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9. ABSTRACT

This booklet describes the activities of the Consultative Group on International Agricultural Research (CGIAR) and the research and training it sponsors. The purpose of the Group is to bring the resources of modern biological and socio-economic research to bear on the possibilities of agricultural progress in the tropics and sub-tropics where nearly all the LDCs lie. The Group seeks to give the LDCs superior varieties of essential crops and improved systems for the production of food, plants and animals. The opening chapter gives a general introduction to these subjects. The remaining chapters describe the work of each of the international institutes. These are: International Rice Research Institute, International Maize and Wheat Improvement Center, International Center for Tropical Agriculture, International Potato Center, International Crops Research Institute for the Semi-Arid Tropics, International Laboratory for Research on Animal Diseases, International Livestock Center for Africa, West Africa Rice Development Association, International Board for Plant Genetic Resources, International Centre for Agricultural Research in the Dry Areas. This Booklet is intended for the use of policy makers, specialists, and interested laymen who may find ways to benefit from or assist the work of the research network.

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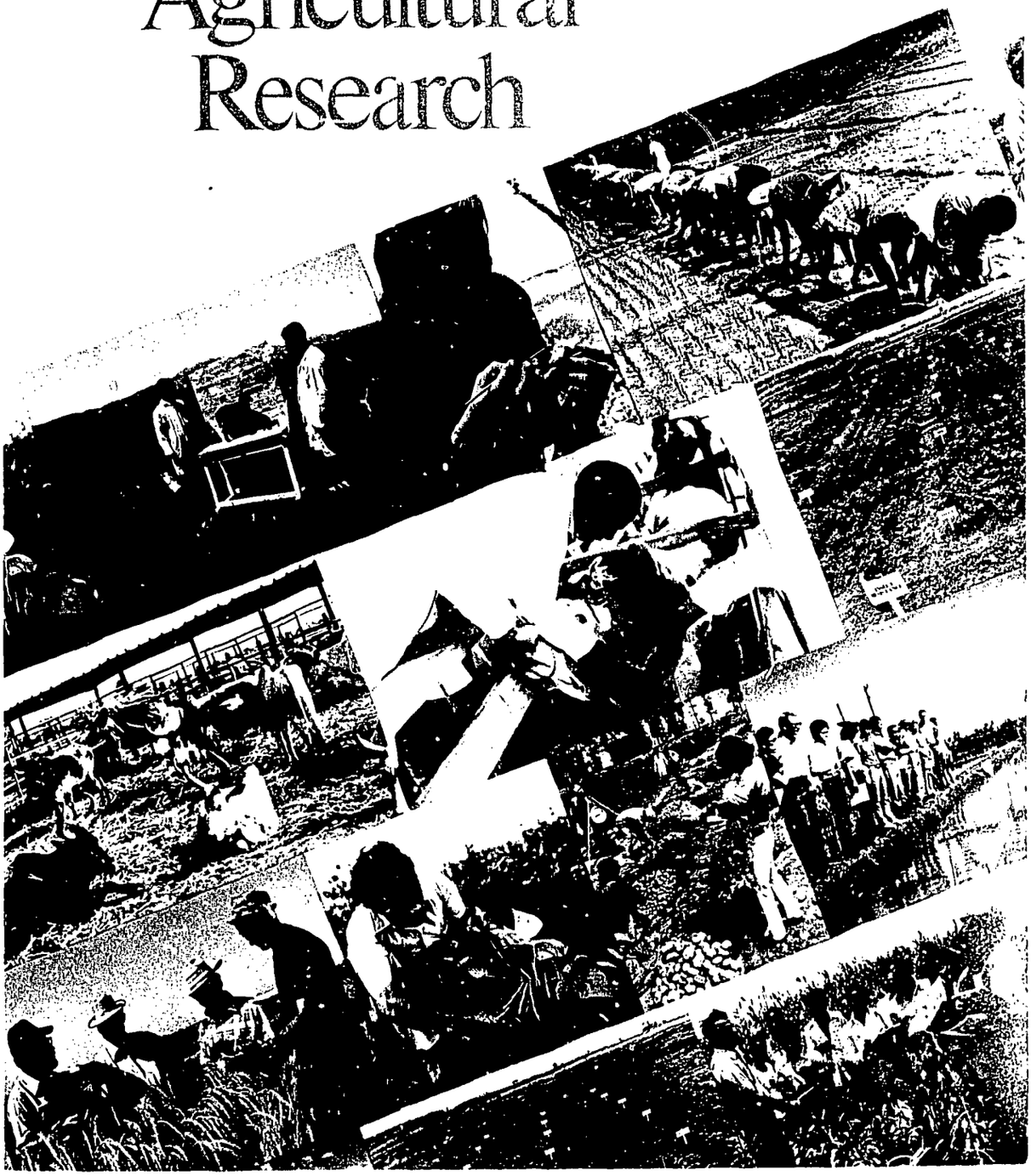
Consultative Group on

International Agricultural Research



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Consultative Group on

International Agricultural Research

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CGIAR
New York, 1976

Preface

Productive agriculture is both an economic and a humanitarian imperative in the developing world. The rural sector must generate savings and production to move development forward; and it must overcome the hunger and malnutrition that are the familiar lot of poor peoples everywhere.

In many developing countries, agriculture is not performing these essential roles. The rural sector is commonly not only the largest but also the most depressed part of the society. It is providing too little employment and too little production to raise living standards and prepare the way for further advance.

The world food situation continues to be precarious. On present form, the food deficits of the developing countries, which were about 20 million tons in 1970, will rise to between 55 and 85 million tons by 1985. At least 400 million people live on the edge of starvation. Throughout the world, another thousand million people subsist on sub-standard diets.

This state of affairs can be drastically changed. The world *can* feed itself. The basic problems affecting food supply result from decisions made by governments and individuals, not from uncontrollable or irresistible forces of nature. Solutions lie in new policies and new actions.

The necessary resources already exist or can be found. To mobilize them, however, requires acts of international cooperation and national initiative on an unprecedented scale—for example, in investment, trade, education, health and technology. The developed nations for some time must expect to continue food aid; but it is plain that the highest priority must be given to achieving a marked increase of food production in the less developed countries themselves.

An essential contribution to this objective can be made by the new and growing international system of agricultural research and training programs supported by the Consultative Group on International Agricultural Research (CGIAR). The Group is sponsored by the Food and Agriculture Organization of the United Nations, the World Bank and the United Nations Development Programme; and it consists, in addition, of 32 governments, international and regional organizations and private foundations. The purpose of the Group is to bring the resources of modern biological and socio-economic research to

bear on the long-neglected possibilities of agricultural progress in the tropics and sub-tropics where nearly all the less developed countries lie. The research and training programs sponsored by the Group seek to arm the developing countries with superior varieties of essential crops and improved systems for the production of food plants and animals.

This booklet describes the activities of the Group and the international research and training system it sponsors. The opening chapter provides a general introduction to these subjects; the remaining chapters describe the work of each of the international institutes composing what has come to be known as the CGIAR network. The booklet is intended to be useful to policy-makers, specialists and interested laymen—both those who may find ways to benefit from the network's activities and those who may find ways to contribute to its success.

Edouard Saouma, *Director-General*
Food and Agriculture Organization of the United Nations

Robert S. McNamara, *President*
World Bank

Bradford Morse, *Administrator*
United Nations Development Programme

THE WORK OF CGIAR

Of about 350,000 species of plants identified by botanists, archaeological evidence suggests, mankind at one time or another has tried perhaps 3,000 as food sources. By the end of the Stone Age, humans had already selected as their chief sources virtually all of the much smaller number of plants that serve them today. Over the space of 10,000 years or so, by a process of observation, selection, intuition and chance, cultivators have enormously improved the plant varieties with which they began.

Plant improvement, nevertheless, became a scientific enterprise only after the start of the present century, when genetics began to be more widely understood and to be systematically applied to the breeding of plants. From this beginning, plant breeding and scientific experimentation were carried out chiefly in the temperate zones inhabited by the industrialized countries — a truly ironic circumstance, since virtually all the plants on which mankind now depends for sustenance seem to have originated in the tropics and sub-tropics populated today by the less developed countries. The system of cultivating food crops (and animals)—evolved in each locality to suit such factors as climate, soil and patterns of work and society—have remained largely unimproved.

In spite of dramatic increases in yields achieved in cereal grains, the greatest achievements of agricultural research in the less developed countries still lie ahead. While the potentials of crop improvement obviously can be estimated only roughly, it nevertheless appears that in the tropics these potentials are large indeed. It is possible that better varieties and better methods of cultivation, including more inputs, could increase the typical yields of many tropical crops several fold. In fact, in a limited number of cases, examples of such multiplication are already occurring.

The CGIAR

It was to finance a revolution in the agricultural productivity of the less developed countries that the Consultative Group on International Agricultural Research (CGIAR) was founded in 1971. Sponsored by the Food and Agriculture Organization of the United Nations (FAO), the World Bank and the United Nations Development Programme (UNDP), the CGIAR is an international consortium that seeks to increase food production in the developing world through research programs and through the training of research scientists and production specialists in the developing nations. In 1972, the first year of funding, the Group supported the work of five international research centers with financial assistance amounting to $15 million. In 1976, the network of centers and programs had increased to 11, and financial support had grown more than four-fold, to $64 million.

Programs supported by the CGIAR now embrace the major crops and food animals and most of the ecological zones of the developing world. The 11 centers and programs (described in the subsequent chapters of this booklet) now employ more than 300 principal scientists, and more than 4,000 persons in all, in their investigations of the problems of tropical agriculture. The centers are:

The International Rice Research Institute (IRRI), Los Banos, Philippines, aims to increase and stabilize the production of rice in developing countries, through the continuing developing of new varieties and the evolution of better agricultural production systems involving rice as a principal crop. It was formally established in 1960.

The International Maize and Wheat Improvement Center (Centro Internacional de Mejoramiento de Maiz y Trigo, or CIMMYT), Los Baños, Mexico seeks to improve the production of maize and wheat. Like IRRI, it has research and testing programs which extend to many nations outside its own host country. Unprecedentedly abundant harvests of wheat and of rice on irrigated land in the 1960s, especially in Asia, stemmed from the work of CIMMYT and IRRI, and earned the name, "Green Revolution." Dr. Norman Borlaug, director of the CIMMYT wheat program, was awarded the

Nobel Peace Prize in 1966; and CIMMYT and IRRI shared the UNESCO Science Prize in 1970. CIMMYT was formally established in 1966; it is an outgrowth of a cooperative program begun in 1943 by the Rockefeller Foundation and the Mexican Government.

The International Center for Tropical Agriculture (Centro Internacional de Agricultura Tropical, or CIAT), Palmira, Colombia, has the objective of improving agriculture in the humid lowland tropics, especially in Latin America. CIAT was formally established in 1967. It was the first of the international centers to be concerned with the improvement of animal production. CIAT's efforts are concentrated on cassava, field beans, beef and swine, and it cooperates with CIMMYT and IRRI in the local adaptation of new varieties of maize and rice.

The International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria, was founded in 1968, on somewhat the same pattern as CIAT. It is concerned with the development of improved farming systems in the lowland humid tropics, especially in Africa; one of its chief concerns is to develop more intensive cropping systems to replace the shifting cultivation now typical of much of tropical Africa. The Institute is also carrying on crop improvement programs for root and tuber crops (cassava, yams, sweet potatoes) and grain legumes (cowpeas, lima beans and pigeon peas), and is cooperating with CIMMYT and IRRI on the local adaptation of maize and rice.

The International Potato Center (Centro Internacional de la Papa, or CIP), Lima, Peru, is a one-crop center, formally established in 1971. It seeks to develop improved varieties, and to expand the production of potatoes wherever they can advantageously be grown in developing countries. It already has established a regional network of production and training specialists for the latter purpose.

The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Hyderabad, India, was formally established in 1972, and was the first international center to be inaugurated under the auspices of the CGIAR. It studies farming systems and water management methods to benefit farmers in the semi-arid tropics, and seeks to develop superior varieties of sorghum, pearl millet, chick peas, pigeon peas and ground nuts.

The International Laboratory for Research on Animal Diseases (ILRAD), Nairobi, Kenya, is concentrating on immunological methods for controlling two major diseases of cattle — theileriosis (also known in Africa as East Coast fever) and trypanosomiasis (the sleeping sickness carried by the tsetse fly). It was established in 1973.

The International Livestock Center for Africa (ILCA), Addis Ababa, Ethiopia, is working to increase the output of animals (for the present, especially of cattle), through improved systems of production and better systems of range management.

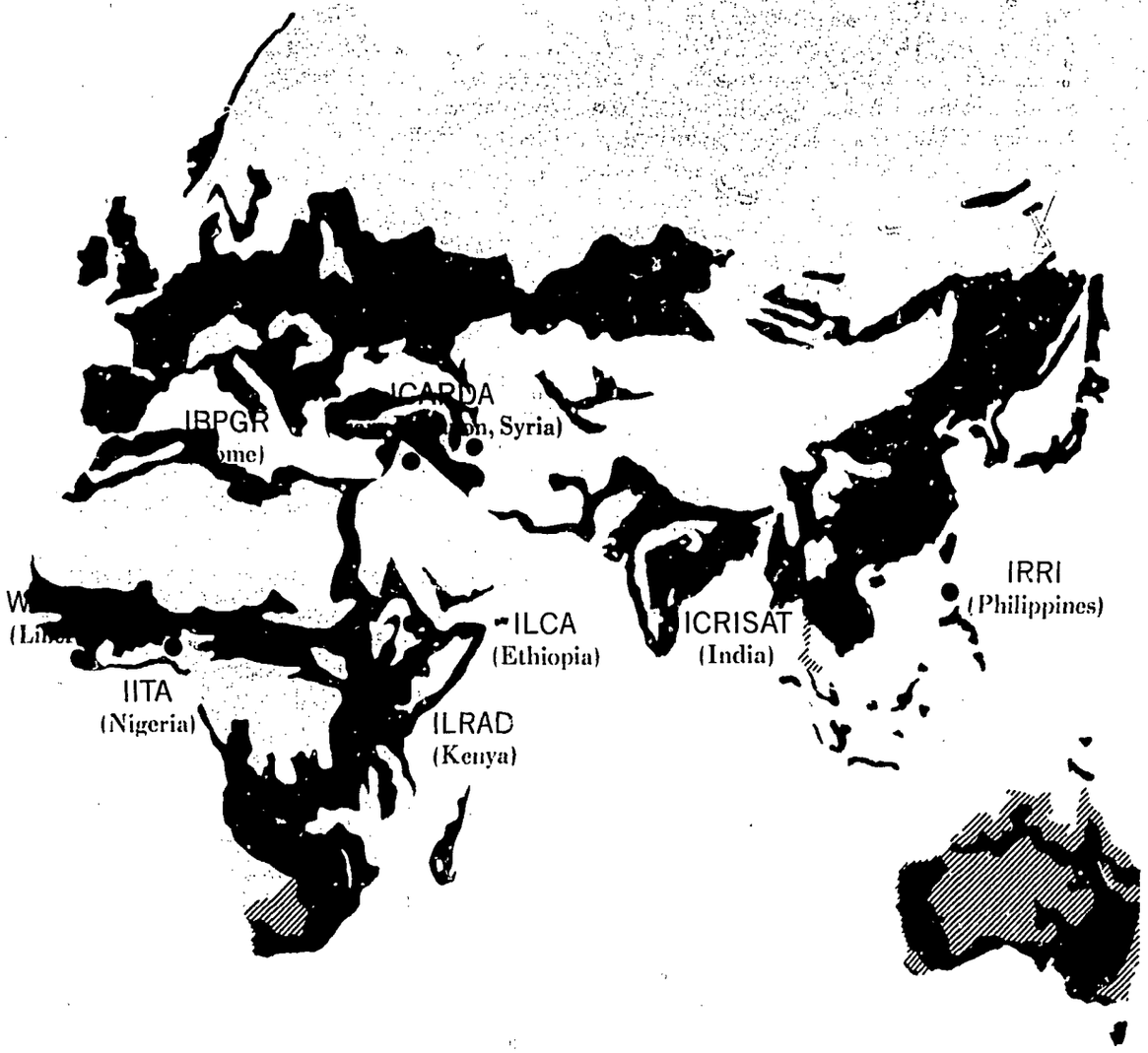
The West Africa Rice Development Association (WARDA), Monrovia, Liberia is a regional organization of West African Governments, devoted chiefly to applied research and aimed at making the region self-sufficient in rice.

The International Board for Plant Genetic Resources (IBPGR), Rome, Italy, began its operations in 1974. It seeks to encourage and to help coordinate the collection and exchange of plant genetic materials of potential usefulness in crop development programs.

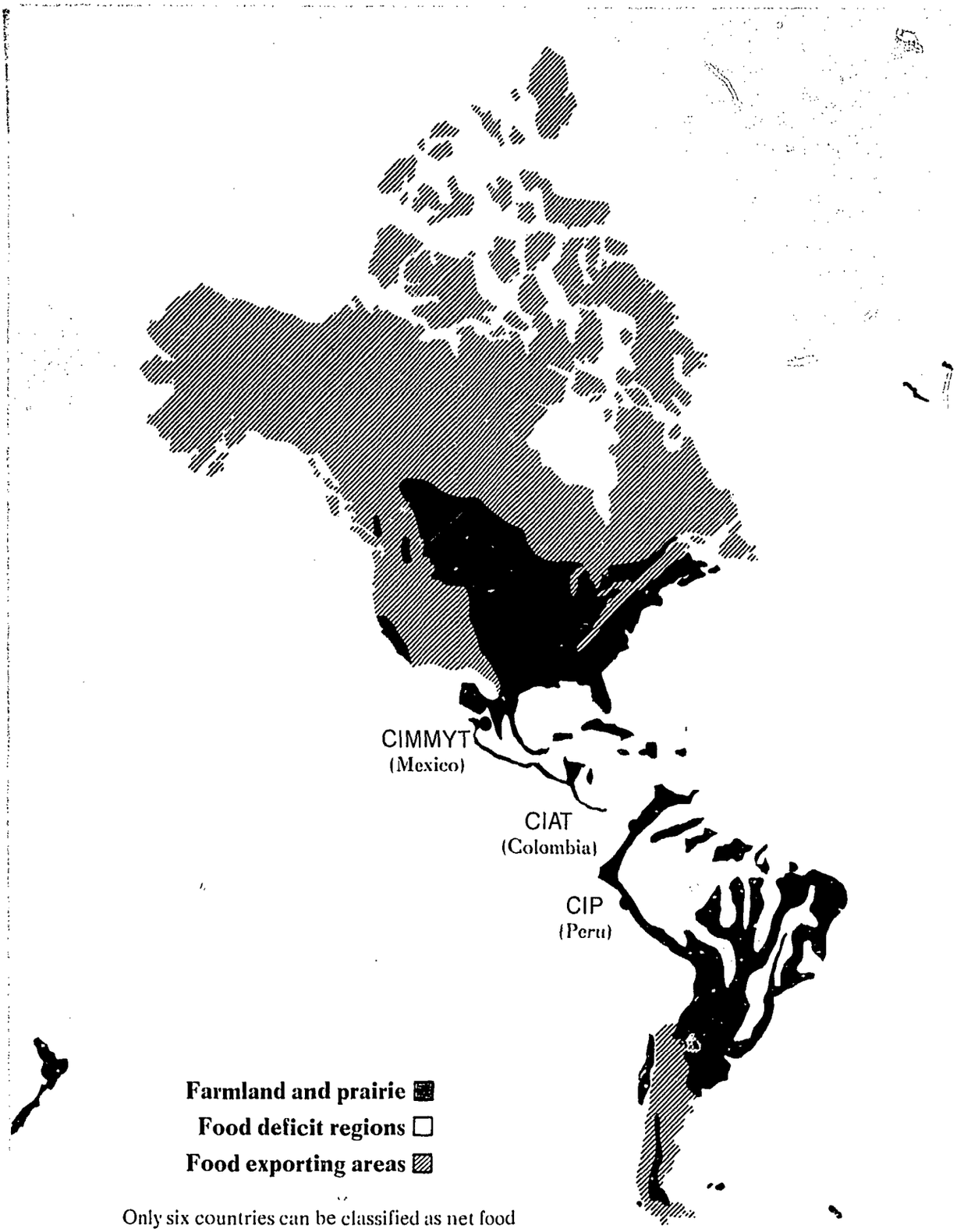
The International Centre for Agricultural Research in the Dry Areas (ICARDA), with temporary administrative offices in Cairo, Egypt. Founded in 1976, ICARDA has taken over the crop improvement programs of a predecessor organization in Lebanon, and also is establishing principal research stations in Syria and Iran. It will study farming systems in countries with Mediterranean-type and cold-winter climates, among them systems including animals (primarily sheep) as well as crops; and it will aim particularly to develop improved varieties of durum wheat, barley, lentils and broad beans.

In addition, for the time being the CGIAR also finances the Current Agricultural Research Information Service (CARIS) in Rome.

By August 1976, some 35 countries, international agencies and foundations could be



THE INSTITUTES AND FOOD PRODUCTION



Only six countries can be classified as net food exporters in the world today. They are Argentina, Australia, Canada, South Africa, Thailand and the United States.

counted as Consultative Group members. In addition to the three sponsors (FAO, World Bank, UNDP) the members were: 18 donor governments — Australia, Belgium, Canada, Denmark, France, the Federal Republic of Germany, Iran, Italy, Japan, the Netherlands, New Zealand, Nigeria, Norway, Saudi Arabia, Sweden, Switzerland, the United Kingdom and the United States; three foundations—the Ford Foundation, the Kellogg Foundation and the Rockefeller Foundation; three regional development banks (African, Asian and Inter-American Development Banks) and the Commission of the European Communities; and the International Development Research Centre (IDRC), an autonomous organization based in Canada. Each of the five major developing regions of the world (Africa, Asia and the Far East, Latin America, the Middle East, and Southern and Eastern Europe) participate in the CGIAR through two representative countries designated for two-year terms by the membership of FAO. In addition, the Arab Fund for Social and Economic Development has expressed an interest in becoming a donor member of the Group.

The members of the Group attend meetings in Washington at the World Bank's headquarters twice a year. On the basis of reports of progress from existing centers and on needs for new research thrusts, the members decide which programs they will support, and to what extent. A member of the Group is free to provide funds for some centers and not for others; most international centers attract funds from several of the donors; none attracts funds from all donors.

The Consultative Group is assisted by a Technical Advisory Committee (TAC) consisting of 13 eminent scientists. Apart from the chairman, the members are drawn equally from developed and developing countries. TAC advises the Consultative Group on research priorities, on specific proposals for which Group assistance may be sought, and on the effectiveness of existing international agricultural research and training programs. TAC's consideration of needs in developing countries takes into account not only the technical requirements of increased agricultural productivity but ecological, social and economic factors as well.

TAC usually meets two or three times a year, in Rome, Washington or one of the international centers. Members of TAC familiarize themselves with the work of the international centers and with research needs of developing countries by visits to centers and other programs of interest.

In order to concentrate on priorities and to achieve the necessary focus in objectives, CGIAR and TAC have to be selective in their support for international research. TAC itself originates research proposals; other proposals have to be channeled to TAC through a member of the Consultative Group. It is not possible for CGIAR to respond to requests to support national research programs, but cooperation between international and national research institutes is recognized as being of great importance.

The Center Concept

The centers and their predecessor programs were an innovative response to the need to increase agricultural productivity in the poorer countries. The very idea of research on tropical subsistence crops was novel; previously, research in tropical agriculture had concentrated mostly on cash crops intended chiefly for export. The weight of scientific talent which the centers brought to bear on crop development, and later on the problems of agricultural systems, was new; and the scale and speed of experimentation likewise had little precedent in the less developed countries.

Each of the crop centers is an autonomous, international, research and training institution, with an international staff of scientists and supported by locally recruited technicians. Each is governed by its own international board of trustees; and each board is non-political and self-perpetuating; each contains leaders and experts drawn both from developed and developing countries.

The international centers have close relations with the countries in which they are based. For a purely nominal rent, the host country provides the sites in which center facilities are constructed and crops are grown. Most centers are situated near an agricultural university or research station of the host country, and may carry on joint programs of research and

study with them and other national research institutions.

Beyond the host country, an international center develops a cooperative network which links it with research centers in other countries through programs of assistance or collaboration. The center builds up a library and documentation service for international reference in the fields of the center's specialty. Conferences, seminars and workshops are organized to enable international scientists to meet and discuss findings. With the help of the IBPGR, several of the international centers are building up collections of the world's germ plasm for the crops which they are studying.

While research is at the heart of a center's activities, the training of research scientists and production specialists to serve in the less developed countries claims a large part of its time, its effort and its budget. The number of persons trained at the centers so far is well over 3,000, and the emphasis on this kind of activity continues to grow.

The centers seek in other ways to apply the fruits of their research directly for the benefit of farmers in the developing countries, often through special projects particularly designed for and carried out within individual countries. These and similar outreach activities are recognized as among the most important functions a center can perform. Measured in terms of budget dollars, outreach activities accounted for one out of every six dollars spent by the centers for operating costs in 1974; in 1975, the proportion rose to one in every four.

The size of the budget of an international center varies according to its scope of work. Centers have needed between $5 million and more than $20 million each for developing their buildings, laboratories, greenhouses, experimental farmlands and housing for staff and trainees. Average operating budgets for 1977 are at the level of $7 million.

A hallmark of the centers is that their research is carried out by multidisciplinary teams of scientists, including plant breeders, geneticists, soil scientists, plant physiologists, pathologists, entomologists, economists and others as a particular problem may demand. This is in contrast to the research methods of a generation ago, when specialists tended to perform their tasks singly instead of telescoping them into a common endeavor. In part because of their international character, the centers have access to an enormous amount of genetic material throughout the world; this greatly aids their efforts to breed many desirable characteristics into a single plant variety. Techniques for duplicating genetic material have been developed which enable a single center to make literally thousands of plant crosses in a single year, and the international testing system administered by each center in the crops of its major interest means that literally thousands of plants representing new genetic combinations can be produced in a single year. All these advantages mean that an international center can produce results five or six times as fast as old-style agricultural research stations.

The center system began with a strong orientation toward purely biological research; but it has broadened its interests beyond the test tube and the experimental plot. The green revolution began on irrigated farms of comparatively large size owned by relatively wealthy farmers; the centers have now turned their efforts to developing plant types and practices to benefit the small farmer, who must operate without the benefit of controlled irrigation or much help from fertilizer and pesticides. Centers also are deepening their studies of constraints to production that lie outside the realm of biology, such as social custom, consumer habits, costs of inputs and the like; and economists and other social scientists are playing an expanding role in the activities of the research network.

For each center, these and other aspects of the work carried on in the international research network are described in the pages that follow.

IRRI trainees in the field (IRRI)

INTERNATIONAL RICE RESEARCH INSTITUTE

P.O. Box 933, Manila, Philippines

As the first international center, the International Rice Research Institute (IRRI) is often cited as the prototype of others that have followed. IRRI won early celebrity with the development and release of IR8 and the host of semidwarf rices that soon followed, varieties that rapidly became the most widely grown in the tropics. Today, about a fourth of the world's rice land is planted to semidwarf rices of the IR8 type.

A minor cultural revolution, as significant as the unprecedented rice yields, took place on the heels of technological change. Farmers not only caught on to the new rice-growing methods—the "package of practices" that allowed the new seed to express its yield potential—but in an analogous leap across barriers of time and tradition, they quickly absorbed the motives and attitudes of the modern producer and entrepreneur. This rapid telescoping of cultural and social evolution took the international assistance community somewhat by surprise, and brought about some strenuous rethinking in the field of agricultural development. IRRI's experience—scrutinized for lessons and guidelines and scanned for possible mirages—influenced the subsequent formation of the other agricultural institutes; it helped determine their nature, their staffing patterns and the directions of their programs.

Remodeling rice At least a third of the world's 4 billion people depend on rice for more than half their food. In fact, rice is virtually synonymous with food for the poor of Asia, where more than half of the people on earth live. It provides a livelihood for hundreds of millions; its growing cycle rules their daily lives; and its abundance or scarcity is a measure of their well-being.

Rice is therefore the central concern of IRRI's researchers, production specialists, engineers and communication experts. The technological advances that doubled yields in some areas were developed by interdisciplinary teams concentrating primarily on genetic manipulation of the tropical rice plant. Agronomists, pathologists, entomologists, geneticists and other scientists worked together to produce a range of high-yielding rice varieties to feed *more* people from the *same* land. The stature of the new rices has been changed from tall to short; stems have been strengthened so that fertilizer can be converted to heavy heads of grain without toppling; short, upright leaves utilize solar energy better and allow denser stands. The new rices tiller profusely; wherever they find room, they send up extra shoots, each topped with a head of grain. Genes for disease and insect resistance have been bred in, and sensitivity to day length has been bred out. The growing season has been reduced from about 160 days to just over 100, enabling the farmer with ample water to grow two or even three crops a year, or to follow his rice harvest with another food crop.

IRRI scientists remodeled the rice plant by collecting and screening thousands of varieties from across the world and, through crossbreeding, manipulating the genes that control each favorable trait. Today, IRRI's germ plasm bank preserves the seeds of more than 30,000 varieties; half of these have been tested and their significant traits recorded. Each year IRRI supplies about 4,000 packets of seeds of parent materials and new experimental lines to hundreds of rice scientists. More than 40 IRRI lines have been released as farmer varieties under local names in Asia, Africa and Latin America.

Packaged technology When the first IRRI rices began to look good in experimental plots, the Institute set about developing extension and demonstration techniques to get them into farmers' hands and to teach farmers how to grow and protect them. The famous package of practices is both a literal and a figurative

concept. Rice-production specialists prepared mini-kits, each containing enough seed, fertilizer and insecticide, to grow a tenth of a hectare, plus instructions for their proper use. The invisible part of the package was institutional support, which means technical assistance from extension agents, backed by the resources of national programs and of IRRI. Often, use of the package gave the farmer access to credit through government programs and a guaranteed selling price. In the early days, the field worker himself may have taken a course at IRRI; later on, he was more likely to have been taught his job elsewhere by a production specialist who had spent six months in IRRI's training program.

During its first 10 years, IRRI has left an indelible mark on rice production in the developing nations, and has helped chart a new course in institutional development. IRRI's impact has been decisive, and its reputation for excellence has helped generate interest in the new rice technology. But many problems remain to be solved.

Genetic evaluation Despite significant increases in productivity in areas where farmers are assured of water control and adequate chemical inputs, the new rice technology has bypassed many less-prosperous areas. The semidwarf rices are too short to grow in vast deep water regions along the mighty rivers of Thailand, Bangladesh, India, Burma, Indonesia and Vietnam. Similarly, high-yielding rices are needed for the salty soils of coastal marshes and of irrigated land in arid regions, and for the drought-prone regions where upland rice is grown. The improved rices developed for all areas must be resistant to major insects and diseases. To meet this challenge, IRRI further systematized its rice developmental efforts by formalizing an institute-wide Genetic Evaluation and Utilization (GEU) program.

The GEU program is an interdisciplinary rice improvement effort, linked with national programs in Asia, Africa and Latin America, to jointly develop and evaluate improved rices and technology for all rice-growing areas. Nine interdisciplinary teams of plant breeders and problem-area scientists, such as pathologists, entomologists, physiologists and soil and cereal chemists, work together to develop rices that are genetically adapted to the following problems and environments:

- agronomic characteristics;
- resistance to insects;
- resistance to diseases;
- resistance to drought;
- tolerance to adverse soils;
- tolerance to deep water and floods;
- tolerance to extreme temperatures (cold or hot);
- grain quality; and
- higher levels of protein.

To develop improved rices, each team first identifies varieties that can withstand the major constraints, and crosses them with varieties that have other favorable traits. The progeny of these crosses are tested under severe stresses, so that scientists can select experimental lines that can withstand harsh environments.

Through such methods, scientists bred resistance to insects and diseases into recent IRRI varieties such as IR26, IR30 and IR34. Without chemical protection, these varieties can withstand attacks of a half dozen of the most widespread insects and diseases. But the job is not over yet. IRRI is building genetic protection to a dozen pests into thousands of experimental lines, and sharing them with scientists everywhere.

To develop rices that can withstand moisture stress, GEU's drought resistance team tests the drought-survival ability of traditional Asian and African varieties and crosses the best with rices of higher yield potential.

The GEU adverse soils team tailors improved rices that will tolerate salty soils, and for regions with other soil problems such as alkalinity, iron toxicity and deficiency of phosphorous and zinc.

The curious ability of floating rices to elongate with rising water to depths of as much as six meters (20 feet) offers an opportunity to breed varieties for deep-water regions, as well as to incorporate a flood-escape mechanism into ordinary semidwarf varieties. The "elongation gene" has been transferred from floaters into modern rices, enabling them to

grow taller when water rises in the field.

Modern varieties have not been adopted in many mountainous and temperate regions because cool temperatures stunt their growth. The temperature tolerance team, by crossing traditional cold-tolerant rices with modern varieties, hopes to develop high-yielding rices for cool climates.

Some consumers like rice that cooks light and fluffy; others prefer their rice to be soft and sticky. These traits are controlled by genes, so the grain quality team is incorporating a range of grain types into pest-resistant rices.

The world's affluent get body-building protein through meat, eggs and dairy products, but millions of the world's poor get most of their protein through rice. High protein modern rice would improve the nutrition of millions, particularly of growing children. The grains of most rices contain about 7 per cent protein, but the GEU protein team has identified high-yielding lines with grains of 10 per cent protein. They are trying to incorporate pest resistance into such rices.

Recent results As prices of fertilizers and pesticides soar, IRRI has found that farmers can make these substances more effective by placing small doses below the soil surface into the rice root zone. Engineers have developed a simple, inexpensive deep placement applicator to speed the process.

The primary nutrient of most chemical fertilizers is nitrogen. Ironically, the air around us contains an unlimited supply of nitrogen which, if available to the rice plant, would decrease its dependence on fertilizers. IRRI soil microbiologists have found that certain rice varieties encourage the fixing of atmospheric nitrogen in the soil. Perhaps rice varieties can some day be developed that encourage high rates of nitrogen fixation, and that more efficiently use fertilizer and soil nitrogen.

Through international rice testing, scientists have found that biotypes of the brown planthopper in India and Sri Lanka differ from biotypes in Southeast Asia. Pesticide research is being coordinated with biological control studies to develop more effective and economical strategies for pest management. One insecticide has been identified that kills rice pests but not common predators of those pests. A species of spider was found that kills 10 brown planthoppers per day.

To develop cheap and efficient weed management systems for small farmers, IRRI supplies herbicides and plans for field trials to collaborating scientists, who then screen them in more than 20 nations.

Irrigation systems are not being used as efficiently as possible in many areas. IRRI cooperates with Philippine scientists to learn how to maximize the efficiency of water distribution systems serving small farms. Sociological studies indicate that dams and canals built by donor agencies often fall short of their purpose unless there is a corresponding program to follow up on the delivery of water at the farm level and unless local farmers are actively involved.

International networks Scientists in the developing nations have the ultimate task of developing and adapting the technology needed to feed a hungry world. IRRI coordinates four international networks through which national scientists can unite their efforts to create a "critical mass" of technology from which all nations can draw.

International rice testing program (IRTP) Elite rices generated by the GEU program and by national programs are evaluated under a worldwide range of environmental conditions through the International Rice Testing Program. Each national program nominates its best parent materials, breeding lines and varieties for global evaluation in 12 yield and screening nurseries. Worldwide testing shows how different rices react to diverse pests, diseases and environmental conditions, and speeds up the identification of rices with yield stability. Testing spreads new germ plasm to broaden the genetic base of the world's rice crop.

International rice agro-economic network IRRI collaborates with economists and agronomists in Indonesia, Thailand, the Philippines and other rice-growing countries to develop methodology to monitor problems that slow down the farm adoption of improved rice varieties and technology.

Scientists conduct experiments on farmers' fields, survey farmers to determine bio-

logical and socio-economic constraints, analyze markets and input prices, and relay their findings back to scientists in national research programs and at IRRI.

Agro-economic teams seek answers to such problems as why rice production has substantially increased in many regions where the new varieties are planted, but not in others. Or why many farmers who have accepted the new rice varieties still do not use accompanying chemical inputs and cultural practices. Once answers are determined, scientists can tailor research to develop varieties and technology to overcome the production constraints.

International cropping systems Although rice is generally the staple crop of small farmers in Asia, it is seldom their only food crop. Farmers can intercrop, or follow rice with other food crops such as corn, soybean, mung, sweet potato, cassava, or sorghum.

Through the International Cropping Systems Network, scientists test different cropping patterns in farmers' fields in Bangladesh, Indonesia and the Philippines, and evaluate varieties of each crop for intensive farming schemes.

Cropping patterns revolve around the best available rice varieties for each agro-climatic zone. As scientists continue to shorten the growth durations of improved rices, the farmers' potential increases to produce more food. For example, modern varieties such as IR28 and IR30 mature in about 105 days—from one to two months earlier than do traditional varieties, leaving the farmer adequate time and soil moisture during the late monsoon season to grow other crops.

The first priority is to intensify cropping in upland and rainfed areas. To ensure that the technology developed will be within the management capabilities of small farmers, trials are conducted in farmers' fields, under farmer management. The experimental sites represent the environmental conditions of specific "agro-climatic zones," or areas of similar soil, climatic and cultural conditions. Knowledge gained at each experimental site can then be shared and used throughout the agro-climatic zone, and in similar zones thousands of miles away, speeding the transfer of technology among nations.

Farm machinery development To intensify food production, farmers in the developing nations need tools and technology to speed certain production practices, such as land preparation, threshing and drying.

Many of the machines designed for large-scale farming in the more developed countries are too costly and complex for farmers in the rice-producing nations. They are hard to service and to maintain because spare parts are scarce and expensive. The machines cannot be economically manufactured in low volume in the developing countries because they are designed for capital-intensive mass production.

IRRI scientists identify and develop appropriate farm machines to overcome the most pressing production problems in farmers' fields. To encourage local production, IRRI releases the designs free to cooperating manufacturers who want to produce and sell the machines. Local manufacture generates employment and saves limited foreign exchange. IRRI cooperates with a network of national research organizations, manufacturers and engineers to develop appropriate machines for small farms and to encourage their local manufacture by small metalworking firms.

Educational programs IRRI's educational program is at the center of widening connections to rice-growing efforts around the world. Both degree and non-degree training are offered. From the start, the rice production course has been in heavy demand. It is offered to candidates from extension organizations, and research and educational institutions. Most trainees are from South and Southeast Asia, where 90 per cent of the world's rice is grown; others come from Latin America and Africa. The approach of the six-month intensive program is to "train the trainer"—IRRI trainees return home to organize and carry out similar training programs. Trainees study the theories of rice production and applied research in the classroom, but spend half of their time in the field learning every step of rice production. A typical class has about 35 candidates from 15 nations. A special five-month course in multiple cropping is now offered, and training was recently initiated in genetic evaluation and utilization, in agro-economic survey techniques and in agricultural engineering.

Formal academic training for about 65 scholars and fellows—mostly M.S. or Ph.D. candidates—lasts from one to three years and is conducted in cooperation with the College of Agriculture of the University of the Philippines. Most participants conduct their thesis work at IRRI. Postdoctoral researchers, special trainees, and visiting scientists collaborate with IRRI's scientific staff and use its experimental facilities.

About 700 man-years of training have been logged since IRRI was established, and graduates have fanned out to bolster national programs everywhere that rice is grown.

International outreach Major responsibility for rice work in Africa is shared with IITA and WARDA; and in Latin America, with CIAT. IRRI provides technical back-stopping for these programs. Rice scientists from national programs gather periodically at Los Baños for symposia on technical problems. A number of scientific publications, including a detailed annual report of research results and an extensive annual bibliography of rice literature, are distributed to interested institutions and individuals. The IRRI library has an active documentation service, augmented by a component in Japan that translates Japanese publications into English.

IRRI outreach scientists participate as members of collaborative research teams in Bangladesh, Indonesia, Pakistan, the Philippines, Sri Lanka and Thailand. Successful outreach programs have been completed in India, Egypt and South Vietnam. National governments and donor agencies provide financial backing.

In the Philippines, IRRI cooperates closely with government efforts to increase rice production, particularly in the training of production specialists for a campaign program called "Masagana 99." In 1975, the Philippines produced the largest rice crop in its history.

Staff The senior staff at Los Baños is made up of about 40 persons from nine countries—about the size of a major department of a typical agricultural university in a developed nation. Twenty other scientists are assigned to international projects. The institute employs about 800 people; more than 95 per cent are Filipinos.

The challenge ahead Rice has shown itself to be extraordinarily responsive to modern science, and rice growers, as well as their leaders in government, have proven themselves equal to the challenge of putting the new technology to work.

But a tougher challenge lies ahead. Demand for rice will increase by 30 per cent over the next decade, just to feed the expected increase in population. Where will the rice come from? IRRI's experience with the crop, with the regions where it is grown and with the scientists responsible for its improvement, will be invaluable in helping to meet this demand.

Better rice farming can substantially raise the living standards of millions of farmers—and of urban consumers—in the world's most densely populated nations.

Examining new wheat strain (CIMMYT)

INTERNATIONAL MAIZE AND WHEAT IMPROVEMENT CENTER

Londres 40, Mexico 6, D.F., Mexico

The International Maize and Wheat Improvement Center (CIMMYT) is one of the oldest and best known of the international institutes. Its research base had been evolving for over 20 years under a collaborative agricultural program between The Rockefeller Foundation and the Mexican Government, and assistance to countries in Central and South America and Asia already had been undertaken by its staff, when it was reorganized as an international center in 1966. Through an agreement with the Government of Mexico, it assumed autonomous status under an international board of directors and began systematic expansion of its research, training, and communications activities.

An almost tangible ingredient in CIMMYT's operations is its belief that traditional agriculture can be changed and is changing; that planners and policymakers can be moved in new directions; that farmers will adopt new technologies; and that farmers' horizons can be widened and their material circumstances improved.

A global mandate CIMMYT has developed two-way research and training patterns that reach out to nearly every major wheat and maize-growing country in the world; it collaborates in agricultural projects in developing countries, and has well-established ties with research and educational institutions in the technologically advanced nations. Today the Center's activities include evaluation of genetic resources, breeding and testing of new grain varieties, agronomic research, biochemical and nutritional analysis of grain protein, assistance with production programs and consultation on agricultural policies, campaigns against plant diseases and pests, training of future wheat and maize specialists, exchange of scientific information and development of new educational techniques and materials.

While CIMMYT's mandate is global, its center of gravity is the research and training programs in Mexico. Crop improvement is the primary objective, but its ramifications are far-reaching. Genetic manipulation of the wheat and maize plants for higher yields and better agronomic performance entails refinement of management techniques and productivity systems; a search for new experimental approaches and more precise statistical methods; closer coordination of scientific projects and exchanges of information and biological materials among the world's wheat and maize workers; and development of ways to reach farmers and persuade them to use new technologies. These several efforts converge toward the ends of bettering the farmer's economic prospects and upgrading the quality of country and village life in the wheat and maize-growing areas of the developing world.

In 1976 CIMMYT staff members were stationed overseas to work in wheat programs in Turkey, Tunisia, Algeria, Lebanon, Pakistan and Nepal; maize specialists were assigned to programs in Pakistan, Nepal, Egypt, Zaire, Tanzania and Guatemala. Consultation is being provided annually to as many as 60 countries of Asia, Africa and Latin America.

In 1975 wheat and maize specialists in 113 countries grew sample batches of experimental lines in 1,521 trials in CIMMYT's systematic international programs of trial nurseries.

CIMMYT's assistance to developing countries is aimed primarily at strengthening national agencies so that they can contribute to increasing production at home and also form

part of the international problem-solving system.

Training programs Training at CIMMYT provides concrete backstopping for this effort by annually increasing the number of wheat and maize scientists who now staff national and regional agencies and lead research, education and extension efforts all over the tropics and subtropics. These graduates keep in touch with the Center's research and often are instrumental in expanding its overseas network of adaptive research.

The number of trainees is about 100 a year; studies last from six months to a year and are geared to the formation of intermediate-level research and production specialists. Candidates are given field experience with wheat and maize research and production, sprinkled with a small amount of classroom instruction, to prepare them to train teams of production specialists, extension agents and subprofessionals in their home countries.

Teamwork is a hallmark of CIMMYT's training program: one approach involves five-man teams, representing five different disciplines, often from five different nations, and as likely as not receiving support from as many or more donor agencies. In this way, an integrated approach is suggested for future training programs of the cooperating organizations.

Postdoctoral scientists, too, work on problems associated with their home countries; they conduct research and take part in the training of field technicians.

Maize research In Central and South America, and in parts of Africa and Asia, large numbers of rural people live chiefly on maize, most of them poorly. Maize also is one of the principal grains raised for animal feed. But even with world production currently reaching over 300 million metric tons, there is not enough to go around.

Gains in maize production trailed behind those in wheat in the peak production years of the late 1960s. Maize is an extremely varied plant, highly sensitive to local conditions. Over the centuries, thousands of lines were evolved by farmers whose survival depended on selecting the best performing strains and perpetuating them. A wide range of color, size and texture in the grain, special milling or cooking qualities and other variations fancied by people of different backgrounds and cultures also influenced the configuration of traits in the maizes handed down from remote forebears.

In setting out to increase maize yields, breeders began collecting these tropical varieties from South and Central America; with later additions from other latitudes and other continents, the total world collection assembled at CIMMYT now numbers over 12,000. Breeders aimed first at development of high-yielding, disease-resistant lines that could serve as a basis for further research in the different maize-growing environments within its precinct; the basic genetic materials were sent out to cooperating programs for testing and selection for local use or for crossing with the best local varieties. CIMMYT is concentrating on development of open-pollinated varieties, as contrasted with the inbred hybrids that have been the basis for increased production in the United States and other advanced countries.

Hybrid maize was the miracle crop of the American Midwest in the 1930s, and the U.S. corn-belt states continue to supply nearly half the world's needs, a large proportion of it for livestock feed. Hybrids have been developed in the low-income countries as well, but generally they are not practical for use by the majority of farmers. Hybrid seed production is a job for professionals; the farmer must obtain new seed yearly, and distribution channels must be efficient. Small farmers in the developing countries, who use most of their produce to feed their families and their livestock, have no cash to spend on commercial seed; they set aside a portion of their harvest each year for the next season's planting as their fathers did before them.

Since the new synthetic varieties, when properly handled, can rival the yields of the sophisticated hybrids, even small commercial producers who have a little cash or credit are well advised to spend it on the inputs that help them get the best results—fertilizers, pesticides, weed killers and the like. CIMMYT maize breeders do not aim to produce finished varieties; they have concentrated on developing maize populations that can either be used directly in cooperating countries (in which case

they are released by the national programs and given local names) or incorporated into local breeding materials to produce adapted varieties.

In the early phases of the maize-breeding program, varieties were developed for high and low altitudes for early, intermediate, and late maturity, so that they could be selected according to the length of the growing season and adjustments could be made for eccentricities of rain or frost; resistance to the diseases prevalent in given areas was bred into the superior populations; and when a high-quality protein trait was identified, efforts to incorporate it into tropical varieties became an added objective. But although outstanding varieties were bred, and per-hectare yields in Mexico showed a 44-per cent gain between 1960 and 1967, maize still ran a poor third in the race to create new super grains for crash production programs like the high-yielding wheat and rice varieties in India, Pakistan and the Philippines.

However, news from CIMMYT in the last three years adds up to a major breakthrough in maize—one that has gone largely unheralded. Research aimed at breeding short-statured plants with wide adaptation, multiple disease and pest resistance and high protein quality has begun to show results. This is a radical departure from past objectives: it aims at developing varieties for use over a wide area instead of breeding a distinct maize type for each narrowly delimited growing environment.

The research techniques used in this effort are as innovative as the concept. Populations of as few as 200 or as many as 5,000 plants of similar aspect but different genetic make-up are planted together to allow natural mixing; then the mix is tested under varying conditions. The plants that show desirable traits are retained, and the poorly performing ones are eliminated. In this way a superior population is developed, with wide adaptation and a broad genetic background.

Structural change in the maize plant has been achieved analogous to the restructuring of the rice and wheat plants in the 1960s. By continuous selection of short-statured plants and by crossing tall tropical plants with short types, dwarf varieties have been developed with low ear placement and fewer leaves. The plants' new features make it possible to increase population density from a traditional 20,000-30,000 to more than 70,000 plants per hectare; the shorter plants show less tendency to topple over as the grain ripens, and they can absorb more fertilizer and use it to manufacture grain; furthermore, the thicker stands make more efficient use of solar energy and soil nutrients, and they compete successfully against weeds. Importantly, too, the higher yields create employment, since more hands are needed for planting, harvesting, shelling, hauling and handling the increased output. Yields of such experimental varieties in the highland tropical experiment station have risen from 5-6 tons per hectare to 9-10 tons, and those in the lowland humid tropics, from 2-3 tons to 5-6 tons.

Another important achievement is the incorporation of day-length insensitivity into the short-statured lines. Wide adaptation to altitude is being sought in much the same manner. Disease and insect resistance is a complicated problem in tropical maize; single-gene resistance has been identified for major diseases, and breeders are now working on multiple resistance, using techniques for deliberate exposure of the plants to the target enemies and selection of resistant plants.

High-lysine maize Breeding for high-quality protein in maize is one of the most significant efforts being made in any cereal program. Maize has 9 to 11 per cent protein—reasonably good among cereals—but maize protein is low in the amino acids lysine and tryptophan. (A protein source is only as good as its "limiting" amino acid.) It was in 1963 that a team of scientists at Purdue University discovered that a mutant gene called opaque-2 modifies the amino acid composition of maize; grain with the opaque-2 trait was soft and dull in appearance, but it had twice as much lysine and tryptophan as ordinary maize. Analytically, this protein was almost as good as that of milk solids; feeding tests with animals and later with malnourished children confirmed the laboratory findings: opaque-2 maize alone was an adequate source of protein for growth and health.

But the recessive opaque-2 gene was not easily transferred to tropical maize, and when this barrier was overcome, other problems arose. Yields of opaque-2 were lower than

those of ordinary maize; storage hazards were increased by its softer kernel; and furthermore, people did not like the look and texture of the kernels. CIMMYT breeders attacked these drawbacks and in 1970 began to incorporate the high-lysine trait into a maize with a shiny, firm grain. Populations of high-quality protein maize with white and yellow grain were tested in many countries beginning in 1973, and selection for improved grain quality still is going on.

These little-publicized advances in maize research are capable of leading into a major production breakthrough for tropical regions. Incorporation of the high-lysine trait gives this crop a privileged place in the areas of the world where protein deficiency is a concern. The availability of high-yielding, short-statured maize, with high-quality protein, wide adaptation and genetic resistance to diseases and pests, may prove to be a turning point in rural development programs for maize-producing areas.

The impact that the new maizes will have on small-farmer projects is yet to be gauged. CIMMYT's research is continuing to focus on development of open-pollinated varieties suitable for use in rainfed areas, where farmers do not have the advantage of controlled irrigation, with incorporation of the high-lysine characteristic into types that are locally acceptable. National agricultural agencies in many countries are working on such varieties, and some countries now are ready to promote them in national production programs.

Introduction of high-lysine maize into rural development programs is one of the global projects being funded by the United Nations Development Programme. In this effort, CIMMYT is providing research and training as well as technical assistance to national programs. The confluence of these two important aspects of CIMMYT's maize research may prove to be of the utmost significance, in terms of improved nutrition and increased farm income, for small farmers in maize-growing lands.

Sorghum research CIMMYT's sorghum improvement program (in collaboration with ICRISAT, the International Crops Research Institute for the Semi-Arid Tropics) stems from work in Mexico begun in the late 1950s. Breeders thought sorghum would prove more drought resistant than maize at elevations above 2,000 meters in Mexico and other Latin American countries, but no sorghum previously tested in Mexico had set seed at these elevations.

Sorghum seed was obtained from the highlands of East Africa (Kenya, Ethiopia), which grew on the central plateau of Mexico but was excessively late in maturity. By crossing the East African lines with short duration materials from the U.S., new lines were created which were satisfactory in Mexico above 2,000 meters.

Good sources of resistance to the three principal sorghum diseases at higher elevations (leaf blight, leaf rust, gray leaf spot) are now being incorporated into the CIMMYT breeding lines. Work is progressing on genetic resistance to three of the principal insect pests: fall armyworm, sorghum midge and greenbug.

International sorghum trials have been organized by CIMMYT around the world since 1974, and the highland crop is expanding, especially in Latin America.

Wheat research The research at CIMMYT that produced the first high-yielding dwarf wheats in the early 1960s and led to their subsequent widely publicized success in Asia, set the stage for even broader experimentation and farther-flung production programs in the 1970s. The widely adapted varieties and their associated technological packages were hailed as a major breakthrough in agriculture; they enabled Mexico to increase production while decreasing wheat acreage and to export wheat for a period, whereas it had traditionally been a net importer. The new varieties could be transferred to spring-wheat areas at varying latitudes and elevations and were equally at home when planted half-way around the globe. They did better than traditional varieties even under dryland conditions, and under irrigation their yields were spectacular. Backed by strong government campaigns, they brought hopes of food sufficiency to India and Pakistan in the late 1960s. Worldwide these CIMMYT wheats or their derivatives covered about nine thousand hectares in 1956-66; in 1970 they were planted on over 10 million hectares, with India, Pakistan, and Turkey growing the largest acreages. By the mid-1970s Mexico-derived wheats

covered 20 million hectares worldwide. The new varieties got such a good press that the public might have concluded that all major wheat problems were solved.

The men at CIMMYT knew better; they intensified their experimental programs, aiming for greater stability of yield, broader disease and insect resistance, and adaptation to drought, cold and other stresses. They expanded their training program and lengthened the list of nations cooperating in research and varietal testing. They entered into a cooperative effort with a number of governments and assistance agencies in the Near and Middle East to monitor wheat diseases and to try to prevent epidemics. They undertook cooperative research with U.S. universities and the Government of Turkey aimed at improving winter wheats; triticale research in cooperation with the University of Manitoba was accelerated; and studies on protein levels in wheat were launched in cooperation with the University of Nebraska.

CIMMYT scientists are well aware that, in order to fill the world's bare cupboards and empty breadbaskets, high-yielding wheats must be bred and farming practices developed for a great many different environments—not only areas previously neglected by science, but those where changing climates and soil conditions create a whole new set of problems, or where new diseases and pests invade overnight or old plant enemies suddenly appear in new and lethal mutations. Wheat improvement, whether on the experiment station or in the wheat-growing world, is an open-ended pursuit. And systematic promotion of improved wheat technology in the many countries where it has not yet penetrated is still a virtually untapped resource for increasing world supplies.

Current top-priority aims of wheat research are to stabilize disease resistance, to spread the use of improved seed and agronomic practices, to raise protein and lysine levels and to find sources of drought tolerance. A primary factor in yield stability is resistance to diseases and insects; breeders are using innovative techniques that include selection of the best lines of resistant material over several growing cycles, inoculation with various pathogens and testing under a wide variety of environments, first in Mexico and then in the international nurseries program. The continual addition of new genetic material has succeeded in developing a series of new wheat varieties resistant to rusts; attention is being focused on *Septoria* leaf spot, mildew and scab. Sources of resistance are being incorporated into the breeding program, and some resistant lines have emerged.

Crosses of spring and winter wheat are being made in the expectation of improving the root system of the spring bread wheats so that they will be more tolerant of drought; the breeders also hope the crosses will result in transfer of cold tolerance and disease and pest resistance to the spring wheats. In the same operation they are aiming to transfer traits such as dwarf stature, responsiveness to fertilizer and disease resistance to the winter wheat lines. Early tests of spring-winter crosses show promising results.

A program to improve durum wheat has been under way since 1968. Durums are used for a wide variety of macaroni-type products and for Arab couscous, which are important in the Mediterranean area and the Middle East. Durum wheat is also raised in India, the United States, Canada, Argentina, Chile and the USSR. High-yielding, fertilizer-responsive dwarf lines of durum have been bred, and genes for resistance to major diseases have been identified. CIMMYT's milling and baking laboratory is testing the lines for industrial quality, and breeders have sent out nurseries to be grown in over 30 countries. Nearly all durum-growing countries around the Mediterranean and in the Mideast have released Mexico-bred durums in the 1970s.

Triticale and barley Triticale, a cross between wheat and rye, is being improved along the same lines as wheat: genes for dwarfing have been introduced, and the shorter plants can absorb more nitrogen and yield up to eight or nine tons per hectare under experimental conditions. The drawback of shrivelled grain is essentially overcome, and triticale already is being grown commercially for food in Eastern Europe, for forage in the U.S. and for distilling whiskey in Canada. It has better tolerance of cold and drought than wheat has, and some experimental lines show higher protein and lysine levels than either of the parent species.

Barley is eaten by some 200 million people, but most research has been focused on the hulled types that are used for animal feed and for brewing. Now CIMMYT is using the same techniques applied to wheat for improving the kinds of barley that are used for human food. Sources have been found for breeding-in high lysine levels as well as good agronomic characteristics. Superior varieties will be important as both food and animal feed in areas of North Africa, the Near East, the Himalayas, the Andes and Eastern Europe, wherever low rainfall, high elevations, cool temperatures and short growing seasons make wheat raising hazardous.

As a general principle, CIMMYT scientists believe in developing alternate cereals like barley and triticale for areas that are marginal for wheat, and sorghum for lands where maize is vulnerable. Barley and sorghum have many of the same uses as the grains they replace, and offer the grower the highly valued advantage of greater security.

New directions In addition to improvement of these crops, breeders are experimenting with wide crosses on the order of the wheat-rye cross that produced triticale. Such research might be long in producing concrete results, but the chance of creating hardier and more prolific food grains for future generations cannot be overlooked. For example, some preliminary work with maize, sorghum and *Tripsacum* — a wild relative of maize — seems to hold promise. CIMMYT is growing a *Tripsacum* garden to multiply the genetic resources available to breeders. Other crosses that are receiving consideration include wheat and barley, wheat and oats, and wheat and wild grasses. CIMMYT will encourage universities and other basic research centers to probe further into the possibilities of wide crosses and other "radical" research it considers promising.

In this, as in its major programs, CIMMYT's role as an international clearinghouse for exchange of scientific information and airing of vital agricultural questions will prove useful. CIMMYT's technical publications in Spanish, English and French are circulated to wheat and maize scientists; its conferences and symposia bring together experts from the four corners of the earth to talk wheat and maize—or national production planning, agricultural education, world food-population balance and other topics that exercise the best minds in the field.

CIMMYT makes available new technology through many channels—the worldwide testing program; cooperative research; the training program and alumni network; consultation services; resident overseas staff serving national programs; official contacts with governments, universities, donor agencies and other institutes.

In the mid-1970s, CIMMYT began developing still another channel: regional programs in the principal maize and wheat growing areas of the world. Typically, one or two CIMMYT staff members are posted to a region where they help to assure the reliability of data from the trials; they also organize the exchange of germ plasm between neighboring countries; increase the contacts of local scientists through regional workshops; and expand the supply of technicians in the region through local training programs. These regional efforts are under way or in prospect for maize in Central America, the Andean region, tropical Africa and Southeast Asia; for wheat in the highlands of East Africa and South America. The regions are multiplying the contacts of CIMMYT's headquarters in Mexico.

Thus, through a variety of delivery systems, CIMMYT has a finger on the pulse of the agricultural world.

THE INTERNATIONAL CENTER FOR TROPICAL AGRICULTURE

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The International Center for Tropical Agriculture (CIAT) represents a departure from the dual or single crop approaches to agricultural improvement typified by CIMMYT and IRRI. Its primary focus is on a region—the lowland tropics of the Western Hemisphere—and more specifically on six commodities that have the potential for significantly improving both food production in the region and the general welfare of the rural and urban poor who live there. CIAT's main aim is to improve production technology in these commodities: beef, beans, cassava, maize, rice and swine.

The tropics of Latin America are marked by sharp contrasts and endless variations. The high-elevation savannas with good farmland and favorable climate, the harsh Andean slopes, the infertile lowland plains with alternating droughts and floods, the rich river valleys and marshy deltas, the impenetrable rain forests—all have such distinctive features, arising from both natural and human intervention, that programs aspiring to benefit agricultural production and improve human welfare in the region must take many forms. And they must pioneer, since little in the way of scientific exploration has prepared the way. Although improved technology is becoming available, often strong traditions must be gently changed to enable efficient use of this new knowledge.

CIAT'S geographical province lies below the well-favored highland plateaus; it includes undeveloped lands of fair to good potential, where agriculturists believe modern technology can effect substantial change. Other target areas—such as the vast plains areas and the rain forests—offer challenging possibilities for the future.

Yields have been traditionally low in every major crop, except for such export commodities as cotton, coffee and sugar, which have received much attention and investment because of their hard-currency value in world markets. Maize, rice, cassava and beans—the foods that sustain the people—generally make a poor showing; beef cattle and swine bring low returns except on modern commercial ranches and farms. Even there, nutrition and health problems frequently are barriers to greater production.

Small landholdings account for the great bulk of food and feed production, and much of this is for home consumption and use. On these small landholdings, farming is geared to the lowest level of investment, innovation and risk—not because farmers are illiterate or backward or slow to sense the winds of change, but because in their experience of the hazards and caprices of nature and the marketplace, caution is the most practical way to insure survival from one year to the next. Survival even at subsistence level requires diligence; in a rural population that is growing at an annual rate of about 3 per cent competition for resources becomes keener each year.

These natural and sociological considerations have shaped CIAT's programs. To make the greatest impact, CIAT focuses on the research which will have the broadest application possible within a given commodity. This is usually production-oriented research in which the CIAT staff can make a substantial contribution and in which the Center has a comparative advantage over the national programs. Such work may be in the form of massive screening efforts to identify sources or genetic resistance to insect pests or diseases. Broad-based research often involves evaluating agronomic or cultural practices, especially those which promise a possibility of fewer purchased

Bush bean field trial (CIAT)

inputs. And it may take the form of broad testing and classification efforts to produce germplasm sources for higher yielding crops. CIAT then makes this material available to the various national programs for final breeding work to produce varieties of crops tailored to the numerous local conditions and preferences.

CIAT's objective of improving the welfare of the peoples of the region dictates that new technology be workable on farms of all economic sizes. This becomes especially significant for the farmer who must produce with only limited inputs. Swine rations which use locally-grown feedstuffs become very attractive in the face of high prices for commercial concentrates. Crop plans which are naturally resistant to the most important diseases and insects and which have the capacity for high yields with limited inputs permit increased production even at the lowest level of farming. Cropping systems designed for the optimum combinations of two or more crop species grown together—as in the common example of maize and beans—offer great advantages for the farmer with limited land resources.

Once such technology is successfully devised, it remains of little use unless efficiently disseminated. This is why CIAT places so much emphasis on its training and outreach functions. The Center offers training for agricultural production specialists and researchers from throughout the region at virtually all levels. Programs are adapted to meet specific needs of the trainee or his supporting agency or institution. Effective communications are maintained with national agricultural agencies within the region to insure mutual understanding of problems and their solutions. A library and documentation center and a publications unit provide a flow of technical information to any scientist who wants or needs assistance. A conference center provides a setting where agriculturists can discuss their concerns and work in meetings, seminars and workshops. And, perhaps most importantly, CIAT's senior scientists spend a significant part of their time in the field in the various countries of tropical Latin America, conducting their research and discussing problems and successes with their counterparts in the region.

CIAT places major emphasis on three commodities—beef, field beans and cassava. Approximately three-quarters of the scientific staff work in these programs. The other three commodity research units — swine nutrition, rice improvement and the Andean Maize Relay Unit — have smaller programs. A seventh research-oriented unit, germplasm development, is now under development. Personnel in the Special Studies Group, attached to the Office of the Associate Director General for Research, will undertake limited-scale, exploratory studies on topics not readily assignable to research of the other commodity programs. One interest will be the problems of the small farmer.

Beef cattle The Llanos of Colombia, Venezuela and Ecuador; the Campo Cerrado of Brazil; and similar areas in Bolivia and Paraguay embrace vast tracts of under-utilized grassland and scrub timber, estimated at 300 million hectares. These lands are largely unsuitable for cropping because of high acidity and infertility of the soil, but they could support a profitable beef cattle industry. Beef production, however, in this area as well as in other tropical environments of Latin America, has a long way to go to fulfill its potential.

There are several important reasons for general low performance of cattle in these areas. Poor nutrition is a primary reason, but health problems, low calving rates (40-50 per cent) and general poor management all contribute to low productivity. In the case of some problems, research has identified solutions which could be realized if adequate investment were made in supportive services and extension; in other cases, progress will only come after extensive practical research.

CIAT is emphasizing research on the improvement of forages for the low-fertility allic soil areas mentioned above. The development and introduction of forages, and particularly forage legumes, which are more nutritious and able to exist in these environments, will improve the nutrition of cattle and help alleviate some of the other problems of health and management. At the same time, continuing research in pasture or range management and in important animal health problems will contribute to an improved technological package.

Scientists have collected a large number of accessions of native forage legumes from the allic soil areas and will assess and improve this material to find the well-adapted and nutritious forages needed. The majority of the accessions are variants of *Stylosanthes, Centrosema, Desmodium, Calopogonium* and *Zornia*. The most common forage legume in allic regions is *Stylosanthes* and about one-half of the accessions are of this promising genus.

A significant part of CIAT's field research in beef cattle production is in the Colombian Llanos, in cooperation with the Instituto Colombiano Agropecuario (ICA). From this work several important findings have emerged for improving beef production on native or improved grassland areas. Examples include early weaning of calves, a practice which helps to increase calving percentages by 43 per cent on an annual basis and reduces the rebreeding interval by four and one half months. Supplementation with phosphorus and trace minerals also has increased significantly calving percentages. Work on animal health problems has identified the prevalence of breeding and hemoparasitic diseases and of external parasites. Researchers are also working on cost-benefit studies of controlling the hemoparasitic diseases anaplasmosis and babesiosis and on comparing the effectiveness of control strategies for foot-and-mouth disease.

Field beans Latin America produces nearly 35 per cent of the world total of *Phaseolus vulgaris*, the common bean. At CIAT, experimental yields of up to 4,000 kilograms of bush beans and up to 6,000 kilograms of climbing beans per hectare have been grown. However, average yields on farms of the region are only about 600 kilograms. Yields are reasonable where beans are grown with irrigation, sufficient fertilizer and protection against pests; on the other hand, yields are extremely low on countless hillside holdings where farmers who depend on beans as a staple food frequently cannot afford even limited fertilizer or plant protection inputs.

CIAT scientists have been working on increasing the yield and productivity of field beans under Latin American conditions since 1972. High experimental yields set goals which may most easily be reached in large-scale commercial production; but in the meantime researchers are working along two approaches which should provide overall improved yields at a relatively low cost to the individual farmer.

Short term emphasis is on improving technology so as to minimize yield variability. One method already confirmed as extremely useful is the production of beans free of seed-borne pathogens. These pathogens are carried in some commercial seed and especially in seed kept from one year to the next on the farm. They not only affect germination but also serve as sources of serious disease outbreaks during the growing season. Yield increases from planting seed free of these disease-causing agents are normally 50 to 100 per cent; but in one area of Guatemala farmers tripled yields with this simple practice.

Because the bean plant has low resistance to attack from many insects and diseases, pest control is necessary for optimum yields under any conditions. Economic surveys on farms of different sizes have identified the different levels of infestations which cause economic loss. Scientists have now prescribed minimal control measures in case of attack from the major plant pests.

Beans need rather high levels of phosphorus and nitrogen for reasonable yields. With high prices for fertilizers, and very limited supplies in many areas, CIAT workers are looking for alternate and more efficient ways of supplying phosphorus and are studying the role of *Rhizobium* bacteria in capturing nitrogen and fixing it at the roots of the bean plant. Recent results suggest that selected bean-*Rhizobium* combinations can fix more than 0.5 kilogram of nitrogen per hectare daily. Over the growing season, this amount would constitute a helpful addition of free fertilizer.

A longer term approach to improving bean yields depends on the progress expected to come from the bean breeding work at CIAT and in national programs. CIAT has been designated as the world center to collect and maintain germplasm of *P. vulgaris* and related species. As new plasm specimens are acquired, they are screened for 52 characteristics, including resistance factors and growth habits. Sources of resistance have been found for many of the important diseases and some of the in-

sects. Hybridization is under way to combine these desirable features into bean varieties of high yield and little sensitivity to day length.

In response to a request by CGIAR, CIAT has assumed responsibility for a Latin American network for collaborative bean research. Cooperative yield and disease nurseries have already been established to provide testing sites for promising plant materials from CIAT and the various national programs of the region. Under conditions of the trials and the many locations, these materials will be observed in a great range of environmental, disease and insect conditions. The best materials will be selected as new varieties or advanced material for further breeding by national programs for local conditions.

Cassava The starchy root cassava, also called yuca, or manioc, is a favorite with the people of Latin America and the Caribbean, who cook and use it in dozens of ways. It is also a staple food in many parts of Africa and South Asia. Although low in protein, it is an excellent source of food energy. Dried or fresh cassava can be used as the carbohydrate in animal rations. Three-month-old leaves contain between 21 and 30 per cent protein, on a dry weight basis, and have been used at CIAT in swine and cattle feeding experiments. The high starch content of the tubers makes the crop attractive as a source for starch for many uses. In fact, small starch extracting plants are common in many rural areas where they form an important part of the economy of local communities.

Like other crops, cassava is plagued by insects and diseases. However, the common problem in almost all areas is general low production caused by many factors. CIAT scientists have shown conclusively that simple practices and relatively few inputs can help raise yields at least three times above present levels. The key is improved germ plasm—plants capable of yielding much more than presently grown varieties. CIAT's large bank of cassava germ plasm contains specimens with superior resistance or tolerance to major pests. Combining these features with plants that use the sunlight in a more efficient manner has already produced cassava yielding as much as 60 tons per hectare under experimental conditions. Average commercial yields over wide areas are probably only about one-fourth or less of that level.

At several locations in Colombia, for example, regional trials of cassava grown with few inputs but with good cultural practices show that relatively simple technology and improved germ plasm can almost triple production. Average local farm production was only 3 to 12 tons per hectare; the same local varieties grown with improved practices yielded 18 tons. But after coupling improved planting stock with the better practices, yields were 30 tons. On highly acid soils with low fertility, which are common to vast areas of the tropics, yields of 25 tons per hectare were obtained with improved technology and good fertilizer practices.

These improved practices are being taught to trainees from all cassava-growing areas. In addition, a regional testing program for improved plant materials has been developed to include 16 countries. CIAT is also assembling, abstracting and disseminating information on all phases of cassava production and utilization throughout the world.

Rice CIAT has cooperated closely with IRRI and the Colombian national rice program to modify, develop and introduce new technology and high yielding dwarf rice varieties in the American tropics. These efforts have shown very positive results.

Figures from a CIAT survey taken throughout the region indicate that new rice varieties along with necessary inputs like herbicides, insecticides, fertilizers and other improved technology were being used on about 0.75 million hectares of the American tropics in 1974. In this area, total annual production of paddy rice had increased about 1.5 million tons, compared to the level attained six years earlier with traditional varieties and cultural practices. Estimates of this increased production include 218,000 tons in Mexico and the Caribbean; 142,000 tons in Central America; 574,000 tons in Colombia; 143,000 tons in Venezuela; 77,000 tons in Ecuador and 122,000 tons in Peru.

Colombia's huge increase in production stemmed from a strong cooperative program between ICA and CIAT. Specifically, it was based on developing and introducing improved

dwarf varieties and the cultural practices for them. The gains came on irrigated lands, as upland area cultivation declined and upland yields remained essentially level. Unfortunately, land suitable for irrigated rice is becoming scarce or is non-existent in many countries. CIAT's economic survey for rice production should help to define future strategies for increasing production. Water control practices will help bring more land under irrigation where yields can be increased, but other possibilities will be in improving upland yields and introducing floating rices for more deeply flooded fields.

A greatly expanded varietal testing program has been launched in cooperation with IRRI and will enable evaluation for yield and disease resistance of advanced lines of rice at many locations in Latin America. More than 100 rice technicians, trained at CIAT and IRRI, are located throughout Latin America and can assist in this effort.

Maize In January 1976, CIAT's maize research and testing activities were fully merged with the maize program at CIMMYT. CIAT's responsibilities involve collaborative services for the Andean Zone and tropical Brazil; major work will be in facilitating the exchange of materials and information between CIMMYT and national programs and strengthening roles of national and regional activities in varietal testing and in the development of better maize production systems.

More specifically, important segments of the collaborative services program include: (1) strengthening the role of national programs in research on problems unique to respective countries or to the Andean Zone; (2) encouraging the distribution and regional testing of promising varieties from national or international breeding programs; (3) assisting national programs to plan and conduct maize production training programs; and, (4) focusing more attention on the improvement of highland floury maize, which constitutes a significant percentage of the maize produced, and which is almost exclusively for human consumption.

Previous research at CIAT has shown a number of short plant varieties from national or international programs to be equal or superior in yield to taller, normal hybrids and varieties, with the advantage of reduced stalk lodging falling over. When subjected to strong winds and rain, normal varieties lodge severely.

Early efforts to introduce opaque-2 high protein, soft kernel maizes met with very poor consumer acceptance. New materials with the same excellent protein quality and an acceptable hard kernel grain type are being tested by national programs in the Andean Zone.

Swine One hundred million swine are found in the lowland tropics of the Americas, up to 90 per cent of them on subsistence farms. Poor nutrition and management as well as substandard sanitation are the main barriers to efficient production. CIAT's Swine Program has previously dedicated a great deal of effort to research activities, with relatively limited inputs for training and international cooperation. Research projects have provided fundamental information on the use of non-conventional feedstuffs in swine feeding. Some of these feedstuffs include cassava, waste bananas, opaque-2 maize, sugar cane molasses, rice polishings, cottonseed meal and leaf protein. Results from this research have formed the basis for cooperative work with national institutions, notably the Instituto Nacional de Investigaciones Agropecuarias (INIAP) in Ecuador and ICA in Colombia.

Although research on nutrition and other aspects of swine production, such as animal health and economics, still continues, increased transfer of available technology will be fundamental for swine production development in Latin America. The program is therefore now emphasizing increased efforts in training at CIAT and within countries. At the same time, an integrated international cooperation team for technical assistance is actively participating in developing swine production in Bolivia, Costa Rica and Peru, in cooperation with institutions of those countries.

Germ plasm development A centralized germ plasm unit is under development at CIAT to assist in fulfilling the Center's responsibilities for maintaining, evaluating and distributing inclusive germ plasm collections of *Phaseolus* beans, cassava and some genera of tropical forage legumes. Maintenance of germ plasm

banks for these groups of materials requires specialized storage and handling facilities, as well as appropriately trained and oriented scientists who can devote full time to this work. Since the three groups of germ plasm materials can be handled in similar facilities, a central unit should be more efficient than three separate units within three respective programs.

Training CIAT's reputation as an international center with a very strong training program has been formed around two primary objectives. First, CIAT seeks to help national programs in developing countries to strengthen their capabilities in agricultural research and development. Second, it attempts to develop a wide and far-reaching network of commodity-oriented research scientists, who will assist with local validation and diffusion of technology generated in CIAT's research programs.

From the beginning of the training operations in 1968 through the end of 1975, some 600 professionals have trained at CIAT. Five major categories of training are available: postgraduate internships, either in research or production; M.S. and Ph.D. level research fellowships; special trainees; and, more recently, postdoctoral fellowships. In addition, the Center offers special work-learn opportunities through short-term employment for visiting specialists and visiting scientists of established prestige from national institutions.

Training activities are commodity-oriented. Major emphasis is on disciplinary research within a commodity, through a multidisciplinary team approach. The main objectives are to train trainers, college educators and leaders for research-production programs. The production specialist level of training features an integrated production system experience, again on a commodity basis.

In recent years, about half the participants in the training program have been financed from the Center's core budget with the other half being sponsored by sources outside CIAT.

International cooperation Outreach activities at CIAT were formally organized in 1976 under an Associate Director General for International Cooperation. This office has the objective of ensuring quick and efficient transfer of new and existing technology for CIAT's commodities to national agricultural research and development agencies in the region. Further diffusion of technology to the farm level is considered to be a function of the various agencies. The office also ensures that cordial and productive relationships exist between CIAT and the client groups. To assist in fulfilling outreach functions, this office includes the Library and Information Services and Training and Conferences programs.

Breeding field for cowpeas (IITA)

INTERNATIONAL INSTITUTE OF TROPICAL AGRICULTURE

P.M.B. 5320, Ibadan, Nigeria

The International Institute of Tropical Agriculture (IITA) was established in 1967 through an agreement with Nigeria. The host government provided 1,000 hectares of land for site near the University of Ibadan, one of Africa's leading educational centers.

The primary objective of all IITA research is to improve the quality and quantity of food crops in the humid lowland tropics. Many crops are important sources of food in this agroclimatic region, and IITA has sharpened its focus to concentrate on those considered of major importance. Among other things, the Institute seeks to deal with the problems that arise when the prevailing system of cultivation is forced to give way. In much of the tropics, agriculture traditionally has been a subsistence-level, low-input, labor-intensive endeavor. Except in rice-growing areas, the predominant system has been shifting cultivation. A short cropping season is followed by a longer period during which the soil rests under natural ("bush") fallow. During the fallow period, nutrients removed by the crops are replenished by recycling nutrients through the fallow vegetation. Organic matter added to the soil from decaying vegetation increases the humus content and supports an active biological population that restores favorable soil structure.

Populations of insects and disease organisms that reduce yields decline in the absence of their hosts. Soil acidity is controlled by the alkaline ash added to the soil when the farmer burns the regrowth to clear the land for a new crop. Soil erosion is minimized because most farmers' plots are so small that runoff from intensive tropical rainstorms has little chance to develop into erosive streams. Also, the usual practice of mixed cropping keeps one or another plant species in the ground during most of the year. By and large, the shifting system is a stable one, in balance with nature, and providing a limited number of people living on sufficient land with adequate food.

As populations of tropical countries increase and land-use pressures intensify, however, the natural balance of shifting cultivation is upset. To meet the increased demand for food the farmer is forced to cultivate more of his land more of the time and to shorten the restorative fallow period or eliminate it altogether. When this happens new problems arise. There is a decline in the fertility level and organic-matter content of the soil, erosion increases, the physical structure of the soil deteriorates, weeds are uncontrolled and there is an increase of insect and disease problems. The net result is less—not more—food produced from each unit of land and serious long-term deterioration of irreplaceable natural resources.

Increasing the quality and quantity of food crops in the tropics thus involves more than developing new varieties and introducing new agronomic practices. IITA has accepted the challenge of finding solutions to the problems associated with replacing shifting cultivation with more productive land-use systems. Such systems are needed to increase tropical food production and, thereby, to improve living conditions for millions.

To meet the challenge IITA has adopted a three-pronged approach. The first is research conducted both on the IITA site near Ibadan and at other locations—mainly, but not exclusively, in Africa south of the Sahara—and through cooperative efforts with national programs, institutions and agencies. Second is training in research and production skills to increase the numbers and competencies of those who work or will work to solve the problems of tropical food production. The third ap-

proach is dissemination of information through distribution of written documents and through conferences, workshops and seminars to share research results and new production technologies with scientists throughout the world.

IITA's research efforts are concentrated in four research programs. Three of the programs are crop-centered: the cereal, grain legume, and root and tuber improvement programs. The fourth program—the farming systems program—is designed to synthesize all IITA research activities and develop viable alternatives to traditional agricultural practices in the tropics. The materials and methods developed in the crop programs are used by farming-systems program researchers to determine the most efficient uses of available resources. The results of this research are fed back into the crop programs to guide researchers in the development of improved varieties and agronomic practices. The needs of the small farmer are considered paramount. The integrated research efforts of all programs are aimed at developing materials, crop combinations and farm-management systems within his economic and ecological range.

Root and tuber crops: cassava Root and tuber crops—high in calories, but low in protein—are staples in the diets of people in many tropical areas. Cassava, for example, is the major source of calories for an estimated 300 million people. Improving the quality and quantity of these crops will help to improve the diets of people in the region.

IITA's root and tuber improvement program puts top priority on cassava, followed by yam, sweet potato and cocoyam. The primary objectives of the research program are to minimize factors that currently limit production, to develop plants adapted to more advanced farming systems and to improve quality for human consumption. Specific research goals are to improve varieties for maximum production per unit of area and time by developing widely adapted plant types that resist major pests and diseases, that respond to better management and that more efficiently assimilate carbohydrates. Other goals are to breed genotypes better suited to simple mechanization, to improve nutritional value while keeping other favorable qualities and to introduce more convenient propagation characteristics, particularly in yams and sweet potatoes.

IITA's work on cassava has advanced to the point where high-yielding, disease-resistant lines now are available for distribution to farmers through national programs. A major portion of the work has been directed toward identifying sources of resistance to two diseases that seriously limit cassava production in Africa: cassava mosaic disease and cassava bacterial blight. Improved cassava lines from Latin America, for example, generally perform poorly under African conditions because of disease and other environmental factors. IITA cassava workers have screened about 100,000 genotypes each year since 1972 for resistance to cassava mosaic disease and cassava bacterial blight. They have identified sources of resistance to both diseases and are incorporating this resistance into high-yielding, locally-adapted cassava varieties. The most promising varieties are being tested over a wide range of agroclimatic conditions. Recent trials in Sierra Leone, Liberia and Togo confirmed resistance of IITA cassava lines to cassava mosaic disease. A high level of resistance also was shown to anthracnose in trials in Zaire.

Yams Recent IITA findings also have opened the door to more rapid improvement of yams. Past attempts to propagate white yams (*Dioscorea rotundata*) from seed to produce plants with greater genetic diversity were largely unsuccessful. In 1972, however, IITA scientists found a way to solve the seed-germination problem: identification of viable seeds and recognition of a previously unknown three-month dormancy period. More than 50,000 yam genotypes that display a wide range of genetic diversity in plant type, flowering and fruiting habits and yield have since been grown from seed at IITA. This broad genetic diversity serves as the base for developing improved yam plants through hybridization. Yam germplasm can now be collected, stored and exchanged among yam workers throughout the world as seed rather than as bulky, easily perishable tubers. Moreover, the groundwork has been laid for possible future commercial production of improved planting material utilizing yam tubers produced from seed, reducing the costs to the producer.

Grain legumes Grain legumes are important sources of low-cost protein for the people of the tropics and have the potential to become even more important as yields are raised. The primary goal of IITA's grain legume improvement program is to develop food legumes that have built-in resistance to pests and diseases and can efficiently use soil nutrients and sunlight to assure consistently high yields. Legumes also are an important part of improved, low input farming systems. This is because bacteria on their roots fix nitrogen from the air and improve soil fertility.

IITA's grain legume improvement program places primary emphasis on work with the major legumes of the region—cowpeas, lima beans, soybeans and pigeon peas. There also is limited work on other legumes that have importance in emerging farming systems—yam beans, velvet beans and winged beans. The integrated approach to grain legume improvement includes screening for yield potential; resistance to diseases, insects and viruses; photosynthetic efficiency; adaptability to management under both sole and mixed cropping; nutritional quality and consumer acceptance.

Cowpea improvement at IITA involves scientists in plant breeding, genetics, pathology, physiology, biochemistry and microbiology. Collaboration on important basic problems is maintained with the Rothamsted Experiment Station and the Universities of Reading, Durham, Cambridge, London (Wye College) and Gembloux. A continuing flow of improved germplasm is delivered through national agencies as uniform trials, collaborative agronomic or protection experiments and as material for testing for insect and disease resistance under different conditions. The integrated approach, as exemplified by cowpea research activities, has produced results. In April 1975, three cowpea breeding strains were announced as genetic stocks suited to the ecological conditions of middle Nigeria. These stocks are being distributed for use in further exploratory studies or as parental stocks. Two additional widely-adapted, high-yielding lines are being described and made available for similar use. Both lines have multiple resistance to certain insects and diseases and have performed well in trials in many locations.

Most of the cowpea lines in IITA's yield testing program now come from the plant breeding program rather than as selections from the germ plasm collection. The number of lines tested in preliminary yield trials doubled to 93 and 127 respectively, during the first and second seasons of 1975 as compared to 1974 figures. Advanced yield trials had 22 and 15 entires in 1974, while 1975 trials consisted of 100 and 115 entries during the first and second seasons.

Sixty-four cooperating institutions in 31 countries in Africa, Asia and Latin America participated in testing new improved lines developed at IITA during 1975. Nearly 70 percent of the trials were in Africa.

Other significant recent developments include a simple method for control of cowpea weevil in storage, which involves mixing inexpensive, readily available groundnut oil with cowpea seeds. The groundnut oil treated seeds were protected against weevils for more than six months and germinated normally when planted.

Cereal improvement The main emphasis of the IITA cereal improvement program is on maize and rice, and there is close cooperation with IRRI and CIMMYT. Emphasis is given to location-specific research that includes all aspects of improved crop production. IITA maize workers breed and select varieties that are suited to forest, savanna and mid-altitude regions of the tropics. They concentrate on such factors as disease and insect resistance, high protein content, short plant stature and problem-soil performance.

IITA scientists are involved in maize breeding and agronomy programs in other African countries. The agronomy work includes variety trials and village research trials. The breeding phase provides improved varieties suited to local conditions and supplies quality seed of released varieties to national seed farms. IITA also is involved in the development of farm-level variety "minikit" trials to improve the present package of practices and to accelerate the transfer of improved technology to farmers.

The rice workers are concerned with varieties adapted to the many ecological zones where rice is grown in Africa. They concentrate on blast and insect resistance, problem-soil tol-

erance and general performance for both lowland and dryland rice. Research is conducted on weed control and other agronomic factors, mechanization, soil problems and physiological adaptation.

Farm production studies in several West African countries provide useful feedback to guide research direction. Outreach activities include agronomic experiments under a wide range of conditions in direct collaboration with national rice research programs. Trial results are passed to the farm level through national extension programs.

Farming systems Helping the farmer change from the traditional system of shifting cultivation or natural fallows to continuous cultivation that makes the most efficient use of land, water and manpower resources is the objective of IITA's integrated, multidisciplinary farming systems research. The program involves a wide range of expertise that covers ecology and environment, cropping systems, farm mechanization and the economics of traditional and improved farming systems. This research integrates the results from the commodity-oriented research programs and feeds back to these programs results that help to determine priority problem areas.

Research conducted by farming systems scientists includes fundamental and applied research on soil management. These investigations are aimed at minimizing the soil loss and deterioration that result from the introduction of more intensive production systems. Minimum tillage techniques and the use of plant-residue mulches appear promising in this respect. A cooperative international soil-conservation network is now being organized with coordination provided by IITA's farming systems program.

Other farming systems research focuses on fertility management. This research concentrates on developing production systems that require low or moderate inputs of chemical fertilizers that often are too expensive or not available to the African farmer. A promising approach capitalizes on the predominant practice of intercropping, by including appropriate grain legumes in traditional cropping mixtures. The studies on the underutilized hydromorphic soils of the tropics indicate their great potential for increased food-crop production based on rice. All farming systems research includes testing for economic feasibility and acceptability to African farmers.

Agricultural engineering recently has been added as a subprogram to IITA's farming systems program. Priority is given to the design and development of implements and tools to complement the new farming systems. The implements and tools are designed primarily for use by small farmers in the tropics. To ensure that they will be easily available at a price the farmer can afford, IITA agricultural engineers make sure that whatever implements and tools are developed can be manufactured locally. Particular effort has been directed toward the objective of maximum cropping (multiple or intercropping) with the least effort and drudgery. The term "minimum toilage" has been adopted as the theme for this subprogram's research efforts.

IITA's farming systems program, in essence, illustrates the integrated approach to problem-solving shared by all of the research and training efforts. Because all of the other research programs feed into and receive feedback from farming systems research, the efforts of individual researchers are more than a series of isolated studies on single production parameters.

Special projects For many years plant scientists have been aware of the need to collect and conserve the genetic diversity of crop plants. Such diversity is an invaluable natural resource, because it is the essential and irreplaceable raw material of present and future plant breeding. It is a vulnerable resource, however, liable to be eroded or even lost as the pace of agricultural development quickens, especially in those areas where diverse and often primitive cultivars abound in traditional agricultural systems. Although such systems remain for the time being underdeveloped, they have great potential for future change accompanied by serious losses of genetic resources.

To ensure that genetic resources of African food crops are not lost, a new project was established during 1975 in cooperation with the International Board of Plant Genetic Resources (IBPGR) to collect and conserve genetic resources of African food legumes and

roots and tubers. Four project botanists, plus supporting staff, will explore Africa south of the Sahara for about six years. They will collect genetic resources of food legumes and roots and tubers, especially from traditional farming systems, and study the collections intensively at IITA to conserve them effectively and to prepare documentation useful to plant scientists everywhere.

The FAO/African Rural Storage Center project is in full operation at IITA. The initial phase has two main objectives. One is to collect information on farm-storage losses, structures and methods in Africa south of the Sahara as a basis for developing research and extension projects to improve rural storage. The second is to evaluate existing and improved methods of drying and storing maize and to stimulate extension programs using structures and methods appropriate to the areas concerned. Early studies have shown a striking similarity in traditional farm-storage structures and methods adopted by farmers in different climatic zones. But new and improved storage methods have generally not been adopted by small-scale farmers, and the center has undertaken work in this area as top priority.

Outreach activities Extending research through national programs, institutions and agencies is basic to the international character of IITA. If the objective to improve the quality and quantity of food crops in the tropics is to be achieved, research program results must reach and have impact at the farm level in all countries IITA serves.

IITA works closely with national programs in several African countries to extend research results. To ensure that the full range of IITA's scientific and technical capabilities is brought to bear in the effort to strengthen the research and development capabilities of the host program involved, the support of cooperative program activities is considered an integral part of the core research programs and receive scientific and technical direction from IITA program leaders.

The objectives of the cooperative programs are linked directly to the objectives of individual research programs of IITA and provide opportunities for testing the value of core research program accomplishments. The contribution to national programs can—and does—take a number of forms. In some instances, IITA may focus its research capability on a specific problem limiting production of a particular crop. In other cases, IITA's research and training expertise is used to support national food crop production programs. In the future IITA hopes to develop new crop improvement outreach programs, initially in several other West African countries and later farther afield.

Because of the importance IITA attaches to the cooperative program concept, it intends to pursue new outreach relationships as rapidly as resources for ensuring a successful project become available. Successful cooperative programs that go beyond normal offsite testing require a concentrated and sustained effort for a sufficiently long period to solve problems and to strengthen national research and development capabilities in a particular crop or production system.

Training Although IITA's training program is in one respect the smallest of its programs, with only three principal staff members, in another respect it is the largest. All of IITA's principal staff and many of its field, laboratory, library and administrative staff are, at one time or another, involved in training. The training program has two primary goals. One is to assist in the transfer of knowledge generated by the research programs to those who need it and can use it. The second is to respond to expressed need for training in research skills, training skills, library skills and administrative skills and to share the knowledge and expertise of the staff with those who need it to improve food production in their home countries.

Two basic types of training are offered. Research training is provided to sharpen the skills of agricultural research workers in tropical countries and to provide opportunities for students to conduct degree-related research at IITA. Crop production technology and extension training are provided for those who train or supervise extension workers in national crop production programs, to familiarize these trainers with improved practices and with methods of conducting accelerated crop production campaigns.

In the general category of production

training courses, the objective is to develop the technical, economic, scientific, farming and communication competencies of extension personnel from tropical countries. IITA has offered five courses of this type: two in rice, one in maize and two in cassava production. Additional courses in cassava and grain legume production are planned.

Not all training is directed toward extension personnel. The grain legume improvement program, for example, offers a course for research workers assigned to the improvement of grain legumes in tropical Africa. The objective is to train workers at agricultural stations throughout the tropics to conduct evaluation trials on new legume varieties so that they will be able to recommend improved grain legumes for release through their national programs.

Another type of course is exemplified by the rice field technicians course designed to train field technicians from the member countries of the West African Rice Development Association (WARDA) in standard field practices for conducting coordinated rice trials, including data gathering and reporting procedures. Group courses at IITA generally are conducted in both French and English.

Research training at IITA includes a variety of activities. Staff participants work on research problems that permit them to acquire or perfect research skills. Programs are tailored to meet the individual's needs and are planned to contribute to IITA's basic research goals. Three categories of research training are offered: degree related; non-degree related; and Vacation Student Research Scholarships. Under the category of degree related research training, postgraduate degree candidates conduct the research portions of their degree work under the supervision of IITA scientists. Non-degree related research is designed for employees of departments of agriculture, universities, research institutes, international organizations and private agencies. Under the Vacation Student Research Program, scholarships have been offered to advanced students in faculties and university-level schools of agriculture in Cameroon, Nigeria, Benin, Togo, Ghana, Ivory Coast, Liberia and Sierra Leone. The length of the scholarship is the length of the long vacation. IITA scientists suggest research programs that can be completed during a three- to four-month period and supervise students selected for these projects.

IITA also offers postdoctoral fellowships to selected, qualified applicants who recently have completed work for their Ph.D. degrees. Through this program IITA helps to increase the number of trained agricultural scientists available to work on food crop production problems in the tropics. Young scientists work with experienced research scientists on relevant problems of crop production. In return, the postdoctoral fellows help IITA to achieve its research goals by designing and carrying out research on priority problem areas. Postdoctoral fellows may later have the opportunity to join the staff of IITA or some other agricultural research institutes or agencies.

Staff and campus About 55 scientists from 19 nations comprise the senior scientific staff at IITA. Technicians, administrative, clerical and other support personnel are drawn largely from Nigeria and nearby West African countries. IITA is located about 16 kilometers north of Ibadan, which with a population of more than one million is the largest indigenous city south of the Sahara. The vegetation around Ibadan is tropical rain forest, but much of the forest is cleared for farming. Annual rainfall is about 1200 mm, most of which falls between May and September. About 60 per cent of the site has been cleared and developed for use as research fields. Construction of research laboratories, screenhouses, dormitories and administrative, conference and support facilities was completed during 1974. A substation in the high-rainfall area of Nigeria is currently under development.

The need to increase the quality and quantity of food crops in the tropics in the face of increasing populations and consequent increasing pressure on available land is imperative. IITA scientists and administrators recognize that improving the agriculture of the tropics, and thereby improving living conditions for all, involves more than developing new crop varieties or finding ways to control various factors that limit production. The integrated research effort that has been developed takes into account existing systems of production and the needs of the small farmer of the tropics.

INTERNATIONAL POTATO CENTER

Apartado 5969, Lima, Peru

El Centro Internacional de la Papa (CIP), the International Potato Center, is a one-crop institute; its mandate is to improve potatoes and potato growing in developing countries, and to extend the potato's range of adaptation to new areas, including the lowland tropics. The potato in question is the white or Irish potato, the tuber-bearing species of *Solanum*.

Potatoes are the world's fourth most important food crop, after wheat, rice, and maize. They are grown chiefly in temperate zones of advanced countries, where they are the staple food of the poor as well as an important element in the diet of the whole population. Technologists have devised new ways of processing and preserving potatoes, which have extended their usefulness and versatility for consumers in the industrialized nations; in most developing areas, however, they are still known as a luxury food.

Like a great many of the world's major agricultural products, potatoes have attained their widest use and importance in lands far from their place of origin. They were first introduced into Europe by the Spaniards in 1570 and have been selected and adapted over the years for the growing conditions in the cool-climate countries of northern Europe, the British Isles, the USSR and North America.

Their native place is the Andes mountains. Potatoes originated, scientists believe, in the intermediate and high-elevation slopes and plateaus of Mexico, Central America, Colombia, Ecuador, Peru and Bolivia. Untapped genetic resources, both wild and cultivated, still exist in this region, but they are slowly being eroded, in part by expanding agricultural development and other harbingers of progress—roads, airfields, human settlements. Logically enough, the collection, classification, maintenance and distribution of all tuber-bearing *Solanum* species are the first priority of the Center's research activities. Only about 5 per cent of the genetic variability of *Solanum* has been used in the development of the potato varieties now widely cultivated.

The potato has made very little progress in the world's hunger belt, where it could add substantially and advantageously to food supplies with its high protein yield per acre, ample carbohydrate content and high levels of Vitamins C and B. In hot climates, however, diseases and parasites are major drawbacks to production, particularly where protective chemicals are too expensive for farmers to use; tropical conditions make storage difficulties greater for potatoes than for grains or legumes; and tuber seed multiplication and distribution present technical and economic problems in countries that lack the necessary training base and infrastructure. Nevertheless, potato research and technology are rapidly approaching the stage where accelerated production programs can be mounted in key areas, and from there they could be systematically extended to neighboring countries.

Strategy CIP was formally established in 1971. The forebears of CIP include a USAID-funded project for the development of a Peruvian National Potato Program, and The Rockefeller Foundation Potato Program in Mexico.

The Center's leaders have designed an innovative scheme in which CIP figures both as a high-level experimental station in the conventional sense, and as a center participating in research and action programs around the world. For this reason, it is putting a smaller proportion of resources into developing its headquarters facilities, and investing more of its energies and funds in research and production programs in other countries, both developing and developed. This approach puts the emphasis on building coordinative, administrative and strategic capabilities.

CIP approaches its work on three levels. The first is research into nine major topics,

Comparing yields of different potato varieties (International Potato Center)

each constituting a program thrust. The second is regional research in various geographical zones of the developing world, each one mapped for potato problems and potentials. The third is the research projects conducted by other scientists under contract with the Center, projects that form a mosaic of individual and team efforts closely related to the two other activities.

Research CIP's professional staff conducts research at the headquarters station at La Molina, just outside Lima, and at three other locations in Peru, one at a temperate climate mountain station at Huancayo, another in a high jungle region at San Ramon and one in a hot, tropical rain-forest environment, at Yurimaguas. In addition, the Center contracts for institutions in the United States, Mexico, the United Kingdom and countries of Western Europe to do work on specific projects that are relevant to its sharply focused research objectives. Adaptive research is conducted in developing countries through the regional research program. Eventually this aspect of the work will comprise a network of cooperating national potato programs coordinated through a system of CIP regional production specialists. CIP will have staff stationed in most of the key locations by the end of 1976.

Periodic planning conferences are held under the Center's auspices, at which world authorities analyze the status of specific research thrusts and the outstanding needs in their specialized fields. In this way high-level scientific knowledge and expert judgment are funneled into the Center's evolving strategy, and other institutions are able to define their objectives and plan long-range programs on the basis of the pooled data.

Planning conferences have dealt with the key problems and potentials for increasing the use of potatoes in the developing world: late blight; bacterial wilt; potato quality; resistance to potato cyst nematode; cold resistance; utilization of genetic resources; regional research and training; and seed production technology for developing countries. At the conferences, five-year plans are drawn up for coordinated activities in the particular aspect of research under discussion; a review after the first three years ensures continuing relevance and flexibility of specific projects and of the general orientation of the investigations.

Germ plasm The research areas defined by CIP for major concentration begin with development of the world potato collection. Accessions in the germ plasm collection now number more than 11,000. These are chiefly cultivated clones from the Andean area, although 700 examples of wild species are also part of the world collection.

Since 1973, CIP has supported 15 collecting expeditions in Central and South America. Approximately 1,000 samples from the collection are sent to scientists in 10 countries each year.

This genetic material is being screened and the information coded for computer retrieval. The collection is maintained in clonal form by replanting yearly; it is also being converted to disease-free true (or botanical) seed, for storage over periods of 15 to 20 years.

Breeding techniques The second research thrust is the development of breeding techniques to provide better adapted potato varieties for use in developing countries. Research at CIP headquarters is coordinated with projects at North Carolina State University, Cornell University and the Plant Breeding Institute, Wageningen, The Netherlands. The breeding programs are aiming to synthesize the diverse genetic resources into potentially useful genetic combinations. Their goal is to produce populations from which clones may be selected for a wide range of environments. Some of the traits that are the object of the research are: frost resistance; high energy content of tubers; resistance to major diseases, insects and nematodes; wide adaptation to day length; and high-yielding ability.

Fungal diseases Control of fungal diseases, defined as the third major program thrust, is focused chiefly on the search for genetic resistance to late blight and studies of the effectiveness of this resistance to the fungus that causes it. Almost every known race of the pathogen exists in the Toluca valley of Mexico, where the Rockefeller Foundation's potato program screened thousands of potato varieties and identified material having polygenic resistance. Further breeding using these sources of resist-

ance is being carried out in developed countries, and some potato varieties having this trait are coming into use. Screening is in progress at CIP's jungle farm at San Ramon as well as in Mexico.

Control of the bacterial diseases is focused primarily on studies of bacterial wilt. A source of resistance to this disease was found in Colombia, and it now forms the basis of material that has been multiplied at the University of Wisconsin for international testing. The first trials have gone out to stations in Peru, Costa Rica, Colombia and Brazil.

A project at the University of Wisconsin is aimed at combining resistance to late blight and to bacterial wilt in a single potato clone. The diseases often occur together, constituting a major obstacle to potato production in most lowland tropical regions. Promising lines with resistance to both diseases have been sent to 18 countries for testing. A new variety has been released in Peru.

Other approaches Viral diseases and insect vectors are another major research area. There are 20 known virus diseases of potatoes and many more unidentified. High priority is given to breeding for resistance to the two viruses that most markedly affect production, potato virus Y and potato leaf roll virus. To date 2,500 clones from the germ plasm collection have been evaluated to detect the presence of the major viruses.

Nematodes, in particular the cyst nematode *(Heterodera)*, attack potatoes in many areas. At least five strains of this pest are present in Peru, and it is prevalent throughout the Andean area. CIP has undertaken a screening program of materials from its germ plasm collection as well as from interested countries. The testing involves four strains of the nematode, and materials are rated for both resistance and tolerance. Other nematodes under study are the important root-knot nematode *(Meloidogyne)*, and the false root-knot nematode *(Nacobbus)*, which is a nuisance in cold climates.

Attention is also being given to development of potatoes with wider adaptation to environmental stress and resistance to insect pests. The role of insects in virus transmission is being studied at CIP, where the germ plasm collection is being screened for sources of resistance to the main vectors, such as the green peach aphid and the potato aphid. Other insects under study include leaf hoppers, leaf miners and weevils. Both cold tolerance and adaptation to the hot, humid tropics are being sought, the former through studies at high elevations in Peru and Colombia, and the latter through the experimental work at San Ramon and Yurimaguas. Clones maturing in 60 days have been grown in the hot, humid jungle regions of Peru. For potatoes growing in cold climates, a solution might be found through the developing of early-maturing varieties which can be harvested before the onset of frost. Clones with a 100-day season have been developed, where normally 150 to 180 days are required to grow Andean varieties.

Per hectare, the potato produces more protein than the major cereals. Potato protein quality is good, and clones with 11 to 12 per cent protein on a dry-weight basis have been identified in the CIP germ plasm bank. The potential for breeding potatoes with even higher protein content is considered excellent: clones with 20 to 25 per cent of the dry matter as protein are known.

Seed production technology must be evolved for developing countries before accelerated potato production programs can be contemplated. For this purpose, CIP is working on tissue culture for disease elimination and on measures that will permit rapid multiplication and distribution of new clones. Seeds of varieties that are free of viruses are being multiplied, and clones resistant to wart disease, blight and several fungal and viral diseases are ready to be processed. In many countries, training in seed production will be necessary to build up local technical capacity for seed industries.

Projects CIP counts the projects under way both at home and abroad as part of its core program. In funding research at experimental centers in the developed countries, CIP can draw on a broad range of expertise and can benefit from sophisticated equipment and experimental facilities it would not otherwise have access to. This collaboration offers reciprocal advantages, since findings in any one of CIP's research areas may be of value to potato growers in the developed countries as well as to the advancement of CIP's program goals.

CIP keeps close track of research in progress, both internal and contractual, through periodic program reviews, in-house seminars and evaluation of written records and reports. Projects may be carried out by one researcher or several; most involve more than one specialist and more than one discipline. As a result, each CIP scientist is usually engaged in two or three ongoing projects.

Regional research The regional research program is one of the most important aspects of CIP's work. For the present it is in the formative stage; preliminary surveys of the target countries have been made, and CIP staff members have been assigned to five of seven overseas regions, where they are working with national leaders toward development of local programs. Training courses, generally dealing with the use of disease-free breeding materials, seed multiplication and commercial potato improvement, have been held annually since 1972 in Peru, Mexico, Kenya and elsewhere. The first annual training school for the Middle East region was held in Egypt. Broad goals of this program thrust include design of research adapted to the needs of the various regions, training of local scientists and technicians, and efficient distribution and utilization of potatoes in developing countries. Socioeconomic studies will eventually be a part of the regional research effort, particularly in view of the need to adapt potato technology to the needs of the small farmer.

CIP has divided the developing world into seven target zones which cover both hemispheres. Each zone has been assessed for characteristics that have a bearing on potato production, from climate to the degree of interest in agricultural development, and further investigations are being focused on specific factors such as ecological conditions, consumer preference, marketing structures and similar considerations which are important in determining the types of germ plasm to be selected for trial in various areas. CIP's intention is not to produce varieties *per se,* but to furnish materials for testing and further development in each zone, so that local programs can ultimately release and name their own varieties.

When the regional research program is fully operative, a program center in each of the seven zones will have a skeleton staff from CIP. Its primary mission will be to cooperate with local leaders in strengthening national capabilities, so that the countries in the region can benefit from the new technology and improved germ plasm made available through CIP.

Training CIP has an agreement with Peru's Agrarian University, located near its headquarters in La Molina, under which Master's degree candidates can do their thesis research in connection with one of the Center's programs. Similar arrangements with institutions in developed countries allow Ph.D. degree candidates to do a major portion of their thesis work at CIP. Postdoctoral scientists are also accommodated in CIP's laboratories for work on projects related to the Center's objectives.

Training for national potato program leaders and technicians for the developing world is being conducted at the regional research centers; formal classroom instruction linked to firsthand planting-to-harvest experience in growing a potato crop is the basic formula around which the educational programs designed by the Center are structured.

ICRISAT trainees at a sorghum field trial (ICRISAT)

INTERNATIONAL CROPS RESEARCH INSTITUTE FOR THE SEMI-ARID TROPICS

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The dryland farmer of the world's semi-arid tropics tackles a stern environment with limited resources and long odds against him.

The soils of his farm are old and worn. He seldom has enough fertilizer. His seed varieties have come down from ages of selection for ability to produce **some** yield in the worst of times — the defense against starvation; such varieties do not produce truly **high** yields in the best of times. His energy sources are usually human or animal, and both are subject to the poor, plodding performance of the undernourished.

But his most limited resource is water: *limited in amount and limited in distribution* in these lands of a short rainy season and a long dry season.

Yet a major part of the food supply of some 500 million people depends on the success of the dryland farmers of the semi-arid tropics. They are found in parts of Australia and Southeast Asia, India, the Middle East, two wide belts in Africa, areas of South America and much of Mexico and Central America. It is true that "miracle varieties" and new "packages" of technology have boosted food supplies to some extent here as in other parts of the developing world. But the increases have come mainly where irrigation can be part of the package. Under the pressure of growing population and of requirements for better nutrition, the need for increased output by the dryland farmer continues unabated.

The dryland farmer, and through him the vast populations of the semi-arid tropics, is the focus of the rapidly developing scientific mission of ICRISAT, the International Crops Research Institute for the Semi-Arid Tropics. The Institute's scientists believe that concentrated work can produce varieties of food crops and methods of managing the soil and water resources for the dryland farmer which can substantially improve the size and dependability of his harvests.

In mobilizing high-level scientific resources for an all-out effort to improve the productivity of arid lands and the potential of dryland crops, ICRISAT's leaders are determined to keep the Institute's sights fixed on the *small cultivator of humble means.* They are developing technology that will make sense to him in his world hedged in by poverty and fear of risk. But at the same time, the crop varieties and farming techniques evolved may *have ramifications of far-reaching significance.*

ICRISAT has primary responsibility for two cereals (sorghum and pearl millet), two pulses (pigeon peas and chickpeas) and one legume oilseed crop (groundnuts), all of them major crops of semi-arid tropical regions. Also, ICRISAT has committed itself to a parallel objective of finding systems of farming that will produce higher output and more dependable results from year to year. The program is still young, but both physical facilities and research projects are developing rapidly. Fortunately, the cereals improvement work in sorghum and pearl millet can draw on years of research in India, the Near East, Africa and the United States. Some work on pigeon peas also has been done in India, Puerto Rico, the West Indies, Brazil and Australia, and on chickpeas in India, Pakistan, Iran and other Near East countries. A substantial wealth of genetic material and information has been accumulated in Africa and the U.S. In addition to consolidating the results of these and similar efforts, ICRISAT is forming ties with national and regional centers engaged in related research in the semi-arid regions of the world in prepara-

tion for reciprocal program activities.

Improved varieties alone cannot solve the farmers' problems, given the milieu of constraints to agricultural production in this region. ICRISAT's Farming Systems Program, the first to have experiments under way at the research station, is embarked on a comprehensive research endeavor embracing climate, soil and water management, hundreds of crop alternatives, agronomic variables and other resources. All these must be taken into account to create technology packages acceptable to the farmer.

In light of the special limitations faced by the farmer, an obvious necessity exists for a strong social science input into ICRISAT research. The Economics Department, one of the most fully-staffed units in the Institute, has launched both supportive research in collaboration with other programs and independent studies to help increase understanding of the presently-operative behavior determinants in the semi-arid tropics. In addition, programs of training, international seminars, cooperative research and support activities have been launched.

Although many of these pursuits have been largely developmental in this initial period, substantial progress can be cited in each program.

Sorghum Sorghum is grown on 43 million hectares in both temperate and tropical latitudes, with yields in the developed countries about five times as high as those in the tropics. Although the crop originated in the region of Ethiopia and the Sudan and is widely grown for food in much of Africa and in India, the highest level of technology has been achieved in the advanced nations, where it is grown for livestock feed.

Where sorghum is a food crop, wide variations exist in the plant types used by farmers; moreover, consumer tastes differ with respect to grain size, texture and color. (Sorghum color ranges from pale to dark red or brown.) Most of the varieties now in use in developing areas do not respond to intensive technology. In Africa, sorghum is the dominant crop in areas with low rainfall, whereas in regions with more reliable rains, both maize and sorghum are raised. The sorghums used in Africa are sensitive to day length, which limits the seasons for successful crops. Breeders take factors like these into account when they make selections for the different sorghum-growing regions. Bred-in resistance to pests and diseases is also important to small farmers who cannot afford pesticides.

Intensive breeding research has been under way in India for a number of years. A world collection of sorghum germplasm, which now numbers over 17,000 accessions is available, and new collections are being made. ICRISAT sorghum improvement teams are using the collection to identify superior lines for given environments, as well as specific genes for traits they want to incorporate into their best genotypes.

Exchanges of genetic materials and trial nurseries, along with international testing of varieties, are routine activities of the sorghum program. Characteristics being sought include genetic resistance to witchweed, or Striga, which attacks the root system of the plant; resistance to downy mildew and other diseases; and resistance to shootfly, stem-borer, and midge, which heads the legions of insect enemies that attack the plant in the field from the time of seed germination through the appearance of the young shoots, the flowering and ripening of the grain and then, after the harvest, cause damage to the grain in storage. Resistance to mold is important if the grain matures during wet periods or has to be kept in storage through the rainy season. Other traits on the wanted list are: higher yielding ability; shorter stature to permit denser plant populations; nitrogen responsiveness; day-length insensitivity; better appearance and texture of grain; higher protein content with higher lysine levels; greater cold tolerance for the high altitudes in the tropics; and tolerance to periods of drought.

Certain high-protein sorghums from Ethiopia hold promise for improving nutritional quality; Purdue University researchers have spotted lines having up to 17 per cent protein, with a high percentage of lysine. ICRISAT is utilizing these lines for use in crosses and incorporation into its trial populations.

Superior hybrids previously developed in India have some of the traits being sought by

ICRISAT's breeding program, but hybrids have limited value for use among poor subsistence populations. Many countries in dryland areas do not have the capital or technical personnel needed to build up a seed industry and distribution system. Nevertheless, as the lower income countries progress in economic development and increase the number of trained technicians in the service of their agriculture, they may want to introduce high-yielding hybrids and advanced agronomic practices. For the high-yielding sorghums, physiologists and agronomists are working on such factors as optimal use of solar energy; improvement of cultural practices, including time of seeding, use of fertilizers and chemical plant protectants; and moisture-conservation techniques.

Pearl millet Pearl millet *(Pennisetum typhoides)* is only one in a large family of millets; it was selected for special concentration at ICRISAT because of its widespread use as food in South Asia and Africa and because of its superior performance under adverse conditions. It is grown on approximately 25 million hectares of land in the semi-arid tropics. Pearl millet tolerates drought and low soil fertility better than sorghum and is a nutritious staple with high energy value. Protein levels normally range between 8 and 12 per cent but some varieties may contain over 20 per cent. Yields now averaging between 400 and 600 kilograms per hectare in the semi-arid tropics have potentials at least six times this level. In addition pearl millet possesses the ability to tiller profusely and to produce two or three ratoon crops in succession. ICRISAT scientists have found that, when sufficient moisture is present, the first and second growth may be cut for forage and the third crops can still produce mature grain.

Breeders' goals—improved yield, stress tolerance, disease and pest resistance, higher protein quality and acceptable kind and color of grain—are similar to those defined for sorghum. However, disease resistance is even more important with pearl millet because ergot, downy mildew and rust are major constraints to increased production of this crop. The millet team is trying to incorporate sources of resistance to these diseases into the best strains in their working collection. As with other grains, broad-based or "horizontal" resistance is their goal. Many kinds of birds are fond of millet, and strong measures must be taken to discourage them in some areas.

The germplasm collection of pearl millets counts 6,600 entries from a number of countries, including a wide variety from India, and additional sources of genetic stock are being obtained from Africa. A systematic collecting effort will be made as ICRISAT's program proceeds, so that breeders can develop synthetics and hybrids having desired characteristics for various uses and for different growing conditions.

Protein quality in millet varies from 11 to 20 per cent, and little work has been done to incorporate high protein into the best-performing lines. Hybrids with potential high yields have been bred, but they are extremely vulnerable to downy mildew; the program is now aiming at development of synthetics, using the method of selection over several generations from a composite population. Such populations are being tested at ICRISAT for yield, agronomic performance, grain quality, and disease resistance; and selections are being made to suit the environmental characteristics of different regions or the needs of local cropping patterns. Yields of over three tons per hectare have been achieved at ICRISAT, and much higher yields are thought to be possible, given good growing conditions. (For people who live under the intermittent threat of famine, however, the prize trait of millet is that it will produce some kind of harvest in the worst of conditions.)

Achievements in the pearl millet breeding program have come rapidly. Since it is a cross-pollinated crop, the latest plant breeding methods developed for maize, which also is cross-pollinated, have been used. Three generations per year have been grown at ICRISAT's Hyderabad headquarters and the Institute has received excellent cooperation from other workers in India and abroad.

As a result, all four major composites (early, medium, late and dwarf) have been moved along as fast as they could be grown and tested and have been subjected to a dynamic selection program. Special interdisciplinary and breeding projects ranging from a search for "bird resistant" types to laboratory-

based investigations on disease characteristics are under way.

Pigeon peas The pigeon pea is grown on nearly three million hectares worldwide, about 90 per cent of them in India. World yields average around 600 kilograms per hectare. Experimental plantings have demonstrated, however, that the yield potential of this crop is much higher; up to 5,000 kilos per hectare and more have been grown under experimental conditions, using local Indian varieties. With genetic research concentrated on improvement of plant type, it is reasonable to expect that even higher yields could be achieved. Total protein can also be increased, since cultivars that range from 15 to 25 per cent in protein content have been found.

At present, many of the varieties grown in India take up to 300 days from planting to harvest, but high-yielding experimental plantings have been grown in 150 days. Short-season varieties could be extremely valuable for climates where double cropping is feasible.

Pigeon peas in India are traditionally interplanted with sorghum or millet; they grow slowly at first, then shoot up after the companion grain is harvested, and then take another five months to reach maturity. In addition to the dry peas, which in India are used chiefly in dal (a kind of split-pea sauce or puree), the green pods are edible, and the woody stems can be used for fuel. The tall plants also have the advantage of a deep root system, which makes them tolerant to drought, and they are fairly resistant to pests and diseases. Plant population density, however, is usually low, a condition further aggravated by the widespread use of large woody plants that grow to a height of eight to ten feet.

Recent development of dwarf types has opened up possibilities for higher plant densities and improved plant types with a higher ratio of grain to foliage. Breeders also have hopes of improving growth in the early stages and developing better resistance to diseases and pests, especially pod-boring insects. Short varieties that can be used to advantage in intercropping systems are being sought, since the grain-pulse combination is nutritionally valuable in semi-arid regions where diets are generally insufficient and protein levels in particular are below minimum needs. Agronomic practices adapted to the inter-cropping combinations are also being worked on by ICRISAT's multidisciplinary teams.

Pigeon pea is a self-pollinated crop. To make crosses, workers must be trained in the skillful art of manipulating minute floral parts. In spite of this constraint—and the limitation of taking a single crop per year—thousands of crosses have been made at ICRISAT and the pigeon pea breeding program is well under way. In addition, a wide range of related investigations have been launched by the interdisciplinary teams to help fill the knowledge gap, which becomes more evident as breeders approach new areas of research.

Discovery of male-sterile plants which could make a valuable contribution to breeding systems; increased genetic variability in the "germplasm bank" through extensive survey and collection trips; critical observations on per cent of outcrossing; and increased understanding of photo-period sensitivity are among the early payoffs. Pathology and entomology studies are continuing.

Chickpeas Chickpea is the world's third-ranking pulse crop and the leading pulse of India, Pakistan and Ethiopia. It is also grown in 28 other countries of Asia, Africa and Latin America where it is called garbanza. Three-fourths of the annual 10.5 million hectares sown to chickpea is in India, where yields average about 400 kilograms per hectare. Experimental yields run up to 3,000 kilograms per hectare.

Both seeds and pods are eaten; the dry peas are also ground into flour and the foliage is used for livestock fodder. Varieties with large, light-colored seeds are most familiar in the Mediterranean region and the West, whereas in the Middle East a small-seeded, black variety is popular. In India and Pakistan, brown and green peas of medium size are preferred. Total protein in chickpeas is about 17 to 22 per cent but, as in most pulses, the protein is low in sulphur amino acids, especially methionine.

In India, chickpeas are a winter-season or *rabi* crop, grown on residual moisture after the main crop has been harvested. It is a plant that thrives in dry weather, and is likely to suffer from a type of fungus blight if too much rain

falls; soil conditions can make a substantial difference in yield. Small seeded "desi" types are characteristic of Southeast Asia and are adapted to winter planting while large seeded "kabuli" types predominate in West Asia, North Africa and the Middle East and are adapted to summer planting. Most varieties in use in the developing countries have a low genetic potential and are susceptible to wilt and blight. In addition, a major constraint seems to be neglect.

ICRISAT plant breeders are seeking varietal improvement in both *kabuli* and *desi* types by combining germplasm from both. Their main objectives are: (1) high yield and good consumer acceptance, (2) stability of yield, (3) resistance to *Ascochyta* blight and wilt diseases, and (4) higher protein content and better protein quality.

These are among the early achievements:

- Thousands of germplasm lines have been collected, catalogued, stored and distributed; expeditions into remote areas of semi-arid Asia have added important variability to the collection.

- Physiology studies on plant type, wilt resistance and other pragmatic questions for which the breeders must have rapid answers are under way. Vital basic research almost without precedent is being conducted to uncover the biological secrets limiting yield.

- Specific, high-priority studies on causes and cures for wilt have been launched. These involve extensive surveys of pulse growing areas to identify symptom and etiology variation of the disease, new races of the pathogen and potential sources of resistance.

- Entomological and microbiological studies have been started as soon as new members of the interdisciplinary team have joined.

- A fully developed breeding program is in operation, involving hundreds of hand crosses; off-season nurseries (including one in the Middle East and one at 10,000 feet in the Himalayas where scientists have been taken by helicopter); cooperative research in the most important chickpea-growing areas of North India; and an extensive program of international trials in Asia, the Middle East, Africa and Latin America.

Groundnuts Groundnuts (or peanuts) became ICRISAT's fifth crop in late 1974, after CGIAR review of a feasibility study conducted by world groundnut specialists. With 25 per cent protein and approimately 50 per cent oil, groundnuts are an important food crop of the semi-arid tropics and, after soybean and cottonseeds, are the world's most important source of edible oil. In spite of their importance as both a food and cash crop, yields in the semi-arid tropics have stagnated around 800 kilograms per hectare, while yields in more developed areas average over 2,000 kilograms per hectare.

In accord with its mandate calling for a gradual implementation of this program, ICRISAT signed a contract with North Carolina State University for accession of a germplasm collection and for other studies on genetic classification, interspecific crossing and the incorporation of important traits from wild species into potentially high-yielding cultivated types. Resistance to *cercospora* leaf spot, which causes premature defoliation and limited yields, and to fungi-producing mycotoxins, looms high in program objectives.

After introduction and assembly of the basic germplasm collection and working out procedures for quarantine inspection and control to avoid transfer of potentially troublesome diseases, a small group of specialists are initiating the research program in 1976. Full program and staff strength is expected to be reached in 1978.

Farming systems Over vast stretches of land in the seasonally dry, semi-arid tropics on three continents, the traditional farming systems are as diverse as man's hard-pressed ingenuity can devise. Basic differences stem from both natural and social conditions. Small landholdings, subdivided over the course of generations into minuscule sub-plots, predominate in some areas, while in others communally worked lands are more usual; in still others, tenants work fractions of large estates, a part to pay their rental fee and a part for their own needs. There are also other regions where land ownership is ill-defined, and semi-nomadic people farm an area for as long as it will feed their families and flocks, then move on. The timing of the monsoons and the amount of rain they

bring, the types of soil and the shape of the terrain, as well as the local customs and the availability of labor, implements and power—all influence the choice of crops sown and determine when and how the planting is done, how well the crops are cared for and what becomes of them after the harvest.

To develop basic farming patterns that can be recommended for reasonably wide areas, ICRISAT is conducting research at its headquarters site. It also is seeking the collaboration of agricultural centers in other countries for assistance in gathering information, testing various cropping combinations and agronomic practices and, eventually, disseminating research results.

A common denominator throughout the area is the need for efficient water management. Low rainfall and water scarcity are the most conspicuous drawbacks; but short periods of excess rain, especially on soils with poor drainage, can ruin crops, carry off topsoil and leach out nutrients. Monsoonal weather is by definition unpredictable and given to extremes. Excessive rainfall at the wrong time can bring insect infestation or virus disease just when the plants are most vulnerable to them; dry periods occurring in the middle of the rainy season can wilt the monsoon crop, or too much rain in winter can damage the dry-season plantings.

Practical water catchment and drainage systems that could be economically and simply built would do much toward mitigating the effects of uncertain rainfall. ICRISAT is starting with a series of experiments on small watersheds, using catchment ponds and grassed waterways, and comparing the effects on two major soil types—red, lighter-textured soils and heavy black soils—which predominate in rainfed farming areas. Soil and agronomic research include work on erosion and nutrient loss; weed control, mulching and shallow tillage following the harvest; double cropping and relay cropping. Land shaping and flat or ridge planting on graded contours are being tried as aids to water retention in the soil and control of erosion.

Since ICRISAT's program is beamed toward capital-scarce economies that have an excess of rural labor and limited access to mechanical power, the technological recommendations will be scaled accordingly. A prime objective of the production package has to be dependability, since the many hazards of aridland farming have conditioned producers to prefer practices and crops that entail little risk, even if they do not promise extraordinary rewards. The indispensable requisite, from the ICRISAT's point of view, is that the package elicit interest and a willingness to cooperate on the part of farmers.

Economics ICRISAT economists describe their operations and goals in relation to their counterparts in industry. Corporation economists often work as members of a product-development team, insuring that the goods manufactured are tailored to the needs and tastes of consumers. At ICRISAT, the product is agricultural technology. The consumer is the farmer who faces special economic and physical constraints. The goal of ICRISAT economic research is to assist all the programs in making sure that their research remains oriented towards the village and real-life problems of the farmer.

To achieve that goal, the economists have launched a number of supportive and independent studies. Research on delineation of semi-arid tropical areas, human nutritional status, price elasticity of major crops and consumer preferences associated with ICRISAT crops was begun soon after the unit began operations. Studies on the economics of farming systems research, village water storage facilities and water harvesting and supplementary irrigation systems have also contributed valuable information. A village-level study is under way in six rural communities in three Indian farming areas to increase understanding of traditional cultivation practices and present resource allocation. The findings are already supplying answers to questions about farmers' behavior. In less than two years of operations, the economics unit has produced over 30 papers concerning research resource allocation, production factors and marketing studies.

Conferences One major factor which has contributed to ICRISAT's rapid development is the tremendous support and collaboration it has received from the international scientific community. Through sponsorship of well-con-

ceived workshops and conferences, it hopes to expand and strengthen this vital communication channel.

In November, 1974, ICRISAT held its first formal workshop. Forty scientists from 14 countries exchanged knowledge and experience about farming systems in the semi-arid tropics. In January 1975, an international workshop on grain legumes brought agricultural scientists from 17 countries to ICRISAT. In both cases the assemblies devoted a large part of their efforts to working out guidelines for ICRISAT research.

Two smaller advisory conferences were held in 1975 to obtain guidance for ICRISAT's Cereals Improvement Program and for setting up research priorities to deal with downy mildew and ergot, two diseases which have seriously affected the yield and quality of pearl millet.

Training Training has a high priority at ICRISAT. Small groups of specialized, short-term trainees from the host country began arriving soon after the Institute started operations. The first group of overseas trainees, four agricultural officers from Nigeria, started a six-month cereals production course in May 1974. More than 30 trainees from at least 10 countries were expected in 1976.

Heavy emphasis is placed on short-term, in-service training, varying from one to twelve months, for agriculturists employed in their home countries who return to positions held for them. Cooperative arrangements have been worked out with neighboring Andhra Pradesh Agricultural University to infuse graduate-level course work with research work conducted at ICRISAT. Plans are also being formulated to accommodate visiting scientists, post-doctoral research fellows and research fellows. When the trainee hostel is completed on the research station there will be accommodations for over 100 students at one time.

International cooperation Cooperative projects are being negotiated and undertaken in West Africa, East Africa, Ethiopia, Thailand and India. The furthest advanced, apart from projects in India, is the West African project, which was started in 1975 under the sponsorship of the United Nations Development Programme.

IRAT, a French research organization, has provided a director for the project. The initial goal will be to generate location-specific technology by working in close collaboration with ICRISAT at Hyderabad but conducting research in cooperation with West African research centers in 12 countries of the region. Uniform yield trials are being initiated, and eventually links will be established with extension and field application programs in countries throughout the region. ICRISAT expects to establish cooperative programs to serve all major semi-arid areas in Asia, Africa and Latin America.

ICRISAT's programs are focused on what have been, up to now, neglected crops, neglected regions, neglected rural populations. International support, top scientific talent and advanced technological resources are being marshaled to serve crucial needs that have long been disregarded. The task is difficult, bearing the unmistakable stamp of high challenge.

Testing for trypanosomiasis (ILRAD)

INTERNATIONAL LABORATORY FOR RESEARCH ON ANIMAL DISEASES

P.O. Box 30709, Nairobi, Kenya

Diseases are one of the major constraints to the production and utilization of domestic livestock and their products for food and other uses in developing countries. Millions of people in vast areas of the world are affected. The purpose of the International Laboratory for Research on Animal Diseases (ILRAD) is to assist in the development of effective control measures for internationally important animal diseases through research and training programs.

Domestic animals are generally regarded as a source of protein for human consumption. Other important aspects of the man-environment-domestic animal interaction are frequently overlooked. Domestic species not only supply meat, milk and eggs, but clothing, fertilizer and materials for housing. Animals, particularly ruminants, are able to convert fibrous plant materials, waste, and plant by-products into a form useable by man. In many societies, animals are important for draft purposes and as beasts of burden, since approximately 70-80 per cent of the farming world is not mechanized. In Africa only about seven per cent of the land area is arable, while 30-50 per cent is permanent forest-grassland. Thus, as in many other parts of the developing world, plant and animal food systems do not compete, but complement each other. They play important interdependent roles in the provision of food and other necessities.

Animal diseases adversely affect animal production. They cause death, weight loss, poor reproduction, poor utilization of forage and the concentration of animals to the detriment of the environment. These factors are exemplified in Africa, where it is estimated that a land area greater than the continental U.S. is not optimally utilized for cattle production because of a single disease — trypanosomiasis. This same area has the highest rainfall and greatest potential for forage production. Theileriosis also causes marked death losses, unoptimal range utilization and increases in the cost of livestock production in large areas of eastern and southern Africa, the Middle East and the Indian subcontinent. But even when these diseases are controlled, care must be taken to use the land and plant resources in the best possible ways. Research on livestock production systems that will result in the proper use of such areas is being conducted by the International Livestock Centre for Africa (ILCA).

Research programs ILRAD was established in 1973 under an agreement with the Government of Kenya after a CGIAR study concluded that significant potential benefits could be derived from an international center focussing its efforts on animal disease control. Active recruiting of the scientific staff began in early 1975. Two diseases with far ranging deleterious effects on livestock production — trypanosomiasis and theileriosis — were selected for initial attack.

Both diseases are transmitted by a vector: the tsetse fly in trypanosomiasis and the tick in theileriosis. In both diseases there is complex interaction between the host, the parasite and the vector. Also, both involve wildlife and domestic species as reservoirs of infection. The complexity of the diseases is such that solutions are beyond the capability of a single scientific discipline or individual. As a result, ILRAD is using an integrated, multi-disciplinary ap-

proach in its research. Expertise in such disciplines as parasitology, immunology, pathology, cell culture, biochemistry, ultrastructure and epidemiology is being focussed on the problems in order to develop control measures. The capabilities of the basic sciences are being combined with those of a medical, disease and applied orientation. In every instance, the goals are to find effective control measures for the disease under investigation, with the research having a strongly immunologic orientation.

Trypanosomiasis Trypanosomiasis occurs in several domestic animals including cattle, swine, sheep, goats, horses and camels—and in man. It is caused by several species of blood parasites of the genus *Trypanosome*. Included are *T. congolense* and *T. vivax*, which are the most important trypanosomes causing disease in cattle. Trypanosomiasis is transmitted by the tsetse fly and in many instances has wildlife reservoirs. The disease occurs in areas where the tsetse fly is not endemic, however, and in these cases appears to be transmitted by biting flies. Trypanosomiasis is observed in many countries of Africa and the northern parts of South America. In Africa, including most of the large area of the continent bounded on the north by a line extending west to east approximately along the 16th north latitude and on the south by a line from west to east approximately along the 10 degree south latitude, cattle raising is either precluded or is greatly reduced due to the disease. This area, with one of the highest rainfalls on the African continent, has some of the greatest potential for forage production.

Trypanosomiasis adversely influences animal production in several ways. Some animals die fairly quickly after contracting the disease, while others may develop chronic infections which may last for months or years with infected animals in poor body condition. It also results in poor reproduction and inefficient utilization of nutrients.

The research approaches being conducted at ILRAD include a study of the functional immunologic processes in cattle and other ruminants. Ways in which the host defense mechanisms may be artificially stimulated to make them more effective in combatting trypanosomiasis and theileriosis are under investigation. Trypano-tolerant breeds of cattle and the mechanisms of Trypano-tolerance also are being examined. The organism itself is being intensively studied, with emphasis on the way trypanosomes cause disease and ways in which the organism eludes the protective mechanisms of the host. The immune responses directed against various trypanosome antigens also are being investigated. The tsetse fly-trypanosome interaction and the tsetse fly-trypanosome-host interaction are also important considerations. The aim is to gain sufficient understanding of the disease and causative organism to be able to develop effective control measures and break the chain of disease transmission.

Theileriosis Theileriosis, known in Africa as East Coast fever, is a blood parasite infection caused by members of the genus *Theileria*. Included are *Theileria parva, Theileria lawrencei, Theileria annulata, Theileria mutans* and others. The first four, however, appear to be the most important—and the most deleterious to livestock production. In all cases, the disease is transmitted by ticks, so the distribution of the disease is confined to the geographic distribution of the tick vector.

Theileriosis is an important disease in 11 countries of East and Southern Africa, in the Middle East and the Indian subcontinent. Some species of Theileria, such as *T. mutans*, occur in cattle throughout the world, but its importance as a cause of disease is not clear.

The disease frequently causes acute death in animals that have been bitten by infected ticks. Intensive preventive efforts are necessary to control the vector ticks. Animals in endemic are[illegible] frequently dipped or otherwise tr[illegible] aracide to prevent the occurr[illegible] ticks on them. This is costly in[illegible] construction and maintenance of fa[illegible] the use of manpower and drugs. Treatment of this kind also harms the environment to an important extent. In some places in East Africa, cattle must be dipped two or thre[illegible] times a week in order to rid them of ticks a[illegible] to prevent the occurrence of theileriosis. T[illegible] results in cattle having to be trekked long distances at frequent intervals, with loss of weight and deterioration of health together with damage to the terrain traversed.

As in trypanosomiasis, a strong immuno-

logical orientation influences the ILRAD research program. Investigations are being carried out to grow the organism in culture in the laboratory in order to provide large amounts of material that can be used for vaccine or other studies. Research is under way to define and isolate the antigens involved in protection, and to determine methods by which resistance to the disease may be most effectively induced. The epidemiology of the disease and geographic distribution of various strains of the organism also are being examined. All these efforts are designed to develop effective vaccine control for theileriosis.

Extramural research ILRAD scientists work both at Nairobi and at other locations. The complexity of the disease situation and the interplay of environment, animal breeds, wildlife, etc., all are factors that influence the diseases under study and require the development of information concerning how, in different parts of the world, these various factors interact to produce disease. Such investigations will develop leads concerning possible ways in which the disease situations may vary from area to area as well as pointing out methods by which they may be controlled. It may be necessary, for example, to utilize different approaches to disease control in different parts of the world. Keeping in contact with the actual conditions in the field is necessary in order for the research to be properly directed.

Cooperative research ILRAD has begun cooperative research efforts in various parts of the world, and the possibility of others is being examined. There are individuals and institutions in developed as well as developing countries that have expertise, capabilities and ongoing research in topics relevant to ILRAD. The purpose of cooperative research is to utilize expertise and activities already available in these institutions. This increases the scope of scientific capability that can be focussed on the problems. It also develops working relationships with experts in various parts of the world, with mutual benefits for ILRAD and the cooperating institution.

It is important for ILRAD to develop and maintain cooperative relationships with national organizations in Africa. Programs of disease control, in order to be effective, require a working relationship with national organizations, not only for implementation, but also for research and development.

Cooperative research with other centers in the CGIAR network also is carried out. ILRAD and ILCA scientists, for instance, work together on common problems and jointly use facilities, personnel and animals in several African countries.

Staff Represented on the ILRAD staff are a number of scientific disciplines. The staff itself is divided into ILRAD core staff, visiting scientists and postdoctoral fellows. The ILRAD core staff are the permanent resident members who provide the continuity for the research program.

Visiting scientists come to ILRAD for one to two years on leave from their home institutions. Others, fully supported by ILRAD, supply expertise not available from core staff. Postdoctoral staff members conduct research, and in interaction with other staff scientists develop their own capabilities. It is hoped that they will maintain contact with ILRAD when they return home.

Consultants come for short periods of time. They are established scientists and experts who visit to observe the research program, provide scientific input, evaluate the research and make recommendations. They provide an important outside assessment of ILRAD and its programs.

The scientific staff has been recruited internationally, with emphasis on obtaining the best staff irrespective of nationality. Nine nationalities currently are represented.

Training The ILRAD training program is diverse, with initial emphasis placed on professional training. The postdoctoral program is directed to professionally trained individuals who have finished their formal degree work elsewhere. These individuals spend 2-3 years at ILRAD and return to their home countries for continuation of their careers. Also included in professional training are graduate students who are enrolled in degree-granting institutions in the Nairobi area or elsewhere. These individuals conduct their research at ILRAD and receive degrees from other institutions.

In addition, seminars, conferences and training courses cover a variety of pertinent areas in animal disease research. ILRAD also maintains an information service with emphasis on parasitic diseases.

Facilities The main ILRAD facilities are located at Kabete, just outside Nairobi, Kenya. Facilities currently under construction on this 180-acre site include the laboratory complex, laboratory support areas, laboratory animal facilities, cattle facilities, necropsy and incineration, administration, library, conference area, food services and housing. The complex is a modern one able to support sophisticated research on animal diseases. The animal facilities provide space for studying disease in various domestic and laboratory animal species.

INTERNATIONAL LIVESTOCK CENTER FOR AFRICA

P.O. Box 5689, Addis Ababa, Ethiopia

In 1974 the Ethiopian Government and the World Bank, acting on behalf of the Consultative Group, signed an agreement for the establishment of the International Livestock Centre for Africa (ILCA). The aim of the center is to support the efforts of different countries to improve systems of production and marketing of livestock and their products in tropical Africa in order to improve the standard of living of the region's people. ILCA's three principal fields of activity are research, training and documentation.

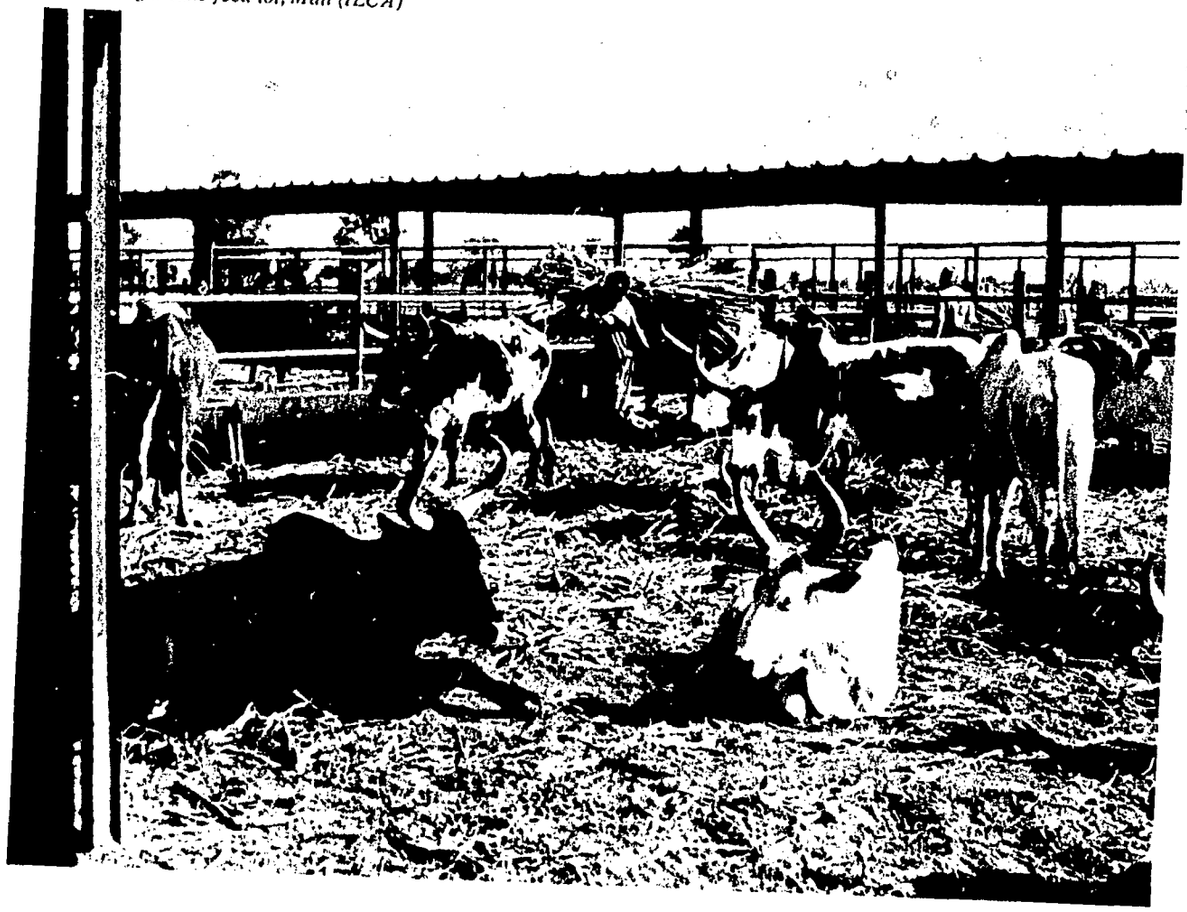
The livestock population of tropical Africa includes about 130 million cattle, 100 million sheep and 80 million goats, but production levels are far below those which might be hoped for. Animal production, nevertheless, represents an important element in the economy; its value has been estimated at more than U.S. $1 billion annually, or about 5 to 6 per cent of the gross domestic product of the region.

Because of the trend toward increased urbanization and economic development, and the pressure of growing populations, the demand for milk and meat is rising. This foreshadows severe shortages within the next decade unless energetic measures are taken to accelerate growth and improve utilization of animal production. The average per capita consumption of meat in Africa was reported by the FAO to be 9.4 kilograms in 1970; it is expected to rise by little more than one kilogram in 10 years, to reach 10.8 kilograms in 1980. Even if the growth rate of meat production (which was 2.7 per cent a year in the 1960s) could be raised to the target level of 4.3 per cent set as a goal by FAO's Provisional Indicative World Plan for Agricultural Development, shortages still would amount to more than a million tons of meat and 700,000 tons of milk. A dynamic livestock industry could contribute much to the economic development of the countries of tropical Africa, as well as to the improved nutrition of their populations. Research conducted over the past 40 years in tropical Africa has made it possible to find technical solutions which, unfortunately, have been applied only restrictedly, if at all. It is known that techniques such as ranching, the improvement of cattle feed resources and improved management practices can be beneficial; however, the sectoral approach has failed because livestock management and exploitation of livestock products must be taken as a complex system combining a number of production factors: physical, biological, economic and, in particular, the human environment. ILCA's program plans to involve interdisciplinary research: animal scientists, agronomists, economists and sociologists.

Production problems On all but a few modern ranches, animal production throughout Africa's tropical latitudes exhibits a familiar combination of shortcomings. Calf mortality is high. Animals are poorly nourished—some are half-starved in the dry season—and growth rates are slow. Poor health and exposure to environmental stresses result in low market weights and the sending of relatively few animals to market. Determining the elements of proper livestock management for tropical Africa's diverse environments and persuading cattle owners to adopt them are matters of considerable complexity.

In spite of physical, biological, and economic limitations, Africans produce meat by simple techniques that contain a certain degree of adaptation to unfavorable conditions. Nomadism and transhumance (seasonal migration of herds) are dictated by the cycles of the

Sugar cane feed lot, Mali (ILCA)



rainy and dry seasons; the overstocking of old cattle is a way of preserving stocks, for animals which have survived drought, disease and an inhospitable environment are the result of an extreme form of natural selection. The myth that stock raisers hoard their cattle for their own enjoyment must be abandoned; they market as much as possible, approximately 7 per cent of their herd.

The widespread use of very effective vaccines against pleuropneumonia, and against almost all viral and bacterial diseases has permitted a much larger growth in the number of cattle over the last 30 years than during the period 1890-1920, during which time more than three-quarters of the herds died from these diseases. There still remain, however, the problems of trypanosomiasis (transmitted by the tsetse fly), which is found over the whole humid zone of tropical Africa, and theileriosis, or East Coast fever (a tick-transmitted disease), which is prevalent in East Africa. These diseases pose a serious obstacle to the development of a large-scale cattle industry in the humid areas of Africa.

Traditional techniques are unable to cope with the increasing demand for meat due to the growth of population. At the same time, owing to the development of agriculture, less land is available for livestock raising.

The droughts of recent years have shown dramatically that something has to be done. Technical solutions to the improvement of livestock production have been discovered in Africa and other tropical areas, but they have been applied only in a very limited way, possibly because their application involves factors that have not been integrated into the total system of production.

If animal production is to be improved, each factor of the system now used by livestock raisers must be studied. It is necessary to identify and quantify the constraints to development and to propose ways of overcoming them, either by the improvement of existing systems or by evolving new ones.

New approaches will have to found for working with herders; their way of life has been disrupted by the evolution of crop and industrial agriculture, and they have not yet found ways of dealing with this disruption. For the most part, the land devoted to the cattle industry in Africa cannot be used for cropping, owing to the absence of agricultural soil, insufficient yearly rainfall or the lack of deep water in the dry season. In these regions, particularly in the West African Sahel, men could not live without livestock.

Over the period of the severe drought of the past 10 years whole groups of herdsmen have moved toward high rainfall areas and thus saved part of their herd; others, for geographical reasons, confined themselves to the areas around wells and water holes (as in the Sahel). The overpopulated pasturelands, impoverished as a result of low rainfall, could not sustain the increasing numbers of cattle, which consequently died of hunger. In other regions — for example, Ethiopia — drinking water failed and the cattle died of thirst. The drought brought in its wake the degeneration of rangelands and the destitution of herders.

The governments of the tropical areas of Africa have, either with their own resources or with the help of bilateral aid, included and carried out within their development plans activities relevant to livestock: the setting up of state ranches, range water development programs, systematic vaccination campaigns, construction of marketplaces and abattoirs, and technical training at all levels.

Most of these programs have relied on the results of research, inventory work or studies carried out in the many institutes and laboratories of the French and English speaking countries. They reveal a considerable potential for the improvement of animal production.

ILCA's program ILCA is intended to serve as an international center for interdisciplinary research to promote the development and demonstration of improved livestock production systems, optimizing the use of human and natural resources in Africa. It also is a focal point for training activities to increase regional competence in a systems approach to livestock production and development; and it functions as a multidisciplinary documentation center for the livestock industries of Africa. The Center will develop close links with national and regional organizations undertaking research and training activities in the same or closely related fields of interest. ILCA has the authority to

support national livestock programs, to complete or strengthen programs being carried out, to provide specialists with information in English and French and to stimulate research and development activities.

ILCA has established a network for cooperation with the principal world documentation centers concerned with tropical livestock raising, and a documentation team has begun to gather non-conventional literature. The purpose of these activities is to create a synthesis of available information and to make maximum use of existing knowledge. This would avoid overlapping and unnecessary repetition in future programs.

The research program, dealing with African animal production systems, will be carried out on a multidisciplinary basis and will integrate research currently being carried out in the region. In its concerted programs it will assist in bringing together research workers involved in programs of a similar nature, to meet, exchange ideas and coordinate methodology. ILCA already has set up multidisciplinary teams in a number of specialized fields: breeding, nutrition, herd management, rangeland conservation and improvement, and analysis of economic factors bearing on livestock operations, including marketing and processing of animal products. Anthropological and sociological studies are being undertaken to understand the functioning of social structures and their capacity to adopt improved methods. This will help to devise training, demonstration and extension tactics designed for the livestock raisers of different social and economic levels.

Some research projects will be carried on by ILCA alone, some in cooperation with other organizations. For the cooperative programs, ILCA, together with national and regional institutions of the country where the research will take place, will create mixed teams in order to conduct research of interest beyond the national level. This type of research involves establishing and maintaining schedules for development programs, in order to estimate the results of new techniques or concepts on the social and economic development of livestock raising, and to protect natural resources.

Whether autonomous or cooperative, research will incorporate all elements of systems. For animal sciences they will be concerned with genetics, physiology, nutrition, reproduction, adaptability to climate, epizootiology, etc. Environmental studies will be concerned with climate, soil, ecology of rangelands and improvement of pasturelands, and husbandry. The socio-economic element of the program will concentrate on the following areas: geography of livestock raising, social structures, cultural environment, value systems of pastoral societies, economic analysis of livestock raising operations, and studies of markets and the relationships between producer and consumer. Data produced by these studies will be applied to the development of integrated models applicable to different types of livestock management.

Four cooperative programs are planned. One in Mali, concerning stratification of production between the Sahelian transhumant zone and the zone of intensive agriculture, already is operational. It covers an area severely affected by the drought. The second, in Kenya, will be concerned with the monitoring of a vast integrated development operation. A third program, in Nigeria, will deal with problems linked to the sedentarization of the transhumant herdsmen in the semi-humid zones. Lastly, the program in Ethiopia will study animal production systems in the drought-stricken arid and semi-arid zones where transhumant livestock raising is practised.

ILCA has an important role to play in the training of livestock specialists of tropical Africa. The number of professionals in veterinary medicine and animal health is increasing in most countries of the region, but Africa needs to develop specialized university level experts in animal production, livestock management, economics, marketing and related fields. Scientists and technicians are needed in every branch of animal production and in every country of Africa; moreover, high priority should be given to training to the director level, with emphasis on interdisciplinary orientation and a sound knowledge of the objectives of development in the animal production industries. Young scientists will be associated with ILCA-sponsored research programs, and studies in relevant fields will be promoted at the undergraduate and graduate levels through co-

operative arrangements with universities in Africa and abroad.

Seminars, conferences, in-service courses and similar activities undertaken by ILCA will contribute to education, exchange of information and the airing of research results. ILCA also will offer consultative, documentary and statistical services to national, regional and international organizations dealing with the improvement of animal production in Africa. ILCA will cooperate with ILRAD (the International Laboratory for Research on Animal Diseases), since the objectives of the two institutions are complementary. A joint program, the study of trypanotolerant cattle, is now being defined.

Field training in rice production (WARDA)

WEST AFRICA RICE DEVELOPMENT ASSOCIATION

E. J. Roye Memorial Building, P.O. Box 1019, Monrovia, Liberia

Rice is a staple food of growing importance in West Africa. An estimated 700,000 farmers grow rice there, but yields generally are appallingly low. Despite the tremendous potential in physical and ecological resources available for growing much larger quantities of rice, West African countries spend large amounts of their scarce foreign exchange resources to import rice to supplement local production.

The West Africa Rice Development Association (WARDA) is a cooperative intergovernmental regional organization aimed primarily at making the region self-sufficient in rice. It was started in December, 1971. Its members are Benin, Gambia, Ghana, Ivory Coast, Liberia, Mali, Mauritania, Niger, Nigeria, Senegal, Sierra Leone, Togo and Upper Volta. Guinea-Bissau is an associate member.

WARDA is financed by member countries and by many donor countries and international organizations. The Consultative Group on International Agricultural Research (CGIAR) has been financing the coordinated trials aspect of WARDA's research program since 1974. WARDA aims to promote and increase the quantity and quality of rice produced in West Africa by executing carefully planned research, development and training programs. The Scientific and Technical Committee of WARDA reviews the association's program, while the policy making body is the Governing Council.

Research activities WARDA's research projects are aimed at providing useful information and improved plant material which can be used for increasing rice productivity. The overall program includes:

- Coordinated trials of varieties, fertilizer and crop protection at a network of locations in the region.
- Special research projects for reinforcing existing research work and for filling existing gaps in rice research in the region, backstopped by available knowledge and experience at the international level.
- Research coordination which involves planning, project formulation, negotiation for funding, and the implementation and supervision of the approved projects.

WARDA's coordinated trials could provide interested international research centers with opportunities for testing new rice types throughout West Africa. A sound program of coordinated trials and effective links between WARDA and the national extension services should lead to a rapid introduction of improved varieties and better cultural practices among the rice farmers in West Africa.

To quicken the introduction of rice materials into the region, three glasshouses and three seed testing facilities have been built at the Regional Plant Quarantine Station at Ibadan, Nigeria. A nursery farm, where new introductions are being multiplied before entry into the coordinated trials, also has been started, as well as a seed laboratory at Fendall, Liberia.

WARDA conducts a research review meeting every year at which a research report incorporating all the results obtained from the coordinated trials and national programs are presented and discussed.

Support to National Research—In supporting national institutions, WARDA aims mainly to assist in building up capable national institutions, in providing adequate facilities to local scientists, in establishing a strong working relationship with national teams, in solving local agronomic production problems and in strengthening particular aspects of national research programs that have regional value.

WARDA could also backstop specific local research problems through its regional research centers—through visits and advice of regional scientists, through the exchange of research information, and in assisting countries to identify and draw up national research programs. WARDA presently is strengthening national research facilities by supplying weather measurement and field equipment to trial points. An integrated training program to aid in the training needs of member states for research personnel is being prepared.

The programs of the international centers —such as IRRI and IITA—and of WARDA can be linked together with mutual benefit. WARDA can help make the research findings of the international centers effective among its member states; and the international centers can benefit from feedback from WARDA. In this light, WARDA has entered into discussions with the international centers to work out cooperation in the area of training and research.

Development activities Since it is primarily a development association, WARDA has gathered together a team of development agronomists, irrigation and rural engineers, economists and loan specialists, rice storage and processing engineers and extension specialists, as well as statisticians and data processing experts. This group is responsible for identifying, preparing and evaluating projects in member states either at their request or in collaboration with international financing institutions.

WARDA's main activities in the sphere of development are to assemble as much data as possible on production and consumption of rice, giving an idea of trends; and to stimulate production in order for the region to achieve self-sufficiency in rice within this decade.

To achieve this, WARDA is helping to implement as many viable rice development projects as possible; helping member states to find financing for new projects; and monitoring improvements from ongoing projects in the fields of better cultural practices, water management, storage and processing, as well as in marketing, both within and among member countries.

Since exchange of ideas among field workers in member states is very important, the development team undertakes case studies of specific projects for dissemination among member states; it also arranges seminars on specific issues in development, and helps personnel from one country to visit projects in another. Member countries often call on WARDA for consultant services in specialized areas of production, processing and marketing.

Training One of the major drawbacks to increasing rice production in West Africa is the shortage of trained personnel for quickly converting accumulated research findings into rice production. WARDA's training center became fully operational in mid-1976 at the University of Liberia Farm, Fendall, Liberia. All courses are given in English and French. The training center will undertake:

Rice Production Specialist Course—A six-month course designed to produce specialists who are to return to member countries to organize, manage and conduct training courses for extension workers, who, in turn, will assist rice farmers to increase their yield. The long training period will allow adequate emphasis on all aspects of rice cultivation and processing as practised at the farm level.

Field Assistants Course—This is closely linked with the successful implementation of WARDA's coordinated trials. This program will aid in insuring standardization of observations and data collection. A total of 57 people have been trained under this program.

Specialized Rice Courses—These are designed to meet changing training requirements of member countries in seed technology, processing, storage and marketing.

Documentation and seminars The documentation division collects, analyzes and disseminates information relevant to rice in West Africa. Two current bibliographies and two world references on rice for West Africa have since been published. WARDA's documents are available on microfiche.

Seminars are organized regularly to tap existing rice knowledge in the region and elsewhere. Five have been held on varietal improvement, soils and fertilizer use, plant protection, socioeconomic aspects of rice cultivation and the management of rice projects. They assisted in formulating and finalizing arrangements for the coordinated trials and in improving the special research projects.

INTERNATIONAL BOARD FOR PLANT GENETIC RESOURCES

Crop Ecology and Genetic Resources Unit
Food and Agriculture Organization
Via delle Terme di Caracalla
00100 Rome, Italy

The innumerable varieties of crop plants which have evolved throughout the world over some 10,000 years of domestication comprise an irreplaceable reservoir of genetic material for breeding new improved crops. But this genetic diversity is now disappearing at an alarming rate. Farmers are replacing a profusion of ancient varieties with a relatively small number of new cultivars bred for high productivity and other characteristics desirable in modern agricultural systems. At the same time, changes in land use and agricultural practice are leading to the disappearance of the wild progenitors and weedy relatives of present-day cultivated crops. The face of agriculture is changing so rapidly that the need to collect the diverse genetic materials which remain is now urgent.

The purpose of the International Board of Plant Genetic Resources (IBPGR) is to encourage and assist the collection, preservation and exchange of plant genetic material. The Board came into being in 1974, along lines recommended by a meeting of experts which was organized in 1972 by CGIAR's Technical Advisory Committee (TAC).

Objectives IBPGR is responsible for formulating policies and recommending action to meet the following objectives:

- To identify needs for exploration, collection, evaluation and conservation of plant genetic resources with particular reference to species of major economic importance and their wild and cultivated relatives; to determine priorities among them; and to ensure to the fullest possible extent that the materials conserved are made available for plant breeding and other scientific activities as required.
- To establish standards, methods and procedures for exploration and evaluation and to determine minimum standards for conservation of stocks of both seeds and vegetative material.
- To arrange for replicated storage of seed and vegetative stocks.
- To promote technical meetings.
- To promote training at all levels.
- To develop a worldwide network of institutions, organizations and programs able and willing to contribute to the above objectives.
- To promote the articulation of ongoing programs so as to avoid unnecessary duplication and to fill in gaps.
- To strengthen the programs of existing institutions and to encourage the establishment of new organizations, institutions and programs, particularly in areas of major genetic diversity.
- To promote the dissemination of information and material among centers and institutions, and to encourage, within existing resources and possibilities, the establishment of inventories of collections.
- To make appropriate recommendations with respect to computerized information storage and retrieval systems, taking into account their suitability for an effective international genetic resources network, and their compatibility with existing systems already in operation at some regional and national centers.
- To estimate the annual financial requirements of those parts of the genetic resources programs not already adequately covered.

Artificial pollination of a potato flower (International Potato Center)

IBPGR has begun to make progress towards these objectives. It is financially supporting several operational programs and has recommended others for support from other sources.

Priorities To provide a general framework within which IBPGR will develop its programs, certain priorities for plant exploration, collection and conservation have been established with regard to both crops and geographical regions. These take into account previous recommendations by the FAO Panels of Experts on Plant Exploration and Introduction, and on Forest Gene Resources, and recommendations embodied in the Report of the TAC *ad hoc* Working Group held in Beltsville in 1972.

Priority regions are those of significant genetic diversity and where agricultural practice is changing most rapidly. Priority crops are determined on the basis of several criteria, including their danger of loss or of replacement by modern cultivars, their economic and social importance, the needs of the plant breeder and whether extensive collections already have been made.

Projects Recognizing that an adequate data classification and retrieval system is essential, one of the first major programs which IBPGR has supported financially is the Genetic Resources Communication, Information and Documentation System (GR/CIDS) project based at the University of Colorado at Boulder. This project was originally set up and partly supported by FAO. It is devising and helping both international and national research centers to install a computerized classification for recording and retrieving information on crop genetic resources. By visits to existing collections and the organization of workshops with both collectors and plant breeders, the GR/CIDS team has initiated a transfer of genetic resources records into machine-readable form through a system (TAXIR/EXIR) which is adaptable to any of the principal computers with an adequate memory bank. It is hoped that eventually the inventories of all major collections will be filed on this or some other compatible system.

IBPGR already is supporting collection and conservation work, especially for cereals and other crops, in Southwest Africa and the Mediterranean region; for grain legumes in West Africa; and for forage crops and grasses in Latin America.

IBPGR cooperates closely with the international agricultural research centers. Several centers have agreed to coordinate the genetic resources activities in those crops for which they already have primary responsibility for improvement programs. Germplasm advisory committees have been set up by IBPGR for wheat, maize, rice, sorghum and millets, and field beans. In addition to the food crops of major importance, IBPGR has also decided to consider support for the conservation of a few forest tree species which are important for agriculture either through maintaining stable environmental conditions in which agriculture can flourish or by providing fuel in agricultural areas.

Current developments Two working groups have been set up, one to consider plant health and quarantine problems related to the transfer of international germplasm, and another to consider coconut genetic resources. Surveys are being undertaken of the work necessary for collection and conservation of tropical fruits and nuts, and of tropical vegetables.

Two international symposia—on wheat and groundnuts — were held in 1975 and proved of value in contributing to an understanding of the many questions relating to the collection, documentation and conservation of these crops.

Training To enable the genetic resources program to expand in the future, young scientists and technicians, especially those from the countries richest in genetic resources, must be given specialist training. IBPGR has provided financial support to increase the size of the International Training Course in Conservation and Utilisation of Plant Genetic Resources given for students from developing countries at the University of Birmingham, United Kingdom. In addition, a survey is being made of institutions around the world which can offer appropriate training in genetic resources work.

Field training center for sheep farming (FAO, F. Botts)

INTERNATIONAL CENTRE FOR AGRICULTURAL RESEARCH IN THE DRY AREAS

c/o International Development
Research Centre
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The International Centre for Agricultural Research in the Dry Areas (ICARDA), established in 1976, is the newest of the international agricultural research centers. Its mission is to help increase and stabilize food production in developing countries of the temperate zone having an arid or semi-arid climate. The ecological zone falling within its mandate is made up primarily of areas with 300-800mm of precipitation per year (although some receive less), mostly during the winter months. Most of North Africa and the Near East, including Iran, Afghanistan, Pakistan and part of the Sudan, are in this ecological zone. Among other countries having similar agroclimatic conditions are Turkey, parts of northern India and Tibet.

The Centre's programs of research and training have two chief dimensions. ICARDA seeks to improve the productivity of farming systems in its zone, including not only crop systems but systems based on both crops and animals (sheep and goats). And ICARDA seeks to improve the yield and quality of the principal crops of the dry areas.

ICARDA is to serve as a world center for research into and the improvement of barley, lentils and broad beans (Vicia faba); in consultation with the International Maize and Wheat Improvement Center (CIMMYT), it may also develop an important role in the improvement of durum wheat. In addition, the Centre is working to adapt, for its own region, other plant varieties developed elsewhere, such as maize varieties from CIMMYT and sorghum from the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT). Throughout its work, the Centre seeks to contribute to solutions of physical, biological and socio-economic problems which impose constraints on the improvement of agriculture in the dry areas.

ICARDA expects to work in three primary locations. Its plant breeding activities are being conducted in the Bekaa Valley of Lebanon; they were begun there in a predecessor project, the Arid Lands Agricultural Development Program, the relevant activities and staff of which are being absorbed into ICARDA. Systems work is to be conducted in northern Syria, near Aleppo, where some breeding work also has begun. Finally, to investigate the particular problems of high-plateau agriculture, ICARDA will establish a principal station in Iran, in the region of Tabriz. This will be the first research within the CGIAR system that attacks problems of agriculture in the high, dry, colder areas where winters are long, snow cover lasts for as much as four months and the summers are hot and dry.

For the formal constitution of ICARDA, the CGIAR's agency for the establishment of the Centre has been the International Development Research Centre (IDRC), an autonomous organization with its headquarters in Canada; and IDRC is continuing to assist in the development of ICARDA. The Board of Trustees of the Centre held its first formal meeting in August 1976, and the recruitment of staff has now begun.