being paid by manufacturers to the special requirements of the tropics, and finally the small but steady research work being undertaken in Africa itself.

Considerable attention has been given to, and progress had been made in, tillage equipment and techniques (4, 5), as this aspect appears, at first sight, to be the initial bottleneck. Experience has shown though, that the elimination of some bottleneck often results in the development of another. Harvesting and post-harvesting processes appear in many areas to be just such bottlenecks, and although some work in this field is being undertaken (6), it is believed that far greater resources and effort could, with advantage, be allocated for this purpose.

Mechanical aid for the small farmer:-

Many examples exist of attempts to bring the benefits of large scale mechanization to the small farmer, notably in the form of group farms, block farms or tractor hire services. There is an increasing realization though, that many opportunities exist for expending the efficiency of the small farmer by the introduction of simple mechanica additions and that it is often neglected in countries where tractor mechanization make overwhelming demands on resources.

However, progress is being made in the study of the argonomics of ahnd cultivations (7). This could obviously result in the development of improved hand tools and techniques, apart from enabling a more precise assessment to be made of the limitations of hand power in agricultural production.

Even more spectacular has been the progress in the development of ox equipment and techniques, ranging from improved ox handling an management techniques, to quite outstanding achievements in the development of ox toolbars and toolframes.

The development of spraying and dusting equipment expecially for use in Africa, has been exceptional (9) although the achievements in this regard are, unfortunately, not universally known.

The provision of a small tractor, more closely matched to the predominant size of holding of African farmess, has been studied for many years (10). One promising line being pursued at present is the possibility of assembling a small tractor on the spot, using imported mass produced components augmented by locally available materials. (12)

For the small farm, as is the case in more extensive production systems, the most serious gaps seem to exist in harvesting and post harvesting operations and the provision of aids in water supplies. Whilst some work is being carried out in this respect, there is clearly a case for intensification of these efforts.

The promise of many available aids for small farmers are, an all too many cases, nullified when communities are pegged down by the subsistence complex. Real progress can ultimately only be attained after the conversion of rural communities through extension, to a more enlightened outlook, as exemplified by the rural development project at Borgo a Mozzano in Italy (11).

One is inclined to the view that the first phase of development would be best achieved through community development efforts, with an advocation of the simplest of new practices and methods. Little room exists at this early stage for direct agriculturist-farmer contact, which should follow in a subsequent phase.

Conclusions and recommendations: -

A study of the experiences in agricultural mechanization in Africa suggests that a mass of information is available on all aspects and factors which make for its success or failure. The greatest single weakness appears to be that this information has not as yet been thoroughly analysed, nor made readily available to all countries.

The considerable contribution to East Africa of its agricultural machinery co-ordinating committee, through discussion, analysis, and pinpointing of research priorities would support the idea (1) of creating a multi-disciplinary, co-ordination center to serve the whole of Africa.

The great diversity of conditions in all African countries, whereby virtually any form and level of mechanization can find application, would suggest the simultaneous exploitation of all these possibilities not allowing one form (usually tractor mechanization), to be carried out at the cost of all others.

In many instances technical developments appear to have reached a stage where they cannot make further useful progress without being put to the test in the environment for which they have been designed. This is currently the case with ox cultivation, and the need for an intensified extension program aimed at improvement in farming standards, combined with the introduction of improved techniques, is evident.

Whilst the priorities for future technical research depend largely on the dissemination of existing information and the intensification of community development and extension programs, some fairly obvious research gaps nevertheless can be indicated.

In the first instance, the study of all aspects of labour intensive and fully mechanized harvesting and post harvesting operations, including crop preservation, need to be intensified. There seems, too, to be a case for the intensification of work in agronomics of hand cultivations, as a basis for the design of improved hand equipment, and for the more accurate assessment of the limits imposed by hand power, in agricultural production.

Finally, the study of equipment for relieving the drudgeries of rural communities, for the provision of water supplies, transport and food grinding, to encourage and stimulate rural development, appears to be justified.

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DEVELOPMENT OF AFRICAN INSTITUTIONS OF AGRICULTURAL EDUCATION AND TRAINING IN RELATION TO URGENT PRIORITY NEEDS IN AGRICULTURAL RESEARCH

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SUMMARY

Agricultural development in African countries is in need of sustained support by a well planned program of basic and applied research. Many research organizations and institutions are facing the greatest difficulties owing to shortage of trained local staff and the frequent changes of expatriate staff. Owing to the late development of faculties of agriculture and their own staffing problems, there are very few organized graduate programs where future research workers, university teachers and other high-level professional staff can be trained. University faculties need themselves to engage in active research programs if they are to function properly. The major constraints to the expansion of agricultural research and graduate studies at the universities are the shortage of professional manpower, finance and facilities. The question examined is whether by better national planning and the development of agricultural education, research and advisory services as a well integrated structure these constraints can be overcome and more effective service rendered to agricultural development.

It is the belief of the author of this paper that very great improvement of the present situation is possible. An effective national council for agricultural research, with adequate representation of the university and all other major interests involved could do a great deal to evolve national agricultural research policies and to effect an equitable distribution of research responsibilities between research institutions, university faculties, and other agencies involved. A considerable strengthening of research effort would stem from the development of graduate courses and research based upon mature university faculties. This development would be the means of training many more local people for research careers. It would have a most stimulating effect upon undergraduate teaching and, indirectly, upon the teaching of agriculture at the intermediate level. The development of formal relationships between research institutions and university faculties would also confer mutual benefits and could result in better research and better teaching. Financial considerations alone make it imperative that there be some sharing in the development of graduate studies between different universities with faculties of agriculture developing specializations in accordance with their facilities, the environment in which they are situated and the support they can attract. This paper calls for study, discussion, and systematic planning to achieve an ordered development both of agricultural research and agricultural education neither of which can thrive or serve national needs in isolation.

INTRODUCTION

It is now widely accepted that rapid and sustained development of the agricultural wealth of many African Countries is the most important single factor in their economic and social progress. In these circumstances agricultural research and experiment, which provide the basic information essential to agricultural change and the development of new and improved techniques, must also be accorded a high priority in national development plans. In order to meet its great responsibilities adequately agricultural research in most African countries needs strengthening enormously in terms of professional staff, facilities, equipment and financial support. It could be claimed, with equal justification, that agricultural education and training (using these terms in their broadest meaning*) are quite basic to agricultural progress and have very similar needs to enable them to play their full and proper part in national development. At a time when highly trained professional staff, facilities and finance are in very short supply agricultural research and agricultural education not only compete with other important interests such as health, education and national security but, what is more serious, they may, in fact, be competing with each other.

The principal purpose of this paper is therefore to discuss the organization of agricultural education, research and advisory services and to consider practicable ways by which they could develop more effective working relationships and make the most use of scarce reso[illegible]s in giving good service to agricultural development. At the outset it should be emphasized that no perfect organizational blueprint of universal application exists and it is very naive to suppose that arrangements which have given satisfactory results in one country or part of the world will necessarily suit the conditions and needs of other countries. Every country - and this applies with force to many newly independent natior. - wishes, and indeed has the right, to develop its own systems in the manner it considers most appropriate in meeting its national needs and priorities. Thus this paper will endeavor to confine itself to an examination of principles and their practical application under widely varied circumstances.

Historical Legacies - African countries have inherited many of the concepts and systems of education, research and agricultural administration of the metropolitan powers which originally sponsored them. More recently, they have been influenced through the acceptance of offers of bi-lateral aid. Thus examples of many different patterns of education and research and many different approaches to agricultural organization and development are to be seen in African today. It would be correct to describe this situation as

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* The term Agricultural Education is here taken to include technical education and training in Agriculture, Forestry, Fisheries, Animal Health and all these subjects directly connected with the development of food and agriculture.

transitional in which new nations are experimenting in ways and means of modifying their educational systems, their organization of agricultural research and services towards the goal of establishing systems based upon their own conditions, needs and circumstances. It is also relevant to observe that the development of general education, which provides the essential foundations for professional and technical education and training, has been introduced and developed in very different ways and at different rates in various African countries. Thus, at the present time, some African countries are relatively well-off as regards skilled manpower at the professional and technical levels while others are still greatly dependent upon expatriates in research and teaching. Between African countries themselves there is considerable disparity in the rates of development of general and technical education and in the extent to which they are able to supply their national requirements of professional manpower. This situation lends special significance to the importance of African universities and institutions of higher technical education opening their doors to students from other African countries where specialized education and training facilities do not exist.

In considering the relationships of agricultural education, research and the advisory services it is also relevant to bear in mind certain legacies of the past. In the development both of research and the agricultural services of many African countries, professional and technical staff were supplied principally from the countries of Western Europe having received their education and professional training in the schoools, technical colleges and universities of European countries. Thus the main training need in former times within the African countries was to produce technical assistants to fill the middle and lower cadres of the agricultural services. This meant that very limited attention was devoted to the planning and development of agricultural education and training in order to meet national needs for trained manpower, at all levels, until after the Second World War... Thus at a time when regional and national research institutions were well established and field advisory services were operating on a considerable scale, university faculties of agriculture in Africa were still in their infancy or had not yet been established. The table below shows the output of university graduates in agriculture 1958-1967 in the universities of the F.A.O. Africa Region.

TABLE

SHOWING OUTPUT OF GRADUATES 1958-1968 FROM INSTITUTIONS OF HIGHER AGRICULTURAL EDUCATION IN COUNTRIES OF THE F.A.O. AFRICA REGION *

Country or University	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967
ALGERIA	-	-	-	-	-	-	7	19	54	20
CAMEROON	-	-	-	-	-	-	-	5	10	13
CONGO (Kinshasa)	-	-	-	-	2	4	1	-	8	-
EAST AFRICA	-	-	-	9	12	11	13	17	17	21
ETHIOPIA	17	24	23	43	31	36	52	**	58	49
GHANA Legon	9	7	13	11	12	23	6	8	8	5
Kumasi	-	-	-	-	-	-	-	19	4	21
LIBERIA	-	-	-	-	-	4	4	4	2	8
MOROCCO	3	6	9	15	21	10	20	21	18	22
NIGERIA Ibadan	9	10	11	7	20	24	22	25	35	32
Ahmadu Bello	-	-	-	-		-	-	6	4	10
Ife	-	-	-	-		-	-	7	12	6
Nsukka	-	-	-	-		-	-	43	18	-
TUNISIA	7	8	10	9	11	21	25	35	-	41
TOTAL	45	55	66	94	109	133	150	209	248	248

* Excluding South Africa and Rhodesia. The Table also excludes Libya, Sudan and the United Arab Republic which are included in F.A.O.'s Near East Region.

** From 1965 all graduates were required to undertake one year's "university service" before receiving their awards.

One result of the piece-meal development of these three major components of agricultural improvement is that they tended to grow up in relative isolation one from the other. Agricultural education, a very late-comer in the field was, for a very long time, hard put to it to obtain the support its importance deserved in terms of staff, facilities and adequate finance. In 1950 the Makerere Faculty of Agriculture (originally started in 1936) which had been set up to serve the professional training needs of Kenya, Uganda, Tanzania and Zanzibar, had one-full time teacher supported by part-time lecturing by staff on the research and experiment stations of the Uganda Department of Agriculture. It had no facilities of its own and the total number of students from the 4 countries was 7. At this same time there were very well developed regional and national research institutions and experiment stations as well as fully staffed agricultural services. Not only was it well nigh impossible to attract suitable teaching staff to serve in institutions of agricultural education but it was equally difficult to receuit promising students to agriculture which, in those days, was not a popular subject amongst preliminary science students at Makerere.

For these and other reasons agricultural education has only within the past ten years or so come into its own as a profession in Africa. Only recently has it been given the more adequate support from governments which its vital importance justifies. Only now are some faculties of agriculture beginning to engage in programs of research and are able to contemplate the development of graduate studies.* National universities have also gained greatly in maturity and esteem and are attracting to their service many of the most able persons who have had the opportunity of advanced university studies abroad. Thus a situation has now arisen in a number of countries where universities are coming into a position where they can make important contributions in research related to national development needs and it is highly appropriate that their relationships with other institutions and organizations concerned in national research be examined.

Interdependence and Relationships of Agricultural Research, Education, and Extension Services. The ultimate objective, as well as the financial justification for agricultural research, education and training, and the work of the agricultural services lies in the development of national agricultural resources and the improvement of agricultural production. These aims are simple to state but complex in execution. They involve many social, economic, and political implications in addition to the technical problems they pose. The three major components of agricultural improvement, already stated, involve, in many cases, different government ministries and organizations for their administration and financial support. In a situation where it is essential that these three components work in the closest harmony in the national interest, there are forces and circumstances which tend to separate them. In what respects are they dependent upon one another and how may a situation which is at present not always satisfactory be resolved by better planning and organization in the future?

* Described in some countries as 'postgraduate studies.'

Teaching of the science and practice of agriculture, at university and intermediate levels, is directly dependent upon scientific research. Teachers, especially those at the university level, need themselves to be actively engaged in research and closely in touch with other research in their own fields of competence, if their teaching is to be up-to-date and inspiring to students. In many disciplines, but especially in the economic and social sciences, much of the essential material for teaching has to be obtained as the result of local agricultural research related to the problems of climate, soil fertility, crop and animal production and health, as well as the study of agricultural systems, and the social and economic background of rural societies and their reaction to change and innovation. Much teaching today in developing countries is inevitably based upon research and textbooks developed under totally different circumstances and conditions having little, if any, relevance to the local problems of agricultural development. There is also much criticism by those who employ university graduates and technicians coming from local institutions that their teaching has not adequately prepared them for the kind of responsibilities and skilled technical tasks which they are required to undertake. There is, therefore, an unanswerable case for an expansion of local research in which educational institutions take a share and from which the whole inspiration of good agricultural teaching is derived.

From the viewpoint of research services, whether national or regional, their dependence upon universities and technical training institutions is very great indeed. In the first place, it is at the university where all research workers receive their basic education, as well as their more specialized post-graudate training, which fits them to embark upon a research career. Not only may they choose a research career as the result of working under an inspiring university teacher, who is himself engaged in important research, but the post-graudate seminars and group discussions organized by university departments can be a source of great stimulus to young graduates. Many universities also organize regular scientific symposia which are attended by local research workers as well as those from other countries. Thus, in various ways, universities and university faculties and departments often become the focal meeting place for agricultural scientists, economists and others, and in this way perform an important service to agricultural research.

The connection between agricultural teachers and the work of the field advisory or extension services is also a matter of practical importance. Students in university and intermediate level institutions of agricultural education are mostly being trained for professional and technical posts in agricultural research, administration, teaching, extension, and other duties It is therefore essential that their teachers are in close touch with what is going on in these services to agriculture. The more applied aspects of teaching need to be related to the actual problems of agriculture in the country. If young people are being trained for extension duties then they require a "laboratory" for their practical work and this can only be provided effectively through close collaboration with the local extension services. Furthermore, field staff of the extension services, often working

in isolated places and with limited technical support, are in need of regular in-service training courses. These, the agricultural faculties and training institutions are best able to give, provided they have adequate staff and facilities. Again, therefore, a convincing case can be presented for the development of close working relationships between teaching institutions and national agricultural extension and other services.

Expansion of Agricultural Research and the Development of Graduate Studies in University Faculties. - In many African countries faced by the urgent need to expand and intensify agricultural production there is justification for a greatly strengthened program of agricultural research. Likewise, in university faculties of agriculture, more especially those which have consolidated their undergraduate teaching and now wish to develop post-graduate studies, there is a real need to expand their research interests and activities. Unless they can do this they cannot offer essential training and experience to graduates destined for research careers. These will, as in the past, have to go to foreign countries for lengthy periods of post-graduate study in order to qualify for research appointments. While this movement between local and overseas universities has many valuable features, it does not always provide ideal or relevant training for a research career in a different environment and many of those who have been sent for such training have not returned to the job for which their training was intended to prepare them. In a number of African countries there is therefore an exceedingly strong case for the development of postgraduate training and research. Both the urgent need for expanded agricultural research as well as the need for development of postgraduate studies in national universities face formidable difficulties in terms of increased numbers of professional and technical staff, expanded facilities and equipment. Is it possible, through better coordination and a more rational sharing of responsibilities to achieve both these urgent needs together - expansion of agricultural research and development of graduate studies - at African universities?

National and Regional Councils for Agricultural Research. - The fact that there are often several different interests and agencies involved in agricultural research in African countries would seem to suggest the desirability of setting up of national or regional councils for the purpose of coordination of effort, the allocation of priorities and possibly the financing of specific projects. University interests in agricultural research would need to be adequately represented on such councils. It is to be hoped that through the operation of a national or regional body a reasonable division of responsibilities for research projects might be achieved and in this way the university research potential might be recognized and integrated within the over-all program of research. There are certain fields of research, more particularly in the economic and social sciences, in which non-government organizations such as university faculties may be in a better position to obtain accurate data than government institutions. Universities, too, with strong faculties of science, engineering and other disciplines closely associated with faculties of agriculture may also be favorably placed to undertake responsibility for specific research projects within the context of the national agricultural research programs.

The establishment of national or regional councils for agricultural research could be one practical step towards making the maximum use of available local resources in resolving the urgent problems of agricultural development.

Relationships of Agricultural Research Institutions with Faculties of Agriculture. - There is a need for the development of much closer and more effective links between research institutions and university faculties of agriculture (and, indeed, between experiment stations and plant and livestock improvement centers and intermediate agricultural training institutions). Cases exist where, by government decision, all agricultural research has been made the responsibility of the university. An example of this is in Northern Nigeria where the Ahmadu Bello University at Zaria has, for several years, been in charge of the Institute of Agricultural Research and its various outlying stations. Research policy and programs are worked out in full consultation with the Ministry of Agriculture. Elsewhere, research institutions continue to be the responsibility of ministries of agriculture or the bodies under which they were developed and by which they are now financed. In nearly all cases there would be very great mutual advantages to be gained through their closer association with university faculties. In East Africa, for example, the regulations of the University permit of the registration for higher degrees through research, of graduates working at research or teaching institutions, without insistence upon lengthy periods of university residence. This in itself is an encouragement to young people to develop their individual research interests under university supervision, for recognized higher qualifications. It is also possible to place post-graduate students at these research institutions under the supervision of senior research workers to carry out their research projects and thesis preparation. In certain instances research institutions have entered into formal relationship with the university faculty associated with their field work. For example, the Namulonge Cotton Research Station in Uganda now has a formal relationship with the Makerere Faculty of Agriculture, and the Fisheries Research Institute at Jinju, (Uganda) with the Department of Zoology in the Faculty of Science at Makerere. Under these formal relationships research staff contribute short courses of lectures on their specialized subjects and are accorded academic status by the university. Likewise, post-graduate students do the practical work for their research projects at these institutes in appropriate circumstances. Such relationships not only make excellent use of available professional manpower both in teaching and research but they also give a considerable stimulus to research effort and encourage wider discussion of research topics.

It follows from what has been said that even without radical change in the present organization of agricultural teaching and research, measures can be taken which result in far better working relationships between research institutions and university faculties. In the design of facilities, both at universities and research institutes, provision should always be made for the accommodation of visiting scientists and post-graduate students, for outside lectures and meetings, and for suitable laboratory accommodation for post-graduate research students.

Graduate Studies and Research in University Faculties of Agriculture. - The expansion of faculties of agriculture into post-graduate teaching and research is essential to their survival as university institutions. Without the stimulus of active research undergraduate teaching becomes monotonous and dull. Post-graduate graduate teaching and research not only make it possible for a faculty with limited teaching staff to expand its research effort but it also provides an excellent training ground for both future research workers and university teachers. Graduate students can also render invaluable help as part-time demonstrators in the large undergraduate laboratory classes where assistance to hard-pressed university teachers is so difficult to obtain. Furthermore, they can also be used to great advantage in a wide variety of field studies involving the collection of data at regular intervals, farm management studies on peasant holdings, and other investigations often requiring the use of local dialects. There is a very strong argument, in many instances, for graduate training of future research workers within the broad environment in which they will eventually work.

A strong case already exists for the development of post-graduate studies in the more advanced university faculties of agriculture in Africa. Their principal purpose would be to provide advanced training for future research workers, agricultural specialists of many kinds, teachers of agricultural subjects, and others. In addition, the development of post-graduate studies is the principal and least expensive means by which faculties of agriculture can expand their research activities. The major problem is finance, since these developments imply more staff, accommodation, facilities and equipment. This presents an important challenge not only to governments and universities but also to sources of external support. If worthwhile results are to be achieved planning, regional consultation, and a rational distribution of post-graduate studies and research are called for. It will have to be recognized and agreed that all faculties of agriculture cannot expand into post-graduate studies in all the fields they would wish and there will have to be regional specializations, at least in the earlier stages of development.

What is proposed is that strong post-graduate schools, specializing in fields appropriate to the environment in which they are situated and in relation to the support they can expect from other faculties of the university and local research institutes, should be developed at selected faculties of agriculture. These would offer courses and research facilities within their specialization to post-graduate students from other African universities and vice versa. Thus it would be anticipated that different but complementary specializations would be developed in the universities of North Africa, the West African forest belt, the highlands of East Africa, and the great forest areas of Central Africa. In some regions the development of livestock is predominant, in others arable farming and mechanization assume special importance, in yet others horticulture and perennial tree crops offer great scope for specialization. Such a concept as this would fit in well to the development of research specialization on a regional and ecological basis. The development of focal points of active post-graduate studies and research based upon selected faculties of agriculture and with graduate students coming from a number of different African countries would provide an immense

stimulus to the expansion of research and the training of African research workers within their own environment working upon problems of immediate practical concern.

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THE DEVELOPMENT OF AGRICULTURAL RESEARCH AND EDUCATION*

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SUMMARY

SECTION 1. THE DEVELOPMENT OF AGRICULTURAL RESEARCH

(i) How and by whom are research priorities decided? The object of agricultural research is to modify the factors which limit yield, profit, and area cultivated. These factors are not solely technical or economic; they include historical, institutional, educational and other social factors. The greater part of the research programme must be aimed at specific practical goals, but speculative research to develop particular areas is also needed. Priorities should be tested by comparative cost-benefit analyses; preconceived, imported or 'theoretical' ideas about priorities are dangerous. The responsible body must be competent, authoritative, stable and continuing, and may often work best if it is partly autonomous. It must have the financial strength to influence the course of agricultural and applied biological research in the country generally.

(ii) Doing the research. Though many countries still have to import research skills and experience, they must aim to provide a competent indigenous cadre as soon as possible. First training should be at home institutions, followed in suitable cases by advanced training elsewhere, but care must be taken not to check indigenous academic research by sending the best graduates abroad. When they go abroad, their training must be adapted to the needs of their own country, and when they come back, they should be able to enter stable and continuing research organizations in which they can develop further. Research must be organized by consultation and agreement so that individual initiatives can combine for common action; and it should be spread through a variety of institutions so as to draw on as wide a range of ability as possible.

(iii) Applying the results. Research not applied is wasted: research workers must ensure that their results are used. Direct contact between research and extension services is essential, and the latter should station research liaison officers at research centres. Commercial extension efforts should also cooperate. Research results must go to the teaching

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teaching institutions. Personal contacts and interchange between research, extension and teaching staffs are usually more effective and often cheaper than large periodic conferences.

SECTION 2. THE DEVELOPMENT OF EDUCATIONAL INSTITUTIONS

Agricultural education can be fully successful only when agriculture itself is advancing. It is important at five levels.

(i) Agriculture in schools. Science and civics courses in schools should explain the technical and policy problems of agriculture to all pupils; and rural schools should offer science-based courses, including field studies and experiments, on the principles of agriculture.

(ii) Intermediate training. Intermediate training is the largest sector of agricultural education in developing countries. Its object is to teach the scientific and economic bases of farm production (and not simply the methods of production), and its graduates must be able to understand and accept changes and help to introduce them.

(iii) University education and training. This produces the innovators, the formers of policy, the intellectual leaders in the community, and the teachers for other levels. Its scientific basis must be strong enough to enable students to understand why different ecological conditions require different systems of agricultural production. Unless it is large enough to contain the full range of related disciplines an agricultural faculty must not be isolated from other departments of a University. In research, academic freedom in a faculty of agriculture carries with it obligations to serve the industry, and to develop an international reputation at the same time.

(iv) Institutional training of farm people. Extension work can be powerfully aided at residential institutions which offer short courses teaching specific skills to farm men and women. The object is not merely to teach skills but to prove to these people, who are often illiterate, that they too can be trained.

(v) Agricultural extension and agricultural change. At all levels, agricultural education must include studies of the social and other non-technical factors which promote and oppose change in agriculture, and an introduction to methods of communication. Science and economics alone are not enough.

SECTION 3. THE RELATION BETWEEN RESEARCH AND EDUCATIONAL INSTITUTIONS

Since in most countries the main investments in both agricultural research and agricultural education are made by governments, the two sectors must be related to each other and to the needs of the country. There are many organizational ways of doing this: the central problem is to combine common organization with individual initiative. The most effective step is to bring the research and educational institutions together physically so that their staffs are associated.

SECTION 4. REGIONAL RESEARCH PROGRAMMES

(i) What is a region and what is 'regionalization'? If sovereign states are to collaborate usefully in agricultural research they must be reasonably near each other and share common problems. Forms of collaboration have ranged from 'supernational' research authorities with their

own laboratories, and established by political agreement, to cooperative schemes of a much less formal kind. The latter seem generally to be more successful in practice.

(ii) What sort of work can best be done regionally? Theoretically, regional laboratories and stations should be suitable for tackling common problems which no one of the countries in the region has the strength to tackle alone. This establishes the regional authority at a higher level of status than the national ones, and this soon comes to be resented. Regional organizations of a less formal sort are very valuable where natural phenomena or diseases extend across frontiers, and as points of discussion of mutual problems, and this can lead to the planned sharing of research responsibilities and results.

(iii) Who formulates and directs the regional programme? This must be done by the workers in the individual states, meeting together, and not laid down from above. The agreed programme is guided and its results collated by a relatively lightly staffed directorate which may be associated with certain central services (such as computing, information, mapping, publications).

(iv) Who pays? The bulk of the cost of collaboration must be borne by the cooperating states, but a neutral outside organization which provides some finance and some key staff members can greatly increase the stability of the scheme.

(v) Who does the work and where? The regional programme is carried out largely on the stations, in the laboratories and by nationals of the individual countries. The leaders of different sections of the programme should not work at a headquarters but at appropriate territorial stations. Younger staff members should work, at least for a time, in countries other than their own, but it is essential to build up the indigenous scientific strength of each country since otherwise the national services will not be able to support the regional one adequately or to give effect to its results. Similar considerations apply to educational institutions, particularly universities. Each nation requires an indigenous intellectual leadership; and provided it is able to maintain a university of the necessary size and quality, it should be encouraged to do so. Regional planning in education should be based so far as possible on agreement between strong or growing national institutions.

INTRODUCTION

The essential development problems of agricultural research and education are much the same in all countries, whether they have only recently started to evolve modern systems of agriculture, or whether they have already progressed some distance along the road towards the maximum utilization of the agricultural environment. How to solve them, however, is greatly affected by the particular circumstances of each country. There is no 'best' model, universally applicable to all countries.

This paper starts by treating research and education separately (section 1 and 2) and the links between them are treated in section 3. In section 4, I set out some views on regionalization of research programmes.

In this paper I am recording my own views and experiences, which are not necessarily those of the British Government, or of any of its ministries or agencies, or of the Faculty of Agriculture of the University of Reading.

SECTION 1. THE DEVELOPMENT OF AGRICULTURAL RESEARCH

The objects of agricultural research are to provide information which farmers can use to produce more output, and to make more profit, per unit area of land, and, where new land is available, to increase the area of land which is profitably farmed. The development of agricultural research presents three facets: (i) deciding what research to do (ii) doing it and (iii) ensuring that the results are applied.

(i) Deciding what research to do. Two questions arise here: (a) how the research priorities are decided, and (b) who decides them.

(a) How the research priorities are decided. The first task here is to decide what factors are limiting yields, profits and the area of land under cultivation. In all countries, yields are less than they could be for technical reasons (climate, soils, genetic potential of plants and animals, diseases, pests and weeds, agricultural methods) but in many they are limited also by economic, institutional and social factors which oppose change in agriculture. It is no good breeding a cotton which responds better to fertilizer, and so yields more than the present varieties, if the price is too low, the market too inefficient or corrupt, or the supply of consumer goods too small, too uninteresting or too costly to spur the farmer and his wife to the extra effort and expense needed to grow and harvest the new variety.

We all know about these non-technical limitations, but we have no clear understanding of how they work or even, in some cases, of how to detect them and measure objectively the constraints they impose on the farm enterprise. It is clear that they do not work in the same way in all countries. Why for instance, has the Rockefeller Program in the Agricultural Sciences been so outstandingly successful in Mexico, but less so in Colombia and Chile? Why has the agriculture of Kenya forged ahead so rapidly in recent years, while that of neighboring countries has not? Why are there still large areas of backward farming even in the so-called advanced countries? We do not know, and we must find out. In collaboration with the Rockefeller Foundation we are arranging an International Seminar, to be held at Reading in September 1968, on change in agriculture and the factors which promote and oppose it. At this Seminar agricultural and social scientists will be brought together to analyze past successes and failures in agricultural development, in the hope of producing mutual understanding and a series of guide-lines for the study of the relation of to social change.

Where necessary, therefore, agricultural research programmes must include research into these matters. Of them, only agricultural economics has hitherto been generally regarded as a legitimate part of agricultural research, which has been preponderantly based on the objective and quantitative natural sciences which got into the field first under such men as Davy, Lawes, Liebig and Pasteur. However as the social sciences come to grips with the real world, and learn how to define and measure quantitatively the concepts with which they deal, they must come into the party too.

Their results must also affect decisions about priorities in that part of the programme which is based on the natural sciences: they will indicate areas in which technical research is not likely to lead quickly to change, and others in which resistance to change is likely to be smaller.

I do not propose here to discuss technical limitations in detail, since that will have been done elsewhere in this Conference, but I do wish to suggest that preconceived ideas should always be rigorously tested, and that the special features of each country be taken into account. For example, in a recent exercise on agricultural research in Ethiopia, it became evident that the first need of all was to know more about the spatial distribution of climate, soils, and agricultural systems and potential—in other words, to conduct an agro-ecological survey. This proposal was criticised and indeed rejected, apparently because work of this sort was not important in the home country of the critic, who seemed to think that the mixture which had served to cure all agricultural ills there was a universal panacea, applicable without distinction to all times and places.

When the factors limiting yield, profit and area have been identified, and placed in order of priority, the next task is to decide how to attack them, and to estimate what the attack will cost and what it will yield. This is a management problem in comparative cost-benefit analysis, though it is of a somewhat novel type, since in many areas the benefits are enormously greater than the cost, if the results are effectively used. It may cost less than $250,000 to produce a new crop variety which will yield several million dollars worth of extra crop per year with little or no increase in production costs. We need to develop the techniques of management planning for agricultural research so that we can replace vague optimism by something more precise.

In all countries, including the most advanced, the main weight of agricultural research must be on projects which will yield direct and foreseeable benefits, or permit other research to realize such benefits. This sort of research has recently been described in Britain as 'mission-oriented'. In addition, it is usually desirable to stimulate a certain amount of research of a more 'speculative' kind in order to develop particular areas in which more knowledge and a greater number of trained and experienced people, are needed for agricultural purposes. (The overworked distinction between 'pure' or 'fundamental' and 'applied' research generally produces arguments about words rather than useful

results: a piece of thoroughly 'pure' work may often be deliberately undertaken in order to solve a specific practical problem, and an applied study, like Pasteur's work on fermentation, may well throw up results which have such general application that they are truly 'fundamental').

(b) Who is to decide the research priorities? Many people are interested in the research priorities—farmers, agricultural advisors and administrators, economists, politicians, scientists (academic and otherwise), business men. Many, though not all, of their interests are legitimate, and they are certainly all different. Some of them, like the farmers and the tax-man from the Ministry of Finance, want immediate results; some want research grants; some want particular benefits for their supporters or constituents; some want to go to international gatherings like this one; some want power and authority; some want opportunities for profitable investments; some may even want to fill empty stomachs and make farm people more prosperous. In this welter of interests, the most important elements are technical and scientific competence, and after them foresight and continuity. Like agriculture, agricultural research is a long-term business, aimed at continually-developing goals. It requires a professional cadre which takes a long time to build, and it requires long-term investments in buildings and land. The machinery for reaching decisions must therefore be preponderantly influenced by the staff of permanent organizations who can relate short-term tactical decisions to a background of stable long-term strategic policy, and who will still be around when the cows come home, so that they can if necessary answer for their mistakes as well as take credit for their successes. The ephemeral politician, the minister who may have to take up a new assignment at any time, or even the permanent civil servant who may move from one ministry to another at short notice, cannot be solely entrusted with decisions whose consequences will affect action thirty and more years hence.

In many countries (including Britain and the Sudan) agricultural research is not the responsibility of the Ministry of Agriculture. This is an extreme position, and it is moderated by the peculiarly British tradition in which informal consultation overcomes all sorts of seeming administrative absurdities. In Mexico a virtually autonomous Office of Special Studies, in which the Rockefeller Foundation provided continuity, directed the research programme. In other cases universities provide an important element of continuity and independent judgment. Evidently there are many different ways of doing the job. In every successful case, however, there is some sort of Council, Office or Advisory Board for agricultural research, in which all legitimate interests have a voice, which can take the long-term decisions, has the financial and organizational means to carry them through, and wins authority and respect, both nationally and internationally, by its works.

(ii) Doing the research. Two questions arise here: (a) who does the research and (b) how is it to be organized and tested?

(a) Who does the research? Research is done by people, and the first need here therefore is for trained and experienced men. In many countries, the domestic supply of trained men is not yet large enough

to meet all the needs, and it is necessary to import skill and experience from other countries. This leads to many difficulties, but they can be overcome provided the newcomers have been properly prepared both technically and morally for their work, and are led and directed so that they and their families not only adapt themselves to their new environment, but identify themselves positively with the aims and aspirations of the society in which they have come to live. They must also be prepared and able to stay there long enough to make a significant contribution. The man who comes for one or two years, to widen his experience, is seldom worth his cost. Even at the best, foreign skill and experience are extremely expensive and are becoming more so. It is essential to train local people and build up an indigenous professional cadre.

A locally born scientist must be appropriately qualified for his work, like any other. At present this often means that he attains his first degree in his home country (and to the content of those degrees I return below) and then goes abroad (preferably after a period of service at home) for research training. In principle, this is a good thing, and it should continue, for some graduates at least, so long as the home country is not itself a leading international centre of thought and action in agricultural science. This presents a problem for the local universities, since it means their best graduates leave them to go abroad instead of helping as graduate or postdoctoral students to build up indigenous research schools. There is no simple answer to this problem until the local universities have research schools strong enough to attract students from other countries to redress the balance. The brain-drain is no new phenomenon; even Leonardo da Vinci spent his last years in France; but the international agencies and foundations could well be encouraged to allocate funds in order to offset it, and the local universities should use the advantages of their special situations to develop research schools which are of international interest.

The man who goes to a more advanced country for graduate work runs another risk. He may be set to work on a highly specialized problem which has no obvious application in his home country. This trains his mind and teaches him method and technique, but it may well leave him isolated and dissatisfied when he returns home and finds that neither the funds nor the equipment are available to enable him to continue work in the only field in which he has experience and confidence. We who train students from such countries have a very heavy responsibility to select wisely the problems we set them, and their home authorities should ensure that the projects on which their young men are put to work are relevant to the needs of the country.

Even if this is done the new Ph.D. may well come back, his apprenticeship completed, into a research organization without any developed professional structure; he may indeed have to assume senior responsibilities himself very early in his career. This deprives him of a very important element in a young scientist's training—a period of successful and more or less independent work in an established real-life organization, in which he can develop his confidence and independent abilities within an existing and stable programme, guided by more

experienced colleagues. In this phase he learns how to choose priorities in his work and break down more complex problems into more manageable pieces, and so acquires the experience, judgment and scientific taste, as well as administrative experience, which will fit him to be a leader in his turn.

(b) How is the research to be organized? Good research is a highly individual business. It depends essentially on the ideas, drive, enthusiasm and initiative of individuals. Yet these individuals and their independent qualities have to be brought together to serve national ends in a common programme. This is the dilemma of all research organizations; the art is to combine individual initiative with common action without destroying either. There is only one way in which it can be done—by a grass roots system of consultation in which every man is encouraged to help as best he can to form the common programme, knows what his objects are and what his part in the effort is, and gets credit for his share in it. Not all directors, and not all less senior workers, are paragons, and the extreme individualist at either level may have to be told that his best contribution is more likely to be made elsewhere, but where communication is easy and responsibility is delegated, the two opposites rub along together well enough. The responsibility for communication and leadership is of course primarily on the senior man: he is paid to select and get on with his juniors and if instead he consistently quarrels with them it is he who must go. It is also his task to preserve continuity and stability by ensuring funds for the work and protecting his staff from capricious external pressures. Research must be organized on the basis of agreed annual programmes for which specific funds are provided; and once the programme is agreed no one must be allowed to rock the boat.

From the national point of view, there are advantages in dispersing research in several sorts of institutions ranging from the specialized government research station at one extreme to the nominally independent university department at the other, provided only that at all levels the work done represents value for money. Where the balance between state-controlled and more independent research lies in any one country will depend on the amount and distribution of scientific strength: there is no unique correct answer. The national programme must have sufficient strength, and that means sufficient money, to give a lead; and once that is assured there are very powerful arguments for drawing in, by means of research grants where necessary, all possible resources from the private and particularly the academic sectors. Specialist advisory committees which include competent senior non-official people may be invaluable.

To get the work started is not enough: there must be means for assessing the results and for stopping it if necessary. The specialist advisory committees can help in this. Particular institutions which are supported by Government should be visited and reported on at regular intervals by groups which include as many senior non-official scientists as possible. Each such institution should have its own board of governors to advise and support its director, and to help him and his staff to formulate their programmes of work. In these ways the national programme and the financial decisions through which it is implemented

come to rest on a broad basis of professional understanding and support.

Further comments on agricultural research in the universities appear below.

(iii) Ensuring that the results are applied. Agricultural research is for use, not for ostentation. If its results are not used, money is wasted. It is the duty of the national research organization, as well as of the individual research scientists, to see to it that the results are put to work. If a project has been correctly selected in the first place this should be easy, unless the industry, for the reasons set out above, is incapable of accepting change.

Usually, the official agricultural service includes an extension branch whose task it is to take the research results to the farmer. In individual states in the United States extension and some of the more applied and practical parts of the research program are both controlled by the state university; and thus certainly ensures that results are taken out to the farmer speedily, often by the research men who have produced them. In Britain we are at the opposite extreme: official research and extension are separate, and both are largely separate from the university system. Nevertheless it moves: numerous personal contacts and the sensible location of laboratories help us to bridge the gap. At many of the more applied research stations a member of the appropriate branch of the extension service is stationed to act as a liaison officer. The same method has been used in Northern Nigeria to link teaching and research in the university with the extension service outside it. These links work in both directions: they lead to a two-way traffic - problems and suggestions from field to research and specialist workers; results and guidance from research workers and specialists to the field. Research workers have a particularly important role in the refersher training of extension workers.

In many countries commercial firms provide even more guidance to farmers than do the offical services. Whenever this is so, it seems essential to find means of associating the commercial and the official effort more closely, particularly when the commercial firms is also actively engaged in research.

The results of research must also be carried to the educational institutions: this is dealt with below, In general, the large and formal periodic conference is less effective as a means of conveying research results to the extension and education services than frequent personal contacts at professional and technical levels.

SECTION 2. THE DEVELOPMENT OF EDUCATION INSTITUTIONS

Institutional education serves agriculture at four different levels- in the primary and secondary schools, in specialist post-teaching vocational training institutions, in universities, and in farmer training conters. Most of this education is provided or at least strongly

influenced by governments. A very great deal has been written about each of these levels. Here I seek only to define the philosophy and objects of education at each level, and to make some comments on the methods of instruction that follow from the philosophy. In general, agricultural education will succeed only as agriculture succeeds: careers in the industry or in the service of the industry will be attractive only if the industry is prosperous. If agriculture itself is not advancing, it is inevitable that agricultural students will have white-collar ambitions and hold practical work in contempt: the critic must ask himself whether he personally would wish to devote his life to the practical work of the industry, or to send his sons into it, and if not why not. An Iron Age technology cannot hope to attract lively youngsters who happen to have been born into the Space Age.

(i) Agriculture in the general school system. All citizens, and particularly those who grow up in towns, must be informed about the sources of their food and of biological raw materials, about the agriculture of their own country, and about the main problems of agricultural policy. To be so informed, they require a general background of information on biological, geographical and physical science subjects. Instruction in these subjects should therefore include agricultural examples from the earliest stages. In secondary schools in towns, applied and human biology and civics should carry this further. Country secondary schools should offer science-based courses in the principles of agriculture exemplified by observations, measurements and simple experiments in the laboratory and particularly in the field, on climate, soils and farm crops and animals. The school garden or farm should be an open-air laboratory for these studies, and not merely the scene of unpleasant labor calculated to reinforce any desire the students may already have to get as far away from the industry as they can.

(ii) Specialist post-secondary training (intermediate training). This training is intended for the young man or woman who wishes to manage a fairly large farm, or to enter official or private employment in agriculture at a level below that of a graduate. It could also, in some circumstances, be useful in the training of primary school teachers. Its object is to convey an informed understanding of the processes of farm production, of current and possible future advances in agricultural technology, and of the methods by which the farm business is run. It is based on science and business management and aimed at current practice.

The intermediate sector is likely, in many developing countries, to be the largest sector of the agricultural education system. It will produce the bulk of the staff of the official services, including those who are in closest contact with the farmers. It must therefore, contain a science base sufficiently strong to ensure that the student (helped by refresher courses from time to time) is able to welcome and understand innovations through the whole of the forty or more years of his or her working life.

The instruction must contain a good deal of practical work, particularly in the field. Once again field experiments are

important as means of illustrating scientific ideas and methods. Students in these institutions will usually have chosen to enter them and can therefore be expected to be interested in the methods of commercial production, provided these are more modern and more successful then the traditional methods.

It is particularly important, especially in societies in which women have substantial responsibility for food production, that a sufficient proportion of students at this level should be women. The western concept of the male extension worker bringing his message to a male farmer may fail completely when food production is women's work, as it is in some African societies. Moreover women have a very special role in rural social development, and often in economic development too—for example in the marketing and distribution of food. Plainly there must be women agricultural officers for this work, and wherever possible they should be trained alongside the men.

(iii) University education and training in agriculture. The object of university education and training in agriculture is to produce men and women who not only understand the scientific and economic bases of farming, and can understand and accept innovations, but can also develop innovations themselves as research workers, direct the introduction or innovations to administrators, and train their successors as teachers. They are high-grade and costly products. Their training is based on the sciences (particularly general biology, anatomy, morphology, genetics, biochemistry, environmental studies and plant and animal physiology), and on economics and engineering; and it must be such as to give them an understanding of experimental method and some training in logical argument and in making decisions. A university syllabus in agriculture is not intended merely to teach the student about the best current practice in crop and animal production in the country concerned; it has to teach him the common applied scientific basis of successful agricultural practice in all countries. The local practice should be one only of a number of examples used (in comparative studies) to illustrate the application of those general ideas. Such a course enables the student to adapt himself readily to different conditions, and it provides the best possible training for research on agricultural systems and practice.

At the same time the university, if it is worthy of the name, must provide intellectual leadership for the community. It does this by educating and training the future intellectual leaders, and by advancing knowledge through pure and applied research, not only in agriculture and agricultural science, but in many other fields also. In my view a purely technological agricultural university, in which all activities revolve round farm affairs, is less well adapted to educate and train, and to advance knowledge and to provide learership, than a university in which a wider range of interests act and react on each other. Any separation of agriculture from other faculties may be particularly dangerous in a country whose academic and research strength is not great, since it is bound to disperse scarce resources and lose the positive gains of cooperation and collaboration.

In all true universities, the academic freedoms include the right of each academic to pursue freely the search for new knowledge, wherever it may lead. At the same time universities cannot neglect national needs. In agriculture, their research should form part of a common national effort broadly aimed at practical goals. Clearly there are possibilities of conflict here between individual freedom and social needs, but the risk must be taken. The universities, for their part, must explicitly accept their social obligations and so earn the trust and support of the community. In appointing staff to agricultural faculties they should seek men and women of distinction whose research interests take account of social needs, and most of whom devote a large part of their research time to 'mission-oriented' research—so long as it is good research. The prestige of 'fundamental' or 'speculative' research too easily draws university research workers in agriculture away from the practical objectives which they should constantly have in view. Government, and university authorities must consciously seek to guide them along appropriate paths by involving them in the national planning of research and by the judicious use of research funds. The individual research worker in a university must be free to choose his research as he wishes, but his head of department, or the national research authority, must be equally free to decide whether or not to pay for it.

These relations are delicate, they grow slowly and they must be tended with care, particularly where an agricultural faculty forms part of a Ministry of Agriculture. They are of the utmost importance, since they determine the intellectual initiative and liveliness of a faculty of agriculture, and hence the quality of its teaching and of its graduates.

A university has a dual role in another field. On the one hand, a university exists to serve the national community that supports it. On the other, it has obligations to mankind as a whole. A university must strive to become an international institution. It forms part of a world community of learning and action which has grown in strength through a historical period of great and accelerating change. As communications improve and the world shrinks, the links within this community become ever stronger. A university faculty of agriculture, like any other, must be able to develop these links by correspondence, visits and publications, by arranging significant international gatherings, and by attracting students and research workers from other lands to work in its laboratories and at its field stations. In new faculties in countries where university research is not highly developed this is particularly important, since it is the only way in which the need to build up strong academic staff and research schools can be harmonized with the need to send many of the best graduates abroad to broaden their experience and put them in touch with the leaders of research in their fields of interest. The exchange aspects of schemes for international cooperation are consequently of the highest importance.

While I should be the last to belittle the importance of the university level of agricultural education, experience suggests that some countries have expanded this sector beyond their capacity to

support it. Graduates are produced for whom there are no jobs, and this leads to disillusionment and to the 'brain drain': the well qualified young scientist is unwilling or unable to work in his own country either because there is no job for him there or because it is too poorly paid. The development of universities must be related to effective manpower needs in the future, and not solely to the numbers of qualified high school graduates who wish to enter them.

(iv) The institutional training of farmers and farm workers. The higher levels of education have a delayed effect on the industry. A university faculty of agriculture founded now will not significantly affect the industry for ten years. The urgent task is to educate the farmers themselves. In many countries the day-to-day work of the extension service is powerfully aided by institutional training of farmers and farm workers and often of their wives also. There are innumberable ways of doing this—all combinations of long and short courses, residential and non-residential institutions, part-time and full-time instruction—are successful in different countries. Where however most farmers are poor, little-educated, or even illiterate, the important thing is not so much to train the farmer, as to convince him that he can be trained. For this purpose a residential course of no more than one or two weeks, built around visual and spoken demonstration and practical instruction in a small group of related skills, has been found in many countries to have a powerful effect in breaking the ice and creating a demand for more education. This requires a network of farm institutes, or training centres, in the countryside, provided with accommodation, feeding and some recreational facilities, and staffed by practically-minded local people, who speak the language and have mastered the skills they have to teach, and who know how to teach without relying on the written word. Where the industry is on the move, such centres can have more immediate impact on change in agriculture than any other level of agricultural education, and consequently they may often deserve higher priority in development programmes than the expansion of existing facilities at other levels.

(v) Agricultural extension and agricultural change. At all levels, those who teach and so far as possible those who are taught should be aware of the nature of change in agriculture in their country, of the factors which promote or impede it, and of its relation to general economic and social advance. This is the philosophy of agricultural extension without which its methodology and practice (education, psychology, teaching method, organization technical content and so on) may not be fully effective. Particularly in countries where the industry is only now starting to advance, or where its advance has not yet begun, extension work requires far more than skill in communication and good material to communicate. In this fuller sense agricultural extension should form part of the curriculum of all courses at the intermediate and university levels, so that the graduates can play a conscious part in transforming agriculture. Agricultural education in the past has been largely science- and technology-oriented. In seeking to change agriculture, particularly in countries where it provides the livelihood of most of the people, we are seeking to change the lives of large numbers of men and women and even the character of whole

nations. These changes cannot be left to take their own course: they must be understood and consciously planned so that they can happen speedily, efficiently and with the minimum of social and human damage. Throughout the developing world the swollen slum cities with their disease, poverty, hunger and social disintegration testify to our failure to do these things in the past. Now that we have entered the most significant phase of the war on hunger, we must do them and do them properly, yet in this we are hampered by almost complete ignorance of the social relations of agricultural change. I hope that the International Seminar on Change in Agriculture, to which I have already referred, will bring together some at least of the essential information on these subjects and that its published proceedings will serve as a manual of agricultural change during the thirty critical years that lie ahead.

SECTION 3. THE RELATION BETWEEN RESEARCH AND EDUCATIONAL INSTITUTIONS

The educational institutions make, or should make, significant contributions to research. They also produce the future research workers as well as the people who will apply the results of the research to the farming industry. A significant proportion of these people are employed in the public service, and both the research and the educational institutions are largely or entirely paid for by governments, which are consequently bound to be closely interested in getting value, in increased farm output, for the money they invest. For all these reasons, it is essential that proper machinery be devised to link together the programmes of the research and educational institutions, and to relate their work to the country's needs. There are many different ways of doing this, including the highly organized system of the United States and the much looser British system. In many countries, the main feature is some sort of central council for agricultural research, to which I have already referred. In other countries, however, and particularly in those in which agriculture is the principal industry, this may not be enough, since it may not sufficiently associate the research and educational effort with general economic and agricultural policy. An apparently simple solution is to place all aspects of agricultural research, education and extension under the control of a Ministry of Agriculture, which has to form agricultural policy as part of general national policy and is therefore best able to determine priorities. Many countries have found however that research, whose nature it is to innovate and to change things, does not fit well in a Ministry which exists to carry out tasks given to it by legislation, and which tends to preserve the status quo: and in others it has not proved easy to allocate one part of the educational system to the Ministry of Education. There is no ideal or universal solution; each country has to work out its own, in accordance with its resources and needs, in such a way as to give research and education the freedom they need to experiment and innovate, while determining their objectives, size and scope in accordance with national interests.

Whatever form of organization is adopted, the most effective way of associating research and educational institutions is to bring them

together physically. Perhaps the best solution is to establish research institutes and universities close to each other, after the style of Wageningen in Holland, and then to establish formal or informal local links between them. A university can give very powerful help in this process. In Northern Nigeria, for example, Ahmadu Bello University was established next to the headquarters station of the official research service, which then became part of the University, though of course its annual programme (which is paid for by government) is approved by a board on which the Ministry is very strongly represented. At Reading we have as neighbors, within a 25 mile radius, a considerable number of official (or officially sponsored) and commercial research institutions in the fields of food and agriculture, as well as the regional headquarters of the National Agricultural Advisory Service. Our Faculty of Agriculture has collaborated with most of these institutions for many years, to our great benefit in both research and teaching. As a result we are very well placed to help overseas institutions, for which we can provide, through our Overseas Service Unit, a direct yet unofficial link with large parts of the British research effort in food and agriculture. One result of this has been that the Ministry of Overseas Development is exploring the possibility of moving certain of its largest laboratories in these fields (the Tropical Products Institute, the Anti-Locust Research Centre, and the Overseas Land Resources Unit and possibly other parts of the Directorate of Overseas Surveys) to Reading, and associating them closely with the University. Needless to say, we shall welcome this if it proves possible; it is bound to increase enormously our capacity to help our colleagues in sister universities and in research institutions overseas.

SECTION 4. REGIONAL RESEARCH PROGRAMMES

There are six central questions here: (i) what is a region, and what is regionalization (ii) what sort of research can best be done regionally, (iii) who formulates and directs the regional programme, (iv) who pays for it, (v) who does the work and where, and (vi) how are the results used? I propose to comment on these questions briefly. Experience of regionalizations are unsafe. I am dealing solely with research, but some of the considerations are relevant to education also.

(i) What is a region and what is "regionalization"? A region in this context must consist of a group of sovereign states, more or less near one another, with common agricultural problems and preferably a common language, which are prepared to work together for long enough—and that is for many years—to permit some form of cooperation between them in agricultural research and education to pay off. If any of these conditions fails, 'regionalization' may fail and considerable investments may be lost. It is seldom, moreover, that a group of sovereign states consists of truly equal partners; usually one or two are more equal than the others, and so the regionalization may appear to give these more fortunate or favored ones a degree of leadership that may sooner or later come to be resented.

'Regionalization' may have many forms. The Inter-American Food Crops Program of the Rockefeller Foundation appears to have developed

at the technical level, without any formal agreement between governments. It is essentially a system of cooperation in planning programmes and pooling results. At the other extreme, a central 'super-national' research organization may be set up, by agreement between governments, with a director and headquarters laboratories. Such a scheme has always encountered territorial jealousies and rivalries, particularly in times of change. Yet individual scientists are usually glad to cooperate across national frontiers: this is inherent in the nature of science.

(ii) What sort of work can best be done regionally? It has often been assumed that regional organizations are suitable to tackle common problems, or more fundamental studies, which need equipment or human resources too expensive or too rare for any one territory to deploy on its own. This starts off on the wrong foot, since by definition such a regional organization is at least one peck ahead of its territorial counterparts, and sooner or later this will be resented. Central organizations can however be very valuable in providing continuity across national frontiers (for example in mapping in climatology, geology, soils, and vegetation; in disease control and quarantine; and in maintaining central plant and animal collections) and in providing a point of exchange contact and discussion on common problems—for the territorial organizations. From these common services and exchanges research may come to be shared between territorial organizations in an orderly way.

I have concluded that the role of a central organization in executing research is less important than its role as a focal point for cooperation, mutual guidance, coordination of action and sharing results.

(iii) Who formulates and directs the regional programme? From this it follows that except in some special fields, I am doubtful of the value of centralized research or educational institutions serving more than one sovereign state. I believe, however, that there are very great prospects for cooperative organizations which bring together the national efforts of neighboring countries. In such an organization, the programme would be formed cooperatively and executed largely in laboratories and at experimental stations in the individual countries. The regional organization would have staff of its own, particularly in specialized subjects, but they would be distributed at territorial or regional stations in the member countries. The execution of the programme would be supervised by a director and a small staff whose location would be determined largely by ease of communications.

(iv) Who pays? Plainly the greater part of the cost would be borne largely by the cooperating governments: this is the importance of long-term stability and agreements. Some guarantee of stability can be provided by a neutral external organization which provides finance and some key staff; and it is plainly an advantage if such an organization is evidently free from political ties or pressures so that no undesirable strings can be attached to its aid. This external finance can also confer an element of insulation against local pressures, though plainly this requires skill and tact. The Rockefeller Foundation has helped in this way during the past decade to build cooperation between the countries of

the Americas in food crop research, and the Cotton Research Corporation has done the same for cotton research in a number of tropical areas for over 40 years.

(v) Who does the work and where? Ideally the work is best done by indigenous scientists of the countries of the region, mostly working in their own countries. Many difficulties (not least of language), can arise in mixed teams of scientists of different nationalities, at least in the earlier stages; but as international collaboration becomes an accepted reality; it may well be fostered if some of the younger and more mobile workers spend part of their career in other countries. If the international cooperation is buttressed by a systematic training scheme, it will often prove most efficient to conduct part of a man's training in a foreign country. One of the disadvantages of central regional stations in regions which are short of skilled people is that national efforts may be weakened if some of the best people are withdrawn from their own countries to work in regional centres.

While a truly international scientific service is a worthy ideal which can do much to promote international understanding, I believe that regional organizations can work best only when the national organizations are strong enough to throw up the problems which can best be solved regionally, and to apply the solutions to the conditions of their own countries. I conclude therefore that in general regional scientific potential must not be developed at the expense of national strength, and this is one of my strongest reasons for preferring a cooperative type of regional organization to a 'super-national' type.

(vi) How are the results to be used? The results of such cooperative regional projects must be communicated to national research organizations, translated where necessary into local terms and then passed on to the extension and education services, and so to farmers, in individual countries. All this reinforces the view that (except in some very special fields or in very special circumstances, for example when the 'nations' are too small to have viable research organizations of their own, as in parts of the West Indies) the first task is to build the national organizations, since without them the regional organization cannot be effectively used. Regional organization of any sort must draw much of its strength from the grass roots in the individual countries; cut off from this support it is all too likely to fail.

I believe that parallel considerations apply to educational institutions. Experience shows too plainly the divisive tendencies in regional universities: sovereign states want their own academic institutions. Thus is often wasteful in strict cost-benefit terms, but a formal analysis will leave out of account the importance to a nation of the independent intellectual leadership and service which a good university, properly staffed and equipped, can provide. Whether we like them or not the facts are plain. We live in an age in which nationalisation is growing; formerly unitary states tend to divide, rather than to come freely together. Across the rising barriers academic cooperation, particularly in research, postgraduate work and specialist undergraduate teaching, has

an important part to play in preserving international ideals against the tides of change, as well as in making better use of scarce resources, but the tides are running strongly and cannot be denied. Once again, therefore, the practical answer seems to be to encourage cooperation in appropriate fields but to recognize that this is mostly likely to grow between independent equals rather than as an international substitute for national institutions.

ROLE OF IRHO IN AGRICULTURAL TRAINING AND EDUCATION

F. Renault, IRHO

SUMMARY

Professional training is an essential element in the overseas agricultural development program and represents the only way of getting the producers to adopt the most recent techniques which have been developed at the research stations.

In this connection, IRHO attaches great importance to this effort and tries to participate in it in proportion to its resources.

This report analyzes the various activities of IRHO in this field; the main effort has been concentrated on practical training under actual cultivation conditions, in the form of training courses or refresher courses and practical work within the framework of its stations, where activities connected with preliminary extension and multiplication have been assigned to it.

* * *

IRHO is actively participating in the training of personnel responsible for the development of oil crops as well as the training of the producers themselves.

This training effort is essentially practical and most often it is handled on the spot, out in the field; it constitutes the most important part of the institute's role in this matter; agricultural instruction, as such, is confined to courses offered at schools in metropolitan France and in some of the regional centers.

A. Agricultural Instruction

Courses on oil crops: at the Higher School of Tropical Agriculture Application and at the National Center of Tropical Agronomy Studies at Nogent; at the Fats Institute (ITERG), Paris; at the Overseas Technical School, Le Havre; at the Rural Foreman School, Kambouinse (Upper Volta); at the Polyvalent Center, Matourkou (Upper Volta).

B. Vocational Training

Here are the most important programs under this heading:

(1) Peanuts

Senegal: School of fertilizer spreading and seed disinfection prior to the 1962-1963 cultivation seasons; this school is tailored to the needs of the growers themselves; this effort was later on pursued by SATEC.

Edible peanut production: training of growers in preparaing lots for export.

Practical activities and visit to the IRHO experimental station, each year, by student-instructors at the Louga school who have also participated in the study of the test village of Bidem: planimetry, topographic surveying, cultivation techniques.

Rural promotion cadre training session, 1963-1964 (resumed by SATEC).

Upper Volta: Training of 16 instructors and 103 basic recruiters in the villages, for the extension sectors.

Togo: Seminar on cultivation techniques in connection with the development of the northern Togo peanut program, in cooperation with the BDPA (1966).

Mali: Seminar, in Paris, for all of the cadres responsible for the peanut program carried out by the BDPA (April 1967).

Madagascar: Training course at the Save test station (Dahomey) for BDPA cadres responsible for castor oil program at Androy.

(2) Oil Palm

Vocational training is handled by the IRHO cadres at the stations; this is done here in very close connection with the practical courses and activities and in line with the future activities of agents in training.

Ivory Coast: The La Mé station handles the practical training and refresher training for all of the higher-level cadres, foremen, and skilled workers of SODEPALM, for which IRHO acts as the technical advisor. This company has built a dormitory for the course trainees, for this purpose, at the La Mé station; the building was completed in 1966. The course trainees can thus get "on the job" training, in the techniques recommended by IRHO which they will have to use in their fields.

In 1966, these training courses involved 32 higher-level cadres, 15 foremen, and many skilled workers. The training course curricula are tailored to the needs of each of these agents.

The La Mé station is also training many students of all nationalities (about a score of engineers since 1960).

Dahomey: Several courses have been held at the Pobé station, throughout the year:

- specialization in palm trees for applicants for management positions in the cooperatives of SO.NA.DE.R. and demonstration session for certain special techniques, such as pruning, fertilizer application, nursery selection;
- training courses for instructors and recruiters of the Rural Development Service (5 successive groups): control of coelaenomenodera and health measures;
- training courses for students from the schools of agriculture at Porto Novo, Ina, and Bingerville.

Cameroon: Project involving the creation, at the La Dibamba station, of a dormitory for trainees; this facility has become necessary as a result of the launching of the Palm Tree Plan for which IRHO is to be the technical advisor.

(3) Coconut Palms

Ivory Coast: A center for course trainees is now being built at the Port-Bouet station, patterned after the one built at La Mé, for the training of SODEPALM coconut palm personnel.

- training courses for many coconut palm plantation owners.

Dahomey: Training courses, at Semé-Podji, for students from the schools of agriculture and for cadres from the Agriculture Service and SO.NA.DE.R.

C. Training of Producers within the Framework of Pre-extension Programs

This training is given within the framework of pilot operations that are intended to confirm the methods and structures to be recommended in the extension operations.

(1) Peanuts

Sénégal: (a) 37 confirmation tests each year covering 111 ha of crops, distributed over the entire peanut zone have been set up among the growers who do all of the work themselves, following the methods of IRHO.

The demonstration involves the following points: crop rotation; careful preparation of terrain; fumigation of seeds; dense planting with the drawn sowing machine (density of 110,000 seeds/ha); mechanized spreading of a low-level of fertilizer; proper maintenance with the hoe.

For all of these tests which, since the start of the operation, have covered about a thousand ha (some of which are now in their 12th year of crop rotation), the application of efficient methods alone, increases the yields by 100-300 kg of shells per ha.

The use of fertilizer leads to a further increase of 300-500 kg per hectare.

(b) Furthermore, in 5 test villages (Bidem-Darou, Taiba, Mamare, Diery, Hanene): study of the effect of improvements proposed in the extension program (economic and agronomic aspects—annual balance sheet). This operation was launched in 1955 and involved about a thousand inhabitants.

(c) Edible peanut program; multiplication of seeds by 325 contract growers—production of 360 tons of seeds.

Upper Volta: Bobo Dioulasso and Banfora extension sectors. This effort, undertaken on a small scale in 1959 in the region of Labola, upon request of the government of Upper Volta, has been progressively expanded to the entire circle of Banfora and then to that of Bobo Dioulasso; in 1966, it involved 4,844 growers. The purpose of the operation is to spread the improved cultivation of peanuts, using varieties that resist rosette, selected by the Niangoloko station, with the help of seed disinfectants and a low level of mineral fertilizer (75 kg/ha of superphosphate); this also includes dense planting and good crop maintenance. In 1966, the two sectors—each directed by one expatriate expert, aided by 16 instructors from Upper Volta and 103 village agents—distributed 132 tons of seeds and 129 tons of fertilizer to the 4,844 farmers who thus cultivated 2,300 ha of improved crops, with an average yield of 1,200 kg/ha.

(2) Oil Palm

Ivory Coast: Between 1959 and 1961, the units at La Mé and Dabou undertook the broad dissemination of intensive cultivation techniques among the village populations, both within the cooperative framework (Attingué-Alépé), and by working with the small landowners.

These units play the role of "basic blocks" and handle the technical training of growers (selection of land, staking and supply of plants, supply of seeds for cover crop, burning, fertilizer, and work supervision); in turn, the people who get these benefits see to the complete preparation of the land and then take care of the planting and the maintenance work.

The satisfactory results obtained during these extension programs (187 ha planted between 1959 and 1961) have made it possible to spell out the structure of the oil palm development program in the Ivory Coast, based on the combination of a plantation block with a refinery supplemented by satellite village plantations that benefit from the technical assistance given by the block.

The success of these village plantations has surpassed all expectations: at the end of 1966, we had more than 1,500 planters who planted an area of 5,600 ha; the rate of the village plantations has increased from 800 ha in 1964 to 1,200 in 1965, 2,300 in 1966, and 3,000 ha in 1967.

(3) Coconut Palms

Togo: Replantation of dwarf coconut palms along the coast of Togo (a zone decimated by the Kaincopé disease)—plantations developed by landowners who were recruited and organized by the instructors of the Agriculture Service, under the technical supervision of IRHO.

D. Technical Documentation

- Publication—within the "Agricultural Techniques and Tropical Production" series—of books on oil palms and coconut palms. The book on peanuts is in print.
- Publication of information brochures, particularly in collaboration with Potasses d'Alsace, the INADES of Abidjan, and the BDPA.

Monthly publication—in the review Oléagineux of practical agriculture pages whose reprints are widely distributed and are intended for all the cadres and basic promotion agents involved in the promotion and development programs. This practical advice is also printed in Spanish, Portuguese, and English, in countries where the institute operates.

NATIONAL AND REGIONAL AGRICULTURAL RESEARCH INSTITUTIONS: PROBLEMS THE SOLUTION OF WHICH DEPEND ON PROGRESS OF EFFECTIVE RESEARCH

Max Diaw, O.C.A.M.

National agricultural research bodies

Research is basic to development, increase in factual knowledge being essential to the acceleration of technological progress, the sine qua non of development. Hence the necessity for placing research among the primary goals in planning. Research also must be sufficiently continuous. If included in well thought-out balanced plans in keeping with realistic expectations as to financial means that will be forthcoming, research will be most likely to merit respect.

Integration of research in national planning and implementation of plans implies the existence of appropriate structures. At the stage when decisions are being taken and scientific planning being put into concrete form and against the background of overall government decisions, the highest level government authorities (ministries, inter-ministerial committees and permanent secretariats) should be in a position to:

1) lay before governments the basic facts on which scientific policy can be laid (guidelines for universities, training of research workers, application of research findings and their integration at the production level);

2) co-ordinate government action in scientific fields (budgetary allocations, implementation of national development plans);

3) urge governments to take measures that are conducive of best possible results from efforts made both nationally and on a regional level.

Several O.C.A.M. countries are already organized along these lines and others intend to do so shortly.

On the regional level, each country when framing its national research policy and programs has an opportunity to reflect on the advantages that would ensue from co-ordination of research with neighboring countries. Such co-ordination seems particularly fruitful if:

1) it avoids duplication of research already done in other countries, whenever transmittal of knowledge as to findings is feasible;

2) advantage is taken of the division of labor organized in such a way as to shorten the period of rechecking of experimental findings;

3) joint research projects of minimum duration are undertaken with pooling of resources in instances where in national decision-making such research has not been deemed feasible for lack of adequate means.

The Comité de la Recherche scientifique et technique (Scientific and Technological Research Committee) of the O.C.A.M. meeting in Brazzaville on 9, 10 and 11 February 1967, was the concrete expression of such an association of O.C.A.M. member countries in the field of research. At that meeting certain intergovernmental research institutes were chosen for assignment of research in specific fields.

The bases for selection were their scientific research set-ups, their past achievements, their acquired experience, their findings, the regional outlook of the center and the common ecological and agro-climatic conditions.

The agenda dealt essentially with regionalization of agricultural (crop and animal production) research. Considering development needs, three points were dealt with by this committee:

1) the need for training of African and Malagasy researchers and technicians. A recommendation was approved to the effect that the Ecole Fédérale Supérieure Agronomique du Cameroon (Higher Federal School of Agriculture of Cameroon) and the Ecole Supérieure Agronomique de Côte d'Ivoire (Ivory Coast Higher School of Agriculture) be regionalized for these purposes: the last summit conference of O.C.A.M. (January 1968) adopted resolutions for the opening of the Faculté Vétérinaire de Dakar (Veterinary School of Dakar) and the Ecole Inter-Etat des Ingénieurs des Travaux Ruraux (Interstate School of Agricultural Engineering).

2) The definition of research goals and the choices of centers for executing regional programs in the hope of practical achievements in increasing agricultural yields and ultimately improving living conditions of the populations. Financing of such research and procedures to be followed were discussed at this meeting by representatives of international organizations. Several such regional programs have already been framed.

3) Encouragement of exchange of personnel, information and scientific material among O.C.A.M. countries. Such exchange with other parts of the world, Europe for instance, was also deemed desirable.

AGROCLIMATOLOGY AND SCIENTIFIC RESEARCH IN AFRICA

Jacques Cochemé

FAO

SUMMARY

Climatology is the study of accumulated weather, its repetitive elements and significant anomalies. In agroclimatology particular attention is paid to those climate parameters which affect agricultural production. The selection of these is the work of crop and herd physiology, parasitology, agricultural engineering, etc., and must precede agroclimatic studies which may nevertheless contribute to determining importance of the parameters chosen.

In tropical and equatorial Africa water availability studies are particularly important and the length of so-called "humid" and "moist" periods are determined by comparing rainfall and different levels of evapotranspiration. Their mean duration and dates are closely related to the growing cycle and main phenological events of crops.

The influence of length of day on Sorghum heading in conjunction with the timing of the humid period and the role of chilling temperatures in pyrethrum production were also discussed.

To illustrate activities of agroclimatology bordering on operational research Turc's climatic index of potential agricultural production based on monthly mean values of meteorological elements was outlined. It is a regression with fodder production in different parts of the world and reflects satisfactorily spatial and seasonal variations in climate.

Finally the handling and analysis of climatic and biological data should be published. The volume of quantitive biological data such as phenological records could and should be increased. It is thought that there is no longer any need to evolve a fixed detailed system of climate classification. Existing simple systems provide preliminary clarification. For the rest, present day machines make it possible to regroup information to meet problems as they arise. The same reasoning applies to ecological analogies.

* * *

The first aim of this contribution will be to try and place agroclimatology more precisely amongst the scientific disciplines and agricultural activities adjacent and overlapping with it. This should be done in terms of, on the one hand, the work it stimulates by its demand for material on which to operate and, on the other, of the action it can render more effective through the information it yields.

Having done this, some examples of agroclimatological work in tropical and equatorial Africa will be then given covering the main climatic agents involved. An example of work in the sector where agroclimatology

borders on operational research will also be given. Finally, methods of treatment and presentation of agroclimatological information will be discussed.

Nature of Agroclimatology

A definition of terms is all the more necessary here because the word "climatology" is taken somewhat differently by different people and also because there is sometimes a small difference between the meanings of the word in French and in English. In French it tends to be given a wider connotation. Thus the word "bioclimatologie" would be used in French to describe, broadly, the type of work which in English would more appropriately be called biometeorology.

The sense in which these words are being used here is that meteorology is science of weather, and climatology is the study of accumulated weather.

Thus climatology, using averages and generalizations, stresses the repetitive element in weather. The features which tend to recur day after day, season after season, year after year, describe the climate of a place. Not the least important result of the repetitive nature of the climate is that it shows up abnormalities, significant departures from average conditions which, in agriculture, often have an importance comparable to that of the weather usually obtained.

Here we are concerned with agroclimatology. The characteristics of climate affecting agriculture taken in the broadest sense to embrace, not only the climatic needs and tolerances of plants, but also those of livestock, and even those of agricultural machinery.

Studies of agroclimatology presuppose that the necessary determination of the weather elements which are of importance to plants, animals, or machines has been done. This is work in plant and animal physiology, or crop and herd physiology, in parasitology and even agricultural engineering. In as far as the weather enters into it, and from the point of view of the meterologist, this work is best described as agrometeorology. It must come first. Once the parametres that matter have been established it is the task of agroclimatology to determine their distribution and occurence and in so doing further qualify their importance. Without this preliminary work the agroclimatologist surveying a region has to fall back on less specialized climatology. A straightforward climatological study is a preliminary step which has to be taken in any case. Furthermore climatology should not begin with mere consideration of accumulated instrument readings. Some broad notions of the general circulation of the atmosphere and of the local reactions to it of the region studied are essential for a proper appreciation of the agroclimate.

However, to return to the definition of where agroclimatology begins, I would say, for instance, that the determination of weather conditions which affect grass production and consequently milk production in the United

Kingdom and of those which favour the attack of coffee berries by a parasite in Kenya, though not in themselves agroclimatology, lead to useful agroclimatology studies. On the other hand, a statistical comparison over a given number of years of yield with certain climatological parametres is agroclimatology.

Spatial scales of agroclimatology

In order to clarify further the nature of agroclimatology the spatial scales at which it can function extensively and profitably should also be discussed. One hears of microclimatology, but this is indeed an expression which is difficult to appreciate with any precision. The impression it conveys is that it deals with the climate of small and rather specially situated positions like, say, the inside of a given standing crop. The micro environments from which sufficient micrometeorological observations are available to evaluate climatic parametres are rare, and yet it is this type of climate which directly influences plant growth and development, and consequently crop yields and production, which agroclimatology tries to relate to climate. In agroclimatology it is often desired to differentiate and compare regions at a geographical scale and the mass of micrometerological measurements necessary to carry out agroclimatological comparisons at this scale is just not available. What we do have is a large number of measurements taken mostly in meteorological enclosures at observation stations. We are in fact in a position to talk about station climate at a geographical scale but nothing or very little which is much finer. Furthermore, even in a small region, the multiplicity of different microclimates is very great and the differences between adjacent microclimates and resulting agricultural production may be greater than the differences between quite distinct regions.

However, there is no doubt that the immediate microclimate of crops which controls production is closely related to its station since it is compounded of that climate and the response to it of an environment of which it is a part. Thus it is quite legitimate to bypass microclimate, about which we know little, and correlate crop behavior directly with our coarse but fairly solid knowledge of station climate.

This is not to say that to obtain detailed knowledge of micrometeorological conditions is not a rewarding pursuit, but, it seems that in this age of specialization it should be left to crop physiologists and micrometeorologists, whilst ready to base agroclimatological work on their findings.

It is suggested that working with station climate at the geographical scale is the main function of agroclimatology and does in fact provide scope for a great deal of useful work.

Availability of water periods

Some examples of agroclimatological work in tropical and equatorial Africa will now be given. Crops cannot be produced at the surface of this earth, assuming possible soil conditions, where it is too cold or where

there is no water. In tropical and equatorial Africa it is water shortage which is the exclusive limiting factor (apart from a relatively small acreage of very high ground). Thus African agroclimatology is largely a study of water availability. When attention is given to this problem it is soon realized that water availability is not simply a question of sheer rainfall amounts but that this water import must be balanced against the maximum amount which a plant cover can use. The same quality of water during the same period of time may be not enough in one place and too much in another. In other words, rainfall must be budgeted with potential evapotranspiration. Fortunately the rate of potential evapotranspiration depends on relatively simple physical characteristics. A certain amount of energy is needed to evaporate a given amount of water whether from the surface of the ground or through the stomata of a leaf and once the available calories have been spent no more water can be evaporated.

In the broad semi-arid area extending from the Atlantic to the highlands of Ethiopia south of the Sahara Desert, which was the object of an agroclimatology survey jointly sponsored by FAO, Unesco and WMO (1967), the general circulation and the ultimate weather mechanisms which bring rainfall appear to be relatively simple and result in a single northern hemisphere summer rainfall season culminating in August. This rainfall season is of increasingly short duration as one moves northward towards the rainless desert zone and the annual amounts are in consequence increasingly small. However, except at the very edge of the desert, more water falls in August than can be evapotranspired, water surplus occurs then at the monthly scale and would be more abundant still if it were reckoned over shorter intervals of time (though still much longer than the duration of the rainstorms themselves).

The occurrence of excess rainfall in the middle of the rainy season contributes to the advisability of reckoning availability of water in terms of the duration of the periods during which rainfall exceeds significant levels of evapotranspiration. This fundamental type of analysis was, to my knowledge, first expounded by an American climatologist, C. W. Thornthwaite, who rightly foresaw that it would outlive his and other methods of estimating evapotranspiration.

Our agroclimatology project has, so far, used for its surveys Penman's method of calculating potential evapotranspiration (1948). It has been in use for quite a time and we think that it is still up to date, largely because of its ability to accomodate improvements in instruments and observations.

The two main levels we used are when rainfall is over half of evapotranspiration and when it exceeds it. The latter criterion determines what is often called the humid period and is considered to be the most important agroclimatic parametre in an area where the temperature is fairly uniform, spatially and seasonally. The humid period varies from 0 to about 140 days in the area, and it is preceded and followed by intermediate periods which are bounded by the dates when rainfall begins and ceases to exceed one half of evapotranspiration. These two intermediate periods are fairly

constant in duration, the second one being prolonged by the excess moisture stored in the soil during the humid period.

The two intermediate and the humid period together we have called the moist period and it varies in the West Africa area between 55 and 200 days approximately.

This purely climatological, physical concept of the moist period represents in fact the growing season and can be matched in the area with the growth cycle of annual crops, stretching from seed to seed, more particularly of cereals like millet, sorghum or even maize. Early millets of very short cycle are used to match the 55 days moist period of the northern edge of the area whilst in the south late varieties of sorghum requiring 200 days can be grown; but this is not necessarily what happens, since there one is approaching the zone where two consecutive or overlapping crops of short cycles might be raised during a single season. The competition of cash and subsistence crops for instance might induce the growing of an early sorghum before getting down to cotton.

In general we found that the mean date for the beginning of the moist period coincided with traditional sowing dates. Furthermore, sample statistical studies showed that, in Niger where the rainfall regime is least variable compared with the rest of the area, breaks in the rains sufficiently prolonged to cause drought and seriously damage the crops occurred, during the 36-year period analyzed, only when the beginning of the moist period had been early. Such breaks did not occur when the moist period had begun after its mean date.

The simplicity of the rainfall pattern in West Africa, where over a large belt of savannah there are no mountains or seas to distort or complicate it, is not met at comparable latitudes further east in tropical Africa.

Over the highlands of northern Ethiopia (part of an area being surveyed at present by the same project), for instance, there is also on the whole a single summer rainfall season with a maximum in August. But before the moist level of availability of water (rainfall equals half of evapotranspiration) is reached there is a period of about three months of insufficient and irregular rain which in practice is seldom used for crop production.

The fact that in equatorial and tropical Africa temperatures are consistently high and the length of day varies little does not mean that the heat and light sections of agroclimatology in these regions are always without importance. For instance, in the case of length of day, we found in the west Africa study that although the agroclimatic gradients are meridional, stretching from the relatively wet south to the desert in the north, the lines of equal rainfall were not strictly aligned with the parallels of latitude but dipped southwards from the Atlantic coast to Lake Chad. Besides the date of sowing, an important step in the development of cereals in terms of availability of water periods is the date of heading, for which it was thought that the best timing is just before the end of the humid period, during which full growth was possible, but

which might prove too wet for proper ripening of the grain and the avoiding of parasitic diseases. With a sorghum of a given cycle length traditionally grown in a given location and adapted to its moisture regime, it was found that heading does in fact coincide with the end of the humid period. On the Atlantic seaboard the movement northwards of the intertropical convergence which brings the rains is delayed and the beginning and end of the various availability of water periods are also delayed.

Several of the varieties of sorghum grown in the West Africa area are sensitive to length of day; flowering is induced or initiated during the shortening days of the northern autumn. When looking for climatic analogy in the savannah belt it is common to go by the annual rainfall amount (and rightly so since the length of the humid period which is the main parametre is closely connected to it). Thus a new variety found suitable for a rainfall regime of, say, 600 mm (which corresponds to a moist period of about 120 days) in Senegal might be tried out at locations with a similar annual rainfall in northern Nigeria or in Cameroun and give disappointing results there because photoperiodically controlled flowering is occurring after the end of the humid season. This because being further south than the place of origin equally shorter days occur later, whilst the actual sequence of availability of water periods occurs sooner than in the west.

Chilling temperatures

The example I would like to give concerning temperature belongs as yet to the borderline between crop physiology and agroclimatology to which I was referring at the beginning of this paper, in as far as not enough is known about it quantitatively to make a proper agroclimatic analysis possible. I quite admit the possibility that this knowledge already exists and that I have not been able to trace it.

The role of low temperatures in pyrethrum production is that moderately cool night temperatures are necessary to induce flowering. In a temperate or mediterranean climate these temperatures occur in the spring and, as it gets warmer, floral production ceases thereby setting a limit to the season for pyrethin production, since it is derived from the flowers. Apparently, in the Kenya highlands and elsewhere when pyrethrum is grown on equatorial mountains, the necessary chilling temperatures can be obtained for a much longer season, thereby lengthing the useful flowering season which is not curtailed by the heat of the summer or the excessive cold of the winter. In fact, in Kenya the restrictions on the productive season seem to be mainly due to lack of water. However, at the moment we lack the data, not so much of temperature but chiefly of yield and production on which to base a determination of equatorial highlands with high pyrethrum yielding climatic potentials. It is realized that factors of soils and people might effectively intervene and prevent the growing of this crop in areas where the climate appears favorable.

It is also realized that the constant efforts of geneticists and and growers widen the climatic needs and tolerances of crops and produce varieties better adapted to given environments.

Climatic indices of potential production

We have defined one confine of agroclimatology as physiology and, in some cases agrometeorology, where the foundations necessary for agroclimatic studies are set. As an opposite end of the domain one might situate work definitely oriented towards operational research or economic analysis. Such work is extremely valuable, especially to an international agency like FAO which is primarily concerned with food production.

In this sector I would like to mention as an example climatic indices of potential production. I have more particularly in mind an index proposed by M. Turc (1967) of the Institut National pour la Recherche Agronomique. which is based on monthly values of what was called earlier in this paper station climate. This index estimates fodder production which, being vegetative and continuous, is more likely to give useful correlations between climate and production. It also assumes a reasonably high standard of cultivation practices in terms of present day achievements. It does not therefore attempt to forecast future production in as far as it is not concerned with estimating improvements in techniques and plant material. The index could be modified to fit any accurate predictions of these improvement There one is treading on increasingly insecure ground although it is realized that attempts should be made to try and forecast, however imperfectly, the increase in agricultural production in order to compare it with the increase in population which nowadays people seem to forecast with a degree of confidence. This difficult prediction of agricultural production is one of the tasks of FAO. Climatic considerations have an important part to play in determining the origin and range of the extrapolations involved in the work of the Indicative World Plan.

However, M. Turc's index as it stands now, as far as I know, is concerned with the past and present only and it is a purely empirical exercise. As he put it himself, it is a regression and not a function. This is not the place to discuss it in detail but I might briefly indicate that it is the product of heat and light and dryness sub-indices become nil and therefore cancel out the whole index. The dryness sub-index balances rainfall and potential evapotranspiration and makes provision for carrying over the effects of drought from one month to the other. The heliothermic index has a flat topped optimum of 30°C for the effect of temperature and also takes into consideration solar radiation either in terms of its intensity or of the length of day, whichever happens to have the greatest effect under prevailing conditions.

The result is expressed in metric tons of dry matter per hectare per year and for the whole globe varies between 0 and 75; for France it varies between 0 and 35. Actual harvests under present day good conditions are about 60% of the index.

Comparisons of actual harvests and indices for various parts of the world show consistent results. Monthly amounts at a given place (of which the annual index is the sum) vary in a way consistent with yields. Comparison of amounts grown in short day and long day conditions also showed agreement with the index.

In semi-arid west Africa south of the Sahara with nearly uniform conditions of heat and light the index is quite closely correlated with the duration of the moist period.

Data, methods and presentation

Agroclimatology is based on a synthesis of biological and meterological data. A common complaint of FAO experts going out to the field is that no meteorological data are available from the areas where they are going to work. These complaints are almost invariably exaggerated. This is certainly so in the case of developing parts of Africa. It is true, however, that a large portion of existing records are neither published nor even catalogued and that some determination may be needed to gain access to them. Great benefit would be derived if a proper census of available information was made and published, telling one where the information is stored, until such a time when it will be transcribed onto cards or tape so that copies will be easy to obtain.

There is no doubt that the situation concerning biological data is much poorer. There is a great shortage of quantitative data of the simplest kind, such as, for instance, dates of flowering. Also of all kinds of yield and production figures. This situation could easily be improved without the need to invest any money at all.

With the development of crop physiology the agroclimatic parametres which can be evolved become more and more specific and involved, and the question of how this information should be organized becomes more pressing. To classify is a natural impulse. It brings apparent order to apparent chaos and by grouping information into classes it brings it closer to the fields in which the urge to classify has had an opportunity to flourish. The word "climate" itself has its origin in an early attempt to classify climate into zonal strips round the earth.

A system of classification can synthesize different criteria: hot and cold, wet and dry, etc., in the case of climate. If it is a system of ecological classification, characteristics of soils and vegetation will be added to those of climate. Furthermore it is natural to wish to extend systems of classification to cover the whole earth.

It is apparent that we are running into a dilemma. Either the system is kept very simple using a few parametres and large classes, in which case its use is very limited, or it is attempted to make it as comprehensive as possible, whereupon the task can become fantastically complicated and involve the use of a fabricated language.

My own views concerning such complicated systems are, in the first place, that it would be most difficult at this stage to impose a single system on the world, secondly that it would be virtually impossible to make it comprehensive enough to include in detail the climatic needs and tolerances of all crops, thirdly that modern storage and computing amenities make it no longer essential to have a fixed, unique system of classification.

If the information available on the variables, climatic or otherwise, is properly stored then ad hoc classification systems can be evolved to meet the needs of the problem in hand: combination of certain humidities and temperatures in connection with a leaf parasite, occurrence of rainfall on arid lands for locust oviposition, vector winds at height for the carriage of rust spores, etc. etc. The answer can be obtained from a machine and the classification system forgotten as soon as it has served its purpose. In this way an adaptable and fluid system replaces a rigid and cumbrous edifice.

This does not mean to say that simple systems are not useful for a first approach to a problem, for instance. Such systems do exist, that of Koepen, for instance. The same usefulness applies to broad ecological zones such as were discussed in earlier contributions, as long as their limitations are clearly recognized. I think that the case of sorghum flowering, rainfall and length of day mentioned earlier in this paper illustrates this point. The concept of climate analogies is a useful one for taking full advantage of the plant material of this earth. but the wholehearted pursuit of analogue regions is fraught with peril.

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AGRICULTURAL RESEARCH PROGRAMS ON ECOLOGICAL BASES BASIC PRINCIPLES AND GENERAL MEASURES FOR STRENGTHENING COOPERATION

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SUMMARY

The development of agricultural research and the improvement of cooperation and coordination of technical and financial aid in this field, are problems of primary importance for agricultural development, as well as social and economic progress in Africa. The development of agricultural research is faced with two main problems; one is concerned with the availability of qualified manpower, and the other with the organization and implementation of research programs.

There are far too many research results which stop at their publication; far too many studies and surveys which finish up in the archives; an enormous number of small specialized projects carried out in isolation and too many so-called research stations conducted by one research worker only.

The proposed solution for strengthening agricultural research and intensifying methods of cooperation is to establish regional agricultural research programs on an ecological zone basis as a frame for intergovernmental and international concerted action. The existence of common priority agricultural problems in ecological zones, calls for intensifying co-operation to carry out research. Regional agricultural research programs on ecological zones basis should be flexible and open to all kinds of co-operation; they should be implemented by the existing national bodies and deal with a limited number of regional major problems of agricultural development. Such programs could guide and streamline external technical assistance to cover key problems and pool dispersed efforts on research topics of common interest to several countries. They would help to work out a better strategy of aid for research aiming to use to their full extent the available resources in multidisciplinary and complementary research activities. This concept of organizing research would not affect any government prerogatives, nor any bilateral or multilateral technical assistance arrangements within countries, but would help to make better use of present available facilities, by overcoming shortage of manpower and avoiding unjustified duplication.

Regional research programs on an ecological basis, will also aim to strengthen the exchange of information through the conduct of specialized technical meetings which would have to make a full inventory of research results achieved, to evaluate their practical application and to decide upon the research to be undertaken, within a joint plan of action.

After several years of co-operative working experience on a given number of regional research problems, the regional research programs could be enlarged progressively so as to provide regional teams of scientists to work together in national institutes. In a latter stage regional institutes may be visualized in each major ecological zone. However, the point to be emphasized is that the final establishment of such jointly financed regional institutes would be the culmination of a long period of co-operative experience, rather than a likely successful starting point. Of course, regional institutes entirely created and financed in the long run by outside funds would be the best as they would facilitate enormously the implementation of the regional programs. It should be clearly pointed out, however, that the proposed programs aim first to develop multidisciplinary agricultural research institutes on a national basis to serve the implementation of national and regional programs.

FAO wishes to organize conferences on the establishment of agricultural research programs on an ecological basis, in cooperation with governments, bilateral and international agencies and private foundations.

In order to facilitate the exchange of information and international co-operation in all scientific and technical subject matter fields of agricultural research and development, FAO suggests the adoption of a standard system for cataloguing agricultural research programs and results.

As the introduction of agro-ecoclimatic analogue data in such a cataloguing system would enable cross references to be made of research program and results between areas with similar environmental conditions, it is also suggested that a joint FAO/UNESCO/WMO study be made in co-operation with governments and interested scientific institutions on the agro-ecoclimatic analogues of the tropical world.

I. INTRODUCTION

1. The development of agricultural research and the improvement of co-operation and co-ordination of technical and financial aid in this field are problems of primary importance for agricultural development in Africa. Agricultural progress achieved in the more advanced countries has been obtained by continuing efforts in research and its application. A similar approach must be adopted by governments of developing countries and supported by the technical assistance agencies helping them.

2. Developing countries, well aware of the importance of research, are making valuable efforts to increase their scientific development. Owing to the large number of problems they have to solve, however, it becomes more difficult every day for the research services to provide answers to all the inquiries raised.

3. The research undertaken and the technical assistance provided to research in Africa are both of considerable volume. It appears, however, that efforts made and the aid given do not sufficiently cover the

subject matter fields involved. As a general statement it can be said that the varied research institutions and sources of assistance are insufficiently co-ordinated and that where co-ordination does exist it is usually established during the implementation of a program or project by which time it is often too late to avoid duplication.

4. Nevertheless, there is a certain amount of experience in intergovernmental co-operation (regional projects) and forms of liaison between different sources of technical aid (joint projects and sub-contracts) which could provide a basis for closer co-operation in the future.

II. MAJOR PROBLEMS BEING ENCOUNTERED

5. The development of agricultural research is facing two main problems. One is concerned with the availability of trained and experienced manpower and the other with the organization and implementation of research programs, including measures for ensuring that the results of research get into the hands of the field services in a form in which they can be put to practical use.

1) Qualified manpower

6. Lack of qualified personnel is certainly one of the major obstacles to research development. Even if funds and material allocated to research were tripled, this would not alter the fact that there are not enough research workers available. With the increasing number of new states, demographic expansion, progress in science and technology, the development of research organizations and the competition to provide or receive aid and assistance, there has been a considerable increase in the number of projects and amount of technical assistance aid in various fields during the last five years, but to date an effective pattern of co-operation and co-ordination has not been established.

7. Financial and physical aspects (infrastructure) appear to be the other main barriers to the expansion of research activity, but is mainly the lack of qualified personnel which limits its development. It is much easier to build and equip a research station than to find the necessary research staff. The demand for qualified research workers far surpasses the available supply, particularly for those possessing tropical research experience.

8. Research workers who are capable of integrating several scientific disciplines, of comprehending technical as well as social and economic aspects of a research project, and who are interested in not only making new discoveries, but also in their practical application, are particularly difficult to find. It is this type of research worker, possessing a wide range of experience who is, however, best suited to agricultural research programs in developing countries.

2) Organization and Implementation of Research Programs

9. In organizing and implementing research programs, the need for an inter-disciplinary approach and to relate research to the requirements of agricultural development plans are factors of prime importance in a discussion on improving methods of co-operation.

10. Much of the agricultural research undertaken in developing countries does not fully reflect the multi-disciplinary nature of the problems involved. Development projects are often embarked upon without the necessary basic technical, economic, social, organizational and institutional studies having been carried out; while in other cases, studies and surveys already completed and published are ignored.

11. There is a pressing need to avoid competition and duplication through closer co-operation between developing countries, between developing and developed countries, and between bilateral, multilateral and international aid to agricultural research.

12. Some countries eagerly accept any offer of technical assistance even if it does not conform to the priority needs of the country. Agricultural research in developing countries should be more concerned with the solution of their most urgent problems which are of importance in relation to national and regional* development plans.

13. There are in existence numerous studies, inquiries or pre-investment surveys which merely end up in the archives; far too much research which stops upon its publication; an enormous number of small specialized projects carried out in isolation and too many so-called research stations conducted by one research worker only. Multipurpose projects led by teams of research workers at multi-disciplinary research centers which also take account of problems involved in the application of research results, are to be found in limited numbers.

14. Political boundaries in Africa today are rarely related to ecological regions. One ecological zone will extend over several countries (see attached map). However, as basic agricultural problems of a given ecological zone are similar, it seems highly desirable that regional co-operation in research be established on an ecological basis.

III. SUGGESTIONS FOR IMPROVING CO-OPERATION AND RESEARCH EFFICIENCY

15. Many measures can be taken to increase the efficiency of agricultural research but it is suggested that the first should be to make better use of trained and experienced personnel already available and to re-organize existing activities, as much as possible, in the form of multi-disciplinary projects at national institutes and as part of regional research programs through inter-governmental agreements. Even without an

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* For the purpose of agricultural research on an ecological basis the word "regional" means a group of countries with similar agricultural problems.

increase in funds and personnel presently available, it should be possible in this way to double or even treble the effectiveness of research and assistance provided.

16. Scientific and technical research in agriculture is expensive and it requires highly trained and skilled personnel and costly field and laboratory equipment. The developing countries cannot afford to duplicate or repeat research already conducted elsewhere unless it can be scientifically justified or is required for the purpose of local adaptation. To a lesser degree this is also true for industrialized countries which are urged to increase their contribution to external bilateral or multilateral aid programs, when it might be more logical to begin by ensuring better co-ordination and thus avoidance of costly and unprofitable competition. It is well known that co-operation and co-ordination raise many difficulties of institutional, organizational, financial and political character. It is believed that some of these difficulties can be overcome by an exchange of views between all interested parties.

17. The proposed solution for strengthening agricultural research and intensifying methods of co-operation is to establish a Regional Agricultural Research Program in each of the major ecological zones, supported by bilateral and multilateral assistance, as a framework for intergovernmental action. The desired goals are:

a) to organize research according to ecology, since most agricultural problems being of an applied biological nature, are more likely to be the same between countries having similar environmental conditions;

b) to approach agricultural research problems on a multidisciplinary basis and within their whole ecological area;

c) to encourage the development of various research projects, their implementation being shared out among the main research institutes existing in the countries of the ecological zone involved;

d) to stimulate co-operation in research through a closer working relationship between countries, institutions and individuals having similar scientific interests and carrying out studies and research activities on the same problems;

e) to conduct co-operative research, regional in scope and applicability, on problems of increasing the quantity and quality of food and agricultural production according to their order of priority;

f) to facilitate co-operation in research among universities and research institutions between developed and developing countries through engagement of the scientific staff in

joint projects and the organization of meetings, seminars, etc., on scientific and technical subjects pertinent to these projects;

g) to develop and maintain intensive exchange of agricultural research information, data and results and to facilitate the shifting of scientific staff throughout the zone so as to give research workers opportunities to become better acquainted and prepared to extend their knowledge and experience far beyond the boundaries of their research station area.

h) to concentrate a portion of the resources devoted to agricultural research on key topics selected on the basis of regional priorities in order to speed up the development of new knowledge, the arrangements for the transfer and adaptation of research findings and the application of research results;

i) to focus the attention of the international scientific community, research institutions, the scientific associations and other organizations, directly or indirectly involved, on specific requirements insofar as fundamental research is needed for the development of applied research in the developing countries;

j) to stimulate and promote co-operation in the implementation of research by encouraging the establishment of partnership agreements and the pairing of research institutions;

k) to make optimum use and to strengthen existing national research institutions and stations with a view to building up within the ecological zones concerned, a network of multidisciplinary agricultural research stations;

l) to avoid as far as possible unnecessary duplications and unprofitable competition in the field of agricultural research in general, particularly for those research activities to be performed within the regional framework of ecological zones.

To achieve these objectives, a regional agricultural research program on an ecological basis would be as applied or as basic as necessary with the primary criterion being its focus on practical results to be obtained for accelerating agricultural development.

18. The interdependent nature of agricultural research problems in some African countries is well known. Ecological zone research programing is therefore an effective and rational way of isolating and selecting the research priorities of the greatest scientific and practical significance to all countries situated in the same ecological zone, in that joint facilities, research implementation and results would be shared,

thus resulting in effectiveness and economy. The proposed pattern of regional co-operation is to attack the major agricultural research problems within ecological, rather than other arbitrary boundaries (linguistic, administrative, etc.). In fact, the solution of major agricultural problems is equally essential to all communities living in the same environmental conditions, whatsoever may be the pattern of their political, administrative or institutional structure.

19. Many research activities are already covered by national programs or regional projects, and as the proposed regional program aims specially to avoid wasteful dissipated efforts, the main objective of conferences on an ecological basis must be to indicate those priority fields in which research should be intensified and to delineate the main lines of action and subsequent measures to be taken for implementing the regional program. It is particularly relevant to include in such a regional program those problems which need to be studied in the entire ecological areas, or those which require standardized methods of investigation. It would be unrealistic and presumptuous to attempt to deal with all the problems of agricultural research, or even too many different research topics at the same time, in a regional program. Firstly, many research activities do not fit within a regional approach; and secondly, all research problems that arise from agricultural development do not have the same overriding priority for all the countries involved. A regional program should not be too ambitious as it is far better to start on a modest scale and have success with fewer but important problems than to embark upon an enterprise which is too heavy and complex and which will never supply the expected results in time. A regional program should only be concerned with high priority topics which by their nature and common interest to several neighboring countries, require regional co-operation.

20. The implementation of a regional program should be flexible, open to any kind of co-operation and permit use of all possible ways and means to achieve its objectives. One of the more forceful justifications for this concept of organizing agricultural research lies in the strengthening of existing national bodies with the aim of building up multi-disciplinary institutions and research stations on a national basis, able to work on both national and regional agricultural research programs. It must be recognized as a basic principle that the ultimate purpose of foreign assistance is to help the developing countries reach the level of self-sustaining development; therefore regional programs must be designed to be implemented as far as possible in local institutions.

21. Although much research on the problem of the developing countries may still be going on in foreign institutions, these activities should progressively be shifted to local institutions of agricultural research. At present this is not possible, as understaffed national institutions and stations cannot carry out an agricultural research program on the multidisciplinary basis necessary to solve the complex problems of agriculture. Better co-ordination and co-operation of external aid efforts organized within the framework of regional programs should make it possible to build up gradually a strong network of multidisciplinary national research institutions.

22. Regional institutions, legally recognized as international and autonomous, entirely created and provided with long-term financial support by private and philanthropic foundations or multilateral schemes of wealthy nations, would enormously facilitate the implementation of such programs, particularly in the early stage of development. Such initiative should be strongly encouraged, on the understanding that those providing funds state their intention to continue such long-term financing indefinitely.

23. At the present stage of development of research in most of the emerging countries, the establishment of regional institutes jointly financed by several developing countries is not a workable proposition. Developing countries, with pertinent reasons are generally unwilling to commit themselves to the long-term financing for the establishment and maintenance of expensive regional research institutes sited in a single country. Individual countries, despite high cost in financing and human resources prefer to have their own national research institutions well established before contributing to the joint financing of a regional institute which is inevitably beyond their immediate control.

24. The establishment of a regional research program on an ecological zone basis to strengthen the exchange of information and promote co-operation and co-ordinated action for a limited number of common problems, will result in technical meetings being held to deal with each of the priority problems selected. These meetings will bring together the interested parties to make a complete inventory of results acquired, evaluate the result of their practical application and decide on the research to be pursued. With this information, joint plans of action would be prepared including the necessary joint measures for their implementation.

25. After some years of co-operative working experience on a given number of regional research problems, the regional research program could be enlarged progressively. It might well be that, in the future, regional teams of research workers would eventually work together in national institutes and in a latter stage, regional institutes would be set up in each ecological zone. The point to be emphasized is that the final establishment of such jointly financed regional institutes would be the culmination of a long period of co-operation, rather than a successful starting point for co-operation. Before proposing the establishment of jointly financed regional institutes by several countries, national institutions should first be developed to serve as a strong basis for the implementation of national programs and joint activities on common problems selected by a regional agricultural research program.

26. The implementation of a regional research program to be shared out among several national research institutes and stations and supported by various sources of external aid, would both strengthen national research programs and facilitate concerned action. This concept of organizing research need not affect any government prerogatives nor any bilateral or multilateral technical assistance arrangements within countries. In fact it should help to make better use of assistance by overcoming the shortage of manpower and avoiding unnecessary duplication.

27. The establishment of a regional research program would promote closer co-operation between countries and foster and increase the contribution of external aid. All official research services are in need of greater funds. Governments of developing countries are unable to satisfy these needs in view of demands made upon them in other sectors of national development and the impossibility of sustained financing of research on a long-term basis. External aid is therefore necessary to provide the financial support indispensable to research and it would be all the easier to organize, as it would be concerned with regional programs.

28. A regional research program must guide technical assistance, streamline external aid to cover key problems and pool dispersed efforts on research common to several countries. It must help to work out a better strategy of aid for research aiming to use to their full extent the available resources in multidisciplinary activities complementing each other. The technical meetings, when preparing the detailed work plan for selected topics of the regional program, should suggest the fundamental studies and the basic research to be carried out to back up applied regional research programs. This expensive long-term and highly specialized research could be carried out by research institutions in the developed countries and by universities.

29. The concept of organizing agricultural research on an ecological basis has many other advantages if applied on a world-wide scale. A world plan of action for the application of science and technology for development, recommended by the Advisory Committee of the Economic and Social Council of the United Nations must be divided up in several regional programs. In the field of agriculture and renewable natural resources, the way in which problems should be solved depends largely on the prevailing environmental conditions in which they occur. Although the continents of Africa, Latin America and Asia are diverse in themselves, in the field of agriculture, research and applied knowledge are more similar between homologous ecological zones across these continents, than within a continent itself.

There is no doubt that research stations in the Soudanian Zone have much more of an interest in establishing working relationships with research stations located in similar semi-arid conditions in Australia (Katherine, Burkestown, Wyndham and Broome); in Asia (Mandalay-Burma, Amadabad, Bellary- India); in Latin America (Iguatu, Monte Santo-Brazil, Merida - Mexico), and other parts of Africa (Diredawa-Ethiopia, Voi-Kenya, Morombe, Tulear, Tsihombe-Madagascar) than with other stations sited in completely different environments. It is also true that research results acquired in research stations in the Guinean zone of Africa (Yangambi-Congo, Adiopodoume-Ivory Coast) are likely to be more useful to their counterpart ecological zones in Latin America (Amazonian zone - Belem-Brazil, Iquitos-Peru, Cristobal-Panama) and in Asia (Indo-Malaysian zone - Colombo-Ceylon, Buitzenzorg-Indonesia) than to the neighboring Soudanian or Zambesian zones of Africa. (See maps in annex).

30. Ecological principles which form the basis of agricultural practice have been used intuitively by farmers and scientists alike a long time before

the word "ecology" came into use.*/ The landscape vegetation, the flora, the fauna, the type of crop farming, etc., in a given geographical region is the true image of the combined effect of the environmental factors. There is a great diversity of climate, environment and form of agriculture throughout the world, but the understanding of the evaluation of environments and biological processes relationships allows the discovery of ecological affinities between very distant geographical areas. The survey of agro-ecoclimatic analogue areas throughout the main world ecological zones can make a definite contribution to the development of international relationships in the field of agriculture and particularly in agricultural research organization. The establishment of closer co-operation or even a simple information link between similar ecological areas may lead to savings in time, effort and cost. It may also bring about a more rational and wider utilization of the scientists' contributions and a more intensive exchange of mutual experience and information between those who are faced with similar difficulties and who try to solve similar problems.

31. An "Inter Tropical Agro-Ecoclimatic Analogue Survey" could be jointly implemented by FAO, UNESCO and WMO in co-operation with scientific institutions and governments concerned. The joint FAO/UNESCO/WMO Agro-Climatology Project of West Africa south of the Sahara should be used as the background study for a first approximation of such a survey in the Soudanian zone in Africa and its counterpart homologues in the tropics.

The introduction of agro-ecoclimatic analogue data in directories of agricultural research stations and in catalogues of agricultural research programs and results prepared with electronic computers would enormously facilitate the exchange of information and international co-operation in all scientific and technical subject matter fields of agricultural research and development.

32. The establishment of agricultural research programs on an ecological basis; the adoption of a standard system for cataloguing research programs and results by electronic computers and the study of agro-ecoclimatic analogues, are the means proposed to promote inter-country co-operation, widen the use of science's contribution to development and rationalize agricultural research organization on a world-wide basis.

33. We all know very well the difficulties to overcome when dealing with co-operation and co-ordination between individuals, institutions or states. In the field of science and technology, however, no country alone is able to fend for itself. It is our duty, and in our interest, to seek the ways and means to better know, understand and co-operate with each other.

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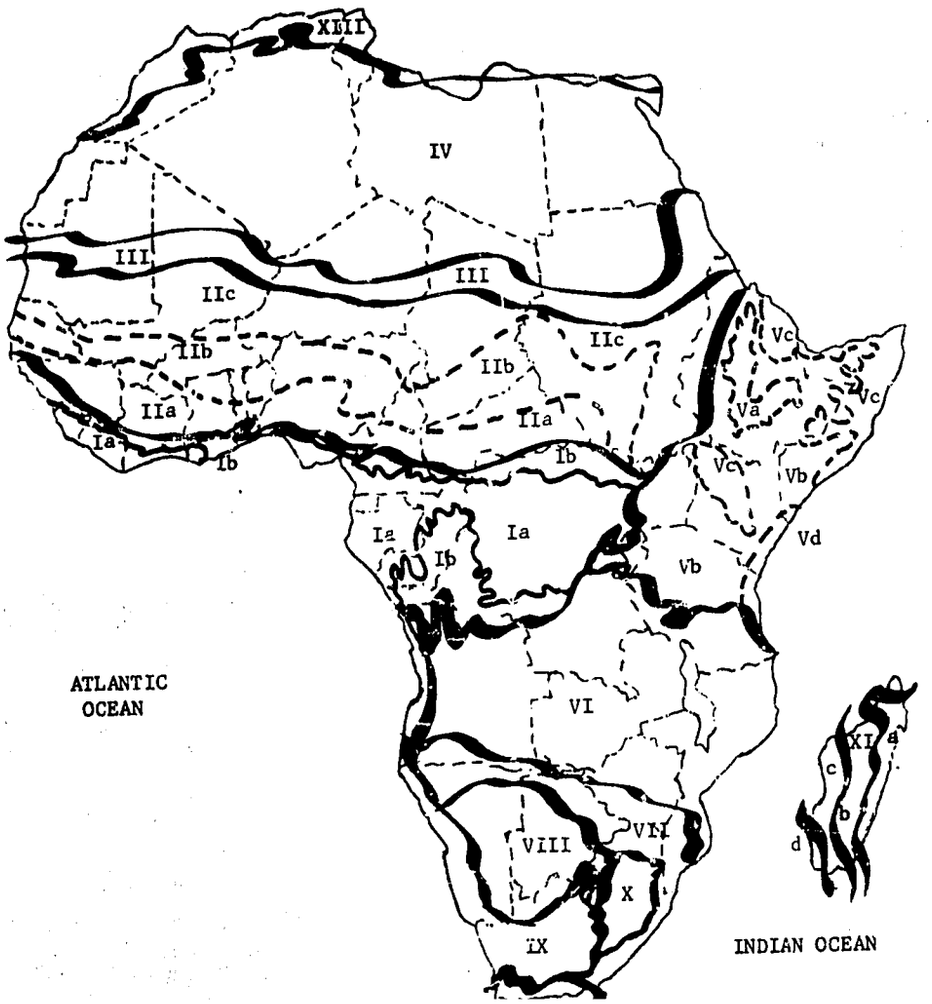
*/ Ernest Haeckel, 1866



ZONES ECOLOGIQUES DE L'AFRIQUE : ECOLOGICAL ZONES OF AFRICA - R. DEVRED

I. GUINÉENNE - GUINEAN
II. SOUDANIENNE - SOUDANIAN
III. SAHÉLIENNE - SAHELIAN
IV. SAHARIENNE - SAHARIAN
V. ORIENTALE - EASTERN
VI. ZAMBÉZIENNE - ZAMBESIAN
VII. TRANSVALIENNE - TRANSVALIAN
VIII. KALAHARIENNE - KALAHARIAN
IX. KARROO-NAMAQUALIENNE - KARROO-NAMAQUALIAN
X. BASUTOLIENNE - BASUTOLIAN
XI. MALGACHE - MADAGASCARIAN
XII. DU CAP - CAPE
XIII. MEDITERRANÉENNE - MEDITERRANEAN

A STANDARD METHOD OF CATALOGUING AGRICULTURAL RESEARCH DATA

G. Dubois

Documentation Centre, FAO

SUMMARY

Working on modern methods of documentation, the FAO Documentation Centre has developed a processing methodology using:

- the microfiche form for the storage of original documents;
- a coordinate indexing system based on a standardized vocabulary of descriptors developed by the Centre;
- an electronic computer for information retrieval as well as the production of bibliographies and analytical indexes.

As a result of its present activities in the collection, selection, analysis and indexing of FAO publications and documents, the Documentation Centre is now issuing:

1. Special indexes grouping in separate volumes, following the broad fields of activities assigned to the FAO Divisions, the bibliographical data and abstracts of the documentation produced from 1945 to 1966.

2. A monthly index of the same type with cumulative issues every six months covering the current production of technical publications and documents as from January, 1967.

Collaboration with other documentation centers is being progressively established to provide exchange of information and a larger coverage of agricultural literature. Further, technical assistance is being given in the form of methodology and training to developing countries desirous to set up national documentation centers on matters of rural development.

As far as agricultural research is concerned, it appears that much duplicating work could be avoided in providing research workers with complete information on research programs, projects and results achieved. The Documentation Centre has already started studying the application of its present basic methodology to a documentation system in agricultural research and welcomes the opportunity of discussing such a system with the participants of the Conference. A sample issue of an indexed catalogue of research projects prepared from data available from eight African countries, seventeen research stations and sixty-one projects will be distributed among the participants, together with more detailed information on its processing.

The system which we may call "CERES" (Computer Elaborated Research Exchange System) aims at establishing and updating an inventory of agricultural research projects carried on in developing countries, indexing and memorizing the related data by computer, publishing appropriate catalogues of such projects, storing the documents produced in microfiche form and finally, retrieving required information from the system.

The basic data required for input in the system will be provided at regular intervals by the participating countries, institutions and research stations and the indexing and processing methodology will be the one used at present for the FAO publications and documents.

In order to ensure compatability with other similar systems already set up or programed to be set up in developed countries, the Documentation Centre will maintain close contacts with other centers.

The participants at this Conference are then invited to make comments and give their expert advice on the proposals herein submitted so that practical steps be taken to start the "CERES" system as soon as possible. Discussions are particularly invited on the operating modalities of the system, inter alia, data collecting and updating, types of indexes desirable, research stations to be considered.

The FAO Documentation Centre

At the end of 1965, the FAO Conference endorsed the creation of a Documentation Centre, as an essential instrument towards the fulfillment of one of FAO's constitutional activities: "to collect, analyze and disseminate information relating to nutrition, food and agriculture" (including fisheries, marine products, forestry and primary forest products).

For its activities, the FAO Documentation Centre has adopted modern methods of information storage, retrieval and dissemination, inter alia: coordinate indexing based on lists of selected terms (descriptors), processing of basic data and information requests through electronic computers, and document storage and reproduction in microfiche form. It has progressively developed a processing methodology suitable for registering and indexing information on various types of documentary data such as contents of documents, activities of institutions, qualifications and experience of experts, etc.

One of the tasks assigned to the FAO Documentation Centre is to make readily available to FAO staff, particularly field personnel, to FAO Member Governments, to U.N. and U.N. agencies, to other interested international and national bodies, and to individuals concerned, the technical, economic and social information contained in FAO publications and documents.

To this effect, the Documentation Centre has undertaken - retroactively for the period 1945-1966 as well as on a current basis - to select, analyze and index FAO publications and documents in the technical and economic subject-matter fields covered by FAO.

As regards publications and documents produced currently, a subject index with the corresponding bibliographical data is issued regularly, since January 1967, in a monthly bulletin entitled "FAO DOCUMENTATION - Current Index" with cumulative issues every six months.

The selection, analysis and indexing of the publications and documents produced from 1945 to 1966 (some 20 to 30,000 documentary units) is in process and will be completed by mid-1968. These operations take place successively in the broad fields of activities and subject matter assigned to the FAO technical and economic divisions. Special indexes and bibliographies are issued as the related documents have been processed. To date, indexes for "Technical Assistance Reports", "UNDP/Special Fund Reports", "Fisheries" and "Forestry" have been issued. Indexes for "Plants", "Animals", "Nutrition", etc. are in preparation.

Bibliographical and indexing data are filed in computer memory and the original documents are stored in microfiche form. Special computer programs permit the retrieval of relevant data from the memory, in answer to specific questions, and the preparation of special bibliographies accompanied by the related documents in original size or in microfiche form, as required.

This documentary system, now centered on FAO's own documentation, is being progressively integrated into a wide network of documentation centers, in order to expand through interchange of specific information when required, the volume of literature covered and provide more exhaustive answers to the users.

For this purpose, the FAO Documentation Centre has already established close contacts with other centers specialized in its fields and is providing technical assistance - in the form of methodology and training - to developing countries for the establishment of improvement of documentation centers in matters of rural development.

The FAO Documentation Centre also intends to make an inventory of existing "gaps" in documentation matters related to agriculture and allied fields, and to take the necessary steps to promote action, at national, regional and international level, to fill these gaps.

The large amount of agricultural research at present undertaken in the world and the multiplicity of research projects scattered over so many research stations have led to duplicating work on the one hand as well as neglecting certain research areas or priorities on the other hand. This is partly due to the fact that in developed as well as in developing countries, it is becoming increasingly difficult to obtain and keep up-to-date a clear picture of the whole research pattern, activities and results.

The introductory paper to the present Conference, aimed at defining Agricultural Research Priorities for Economic Development in Africa, indicates that "Research in agriculture in Africa has reached the stage where a sustained, systematic exchange of information among specialists

concerned with African agriculture is necessary".

The FAO Documentation Centre had already under study the adaptation of its basic methodology to a documentation system in Agricultural Research when this Conference was called. It welcomes this opportunity to discuss the requirements and modalities of such a system with the participants of the Conference. Their experience and cooperation will be of primary importance in contributing to make the proposed system an essential working tool for "the most effective deployment of resources in research to improve agricultural production" and contribute to economic development of Africa.

A Documentation System for Agricultural Research - Project "C.E.R.E.S." (Computer Elaborated Research Exchange System)

The following paragraphs are intended to give an outline of the system and of the proposed methodology. More detailed information and a sample issue of an indexed catalogue of projects will be distributed at the Conference. This index has been prepared from data available from eight African countries, seventeen research stations and sixty-one projects. The system aims essentially at:

(a) establishing and keeping up-to-date an inventory of agricultural research projects in research stations of developing countries (e.g. of Africa), of their status and essential characteristics;

(b) memorizing the related data into computer files, after proper indexing (by subject, area, status, etc.);

(c) publishing, at suitable intervals, catalogues of projects, with indexes by country, area, subject, status and other topics of interest;

(d) storing in microfiche form other complementary details on the projects (outline of operations, approach, administrative items) and/or final or intermediate results reports;

(e) providing on request specific information, from computer and from microfiche files, on relevant projects, their status and characteristics, their results (with the assistance of the technical FAO divisions involved).

The basic data to serve as input for the system will be collected at suitable intervals (for instance, twice a year) from the participating countries, institutions or research stations, in standardized form to insure completeness of information. For projects already registered in this way, subsequent questionnaires will contain the information already available, so that only variations will have to be entered.

The indexing and processing methodology for the system will be - mutatis mutandis - the one used at present for the indexing of FAO

publications and documents. This methodology will also be applied for other documentary data such as data on institutions, experts, etc. In this manner, an integrated storage and retrieval system will be achieved, capable of providing exhaustive and multi-faceted answers to queries (documents, institutions, research projects, experts, etc. related to a given topic).

As in the case of publications and documents, the FAO Documentation Centre will establish close contacts with other international or national institutions who already have or intend to set up documentary systems on research projects (in developed countries) in order to insure the compatibility and complementary character of the systems, for the benefit of the users.

After the participants at this Conference have had an opportunity of examining the sample catalogue and details on methodology mentioned above, it appears desirable that a discussion should take place to firstly, receive comments and expert advice on the proposals and secondly, determine the practical steps to be taken so that the "CERES" system can make a start towards the end of the present year.

This discussion should, inter alia, bear on the following items:

a. Steps for updating the Index of Agricultural Research Institutions and Stations in Africa (published by FAO in 1965);

b. types of research stations and research projects to be included in the system;

c. mode of collecting data. Through governmental agencies and/or directly from research stations. Frequency of collecting;

d. ways and means of insuring collaboration from the research stations;

e. basic data to be included in each "Research Project Documentary Unit";

f. types of indexes (or access to memory) desirable;

g. desirability and feasibility to store projects reports. Possible restrictions to distribution to requesters.

ECOLOGICAL BASES FOR AN EFFORT TO REGIONALIZE AGRICULTURAL RESEARCH IN FRANCOPHONE AFRICA - PROPOSED AGRO-CLIMATIC REGIONS

IRAT

SUMMARY

This paper is based on the principle that organizing certain types of agricultural research on a regional basis can only be done within the framework of large ecological zones, within which the action of certain basic ecological factors creates a certain homogeneity as to species grown. cultural methods, and exploitation methods and systems.

Thus, by taking into consideration the duration of the wet season, the average annual rainfall and the altitude, and without taking desert and pre-desert climates into consideration nor certain very different local climates (such as certain coastal climates), Africa can be divided into three large agro-climatic groups. These are:

- Guinean or equatorial climatic zone, of low and average altitudes, which includes:

  - equatorial dense forest region or equatorial forest region
  - equatorial region with grassy wooded savannahs.

- Tropical climate zone, with low and average altitude, which includes:

  - wet tropical region
  - dry tropical region

- High altitude Tropical and Equatorial Zone

The paper includes an agro-climatic map of the regions under consideration and three bibliographical references.

PROPOSED AGRO-CLIMATIC REGIONS

Numerous authors have studied the African and Madagascan climates and have come up with as many classifications, that are often quite complex. As certain types of agronomical research on a regional basis cannot be organized because of the myriad climates thus defined, it seemed reasonable to take as a framework the larger ecological zones, within which the action of certain essential climatic factors creates a certain homogeneity of the species of plants grown in the area, and creates homogeneity as to cultivation methods and means and systems of exploitation.

If one takes into consideration:

- the duration of the wet season, that is to say the number of months during which there is enough rain to fulfill the needs of the plants being grown;
- the average annual rainfall;
- the altitude, which influences the temperature,

Africa can be subdivided into three large agro-climatic groups, if one ignores the desert and pre-desert climates and certain local climates, very different from the norm, such as certain coastal climates:

1. Zones with Guinean or Equatorial Climates, at low and average altitudes

The climate of these zones is characterized by an annual total of at least eight wet months (average monthly rainfall greater than 50 mm); the pattern is either for a wet season alternating with a more or less pronounced dry season, or two wet seasons alternating and separated by two more or less pronounced dry seasons.

This long-lasting wet season or these wet seasons, allow for two annual planting cycles and lend themselves to perennials.

This large agro-climatic region can be further subdivided into two sub-regions, which it is expedient to classify by the type of vegetation found in each:

1.1. Equatorial region with dense, shady forest or equatorial forest region:

The nature of the vegetation calls for special methods of exploitation. The intensification of agriculture requires long and onerous tasks for clearing away vegetation (felling and stubbing).

This forest, which is 2,400,000 square kilometers in size, of which 500,000 are in West Africa and 100,000 in Madagascar, includes ferrallitic soils, ferric soils, young soil on fluviolacustral alluvium, and hydromorphic soils.

1.2. Equatorial region with grassy and wooded savannahs:

This region where it is easier to clear and cultivate, contains ferrallitic soils and vertisoils and also tropical ferruginous soils.

2. Zones with tropical climate at low and average altitudes

This zone will include all regions where the wet season (average monthly rainfall over 50 mm) lasts between two to eight months; in other words, this includes all areas where, without bringing in supplemental water, there can only be one cycle of cultivation per year.

The annual rainfall in this area is approximately from 400 to 1400 mm on the average.

According to average annual rainfall and duration of the wet season this zone can be further divided into two sub-regions:

2.1. Wet tropical region, characterized by:

- Annual average rainfall greater than 800 to 900 mm;
- A wet season of from five to eight months long (average monthly rainfall greater than 50 mm)

This region encompasses most of the dry grassy and wooded savannah region, as well as the southern half of the grassy and wooded steppes.

In the less dry areas, tropical ferruginous soils, vertisoils, lithosoils, young soil on alluvium, and halomorphous soils are predominant. On the wooded steppes, one finds mostly the brown soils of the tropical arid and sub-arid regions, vertisoils, lithosoils, halomorphous soils, and tropical soils on top of sandy soil.

3. Equatorial and tropical zones at high altitudes

Through its influence on the temperature (extremes, etc.) altitude causes certain types of vegetation, special varieties and species must be grown and special techniques and methods for exploitation must be used.

It seems reasonable to include with this zone the high altitude regions compatible with the cultivation of cafeir arabica. The minimum altitude defining the limits of this zone varies with the latitude between 300 and 900 meters.

The map following shows a sketch of the boundaries of these proposed agro-climatic zones and regions.

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/Key to map/

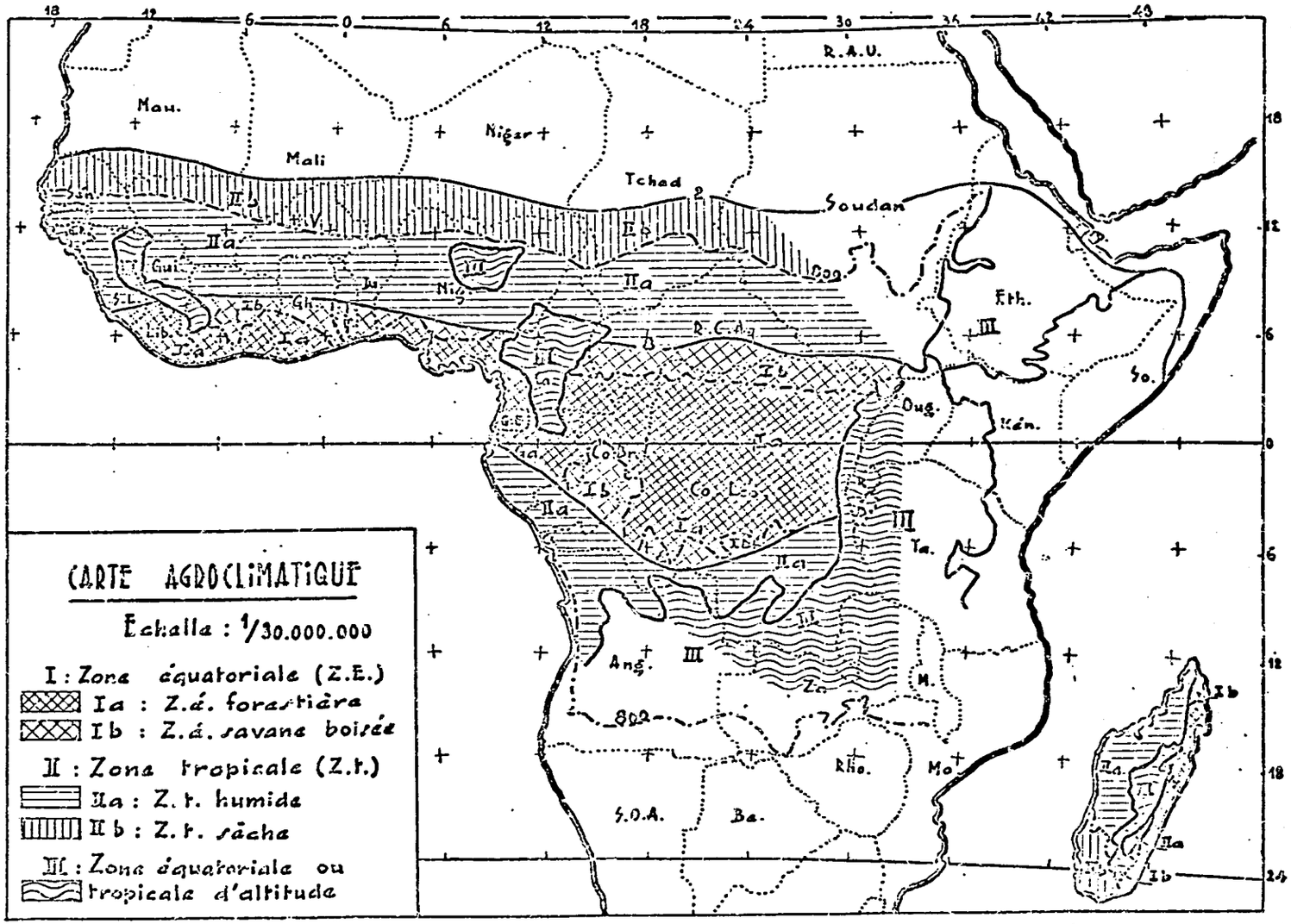
Agroclimatic Map

Scale: 1/30,000,000

I. Equatorial Zone (E.Z.)
   I.a. Forest region e.Z.
   I.b. Wooded savannah e.Z.

II. Tropical Zone (T.Z.)
   II.a. Wet t.Z.
   II.b. Dry t.Z.

III. Equatorial or Tropical Zone at high altitudes


CARTE AGROCLIMATIQUE
Echelle : 1/30.000.000
I : Zone équatoriale (Z.E.)
Ia : Z.é. forestière
Ib : Z.é. savane boisée
II : Zone tropicale (Z.t.)
IIa : Z.t. humide
IIb : Z.t. sèche
III : Zone équatoriale ou tropicale d'altitude
R.A.U.
Mau.
Niger
Mali
Tchad
Soudan
Eth.
So.
Ken.
Oug.
R.C.Af.
Ang.
Ta.
M.
Mo.
Rho.
S.O.A.
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ORGANIZATION OF FORESTRY RESEARCH IN FRANCOPHONE AFRICA BY ECOLOGICAL ZONES

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SUMMARY

As successors to Forest Research Divisions, which were already in existence or as new organizations, Forestry, Fish-Culture and Soil Conservation and Protection Research Centers were set up for Francophone Tropical Africa following independence.

Within the framework of bilateral aid treaties, France financed approximately half of the cost for establishing and operating these centers and the countries financed the other portion.

The management of these national Forestry Research Centers was entrusted to CTFT, a French Government research center with substantial research laboratories on tropical woods.

Setting up the Centers caused many problems, because each of the Francophone African countries wanted a Center on its own territory. However, for both financial reasons and the dictates of common sense, these Centers were set up according to the ecological forest zones known in Tropical Africa: the idea was to avoid overlapping of programs while at the same time supplying each zone with a center capable of studying the problems that arose.

An enumeration and classification of the ecological forest zones is then given in detail, but one can briefly set them forth as follows:

Dense Forest Zone

-Limba forest (Terminalia superba)
-Okoume Forest (Aucoumea klaineana)
-Azobe forest (Lophira procera) and Doussie forest (Afzelia sp.)
-Niangon forest (Tarrietia utilis)
-Avodire forest (Turreanthus africanus)
-Ayous forest (Triplochiton scleroxylon)
-Frake forest (Terminalia superba)
-Sapelli forest (Entandrophragma cylindricum)
-Sipo forest (Entandrophragma utile)
-Dense Malagasy forest

Savannah Zone

-forest savannah

-Guinean and semiforest savannah
-Sudan-sahel savannah
-semidesert savannah

It was on the basis of this simplified classification that Forestry Research Centers were established. A table summarizes these and gives the special characteristics of each zone.

In conclusion, it seems that under present conditions these centers established are sufficient and adequately reflect the basic problems on forestry facing Francophone Tropical Africa.

I. INTRODUCTION

1.1: Forest Research Divisions were created at the level of the old Federations of French Equatorial Africa, French West Africa, and the Territories where the most serious forestry problems existed: Ivory Coast, the Cameroons, Gabon, the Congo, and Madagascar. Because of the complexity of the phenomena and the modest means at their disposal, the development of the activity of these divisions remained minor as compared with the huge tasks they had and the goals they had set themselves.

1.2: As soon as the independent states were set up, France set out to help the young governments, through bilateral treaties, to develop their technical and scientific research, including forestry research, by supplying specialized personnel, financial means, and help from the tropical agricultural research institutes that had long existed in France, with their central laboratories and traveling experts. On their side, the young nations supplied approximately an equal share of financing and supplied buildings and installations.

1.3: In the area of forestry research, fish-culture, soil conservation, and soil restoration, the task of organizing and managing the national forestry research centers fell to the Technical Tropical Forest Center, a French organization which carried on in each country an annual program established beforehand by the National Council on Forestry Research.

1.4: The countries which belong to this system are at present: the Cameroons, Congo-Brazzaville, the Ivory Coast, Gabon, Madagascar, Niger, Senegal and Upper Volta. In addition, there is research going on in other countries, such as in Dahomey, on specific problems.

II. ORGANIZATIONAL BASIS - THE ECOLOGICAL ZONES

2.1: It is a fact that all Francophone tropical African countries quickly realized how important it was to establish research programs before large-scale forestry programs could be undertaken: reforestation, forest management, control of erosion, etc. They solicited help from France in creating their own national forestry research centers.

2.2: It is clear that the creation of a research center for each country, even though this might have been desirable from a national point of view, would have meant duplication and dissipation of research efforts for the whole area. Beyond this, funds were limited, and it therefore seemed much more reasonable to establish one research center per ecological zone, but the programs would be coordinated and the results obtained distributed to all; this is what the CTFT tried to do through its services in the field and its central organization.

2.3: With regard to forest lands in tropical Africa, one can identify the following large ecological zones:

2.3.1: Dense forest zone: annual rainfall is between 1500 and 3500 mm and the following main forest types can be found there:

2.3.1.1.: In the Southern Hemisphere:

-Congo (Brazzaville): Limba forest (Terminalia superba)
-Gabon: Okoume forest (Aucoumean klaineana)
-Madagascar-Eastern Ramy forest (Canarium madagascarensis) and Mantaly forest (Terminalia mantaly)

2.3.1.2: In the Northern Hemisphere:

-The Cameroons: Azobe evergreen forest (Lophira procera) and Doussie forest (Afzelia sp.)
-Ayous deciduous forest (Triplochiton scleroxylon)
-Frake forest (Terminalia superba)
-Sapelli forest (Entandrophragma cylindricum)
-Central African Republic: Deciduous forest identical to that found in the Cameroons
-Ivory Coast: Niangon evergreen forest (Tarrietia utilis) and Avodire forest (Turreanthus africanus)
Samba deciduous forest (Triplochiton scleroxylon)
Sipo forest (Entandrophragma utile) and
Bete forest (Mansonia altissima)

2.3.2: Savannah zone: the savannah is an open forest type, more or less grassy. It usually touches the dense forest and is distinguishable by its appearance and its climate which is always drier; it can often have a wide variety of soil and climate One can distinguish:

2.3.2.1: In the Southern Hemisphere:

-wooded savannahs: Congo and Gabon
-Guinean savannahs: Madagascar
-Sudan-sahel savannahs: Madagascar

2.3.2.2: in the Northern Hemisphere:

-wooded savannahs: Ivory Coast, Dahomey, Togo, Guinea

-Guinean and preforest climate savannahs: Central African Republic, Chad, the Cameroons, Dahomey, Togo, Niger, Upper Volta, Ivory Coast, Guinea, Mali, Senegal, Mauritania
-semidesert savannahs: Chad, Niger, Mali, Mauritania

2.3.3: Comments: In reality, altitude and maritime or continental location further diversify these large regions, especially in the Cameroons, Guina and Senegal. One can, however, regroup these zones in a more simple way, according to their dominant forest types. In this way one can list:

2.3.3.1: Dense forest:

-Limba forest
-Okoume forest
-Azobe-Doussie forest
-Niangon Avodire forest
-Ayous-Frako-Sapelli-Sipo forest
-dense Malagasy forest

2.3.3.2: Savannah:

-wooded savannah
-guinean savannah
-Sudan-sahel savannah
-semidesert savannah

2.4: The Forestry Research Centers have been set up by the CTFT according to this simpler format which, although it is less complex, agrees with the reality of the forests. The table below summarizes this, as does the map attached as an appendix:

Ecological Forest Zone	Research Centers	Headquarters	Observations
Limba forest	Congo-Brazzaville	Pointe-Noire	
Okoume forest	Gabon	Libreville	
Azobe-Doussie forest	Cameroon	Douala	
Niangon-Avodire forest	Ivory Coast	Abidjan	
Ayous-Frake-Sapelli-Sipo forest	Ivory Coast	Abidjan	At low altitudes
	Cameroons	Douala	At medium altitude (500 to 1000 m)
Dense Malagasy forest	Madagascar	Tananarive	Research had to be interrupted temporarily due to lack of funds

Ecological Forest Zone	Research Centers	Headquarters	Observations
Wooded savannah	Congo-Brazzaville	Pointe-Noire	Average annual rainfall of 1000-1400 mm
	Gabon	Libreville	Average annaul rainfall of approximately 2000 mm
Guinean savannah	Ivory Coast	Abidjan	continental climate
	Senegal	Dakar	maritime climate
	Madagascar	Tananarive	medium altitude
Sudan-Sahel savannah	Niger	Niamey	Continental, rather Sahelian climate, light soil
	Upper Volta	Niamey	Continental, rather Sudanese climate, lateritic soil
	Madagascar	Tananarive	Southern part of main island
Semidesert savannah	Niger	Niamey	Research had to be interrupted temporarily due to lack of funds

2.5: One can thus observe that the seven forestry research centers set up in African each cover a particular ecological zone. Within each of these ecological zones, the installation of the experimental stations was governed by local differences such as climate, altitude and soil. This classification can be argue with: ecological notions can only be discerned after a great deal of research and at the beginning errors may have been committed. Nevertheless, up to now experience has shown that all the main problems encountered in the tropical zone have been proper to the activitie of one of these centers, whether they pertained to forest problems or to soil conservation, or erosion.

We believe that at the present level of our knowledge, the classification is satisfactory.

Later, perhaps, when forestry research will have accomplished the great steps forward that we all expect, it will be time to complete and extend these research centers to other locations.

TYPES OF CLIMATE

AND VEGETATION

TECHNICAL TROPICAL FOREST CENTER

X = Headquarters of Overseas Research Centers

• = Secondary experimental stations

I. EQUATORIAL AND WET TROPICAL CLIMATES

Dense forest

Wooded savannah

II. SUDANO-GUINEAN SEMI-HUMID TROPICAL CLIMATES

Guinean savannahs

III. DRY TROPICAL SUDAN-SAHEL TYPE CLIMATES

Sudan-Sahel savannahs

IV. SUB-DESERT CLIMATES

Semi-desert savannahs

V. DESERT CLIMATES

Desert

GENERAL FORESTRY RESEARCH CORRESPONDING TO THE ECOLOGICAL ZONES OF FRANCOPHONE TROPICAL AFRICA

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SUMMARY

As a continuation of the previous paper, this document points up the main themes of research in Forestry and Soil Conservation and Restoration according to the large African ecological zones and the problems faced by each.

Forest Research is concerned with the following main themes:

1. Determination of natural forest resources - accomplished through "inventories" of available statistics which, since 1960, have made it possible to determine the volume, number and nature of exploitable trees on more than 13 million hectares of dense forest; these inventories will continue for many years to come.

2. Sylviculture - forest culture concentrating on:

- ecology: it is necessary to attempt to explain the natural distribution of the main species, observe the acclimatization criteria of species introduced from abroad, systematically introduce new species based on knowledge about their ecologies (American, Asiatic, Indonesian species, etc.).

- genetics: this research aims at obtaining the genetic improvement of the main reforesting species so as to obtain optimum types, rapid growth, and resistance to diseases and drought; this type of research has only recently begun in the Congo and Gabon and should be extended to other countries and intensified.

- pedology: this is primarily a question of defining soil-vegetation relations making it possible, on the one hand, to explain distribution of species and on the other hand, to orient the choice of soil in which artificial plantations will be planted; this is a very new doctrine and is facing many problems.

- plant physiology: it is necessary to analyze the observed biological phenomena and try to explain them and learn from them how to improve plantations and other forest operations.

This type of research has only been pursued for the last few years and started out as research in dense forests on the influence of light on the growth, size and shape of trees, and in savannahs on the determination of the quantity of water necessary for different species to guarantee their proper growth and on the quantity of water given trees by various soil-management techniques.

- phytopathology and entomology: here it is a question of defining the parasites which may attack forest plantations, determine their causative and vector agents, and finally develop the proper means of control. This is an area where knowledge is still very incomplete, and because of the present constant danger to plantations from pests, it is a particularly important field for applied research.

- forest management: this involves assuring the productivity of forests by organizing their exploitation and regeneration. The development of this kind of activity is particularly difficult in dense tropical forests because of the complexity of forest formations and the sketchy knowledge we have on their growth rates, and the unprofitable aspects of regeneration.

Research on Wood. Research on the physical and mechanical aspects of the main forest species is very advanced and has been carried on up to now in very specialized laboratories with a great deal of money at their disposal; these have usually been situated outside Africa, in the countries of high wood consumption and utilization. This type of research should be pursued and completed, and account should be taken of the differences which may arise due to different soils in which the same species may be grown.

Beyond this, research on the use of this wood in tropical climates has been underway for several years; it involves studies of the protection of the wood in all its forms against pathogenic agents, and studies of the best techniques for preparing the wood for use (air drying, artificial drying, painting, etc.).

Soil Conservation and Restoration. Vast areas of tropical soils are subject to erosion, either caused by the climate or by man. In certain countries, especially Madagascar, there has already been much research on this phenomenon to analyze the problems and causes and find the means of control.

Experimental plots on land are systematically observed and analyses are made based on slope, exposure, climate, nature, and crop rotation, etc.

Soil conservation techniques have already been perfected and the need for an all-out program of this nature is recognized by most countries.

INTRODUCTION

In a previous paper, we showed how the establishment of forestry research centers was conceived in Francophone tropical Africa in terms of the ecological zones. Now we shall try to point out the main research themes which have been suggested by the local economic problems, or by observation and thought in each one of the large research zones.

Primarily, the principle problems concern:

the forest - determination of natural forest resources, their production and management.

wood - determination of the technological value of the different species and best ways of using them.

soil conservation and restoration.

Research themes in tropical forests are dominated by the vast number of ligneous varieties (several hundred in dense forest) which makes problems at all levels very diverse and complex, from information on the forest and sylviculture to the use and commercialization of the wood.

Forest Research Themes

A. Determination of Natural Forest Resources

This is an indispensable prerequisite for any forest use of improvement operations and it is realized through an "inventory" system. This is done through statistical sampling, and levels vary from 0.5% to 1-2%. giving a probability calculated at a level of 0.95. More than 13 million hectares of dense forest have thus been inventoried since 1960, giving, by size categories, the number and volume of exploitable trees per hectare of the main commercial species. However, we are far from knowing exactly how to use all the statistical information available and the level of sampling for each specific problem, nor do we know the precise level of commercial volumes; these are the general themes which must be looked into further.

B. Sylviculture

Forest culture must concentrate on the following themes:

1. Ecology - It is infinitely more complex than for temperate zones because of the great diversity of natural formations, and we have not as yet been able to differentiate vegetal associations, but only the large forest formations based on climatic distinctions. It is possible to distinguish, going from the Equator North or South:

dense forest zone:	evergreen forest
	semi-deciduous forest
savannah zone:	Guinea savannah
	Sudan-sahel savannah
	Semi-desert savannah

Obviously the boundaries between these large zones are not very clearly defined, and so we had to characterize one or two of the most homogenous formations within each zone: Limba dense forest, Okoume dense forest, etc., Daniella-Lophira savannah, Acacia savannah, etc. Although this classification is not perfect scientifically, it has the advantage of being practical.

Ecological research can, in our opinion, be done according to three different approaches, which we think of as the three main research themes to pursue:

(a) observation and study of the biology of the main dense forest species in order to explain their natural distribution and define the criteria for their use and adaptation.

(b) observations on the growth and phenology of foreign species which have already been introduced (Okoume in the Ivory Coast and the Cameroons, Limba in the Ivory Coast, Niangon in Gabon, etc.)

(c) systematic introduction of new exotic species and races whose ecological needs seem to correspond to those of the area, according to classical statistical implantations (comparative statistics according to place of origin); a few of these introductions have been done or are in process: tropical resinous trees from America and Asia have been introduced into the Cameroons, the Congo, the Ivory Coast, Gabon, Madagascar, and Senegal; humid zone Eucalyptus trees have been introduced into the same countries, dry zone Eucalyptus trees have been introduced into Niger, Upper Volta, Senegal, etc.

All of this research should be pursued, based on the first overall rules that have been determined (summer rain climates, winter rain climates, etc.)

2. Genetics - This research aims at the genetic improvement of the main species used in reforestation (Gaboon, Teak, Mahogany, Niangon, Limba, Resinous trees, and Eucalyptus), and aims at the following goals:

(a) the goals:

selection for shape (straightness, branching, etc.)
selection for growth pattern
selection for resistance to disease and drought

(b) methods to put into operation:

selection of "mother trees" and careful sorting of plants in nurseries,
determination of eventual races (ecotypes) through comparative plantings,
selection of the best ecotypes; hybridization,

production of seeds from the best ones chosen (seed gardens, cuttings, seedlings, etc.).

This type of research has only just begun in the Congo and Gabon; it needs to be extended to other countries and followed much more extensively.

3. Pedology - When we spoke of ecology we mentioned that we could not explain the distribution of the main species and the extension of their areas: this is a proof of our ignorance on soil-vegetation relations.

How can the distribution be explained particularly of many species that are very important economically, such as the Ayous-Samba, the Frake-Limba, and the Mahogany-Khaya which can be found in the tropical humid zone across 5000 kilometers of longitude and 1000 to 2000 kilometers of latitude?

(a) Orientation difficulties: tropical forest pedology is a very young science which came up against big obstacles from the first:

- we have only had large area forest inventories, making it possible to know the broad outlines of the distribution of species, for a few years;
- we have also only had valid information of the large geological and pedological formation of the tropical zone for a short time, and beyond a very few special cases, we have no detailed pedological information;
- it now appears that if the soil directly influences the rapid growth of species, it does not necessarily eliminate species from certain areas and because of this fact, study of the soil/vegetation phenomenon is rendered more difficult.

That is why forest pedology first concentrated its efforts on forest plantations where the study of soil/plant relations is easier, in spite of the frequent heterogeneity found there due to the imperfect planting techniques used at present.

(b) Research techniques used: We are trying to relate a measure used in the plant (diameter, height, volume) with a measure of a soil characteristic, through a linear correlation; then we seek further possible correlations by varying the soil conditions or the sample trees (the biggest trees, the smallest trees, etc.).

It seems hopeful that progress can be made by using statistical sampling to define the sample trees corresponding to the objectives.

Therefore, the main research themes concern amplification of the research on forest plantations by using statistical methods and insisting on the physical characteristics of the soil, too often discarded in analysis: finally, this analysis should be extended to the natural forest.

4. Plant Physiology - Plant physiology research should lead to determination of the best forest regeneration and improvement techniques which is the main goal of sylviculture.

We must distinguish between:

(a) Dense forest research: In our discussions of ecology and pedology we saw that we have as yet no precise knowledge of the influence of soil on the growth of trees. An analysis of the factors influencing the latter has led us to decide that since water resources are generally adequate in the dense forest and since the influence of soil is practically unknown, we should concentrate our efforts on the third determining factor - light. We have thus oriented our research in two directions:

(1) Influence of light on growth of trees - We tried to determine the optimum quantity of light required by the main species; the quantity of light given the plants by the different planting techniques and natural regeneration (by calculations and the use of measuring instruments); and the influence of lateral lighting on growth in height.

The first results obtained have led us to propose modifications in some traditional planting methods, devise new ones, and define reasons why the natural regeneration methods never gave good results.

(2) Influence of light on the shape of trees - We are trying to show at present that classical defects of shape (humps, gnarling, etc.) are often due to unequal lighting of the small tree, and these phenomena seem to be predominant over any hereditary factors. This research could have considerable practical impact on planting techniques and spacing (Okoume, teak, Limba, etc.).

(b) Savannah research: In increasingly drier climates, the analysis of natural phenomena conditioning growth has shown that the water factor is predominant; soil and light are rarely limiting factors. Water has double effect, on the survival of the trees and on its growth. We have oriented our research towards:

(1) Quantity of water available to the trees;
measure of the quantity of infiltrated water (rainfall and run-off);
measure of the quantity of useful water (field capacity, wilting point).

(2) Determination of amount of water trees need;
measuring the amount of water lost through evapotranspiration and establishment of a complete moisture cycle in forest plantations.

(3) Determination of the amount of water given the trees by various soil-management techniques; establishing a moisture profile corresponding to each of these techniques and the corresponding growth of the trees. The techniques tested are hand planting, rooting, plowing, ridging, and steppe method.

These research themes must be dealt with in each ecological sub-zone because one must be wary of overly broad extrapolations in this area.

5. Phytopathology and Entomology - This research doctrine is oriented towards the dual goal of:

(a) Research proper, following two directions:

(1) Study of the biology of the main parasites, either through observation in their natural environments and manifestations or through artificial breeding.

(2) Perfecting of means for fighting parasites; these may be chemical, biological or cultural. One must keep in mind the nature of forest plantations; they have modest means which eliminate costly treatments which other types of agricultural plantations might be able to sustain, and beyond treatments with airplanes, there are many that are not applicable.

(b) Phytosanitary control of forest plantations: Up to now this has been carried out over the whole area; in future, it will require the use of representative samples, since the plantations are becoming too extensive.

If the main research themes to be pursued are easy to identify, the amount which should be accorded to each is difficult to ascertain, because in a totally unpredictable manner some relatively unknown parasite can suddenly cause a widespread and costly problem. But one must be vigilant, because the consequences of an attack observed too late can be catastrophic.

C. Control and Management of the Forest

This activity of the forest aims at assuring forest productivity by organizing its rational exploitation and regeneration. Normally, forest control and management is a study program and does not involve research per se: nevertheless, in the tropical zones, basic facts are still relatively unknown and research should be undertaken in order to define them. This research should concentrate on:

1. Knowledge of the Rhythm of Growth of the Natural Forest - We have very little knowledge on the growth and rhythm of growth of many of the myriad varieties of vegetation in the dense forests; we do not know this as a function of their light reception either. We are trying to fill this vacuum by setting up a statistical estimating process through the use of several thousand sample trees; and by trying to "read" the growth rings of various species and showing that they are annual.

2. Perfecting of Sylvicultural Techniques - They are simple but sufficiently effective; they could be used over very extensive areas so that it would be possible to improve the forest after development by clearing and giving more light to good trees that are left standing, in order to increase their growth rate; and to regenerate the forest by using work done for development so that the cost of this operation would be lessened.

This type of research is essential for the future of dense tropical forests if one wants to maintain the large wooded areas and if one wants to maintain an equilibrium in the wood resources of the countries and keep the forests from being depleted.

Research on Wood

The great variety of forest species makes it difficult to determine the use of tropical wood, because it deters users and requires long previous research and trials, and because the volume of each variety may be low and therefore there may be a problem in supplying purchasers with required amounts of wood which is a very bad thing from a commercial point of view. In order to assure that tropical wood will successfully find and sustain a market, the following research must be done:

A. Research on the Anatomy of Wood

Rules must be established for making it possible to identify the various species from small wood samples. This type of research has been going on for a long time and the specialists can now recognize most of the species from their "ligneous plans." However, this requires the use of magnifying glasses and often microscopes.

B. Research on the Technology and Manufacturing of Wood

Here it is a question of measuring the physical and mechanical costs of tropical wood and calculating and developing the most appropriate tools for manufacture. This kind of research can only be successfully carried out in large laboratories with very specialized personnel and equipment; this kind of laboratory has for a long time been established outside Africa.

Besides these traditional research themes, research should be oriented towards the modern use of wood: particle and fiber panels, sheet-wood, paper cellulose, etc.

C. Research on the Preservation of Wood

This research which has already been carried out in Africa concerns:

1. Determination of natural resistance to the main species of parasites and so on;

2. Perfecting of methods and products of preservation for wood shavings, small round wood, cut wood and so on;

3. Perfecting the utilization of paint and varnish.

D. Research on Wood Use

This is generally worthwhile research to determine all the possible uses of wood. Research would concentrate on:

1. Open-air drying of wood: wood dries very quickly in the tropics (a few weeks): "drying tables" must be established for the main species and the main experimental stations;

2. Artificial drying: to be used on certain types of wood and cuttings;

3. Use techniques (exposure, assembly, preservation) to make sure wood has equal chance with other materials.

Except for the types of research which require highly specialized and costly equipment, all other research is undertaken in African research centers, and should be extended if we are to get greater and greater profit from the tropical forests.

Research Themes on Soil Conservation and Restoration

The combined efforts of climate and human action have been so detrimental in certain tropical countries such as Madagascar that a great deal of the vegetation and fertility potential of the soil have disappeared. A similar situation is developing and may get worse in the dry areas of Africa with the population increase, because average annual rainfall is so brief and so violent that there is a great deal of erosion; the rain is useless for the crops and takes away many vital elements from the soil. Therefore many countries, especially Madagascar, have decided to engage in an all-out campaign and spend a great deal on a soil conservation and restoration program.

The CTFT has been asked to do a great deal of research on this in Madagascar, Niger and Upper Volta.

A. Nature of Soil Conservation and Restoration Research

First, this research consists in defining rules on erosion as a function of certain parameters (climate, soil, slope, exploitation, natural vegetation and crops); then, it must describe and perfect means and measures available for mitigating the harmful effects.

B. Research Used

This research is carried on through:

1. Elementary, Basic Plots - Small plots of a few areas where rainfall, streaming, quantitative erosion (weight of elements carried away) and qualitative erosion (nature and composition of elements) are studied as a function of the slope, exposure, nature of the vegetation and types of crops.

2. Basic Basins (large plots) - Large plots for comparing farming methods of neighboring geographic surfaces.

3. Special Tools - Making it possible to measure particular influences such as the rain interception of the trees, action of wind-breakers, etc.

4. Test-Operations - Installations for testing certain restoration and regeneration techniques as a function of the weather: methods used against soil erosion and research results are tested usually with the cooperation of other institutions (IRAM, IEMVT).

C. Results

Results have already been great and can be summarized as follows:

1. Runoff coefficients, soil loss, etc. have been determined for many types of stations (Madagascar) or for only a few (Niger, Upper Volta).

2. It was shown that certain simple types of soil-management techniques (ridging, contour plowing) were very effective and greatly increased crop yield through improved water utilization and reduced leaching (with or without bench terraces).

3. In the savannah zones of Madagascar (Lac Alaotra) it was shown that proper use of the grassland steppes was enough to mitigate erosion.

4. The effectiveness of certain agro-sylvo-pastoral forestry pasture management tests (Manankazoa) was proved by using typical crop rotations with inclusion of temporary grassland lasting three years in the rotation.

5. We were able to pass to the management of certain areas and use principles arrived at through research after their soil vocation was determined (protection, production) and after soil-utilization maps were developed.

D. New Research Themes

1. In Madagascar - Beyond experiments on the influence of the natural vegetation, we are seeking to geographically diversify the basic plots and the drainage basins, define and classify the erosion risk zones (Wischmeyer's universal equation), study the influence of reforestation on underground layers, establish other test operations and compare different anti-erosion methods.

2. In Niger-Upper Volta - We are trying to continue and enlarge first research done on basic plots (Ader-Doutchi, Mossi Plateau) in order to define the main aspects of the phenomena and to pass the first proven results of experimentation into practical use (benched terraces with grassy edges made by hand, contour plowing).

It is possible that modern research methods such as the rain simulator technique used in the United States would make it possible to make quicker progress.

E. Special Case of Acacia Albida

The influence of this forest specie of the Sudan-sahel zone on maintenance of soil fertility, of which African farmers are aware, was proven in 1964 by Charraut and Vidal for millet and sorghum. A concerted research program undertaken in 1966-67, initiated by the CTFT and thanks to the support of the Secretary of State for Cooperation, grouped together all the French research organizations working in this zone (ORSTOM, IRAT, IEMVT, IRCT, IRHO, CTFT); the results of the 1967 campaign are particularly encouraging because they show that this fertilization is equally valid for peanuts and cotton (60%-80% increases in yield).

These experiments should be repeated but make it possible to hope for practical application on large surfaces, because we now know how to plant this forest species under good conditions.

Speed of growth, rhythm of growth and function of soil and climate must be determined and the best planting techniques must be perfected with the help of agronomists so that Acacia albida can be successfully planted in cultivated land.

THE EAST AFRICAN AGRICULTURE AND FORESTRY RESEARCH ORGANIZATION

A. Present Role, T. Jones, Deputy Director
B. Priorities and Problems, O. Starnes, Director

SUMMARY

A. Present Role. E.A.A.F.R.O. is an international research organization serving Kenya, Uganda and Tanzania, and is concerned with the solution of those problems which, singly or in concert, limit the speed and scope of development in agriculture and forestry in East Africa. Its current program, designed to undergird crop and animal production in East Africa, is described.

This paper gives an outline of the research staff strength and financial resources of E.A.A.F.R.O. and inventories the major facilities available at its central laboratories at Muguga. In the description of the current research program no attempt has been made to record research achievements as details of these are easily available elsewhere, but rather the main lines of research have been indicated in order to give an insight into the depth and scope of E.A.A.F.R.O.'s activities. For convenience the program has been described under disciplines or fields of research, but the multidiscipline approach adopted at E.A.A.F.R.O renders this subdivision largely artificial. The current program retains a considerable degree of flexibility and can be adapted to meet changes required in the emphasis of research and is capable, given adequate resources, of very considerable expansion. Much of the program is already being given realized by the team approach to specific projects, an approach currently favored by aid agencies concerned with research in developing countries.

B. Priorities and Problems. Agricultural research priorities in (a) water availability and use efficiency, (b) soil fertility and plant nutrition, (c) crop production, (d) animal production, (e) crop protection, (f) cultivation, harvesting, handling and storage are identified.

Problems confronting the regional research institution are identified. These in terms of personnel, facilities, funds, program and organization must be overcome if the regional research institution is to be strengthened. A number of actions designed to cope with these problems are being taken and alternatives for other problems are suggested.

INTRODUCTION

A. Present Role.

1. Resources

Staff

Directorate

Director - Ordway Starnes
Deputy Director - Tecwyn Jones

Research Staff

Approximately fifty specialists in the following disciplines or fields of research:

Physics (soil physics, hydrology, climatology, agrometeorology);
Chemistry (soil fertility, plant and soil analysis);
Agricultural Machinery;
Sorghum; Millet; Maize and Sugar Cane (breeding and agronomy);
Plant Pathology; Nematology; Coffee Berry Disease; Armyworm;
Tree Breeding (and silviculture); Entomology; Pathology;
East African Herbarium;
Animal Husbandry; Wildlife; Plant Ecology and Physiology;
E.A. Plant Quarantine Station; Statistical Services; Joint EAAFRO/EAVRO Library; E.A. Scientific and Technical Literature Service; E.A. Agriculture and Forestry Journal.

Supporting Staff

Some 20 Scientific Assistants (minimum qualification City & Guilds Certificate) and some 65 Laboratory Assistants (School Certificate level) supported by 160 subordinate staff. Casual labor strength variable.

Training Programme

Provision exists for the simultaneous training of 20 local graduates to the higher degree level, partly by a period of in-service postgraduate training at EAAFRO followed by formal training at overseas universities. Under this program, designed to provide African officers for posts now held by expatriates, local graduates have been trained or are undergoing training in Sorghum Breeding, Physics, Nematology, Animal Husbandry, Plant Physiology, Forest Pathology, Horticulture, Wildlife, Earth Sciences and Librarianship.

Facilities

The present headquarters and central laboratories are situated at Muguga, some 17 miles northwest of Nairobi on a 1,600 acre estate which is shared with the E.A. Veterinary Research Organization. In addition to the administrative building which houses the Directorate and the Joint Services Division which provides an administrative and accounting service

for the two organizations, there are four large laboratory blocks which house some 15 research divisions, a large library with working facilities for visiting scientists, an experimental farm of some 360 acres, an arboretum containing 1/10th acre plots of some 189 tree species, a forest nursery and 600 acres of exotic plantations. At an altitude of 7,000 feet, Muguga is the ideal site for a tropical Plant Quarantine Station and this is housed in isolation on the estate, while adequate space is also available for open quarantine. The EAAFRO Maintenance Division undertakes all capital development, routine maintenance of buildings and essential services and maintains the large fleet of vehicles. Staff are housed on the station and bachelor quarters are available for visiting scientists at the Joint EAAFRO/EAVRO hostel, Muguga House, which is fully catering.

Not all the EAAFRO Divisions are at Muguga. The Sorghum/Millet substation is at Serere in Uganda, the Maize Research Unit is at the Kenya Government Grassland Research Station, Kitale, the Coffee Berry Disease Research Unit is housed in the University College, Nairobi, the Herbarium is located in the grounds of the National Museum, Nairobi, the Forest Pathology Division is accommodated by the Kenya Forest Department near Muguga, and the Sugar Cane Breeding Station is being established at Kibaha near Dar es Salaam in Tanzania with its Disease Testing Unit at Kawanda near Kampala, Uganda.

EAAFRO's Research Projects, as indicated in the Record of Research for 1965, are distributed over some 260 locations throughout East Africa.

Budget

Basic Finance

As a Department of the Social & Research Services of the East African Community, EAAFRO derives its basic budget in part from the General Fund of the Community and an equal sum (i.e., matching grant) from Her Majesty's Government through the Ministry of Overseas Development.

Supplementary Funds

The following aid agencies contribute to various special projects:

Rockefeller Foundation: Provision of Director and funds to meet associated expenses; $60,000 towards instrumentation; $100,000 for support of a 5-year project on sorghum research; full financial responsibility for 3 years for the E.A. Scientific & Technical Literature Service; $10,000 for the purchase of textbooks; postgraduate scholarships and travel grants.

United States Agency for International Development (USAID): Provision of research staff for Maize and Millet research and $40,000 in support of this program; $60,000 towards Sorghum research.

Her Majesty's Government: Secondment of research staff through CDM and the Hydrological Research Unit with supporting equipment; £24,000

through the Anti-Locust Research Centre in support of a 3-year Armyworm project; postgraduate scholarships and travel grants.

Norwegian Agency for External Aid: Provision for four research officers and various grants totalling over £6,000 towards equipment.

International Atomic Energy Agency: Funds and equipment for research on water use efficiency and changes in isotopic composition of rainwater in the soil.

Food and Agriculture Organization: Provision of Wildlife specialists and short term specialists in Forestry.

Ford Foundation: A grant of £8,000 towards the Wildlife and Land Use Symposium; travel grants and scholarships.

Canadian Office for External Aid and Canadian University Service Overseas: Provision of research and technical staff; support of the agro-meteorological research program.

Munitalp Foundation: Provision of mobile laboratory for agro-meteorology research.

Netherlands Aid: Provision of a research officer.

Danish Aid (Volunteer Service): Provision of two technicians.

Other external sources of contribution in terms of services, staff and funds include: the University of Wisconsin, the Commonwealth Forestry Institute and the Canadian Sportsmen's Show Fund.

East African contributors to special projects include the Coffee Industries of Kenya, Tanzania and Uganda, who underwrite all costs of the C.B.D. Unit; the Sugar Industry which meets all costs of the Sugar Cane Breeding program; and the Forest Department of Kenya which contributes towards catchment research. Several local companies contribute material for experimentation.

The annual budget of the Organization is almost £450,000.

2. Research Programme

General Policy

EAAFRO is responsible to the Research and Social Council for all matters of general research policy and its program of research is governed by the East African Natural Resources Research Council.

Terms of Reference

EAAFRO is responsible for undertaking research in the fields of agriculture and forestry on problems that:

(i) are common to at least two of the East African countries and which can be investigated most efficiently and economically by a central research organization;
(ii) require longer-term investigations or more intensive study than can be undertaken by National Departments;
(iii) require highly specialized and expensive equipment or the services of such specialists as can only be justified on an East African basis.

EAAFRO is not concerned with purely local problems unless specifically invited to investigate them by a National Department. Likewise, EAAFRO is not an advisory organization as such, though scientific advice and guidance are readily given by the research staff on request to National and other research workers.

The current research program illustrates that research at EAAFRO is as much concerned with the solution of problems as it is with the acquisition of new knowledge, and also that much of the research consists of projects carried out with the cooperation of other research institutes. The program is designed to meet the needs of the National Departments of Agriculture and Forestry and is determined by the requests and recommendations which emerge from the deliberations of a series of committees on which these departments and EAAFRO are represented.

EAAFRO's program of research in any particular field is first discussed by the appropriate Specialist Committee whose recommendations are then considered by the relevant Coordinating Committee (four of which are concerned with EAAFRO) and finally by the Natural Resources Research Council. This process which ensures that priorities are kept in proper perspective and which eliminates unnecessary duplication of effort by National Departments and EAAFRO is indicated graphically below.

East African Authority

↑

East African Natural Resources Research Council
(Nominees of the East African Ministers, representatives of each Government, nominated scientists and Directors of E.A.C. Departments)

↑

Research Coordinating Committees
(Directors or Commissioners of Agriculture, Forestry, Veterinary Services, National Parks and Game Parks, and the Directors of the appropriate Departments of E.A.C.)

Agriculture | Forestry | Animal Industry | Wildlife

↑

(To appropriate R.C.C.)

↑

Specialist Committees
(Research workers from National Departments and EAAFRO in the following fields)

Soil Fertility, Soil Chemistry, Herbicides, Coffee, Agricultural Botany, Agricultural Machinery, Agro-meteorology, Hydrology, Insecticides & Entomology, Pasture, Rangeland Management, Animal Production, Animal Physiology, Nutrition and Breeding, Animal Diseases, Animal Industry, Wildlife, Statistics, and various 'ad hoc' committees such as those on specific crops (e.g., Pyrethrum), game problems (e.g., elephant control), special problems (e.g., crops for areas of low and erratic rainfall), and specific pests (e.g., Nematodes).

Summary of the Current Programme

The following is not so much a progress report on research achievements, an account of which is freely available elsewhere, but rather a precis of the scope and depth of EAAFRO's present program. In the interests of brevity the program is described under several conventional subheads representing major fields of research, but in view of the increasing prevalence of the multi-discipline team approach, this subdivision is somewhat artificial.

Physical Sciences

Physics Division. This in essence is concerned with seeking a better understanding of East Africa's water resources and in particular with crop water requirements and plant-water-soil relationships. Catchment area research is designed to determine the changes in emergent steamflow induced by different land-use regimes, the relation of transpiration loss to effective evaporative demand and soil conditions, and to relate storm run-off with soil moisture and rainfall intensity. Reliable methods of estimating evaporation rates have been developed and maps indicating monthly values have been compiled. Using the Muguga-type lysimeter and micro-meteorological methods, it has been possible to determine specific rates of water use by several crops. The efforts of different methods of cultivation on the rainfall acceptance of the soil and on surface run-off are being assessed in the field and by supplementary laboratory techniques. Several agro-meteorological problems are under investigation, notably studies on espacement of tree-crops at different ages, investigation of the micro-meteorology of coffee trees in relation to the incidence of C.B.D.

Chemistry Division. Research effort, as opposed to the general chemical and analytical services in this Division, is directed towards the evaluation of chemical fertility of soils and its relation to crop yield. An index of the potentially available natural nitrogen in soils has been developed, and the calibration of the soil mineral nitrogen index, using maize, against crop yield and foliar analysis is under way. The evaluation of a water hydrolysis index to potentially available nitrogen is also in progress, and the magnitude of the natural nitrogen flush following rain under varying soil and climatic conditions is being studies. The suitability of water soluble silica as an index to available soil phosphorus is being investigated as is the effect on crop yield of planting date in relation to the rainy season.

Agricultural Machinery. Although not involved in a specific research program of its own, this Division is responsible for the coordination of all research in the field of agricultural machinery, in its broadest sense, throughout East Africa. Current research priorities include the appraisal of various methods of cultivation in relation to tilth of the seed bed and their effect on water conservation and fertility; the development of ox-drawn and power machinery for small-scale farmers; the development and local manufacture of efficient crop processing equipment and crop storage facilities; and the development of crop-spraying machinery. An exercise in economics is in progress—namely the appraisal of costs and benefits of mechanization—and hence a study of the desirability and feasibility of mechanization on large and small agricultural schemes.

Crop Production

Sorghum Breeding. The value of sorghum lies in its ability to give consistent yields in low-rainfall areas where other cereals, such as maize, cannot survive. The current program at Serere is designed to produce high yielding varieties and hybrids with low susceptibility to bird damage but acceptable in terms of palatability for human consumption. Notable successes in producing heavy yielding varieties are Serena and Dobbs which consistently out-yield all local varieties.

Millet Breeding. Both finger millet and bulrush millet are important in certain ecological conditions; the former in that it dries rapidly and the latter in that it withstands drought even better than sorghum. A breeding program designed to produce high yielding varieties of finger millet resistant to blast disease was initiated recently, while in the case of bulrush millett, attempts are under way to locate varieties in the World collection that have the desirable characters for making hybrids (using locally available male sterile mechanisms).

Maize Breeding. The maize improvement program at Kitale has made rapid progress. Local collections have been made and exotic material has been introduced from diverse sources. This material has been composited into broad-base populations (composite varieties) that not only give high yields initially, but have tremendous potential for further improvement by recurrent selection because of the sizeable genetic variation. The variety cross hybrids from these composite varieties are now being produced commercially; meanwhile methods of making recurrent selection more effective are being compared.

Sugar Cane Breeding. This recently established Division is concerned with the selection and breeding of varieties better suited to East African conditions than the existing ones, both in terms of yield of sugar per acre and disease resistance. Smut is by far the most important disease and only one local cane appears to show resistance to it, whereas there are many varieties resistant or immune to mozaic disease.

Note: All of the Divisions concerned with breeding are involved in supplementary investigations on crop yields - i.e., crop management and nutrition cultivation techniques, fertilizer trials and pest and disease control.

Crop Protection

Plant Pathology. As a direct result of research by this Division, the serious virus diseases of maize (streak), cassava (mosaic) and sweet potato are being brought under control: also tropical maize rust (*Puccinia polysora*) has been overcome. A survey of virus diseases affecting the main food crops (with special reference to the tropical legumes: beans, groundnut, soyabean, cowpea) and those cash crops which form the main source of income for small-holders. To date, nine viruses have been isolated and are awaiting identification: and a further three, which cause debility and poor crop yields, have been isolated from papaya. Work is also in progress on isolating tobacco vein browning virus, and screening of bacterial wilt resistant potato clones, and detailed studies are under way on the lethal bole rot of coconut.

Nematology. The present program involves a study of nematode infestations in papaya, tobacco, sugar cane, cucumber, pepper, dahlia, coffee, carnations, wattle, wheat, citrus and maize, and investigation of seasonal fluctuations in the nematode populations in soils under certain crops. Fumigation trials using dibromochloropane and other nematicides are in progress in such crops as coffee, finger millet, sorghum, groundnuts, cassava and grass leys.

Coffee Berry Disease. This is a threat to all tropical countries in Africa where coffee is grown, and when conditions favor it the disease can become uncontrollable and causes losses of up to 80 percent in crop yield. The only foreseeable method of control is the use of fungicides, and the main effort of the EAAFRO research unit is therefore directed at determining the time and duration of spray-series on a rational rather than empirical basis. The reason behind the variation in effectiveness of sprays applied at different times is being sought; the possibility of a future forecasting system for determining the most effective timing and the effective duration of sprays is being studied; and finally the mechanism of control is being investigated.

Armyworm Research. An investigation of the biology and ecology of the armyworm moth, *Spodoptera exempta*, is in progress. The caterpillars of this noctuid moth appear suddenly in vast numbers and can, in years of large populations, cause considerable damage to graminaceous crops of all kinds. Studies in the fluctuations in numbers of moths caught in a network of light-traps in East Africa, and the fertilization rates of female moths and sex-ratios of samples from light-traps, together with field studies of moth behavior immediately following emergence, have established that *S. exempta* is a migrant. Records of infestations of larvae and light-trap catches of moths have revealed a seasonal exchange of populations between East Africa from November or December to June and Ethiopia and the Somali Republic mainly from April to September. These movements appear to be related to the seasonal shift of the Inter-Tropical Convergence Zone or equatorial trough, between more northerly and more southerly winds. Work in cooperation with the Anti-Locust Research Centre has demonstrated that in two seasons the first appearances of moths in East Africa were associated with advancing north-easterlies as this major synoptic feature reached its

southern position, and that in the more northern areas appearances of moths were similarly associated with marked wind-shifts which could again be recognized as the change of the monsoon. Work on S. exempta migrations in Africa is continuing. Other investigations in progress include a comparison of light-trap and suction-trap catches and the beginning of an examination of the possibilities of using light-traps to forecast armyworm outbreaks.

Forestry

Tree Breeding. The aim is to increase the volume and value yields of the three major exotic softwoods, namely Cupressus lusitanica, Pinus patula and P. radiata, which are already grown extensively Africa. This is being achieved by: selection of large, straight, narrow crowned 'efficient type' trees from existing plantations for propagation in seed orchards; selection of disease resistant varieties and improving existing seed sources by collecting seed from superior trees in registered seed stands; selection and breeding for desirable morphological characters and wood property; and finally the introduction of alternative species and provenances.

Forest Entomology. EAAFRO is the agreed location for the East African Forest Insect Reference collection, which has been assembled as a result of surveys of the indigenous forests and plantations throughout East Africa. This appraisal of the forest insect fauna, with particular attention to the migration of species to exotic plantations, is a continuing process, yielding essential background data on insect/host and host/insect range and relationships, seasonal activity, the ecology and biology and pest potential of important species. Special studies include an appraisal of the impact of defoliation on increment and an assessment of the economics of chemical control measures in plantations.

Forest Pathology. Research into Dothistroma blight of pines has concentrated on developing copper fungicide sprays for control and on the selection of blight resistant strains of P. radiata. Control measures have proved effective in the field and their economic feasibility is now being investigated; likewise a range of P. radiata trees of desirable form and vigour has been found which are resistant to blight and are being propagated. Studies on Stereum sanguinolentum a pine rot fungus, and a survey of Monochaetia canker of cupressus have been successfully concluded. Preliminary investigation of the biology and possible control of heart rots in Ocotea, Cupressus and Khaya are under way, and studies on Poria root disease of cypress and of nursery diseases of pines are being continued.

Taxonomic Botany

East African Herbarium. Apart from providing an authoritative plant identification service to national, regional and individual organizations, which involves some 10,000 determinations annually, the Herbarium contributes significantly to taxonomic publications of value to East Africa. Notable amongst these publications is the Flora of Tropical East Africa and the compilation of the Vernacular-Botanical English Dictionaries for

the Luo, Swahili and Kikuyu languages; a Kamba dictionary has also been begun.

Animal Sciences

Animal Husbandry. The objective of research is to effect economical improvements in animal production and hence increase the availability of animal protein for local consumption. It is accepted that the richest potential source of protein is local beef cattle reared on the range, and hence improvements in rangeland and pasture management is a priority requirement. Pasture nutritional studies are in progress aimed at characterizing the nutritional environment under different managements to determine the limiting factors and to assess what agronomic improvements can be achieved. This is closely linked with studies to determine the diet composition (i.e., forage intake) of animals under contrasting conditions and investigations of the nutritive value of the edible parts of all browse and herbage species throughout the year. Simultaneously, in acknowledging the potential of feed-lot, cattle production studies of the responses of indigenous and exotic cattle to diets containing varying amounts of concentrates and roughage are in progress, and an assessment is being made of the effect of such diets on carcass composition with particular reference to the time and economy of production relative to that of grass-fed beef. The differences in carcass characteristics of comparable groups of different breeds and species (both wild and domesticated) are being defined.

Wildlife Research. This newly initiated Division is concerned with the coordination of wildlife research in East Africa and the establishment of a bureau for the documentation of research findings. Its field program is barely under way but encompasses studies on population structures, food habits, reproductive rates and group movements of Sykes monkeys and Thomson's gazelles. Efforts are being made to develop better control measures against Sykes monkeys which are serious pests in exotic plantations. The Division is in the process of assembling data for the compilation of distribution maps of economically important species of wild mammals in East Africa.

Plant Ecology and Physiology. In view of its commitment to research on Land-Use Management and particular studies on ecological zones, the classification of general and grassland vegetation and especially the determination of range condition and trend, the major effort of this Division is an integral part of the Animal Husbandry and Wildlife research
The study of ecological land units has already defined six broad ecological zones, and present efforts are directed at subdividing these, using more critical criteria, into desirable land units as part of classifying their land-use potential. The development of a system of physiognomic vegetation classification, whereby descriptive terms for vegetation were standardized and a series of physiognomic types were devised with subdivision by species composition, has been completed and generally adopted in East Africa. Similarly, a method for identifying grasses from purely vegetative, as opposed to floral, material has been evolved which will greatly assist in grassland surveys and is a major aid in determining range condition and trend. Studies on the latter have only recently begun, but associated

investigations, such as those on selective intake of vegetation by cattle in semi-arid areas, are well under way. They are designed to evaluate the relationship of shrubs and grasses in the intake of cattle, the role of edible shrubs as a source of cattle food, the nutritional value of fodder as taken in by cattle compared to that on offer, and to compare the intake of browse in overgrazed and improved rangeland areas.

The Division is also concerned in studies of root-systems of plants as its contribution to water-balance studies of individual crops, e.g., maize, banana, coconut, pyrethrum, peanuts and some 50 species of range and pasture grasses.

Technical Services

The divisions and activities described here do not have a specific research program but rather provide an essential service to both research and development in agriculture and related fields.

E.A. Plant Quarantine Station. All vegetative material imported into East Africa by the Community, National Departments, private organizations and individuals is required by law to be cleared through this station. Facilities and plant quarantine procedures are of the highest standard and the interceptions to date of soil-borne pests and pathogens of many plant species, seed-borne nematodes of rice, fungal diseases of pines and potatoes, bacterial diseases of sugar cane, napier grass and potatoes, seed-borne viruses of soya, virus of cacao, and of potatoes, that causes severe disease in tobacco, and many others, emphasize the value and need to continue this service.

Statistics. This Division provides an advisory service and assists with data processing and extension computation on electronic computers for EAAFRO, other regional research centres, national departments and various other affiliated organizations. Notable examples of present commitments are: forest seed orchard design in areas of constant and variable wind direction; collaboration with fungicide trials; evaluation of the reliability inter-relationship and predictive value of linear measurements on carasses.

Library. The Joint EAAFRO/EAVRO Library is the most complete library for agriculture and related sciences in East Africa. Its holdings exceed 30,000 text and reference books and it receives some 900 journals. The Library is in great demand by researchers from all over the region and it provides excellent working facilities for visiting scientists.

E.A. Scientific and Technical Literature Service. This provides photo-copies of journal articles on request to the research staff of some 90 institutions and or substations which lack adequate library facilities in East Africa, and to others in Zambia, Malawi and Ethiopia.

E.African Agriculture & Forestry Journal. This journal, which began in 1935, appears quarterly and publishes some 60 papers annually, most of

which relate to research in East Africa. Circulation is over 1,000 copies per issue to 72 countries. Over 300 journals are received in exchange.

B. Priorities and Problems

The object of this paper is to identify agricultural research priorities or opportunities in East Africa and problems to be solved if the Regional Research Institution is to be strengthened. The present role of EAAFRO as a regional research organization in seeking solutions to problems in agriculture and forestry in Kenya, Uganda and Tanzania is described above.

By way of introduction to this topic it is suggested that agricultural productivity in East Africa is limited, not so much by the lack of research findings and technology as by:

1. The limitations in education;

2. The lack of, or failure to adopt innovations such as improved varieties, fertilizers, pesticides and equipment, and better practices in tillage, cultivation, protection, harvesting, handling, marketing and utilization;

3. Known limitations of the physical resource and inefficient resource allocation; and

4. An illogical adherence to certain inefficient traditional methods.

On the assumption that this is the case it follows that the impact of investment in agricultural research is directly related to concurrent development in 1 and 4 above. If it is accepted that these particular problems, rather than the limitation of research and technology, are the major retardants to agricultural progress it should also be recognized that they are equally, if not more, amenable to solution than many priority research problems in East Africa.

Priorities

The two most limiting agricultural resources are land and water and hence it is in this field that research opportunity is greatest. The greater part of East Africa is without adequate water supplies. Permanent rivers and streams are rare in many areas and water supplies temporary and erratic.

Land we have in plenty--a total of 635,000 square miles. Of this it is estimated that only some 11 percent is developed, i.e., being used for agricultural purposes. Of the remaining 89 percent mountains, forests and deserts account for perhaps 9 percent, leaving 80 percent or more than 500,000 square miles underdeveloped.

The greatest single factor limiting the development of East African land is water. Firstly there is a lack of it; approximately 75 percent of the land area in Kenya and Tanzania receives less than 20 inches of rainfall per annum. This fact alone renders vast areas of land uninhabitable by man and stock. Secondly, even in areas where the total precipitation is apparently adequate, i.e., as much as 50 inches, rainfall is so unevenly distributed throughout the year that severe dry periods prevent the full utilization of the land. Thirdly, much of the rainfall received over large areas is not accepted and retained where it is needed, but is lost in rapid runoff due to the unresponsive nature of the soil, the poor catchment properties of its vegetative cover, and by evaporation.

The nature and composition of the soil itself is the second limiting factor. Both the chemical and physical fertility of the soil is often of such low level that neither crops nor animals can be supported on it.

These natural factors therefore, poor water supply and utilizatic poor soil conditions and low fertility, limitations of the crops and animals now available, and pests, either singly or in combination, have severely limited the area of East Africa that has been developed for agricultural purposes. Where these factors are not limiting the potential is high; where they are severely limiting the potential is low, and all intermediate conditions exist. At present East Africa relies almost exclusively on the comparatively small area of high potential. The most urgent need in East African agriculture today is that of developing and making productive the vast arid and semi-arid areas of the three countries. This must be the priority objective not only in research but in developmental activities, and to attain it research in various problems is indicated. Priority determinations are:

1. The actual and potential water supply available to plant life under various rainfall, climatic and vegetation regimes;

2. Chemical and physical characteristics of the soils and their crop potential;

3. The water and nutrient requirements of crops;

4. The suitability of crops and varieties to the soil, water and climatic regimes, including the development of crops suited to these regimes;

5. Effective and economic control programs to minimize losses from insects, diseases and weeds;

6. Techniques and equipment for cultivation, harvesting, processing and storing with minimum wastage.

These are deserving of some elaboration.

1. Water-use deficiency.

a) The planning and the prediction of water balances in crop water use, including mapping of evaporative demand, determination of seasonal pattern of the relation of transpiration to evaporative demand for different crops, and an assessment of the water holding capacity of different soils coupled with the survey of the depth of rotting of important plants.

b) The development of methods to prevent surface runoff of rainfall—where water is so limiting any surface runoff is sheer loss and runoff rates as high as 30 percent are quite common. The solution will involve coordinated investigations by agricultural engineers, soil physicists, and agronomists into the efforts of different methods of land preparation, cultivation and management on water conservation.

c) To determine the effects of changes in land use on streamflow in areas of high rainfall, which give rise to perennial streams and an assessment of underground water resources. Closely integrated with these are high priority investigations in the field of soil chemistry and fertility.

2. Soils.

To establish the quantative relationships for different crops between measurable soil and plant nutrient parameters that relate to:

a) Chemical soil fertility;

b) Chemical leaf analysis;

c) Crop yield; and

d) Crop response to fertilizers.

3. Crop production.

For some seventy years we have been systematically accumulating knowledge of the flora of East Africa, a taxonomic work. This needs to be expanded into firstly, a determination of the nutritional value of our present and potential food and feed crops, and secondly, a horticulture and agronomic crops program predicated on a knowledge of the biological, chemical and physical properties of our present and potential adaptable species.

In the case of low potential areas there is a clear field of work to elucidate the basic ecology of the natural vegetation. The natural vegetation of these areas is grass, and grass with trees and bush. This would suggest ranching as the best method of exploiting the region with least disturbance to natural vegetation. Land devoted entirely to ranching, however, will only carry a small population so there must be introduced some form of grain crop or arid land cash crop. Work is required, therefore, on:

a) Grass production;

b) Bush control; and

c) Grain and cash crop production.

Research priorities are:

(i) Grass Physiology

(a) grass-water relations,
(b) root growth and development,
(c) effects of burning and grazing,
(d) adaptive physiology,
(e) nutritional physiology.

(ii) Bush-Plant Physiology

(a) seasonal growth physiology of the individual species and in the community as a whole,
(b) the effect of cycles of burning and clearing,
(c) leaf development and physiology of component species, and
(d) root growth and development.

(iii) Grain Crop Physiology. While much has been done in the development of drought tolerant varieties by plant breeders this work must be increased in scope and value by physiological and biochemical studies of factors which enable drought tolerant varieties to succeed. This would include water relation, cell size and structure, food content, composition, leaf area, root range and activity.

A vigorous program is essential in the field of genetics and breeding. Successful work has been carried out with wheat, maize, sorghum and millet in recent years, and this work must be augmented to provide high yielding varieties of grain legumes and rice

suitable for East Africa. It is desirable that the existing strong program in cereal and grain legume research be further strengthened and that its influence be extended to serve the largest ecological area practical.

4. Animal production.

It is clear that with the vast tracts of non-arable and marginal land available for ranching, work must be directed towards the technology of extensive rather than intensive animal production. Improved nutrition is considered to be by far the most promising way of enhancing production. Thus the real need is to improve rangelands. Grass which is the lowest cost feed must be improved in terms of its nutritive value and productivity. The following determinations are required.

a) The effect of grazing pressure on ecological and nutritional changes in grassland;

b) Procedures for the introduction of legumes into rangelands to improve the protein content of the feed;

c) The economics of supplementation of grazing with cheap concentrates;

d) Techniques of rangeland assessment;

e) The value to animals of browse plants as feed as compared to grass in semi-arid areas and methods of controlling bush encroachment;

f) The effect of sheep, cattle and game, singly and in combination on the ecology of arid and semi-arid areas; and

g) Water requirements and distribution in relation to need of animals and the preservation of rangeland;

h) Types of stock tolerant to stress factors, and therefore best suited to extensive and relatively unimproved conditions, and a determination of their potential under improved conditions.

5. Crop protection.

In East Africa there are but a few scientists in mycology, bacteriolcgy, virology, nematology, entomology and weed control; therefore, it is not until an abnormality in a crop or the depredation of a pest become widespread that any serious attention can be given to it. Little research is in progress. The priority need is to determine environmental

conditions under which pests and pathogens survive and multiply and the factors controlling their population.

Meanwhile, with the limited staff and facilities available in East Africa the import control of vegetative material to prevent the introduction of new pests and pathogens and, consequently, new problems, is of the utmost importance and plant quarantine facilities must be maintained and strengthened.

6. Cultivation.

In peasant agriculture preparing the seed bed is the heaviest task and often limits the acreage planted. Even with the use of oxen or mechanical power it remains a limiting factor, but more importantly it often causes late planting especially in monomodal rainfall areas and of light rain crops in bimodal areas where in both cases timeliness of planting is all-important. The availability of Government hire tractors is only partially successful and as yet more work on basic tillage techniques is essential.

No small and inexpensive tractor has yet been developed and adopted as suitable for use in East Africa. One is urgently needed for a wide range of uses.

7. Harvesting and drying.

Methods for the harvesting of crops on small farms have been neglected. With improved hand and ox-tools in use and the spread of semi-mechanization, i.e., ploughing, discing, ridging, planting and weeding in various degrees and combinations through tractor hire services, group farms, etc., harvesting is now often the limiting factor to increased production. Although basic data on drying of most crops are known there are still many gaps, and of importance is the development of inexpensive driers for small farmer use especially where electricity is not available.

8. Storage of products and processing.

With increased production, either due to higher yields or greater acreage, have come storage problems. There is great wastage of foodstuffs due to the lack of satisfactory storage facilities on farms.

9. Agricultural statistics, economics and marketing.

The highest priority is assigned to survey and research in these subjects. Not only does East Africa lack knowledge, but also trained personnel and a really substantial program. The following are considered particularly important and appropriate as regional activities:

a) The Development of a Land Use Plan. Resource allocation must be predicated on a knowledge of land use capabilities. At this time the East African land resource is not sufficiently well

characterized in terms of its soil and climate, nor are the requirements of our major crops sufficiently well known as to permit locating the right crop or agricultural activity in the right place and climate.

b) The estimation of agricultural commodity production.

c) The economic feasibility of implementing the results of research.

d) Analysis of demand and price data.

e) Competitive studies on a continuing basis.

Problems to be Surmounted

Staff, funds, facilities and a program of work are the basic ingredients of research. Problems being encountered by EAAFRO with these inputs into regional research include,

a) Personnel - Prior to the independance of the East African countries EAAFRO was staffed by expatriate officers holding permanent and pensionable terms. There were no qualified African research officers. Today, but about ten percent of the posts are held by expatriate officers under P. and P. terms, and approximately the same percentage of posts are held by qualified African officers. The majority of the expatriate Research Officers are on contract terms. In terms of permanency of experienced staff therefore, EAAFRO is probably at its most unstable state and the rate of turn-over of staff is at its peak. This turnover will steadily decline as African officers now in training return to fill establishment posts. Two important factors will however contribute to reduced productivity by EAAFRO Research Officers for perhaps a decade. These are the lack of experience of recently qualified local officers, and the inefficiency inherent in employing expatriates on short-term contracts of approximately two years. The expatriate contract officer requires most of a year to become oriented and productive by which time unless he has a home-based appointment he understandably becomes concerned as to whether he will be offered a further contract or not, i.e., whether his post will be Africanized or not.

The most primosing solution for the provision of staff in this transitional period would seem to be the posting of research teams wholly home-based by donor countries or agencies to work

on mutually agreed projects, and with provision perhaps for local counterparts for expatriate officers.

The position of the regional research organization in East Africa in competing for qualified trainees is not very strong. The National Ministries seek out their best qualified citizens, provide them with study scholarshops and bond them to return on qualifying to the national service. Recruitment by the regional research organization is limited to those relatively small numbers of graduates not bonded by National Governments.

b) Facilties - The provision of adequate facilities is becoming a limiting factor as donor agencies are becoming increasingly reluctant to provide bricks and mortar. The magnitude of this problem is ex-explified by the situation at EAAFRA where in a period of five years the number of senior officers has doubled in the absence of any increase in laboratory facilities or housing.

The Organization's responsibility for providing housing, medical, school, shopping and related facilities and services must be critically re-examined as localization proceeds, as a disproportionate percentage of the facilities and effort is being devoted to perpetuating the institution at the expense of productive work.

The provision of housing for senior officers is essential so long as reliance is on expatriates. However, with the prospects of career local officers, the feasibility of a policy whereby local officers meet their personal housing obligations is deserving of serious study.

Member countries in the region are understandably desirous of having the regional coganization in their particular country, and are understandably reluctant to support the increase of physical facilities at locations outside their national boundaries.

The availability of modern instrumentation in East Africa is reasonably good. The problems are:

a) lack of trained technicians.

b) poor utilization due to lack of an organized "pool arrangement" between the various research and educational institutions in an area;

c) funds. Capital funds are always difficult to acquire and if obtained as external aid can be a serious liability unless accompanied by recurrent funds.

East Africa has made reasonable budgetary provisions for recurrent costs of the organization's regular establishment, i.e., funds for

the recruitment of local officers deemed to be required on a continuing basis. Local fund provisions have not been made for the recruitment of expatriates. Expatriates are recruited through external aid and although donors are generous in making personnel available, they usually request the recipient country or region to provide a local salary element, housing, local travel and maintenance costs. In an eagerness to acquire more trained staff EAAFRO has too frequently accepted this proposition and in so doing over-committed its limited recurrent funds with the result that neither the regular establishment officers nor the supernumerary officers can be entirely effective. The position is that EAAFRO is unable to accept supernumerary technical aid personnel unless they are fully funded, including salary, passages, housing, or housing allowance in lieu thereof, and funds for local travel and maintenance.

An alternative to the present procedure of annual budgeting is needed. Triennual or quinquennial research programs are constantly being prepared and it is essential if they are to be implemented that capital and recurrent funds are also planned and committed for corresponding periods.

d) Program - The introductory section to this paper entitled "Opportunities", identified research priorities, some of which are now reflected in the EAAFRO program of work, and all of which should be receiving attention at EAAFRO or at the national level. Unfortunately, many of them remain untouched.

The major problem in program development is not that of selecting problems of high priority, but rather of selecting problems that are amenable to solution with the available resources of personnel, facilities and funds. Program problems include:

(i) the identity of the community which EAAFRO serves, and its needs in relation to the Organization's terms of reference. In other words, what specific problems is EAAFRO committed to solve and for whom. A decision has yet to be made as to whether emphasis is to be placed on problems of subsistence or cash crop production; and on those of the cultivator or the pastoralist.

(ii) a clear recognition that the problem is amenable to solution by research or not is essential, as further investment in research is futile if the problem is one of extension education, or one of motivating agricultural people to do something.

(iii) there is difficulty in distinguishing between what is being done and what is needed to be done. In East Africa both at the regional and national level there is the tendency to carry as active research projects an extensive list of subjects,

but close examination shows that this is more of an inventory of research needs than a list of currently active research projects receiving sufficient effort as to promise that the work will be brought to a logical conclusion in a reasonable period of time.

e) Organizational problem - The regional agricultural institute should be organized and staffed in such a way as to enable it to scrutinize any problem in the climate/soil/plant/animal cycle. This is seldom the case, as in the course of responding to requests for research from member governments the regional organization invariably has developed focal points of very considerable strength, and also areas of serious weaknesses. This situation poses problems of inflexibility and inefficiency in resource utilization when new work must be undertaken.

There must be an effective mechanism whereby priorities are identified for the regional research institute. The mechanism employed in East Africa outlined in our descriptive paper is inefficient, requires a year to clear all incremental levels of authority, and is otherwise unwieldy. In that the Natural Resources Research Council which has authority to approve programs, has no executive power in resource allocation, its effectiveness is limited.

It seems important that in East Africa the terms of reference and research resource allocation within and between research departments be under continuous scrutiny by a scientist cum administrator. A directorate of natural resources research staffed by scientists working under the supervision of the policy maker would seem to promise a solution to this problem.

There must also be an effective mechanism to assure that findings of research in the regional institution are reflected in the welfare of people. Yet it is very hazardous for the regional institution to become involved in extension education or to involve agricultural production people in planning its program. Extension in terms of the when, what and how of agricultural practice must come from one and only one source, and this logically is the National government.

Internally the regional research organization should be so organized as to ensure continuity of research when project leaders are on vacation or other leave, ensure continuous supervision of trainees, and ensure efficient utilization of special equipment and facilities. (EAAFRO is too fragmented to achieve these objectives and is in process of reorganization). This problem is accentuated when decentralization of the regional research

organization becomes necessary either to meet the ecological requirements of the research problem, or to meet the wish of member governments for a presence of the regional research institute in its country. Even if decentralization does result in improved rapport with the community, this benefit will be more than offset by problems of communication and logistics.

It is sometimes true that reluctance on the part of the regional institution to decentralize its program and facilities may encourage national governments to develop their own program and facilities. In principle, this is undesirable. What is needed is fewer and stronger rather than more and weaker research institutions, particularly in long-term work such as plant and animal breeding.

A problem of common concern in the development of both the national and regional research institution is that of defining where the national obligation ends and the regional obligation begins, and vice versa. It is patently obvious, however, that strengthening at both levels is necessary and furthermore is an essential prerequisite to the development of effective regional programs.

A relationship between the agricultural research institution in East Africa and the academic institution is highly desirable. Second only to our commitment to research is our commitment to the training of local officers. A relationship with the university which ensures the availability of first-degree students, provides facilities of the research institute for the post-graduate training of students from the university and encourages collaborative research between the research and the academic institution, can only be mutually enriching.

ORGANIZATION AND RESEARCH GOALS IN TROPICAL AFRICA AND MADAGASCAR

J. Lhuillier, IRCT

SUMMARY

The Institute for Research on Cotton and Exotic Textiles (IRCT) which was created in 1942 is mainly oriented towards developing the production of plant textiles in warm climates.

Its main headquarters are in Paris and from there, the research carried on overseas is directed, coordinated and controlled. Basic research, requiring highly qualified personnel and specialized equipment, is carried on in each of the four main zones where IRCT works: sudanian, tropical humid, preguinean, and Madagascar. Regional stations and experimental sectors are distributed in a network throughout the four zones and they are in charge of testing and trying out the problems studied at the main stations.

Research is divided into three main areas: agronomy, genetics and phytosanitary protection.

The cultivation techniques for cotton are now for the most part known. The two main preoccupations of the Agronomy Section are studies of mineral fertilization and of cultivation systems; these two things are intimately connected:

- mineral fertilizer is very well looked-upon by farmers of the cotton zone, which means that fertilizer maps are urgently needed for these areas. Transition from itinerant to fixed agriculture is also an essential objective.

The cotton market is more and more demanding and requires the creation of new varieties. In addition to a classical program of selection, there are also a few special programs for obtaining perfected plants to satisfy this demand.

- Adequate phytosanitary protection requires knowledge of the biology of insects and knowledge of diseases of economic significance. Products, supplies and application procedures are all in our field of study. A program of biological control seems to be interesting for the future. In relation to genetics, genes resistant to various diseases are studied. The problem of capsule rotting is one of the main problems currently being investigated by our phytopathologists.

Besides the control of new varieties through a great number of technological analyses, the Technology Center is studying methods for improving ginning.

- Finally, at the request of several Francophone African countries and Madagascar, research is also being undertaken on production and processing of long fibres (jute and sisal).

* * *

The Institut de Recherches du Coton et des Textiles Exotique (IRCT) is a French non-profit organization which was created in 1942. It is an organization oriented towards international technical cooperation. Its activity in Francophone Africa has been developing since 1946 and IRCT has made a substantial contribution to the unprecedented effort France has made in the last twenty years in the African countries with which it has close ties.

The purpose of this paper is to show the organization of our Institute and to sketch out our main research goals in various areas of tropical textile production.

The activity of IRCT is essentially oriented towards the development of vegetible textile production in warm climates and its goal is to undertake all investigations, research, studies and experiments on cotton, textile fibre plants and rope-fibre plants. This must be done to develop the production of vegetable textiles through the improvement of cultivation techniques, the plants themselves and extraction and fibre expertise methods and equipment.

1. Organization

IRCT is under the aegis of the Secretariat of State for Cooperation. Its headquarters are in Paris. The Director General is assisted, on the technical level, by an Inspector General for Research. A Scientific Council, composed of eminent figures from the French scientific world, gives its advice on programs and results.

The IRCT research activity goes on in France and the tropics.

1.1 Metropolitan organization:

IRCT research is subdivided into three main sections, and each is under the direction of a Research Division: Agronomy; Genetics; Phytosanitary protection.

The Chiefs of the Research Division direct the research and follow the development of the research work at the experimental stations, coordinate and give advice on what to do to increase its effectiveness.

The Documentation, Information and Publications Division plays a double role, along the same three lines as above:

- it collects as many documents as possible on cotton and the vegetable fibres of the tropical regions.
- it publishes "Coton et Fibres Tropicales" in order to disseminate the IRCT findings in this area.

Technological problems are studied by a Center which includes:

- a fibre analysis section
- a hard and jute fibre section
- a ginning expert to do research on the physical properties of fibres and on the mechanical, biological or chemical extraction of fibres.

1. 2. Organization overseas:

IRCT is represented in every country where there is an installation set up by a Regional Director in charge of arranging that the research programs are properly executed and that the organization functions normally. The research level of the activities we are called upon to execute in various countries which make such requests varies according to the problems to be solved. It goes from basic experimentation to refined biological research. To assure the maximum efficiency of our experimental stations and centers and to achieve regionalization, basic research is done at four main stations:

- Bebidjia (Chad) for the sudanian zone
- Bambari (Central African Republic) for the humid tropical zone
- Bouaké (Ivory Coast) for the preguinean zone
- Tulear for Madagascar.

These four ecological zones, which each have their experimental station, can be defined as follows:

- The sudanian zone:

This zone has only one rainy season, with average annual rainfall of 1000mm or less. Soil there is generally lacking in phosphorus. Livestock is abundant and food crops are usually cereals, grown for subsistence. Artificial grasslands are very difficult to set up and use there. Irrigation can be envisaged.

The humid tropical zone:

There is only one rainy season, but average annual rainfall is always greater than 1000 mm Food crops are usually grown for subsistence but are more diversified than in the previous zone: sorghum, rice, cassava and yams. Artificial grasslands are feasible.

- Preguinean zone:

The very distinct rainy seasons make two crops possible on the same land. The second season usually has insufficient and irregular rainfall.

The main food crops are maize, rice, yams and peanuts; they are often grown on hillsides and lead to a certain amount of marketing. The eroded ferrallitic soil of this area rapidly shows potassium deficiencies.

- Madagascar:

Production conditions are very varied according to the average rainfall and the nature of the soil.

The three research sectors are always represented at the main stations through an Agronomy Station, a Genetics Station, an Entomology Station and a Phytopathology Station (Bambari and Bouaké only), each with a Section Chief with an assistant and some technicians.

To these main stations are added other regional stations or experimental sectors:

Sudanian zone: Cameroon: Marova Station
Mali: M'Pesoba and Kogoni Stations
Upper Volta: Bobo-Dioulasso and Ouagadougou experimental sectors
Dahomey: Kandi experimentation sector

Humid tropical Zone: Togo: Anié-Mono station
Ivory Coast: North Ivory Coast experimentation sector

Preguinean zone: Central and South Dahomey experimental sector

Madagascar: IRCT-Samangoky Station (Bas-Mangoky)
Mandrare Station
Majunga experimentation sector.

2. Research Objectives

We will study research goals for each of our main areas of activity:

2.1. Agronomy and Physiology:

Our main goal for agronomic research is the profitability of cotton production in countries with poor financial possibilities. At present, in certain regions, we are contributing to a profound change in the structures leading to intensive cultivation methods. This trend will be increasingly more pronounced so agronomy must be envisaged at various levels:

- an agricultural experimentation program for simple and rapid extension. This is a short-term program which should vary with local needs and conditions. Multi-local experimentation is required.

- an agricultural research program for studying the development and improvement factors of traditional agriculture. This is a long-term

program which can only be carried out at basic research stations well-equipped in equipment and personnel.

2.1.1. Agricultural Experimentation:

Simple cultivation techniques (time of seeding, density, etc.) which are what we call agronomical prerequisites to any higher level improvements, are now known in the majority of cases. An exception is the chemical weeding technique which may be an extremely interesting solution in the framework of fixed and semi-intensive African agriculture.

Once this prerequisite is accomplished, mineral fertilization is an important improvement factor. Our first goal is to establish a map of major mineral element deficiencies (N, P, S, K and sometimes Ca and Mg). The determination of the optimal composition and the levels of fertilizer formulas for extension purposes are the next two objectives to be pursued.

Connected problems may need solution, such as methods of supplying different elements (dates, localization, leaf-spraying, etc.) African farmers are increasingly sensitive to the value of mineral fertilizers. More than 50,000 hectares of cotton trees were fertilized in 1966. That area was doubled in 1967.

2.1.2. Agronomic Research:

Three main points are studied: water economy and use; leaf analysis; and cultivation systems.

The importance of study of water use and economy in the framework of the irrigated sector for the rational use of irrigation is obvious. Knowledge about the water needs of a plant grown in the rain-farming zones is also important for determining the best seeding and harvest times and for controlling the production factor better during vegetation.

Very good results have already been obtained with leaf analysis, especially for defining the critical levels of P and S. We have there a valuable research method which will make it possible to quickly and accurately draw up a map of the mineral deficiencies in a zone and to follow the evolution of mineral nutrition in different situations put in place in our cultivation system experiments. But these first results need to be refined.

By studies of cultivation systems we mean all experimentation dealing with crop rotation, fallow experiments with different combinations of mineral, organic and organomineral fertilizer. Taking account of different techniques proposed, we must define the relative importance between the exploitation phase and the restitution phase (fallow or pasture-land). It is a very long research process which is being undertaken at all our stations and at a certain number of places outside, and it must be followed up with numerous analyses.

2.2 Genetics:

IRCT has a rather diversified program as it must make basic studies for attaining perfected plants making it possible to create commercial types adapted to the evolution of a constantly developing market and it must furnish seeds to organizations engaged in extension programs.

Basic but long-term research is undertaken in basic stations, with regional outposts. Local action consists mainly in furnishing improved seeds to the participating countries; they have been tested under conditions similar to those in which they will be utilized and seeds which answer the needs of the farmer as well as commercial needs are sought.

The cytogenetic section of Bouaké Station (Ivory Coast) studies the relations among the different cotton species.

G. Arboreum x G. thurberi x G. hirsutum (ATH)
G. hirsutum x G. arboreum x G. raimondii (HAR)

Other factors which occur are studied: male sterility, decayed bracts, atrophied bracts, etc.

The Bebedhia Station (Chad) works on glandless cotton plants in order to improve the seed and assure a new food source to the people of tropical Africa, rich in protein.

The Anié-Mono Station (Togo) studies the practical possibility for using the sterile male character for the production of hybrid seeds.

Bambari Station (Central African Republic) studies the possibilities of reducing the capsulization period to lessen the effect of rotting in capsules.

Parallel to these special programs, the classical solution is pursued for each ecological zone for the perfecting of commercial varieties adapted to the different environments and an increasingly demanding market. Substantial results have already been obtained particularly in very important zones of Chad and the Central African Republic, thanks to a rather extensive reserve of regional experiments (more than 120 experiments for Francophone Tropical Africa) which makes it possible for countries without experimental stations to enjoy the results obtained elsewhere. That is one of the advantages of our regionalization.

2.3. Crop Protection:

The activity of the Phytosanitary Section which is applied to the cotton plants as well as to other fibre plants is done primarily at the existing IRCT Stations: Bambari, Bebedjia, Tikem, N'Tarla, Bouaké, Kogoni, and Tulear, where there is one entomologist per station, and Bambari and Bouaké where there is one phytopathologist per station.

The regional stations of N'Tarka, Anié, Majunga and Tanandava as well as the experimentation centers of Marova, Cotonou, and Bobo-Dioulasso, are obcservation points which are followed closely, and experiments are undertaken under the supervision of specialized experts.

2.3.1. Entomology:

The present activity of the Division is based on studying the biology of insects and diseases with economic impact. Control procedures have been developed as solutions to the problems posed.

Even though it may seem routine to continue research which has been going on for twenty years, one must not forget that the appearance of new products and the possible development of the parasites in contact with old insecticides mean that the following work must be continued:

- the nature of the products: research on the wide range of new existing products
  - the association of products and their behavior
  - effects on the flora and fauna
  - problems of toxicity to man, animals and beneficial insects.
- practical duration of effectiveness of products, which in part conditions the rate and frequency of applications
- doses for use of products with high economic effect
- number of applications, keeping in mind: the pre-established program, the determination of critical periods, beginning the treatment.
- methods of applying the products from fumigation and coating the seeds to aerial spraying.
- study of the various materials to be used, for example, going from classical spraying to micronizational of the dorsal ramp have greatly increased application facilities for protecting cotton crops.
- study of the various application procedures: pneumatic spraying, nebulization, oil treatments, very small volume treatments.

The methods of biological control constitute at present an important part of the programs of the various governments and are an important part of defense methods against the ravages of parasites. We are especially trying to know better the reactions of the species or varieties of Gossypium vis-à-vis the diseases and insects by researching genetic resistance or tolerance characteristics (rotting, scant folliage, thickness or carpellary walls, resistance to virus) as well as the possibility of using natural parasites or predators and microbiological control on fauna harmful to crops. Most of the activity at present is centered around using micro-organisms such as viruses, bacteria, and bacilli.

We had begun using radioactive elements but we had to limit it using tracer elements because we did not have the means to engage in more advanced techniques of direct intervention. Certain easier possibilities than ionizing rays are being studied, such as the use of juvenile hormones.

2.3.2. Phytopathology:

Various studies on phytopathology are undertaken along with genetics and entomology because they are closely inter-related.

Transfer of genes resistant to fusariosis, bacteriosis, and leaf curl must be constantly redone as gradual genetic improvement of the fibres is undertaken.

Capsule rotting is more and more important as one approaches intensive cultivation as it needs extra care in order to achieve maximum production, and yield. The pathogenic agent and the insect vector are now under study in order to determine resistance possibilities to rotting.

Various known genetic characteristics also coincide with the control of disease vector agents: jassides with pilosity and various parasites with gossypol.

2.4. Cotton Technology.

The fibre expertise Center plays an important part in the varietal improvement of cotton plants through technological analyses.

In the last few years a special effort has been made to study yield at ginning of factories in different zones of production. The humidity of cottonseed, losses or gains in humidity at ginning time, the influence of the feeding of ginning-machines on the quality of the seeding, the influence of the frequency of harvest on the technology of the fiber are all factors that are currently being studied.

2.5. Long Fibers.

Research on the production of long fibers:

With the diversification of crops and industry in mind, an increasing number of Francophone African countries and Madagascar have shown an increasing interest not only in the production of long fibers for ropes and string (sisal and jute) but also in their transformation on the spot into manufactured goods, if there are not already in existence (as they already are in Madagascar, the Ivory Coast, the Central African Republic, and Dahomey).

In most of these countries, IRCT has been carrying on routine experimentation for a rather long time; in the countries which already manufacture rope and string, this type of research has already passed to the production support experimental stage.

The main object of this experimentation is to be able to propose to the producers:

- where the best varieties of long fibre plants are located;
- a cultivation technique adapted to the conditions of the production environment;
- proper procedures and management of fibre preparation.

2.5.2. Chemical research on vegetable fibres and the possible utilization of their preparation by-products.

Chemical research deals mainly with procedures and equipment for the industrial treatment of jute fibres (degumming) and with the control of the nutritive value and the wholesomeness (absence of gossypol) of cotton-seed flour which is being studied for food.

At IRCT this kind of research is being undertaken on the one hand at certain cotton experimental stations in true agricultural trials, and on the other hand at the Technology and Chemistry Center at Nogent-sur-Marne (France) to perfect extraction procedures and equipment and look into the treatment of fibres; they are also investigating markets for industrial by-products and looking into methods for preparing them.

At present a cultivation experimentation program is going on at the N'Tarla and M'Pesoba stations in Mali (on the Dah or Hibiscus cannabinus), at Bambari station in the Central African Republic (on Roselle or H. sabdariffa), while experiments on sisal are being done at the Mandrare station in Madagascar.

CONCLUSION

Cotton production of the Francophone African countries went from 195,000 tons in 1960 to 320,000 cons in 1966.

This improved production is primarily due to the improvement in techniques of production: improved phytosanitary protectiion and the increased use of mineral fertilizers. Our research efforts in these areas should not be relaxed and we must carefully follow the extension of new techniques and products so that we may be ready to deal with any new problems which may arise. Faced with an increasingly demanding market, the improvement of the quality of currently cultivated cotton plants must be our constant preoccupation as well.

Finally, the improvement of this sector of activity has vital social importance for these countries as well. As cotton is a cash crop, it opens up the possibilities for remuneration from agriculture to a great mass of the people, who can hope to see their standard of living rise substantially. The indirect repercussions on food resources are certain.

Agricultural Research Priorities for Economic Development in Africa

Yuen-liang Ku

In the last one or two decades many independent new countries have come into existence on the continent of Africa. The government authorities of these new countries have been exerting ceaseless efforts to develop their economies for the purpose of raising the standard of living of their people. Generally speaking, the natural resources in most African countries are abundant and this provides excellent opportunities for agricultural development. In a majority of cases, the people of African countries are still largely, if not entirely, dependent upon agriculture for their livelihood. The rapid increases in population, the need of capital accumulation for city industrial establishment and foreign exchange earnings all point to the necessity of increasing agricultural production in these countries.

The full exploitation of agricultural resources often requires over-all planning so as to ensure a higher level of development with a greater efficiency. In planning any sound program for economic development there are always many factors which should be taken into consideration. The political, social, economic, and climatic factors all, directly or indirectly, play a significant role in effecting the improvement of agriculture. Many of the factors are complex in effect and usually are specific to certain countries or environments, so that the exact effect of each of the component factors is sometimes very difficult to evaluate owing to the mutual correlations of the factors. Research, then, is the only means of finding ways to the solution of problems.

As has been mentioned earlier, there are so many factors involved in the successful carrying out of an improvement program in agriculture, the question may soon be raised as to what problems should be tackled first, i.e., the question of agricultural research priorities. One might think policy-making study should be placed high on the list. The breakthrough from traditional backwardness and the providing of a solid foundation for later development rely greatly on the policy being adopted. The policy under which farmers could be encouraged to develop their farms into highly productive ones is one of the key points in a successful production program. Following agricultural policy are the institutional and organizational factors. Then the economic and technological factors begin to play an integral part in the solution of the entire range of problems in a development program. Obviously all such problems are too extensive in scope to be covered in the present paper; therefore only those related to the technological factors will be touched on here.

From the technological point of view, man has, today, developed agriculture as an enterprise rather than merely a life-sustaining activity in some parts of the world. However, large areas where low agricultural productivity prevails still exist. Farmers in such areas are usually poor and lack knowledge of low-cost technology. Sometimes the backward skills they use are little different from those used a thousand years ago. This emphasizes the fact that the agricultural research must be realistic in nature in such areas, at least in the early stage of development. Perhaps it would be more desirable to give priority to agricultural research which, more or less, aims at direct material increase in the productivity of agriculture. This, of course, does not mean that the other kinds of research are unimportant, and in fact some of them should be placed high on the list too. Under such circumstances, agricultural research priorities could be set, in principle, according to economic advantage. Only such research as is intimately connected with the available resources and skills of the nation which will yield immediate results and best returns with a minimum amount of capital investment should be first tackled.

As history has recorded, agriculture started basically from the utilization of land for crop farming and animal husbandry. Man had also given continuous efforts toward better productivity in the breeding of better varieties of crops and animals through selection, and combating pestilence as well as providing a better environment for the growth of crops and animals. The present type of farming has made almost no changes in the basic principle of utilizing natural resources. This means that the present research activities in agriculture will also involve problems about varieties, soils, protection, nutrition, farming tools, etc. It may be reasonable to conclude that priority in agricultural research should be given to the fields as above mentioned. Moreover, the scope of research activities can be further narrowed down by considering those problems first which are specific to the country or region in question.

It is quite common for farmers to start agricultural production with the choice of better adapted varieties. The fact that the breeding of better varieties, which often yield remarkable and immediate results without additional outlay or great modification in management by farmers, is one that deserves our special attention in agricultural research priorities. This is because improved varieties will readily be accepted by those farmers who, as a rule, lack adequate capital and skill. The adoption in China before the second World War of American cotton variety "Stoneville No. 4" which later on was re-named "Ambassador", is excellent example of this nature. The welfare of Chinese cotton growers was greatly enhanced by the variety and the benefits derived from it by the Nation were almost incalculable. Research of a practical nature in soils, protection, nutrition, farm equipment and irrigation should go along concomitantly with the breeding program, as their results will give combined effects if they are simultaneously and wisely applied to practical agricultural production. The recent application of this

principle to the so called "joint operation or package deal of rice improvement program in Taiwan" has given remarkable results of this combined effect under which rice yield has been further increased by 32.5 per cent (the average of 7 crop seasons in 4 years at 116 localities). It amply demonstrates that the improvement in one single technology may not bring the desired effect as fully as anticipated.

At a first glance, it may seem that the given "panorama" is too narrowly depicted. However, it should be noted that the development of agriculture in countries as a whole frequently follows a certai order of sequence in the process of advancement. In other words, the development of agriculture is usually phasic in nature; not all things can come at the same time. With the progress of time, farming experiences and capitals may have gradually accumulated; then come the skill and vision of farmers. These, in turn, will yield motive power for further progress in agriculture. Thus, in the planning of programs for agricultural research projects, such a view point on the order of sequence has also a direct, important bearing on the priorities of agricultural researches that should not be neglected.

One more point which may be worth mentioning is that in countries even endowed with very rich natural resources, farmers may not be able to start farming on a plantation system under a situation with limited investment capital and skill. For instance, Japanese farmers emigrated to Brazil and colonized the Amazon region allocated by the local government. They were given ten or more hectare of very fertile land but many of them found that they could work with only a fraction of it. Unless the farmers in a developing country can be popularly and adequately fed and clad and equipped also with low-cost and yield-increasing technology, the plantation system of farming can hardly be realistic even though there are exceptional cases. Perhaps the evolutionary process of farming from one type into another will be gradual unless a special united effort is given with national strength.

With the growth of farm productivity, and soon after the demand for local consumption of the farm products has been met, the farmers will begin to look for some market for the outlet of their surplus products. If the price of farm products is profitable, an incentive to expand production by the farmers will naturally ensue. But this may be greatly depressed by the problems of land ownership, the lack of good marketing systems, warehousing, transportation, and farm product processing facilities, farm financing and credit loans, availability of cooperative societies or farmers associations, the need of extension work, educating more young farmers, establishing factories for manufacturing chemical fertilizers and pesticides, etc. They all will then be shown to play an important part in the renovation of agricultural production.

Thus one can easily see that the later stage of agricultural development may involve a multitude of farmers which will affect the level of productivity in agriculture. It is impossible to even touch

on these here. Many of the problems may be considered primarily political rather than agricultural, but their effects are inseparable from increased agricultural production. Whatever different views peoples may hold regarding the priorities in agricultural research in African countries, the principles laid down above can be taken into consideration with advantage.

CONVERSION TABLES

Currency

US $1.00	245 CFA francs or FMG or 4.94 NF or 492 FM 8.33 UK shillings, 7 Nigerian or East African shillings 1.02 Ghanaian New Cedis
100 CFA francs	40.51 US¢, 3/4d UK or 2.85 Nigerian or East African shillings

Area

1 hectare	2.471 acres
1 acre	0.4047 hectares
1 sq. km	0.3861 sq. miles
1 sq. mile	2.59 sq. km

Dry Measure

1 liter	61.02 US cu. ins.	0.908 US quart
100 liters	3.53 US cu. ft.	2.84 US bushels
1 US bushel	2150.42 US cu. ins.	35.238 liters
1 Imp. bushel	2219.36 US cu. ins.	0.036 cu. m

Liquid Measure

1 liter	1.057 US quarts	0.22 Imp. gallon
1 Imp. gallon	1.2 US gallons	4.545 liters
1 US gallon	0.833 Imp. gallon	3.785 liters

Weight

1 kilogram	2.2046 lbs.	
1 lb.	0.4536 kg	
1 US short ton	2000 lbs	0.907 metric ton
1 US long ton	2240 lbs	1.016 metric tons
1 metric ton	2204.6 lbs	1.1 US short tons or 0.984 US long tons
1 US short cwt	100 lbs	45.359 kg
1 US long cwt	112 lbs	60.802 kg

Ratios

1 quintal/ha	89.2 lbs/acre
1 long ton/acre	4.11 metric tons/ha
1 metric ton	892 lbs/acre
100 persons/sq.mile	38.6 persons per. sq. km
100 persons/sq.km	259 persons per sq. mile

GLOSSARY OF ACRONYMS AND ABBREVIATIONS RELATING TO AFRICAN AGRICULTURE

ADB	African Development Bank (Ivory Coast)
ADC	Agricultural Development Council
AID	Agency for International Development (United States) Agence International pour le Développement (Ivory Coast)
ARCCA	Agricultural Research Council of Central Africa
BAD	Banque Africaine de Développement
BDPA	Bureau pour le Développement de la Production Agricole
BIRD	Bureau Internationale pour la Reconstruction et le Développement (Ivory Coast)
BIS	Bureau Interafricain des Sols
BNETD	Bureau National d'Etudes Techniques de Développement (Ivory Coast)
CBD	Coffee Berry Division
CBPP	Contagious Bovine Pleuropneumonia
CCTA	Commission for Technical Cooperation in Africa South of the Sahara Commission de Coopération Technique en Afrique au Sud du Sahara
CDC	Cotton Development Corporation (United Kingdom)
CEA	Commission Economique de l'Afrique des Nations-Unies
CEEMAT	Centre d'Etudes et d'Experimentation du Machinisme Agricole Tropicale
CEK	Centre d'Elevage de Korhogo (Ivory Coast)
CFDT	Compagnie Française pour le Développement des Fibres Textiles
CFRB	Centre de Formation Rurale de Bingerville
CGOT	Compagnie Générale des Oléagineux Tropicaux
CIMMYT	Centro Internacional de Mejoramiento de Maïz y Trigo
CMAOM	Comité du Machinisme Agricole d'Outre-Mer
CNRST	Comité National de la Recherche Scientifique et Technique (Madagascar)
CNZRS	Centre National de Recherches Zootechniques de Sotuba (Mali)
COMACI	Commission et Approvisionnements de la Côte d'Ivoire
COMEX	Comité d'Expérimentation pour le Mécanisation des Cultures (Ivory Coast)
CRA	Centre de Recherches Agronomiques de Bambey (Senegal)
CRAC	Centre de Recherches Agronomiques de N'Kolbisson au Cameroon
CRC	Cotton Research Corporation (United Kingdon)
CRI	Coconut Research Institute (Ceylon)
CRIG	Cocoa Research Institute of Ghana
CRIN	Cocoa Research Institute of Nigeria
CRST/OUA	Commission de la Recherche Scientifique et Technique de l'Organisation de l'Unité Africaine

CSA	Scientific Council for Africa Conseil Scientifique pour l'Afrique
CSNRD	Consortium for the Study of Nigerian Rural Development
CSSV	Cocoa Swollen Shoot Virus
CTAB	Centre Technique d'Agriculture de Bingerville (Ivory Coast)
CTFT	Centre Technique Forestier Tropical
DRPLC	Département des Recherches des Plantations Lever au Congo
EAAFRO	East African Agriculture and Forestry Research Organization
EACSO	East African Common Service Organization
EASIR	East African Institute of Social Research
EATRO	East African Trypanosomiasis Research Organization
EATU	East African Testing Unit
EAVRO	East African Veterinary Research Organization
ECA	Economic Commission for Africa of the United Nations
ECGC	Empire Cotton Growing Corporation
EFSA	Ecole Fédérale Supérieure Agronomique
ENCR	Ecole Nationale des Cadres Ruraux
ENSA	Ecole Nationale Supérieure Agronomique
ENSG	Ecole Nationale Supérieure Agronomique de Grignon (France)
ETSSA	Ecole Technique Secondaire Supérieure d'Agriculture
FAC	Fond d'Aide et de Coopération
FAO	Food and Agriculture Organization of the United Nations Organisation pour l'Alimentation et l'Agriculture (ONU)
FED	Fond Européen de Développement
FEG	Fonds d'Entraide et de Garantie
FIDES	Fonds d'Investissement pour le Développement Economique et Social des Territoires d'Outre-Mer
GAS	Ghana Academy of Sciences
HSIU	Haile Sellassie I University (Ethiopia)
IBAH	Inter-African Bureau of Animal Health (Bangui, CAR)
IBRD	International Bank for Reconstruction and Development
IEAAC	Institut d'Etudes Agronomiques d'Afrique Centrale
IEMVT	Institut d'Elevage et de Médecine Vétérinaire des Pays Tropicaux
IFAC	Institut Français de Recherches Fruitières Outre-Mer
IFCC	Institut Français du Café, du Cacao et Autres Plantes Stimulantes
INADES	Institut Africain pour le Développement Economique et Social

INEAC	Institut National pour l'Etude Agronomique du Congo (Kinshasa
INRA	Institut National de la Recherche Agronomique
IRAM	Institut de Recherches Agronomiques de Madagascar Institut de Recherches Agronomiques de la Republique Malgache
IRAT	Institut de Recherches Agronomiques Tropicales et Cultures Vivrières
IRCA	Institut de Recherches sur le Caoutchouc en Afrique
IRCT	Institut de Recherches du Coton et des Textiles Exotiques
IRHO	Institut de Recherches pour les Huiles et Oléagineux
IRLCS	International Red Locust Control Service
IRRI	International Rice Research Institute (Philippines)
IRSAC	Institut pour la Recherche Scientifique en Afrique Centrale
ISABU	Institut des Sciences Agronomiques du Burundi
ISAR	Institut des Sciences Agronomiques de Rwanda
ITEPAT	Institut pour la Technologie et l'Industrialisation des Produits Agricoles Tropicaux
ITERG	Institut des Corps Gras (Paris)
IUCN	International Union for the Conservation of Nature
LDC	Less-Developed Country (ies)
MRS	Maize Research Station (Kenya)
MSIRI	Mauritius Sugar Research Institute
MSU	Michigan State University (United States)
NARS	National Agricultural Research Station
NAS	National Academy of Sciences (United States)
NRC	National Research Council
OAU	Organization of African Unity
OCAM	Organisation Commune Africaine et Malgache
OCDE	Organisation de Coopération et de Développement Economique
ODM	Ministry of Oversea Development (London)
OECD	Organization for Economic Cooperation and Development
OICMA	Organisation Internationale contre le Criquet Migrateur Africain
OIE	Office International des Epizooties
ONI	Office National des Irrigations
ORANA	Organisme de Recherche pour l'Alimentation et la Nutrition en Afrique
ORSTOM	Office de la Recherche Scientifique et Technique Outre-Mer
PNUD	Programme des Nations-Unies pour le Développement
PPR	Peste des Petits Ruminants
PVD	Pays en Voie de Développement

REMVPT	Revue de l'Elevage et Médecine Vétérinaire des Pays Tropicaux (Paris)
RTAC	Regional Technical Aids Center
SAG	Station Agricole de Guetalé
SAL	Scott Agricultural Laboratories
SAP	Société Africaine de Prevoyance
SHMD	Société des Huileries Modernes du Dahomey
SNAHDA	Société Nationale des Huileries du Dahomey
SODEFOR	Société pour le Développement et l'Exploitation des Forêts
SODEPALM	Société pour le Développement et l'Exploitation du Palmier à l'Huile
SOGETA	Société Générale des Techniques Agricoles
SOMALAC	Société Malgache d'Aménagement du Lac Alaotra
SOSUMAV	Société Sucrière de la Mahavavy (Madagascar)
SOTROPAL	Société Tropicale des Allumettes
SPROA	Société des Plantations Réunies de l'Ouest Africain
SREA	Station Régionale d'Expérimentation Agricole
SRU	Soils Research Unit
STRC/OAU	Scientific, Technical and Research Commission of the Organization of African Unity
TPI	Tropical Products Institute
TPRI	Tropical Pesticides Research Institute
TRIEA	Tea Research Institute of East Africa
TSGA	Tanzania Sisal Growers Association
UNCC	Union Nigérien pour Crédit et de la Coopération
UNDP	United Nations Development Programme
Unesco	United Nations Educational, Scientific and Cultural Organization
USAID	United States Agency for International Development
WAIFOR	West African Institute for Oil Palm Research
WAITR	West African Institute for Trypanosomiasis Research
WAMRU	West African Maize Research Unit
WASPRU	West African Stored Products Research Unit
WHO	World Health Organization
WMO	World Meteorological Organization