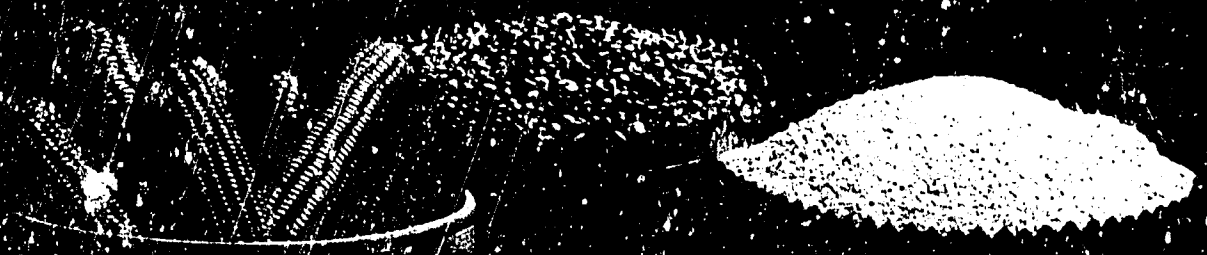
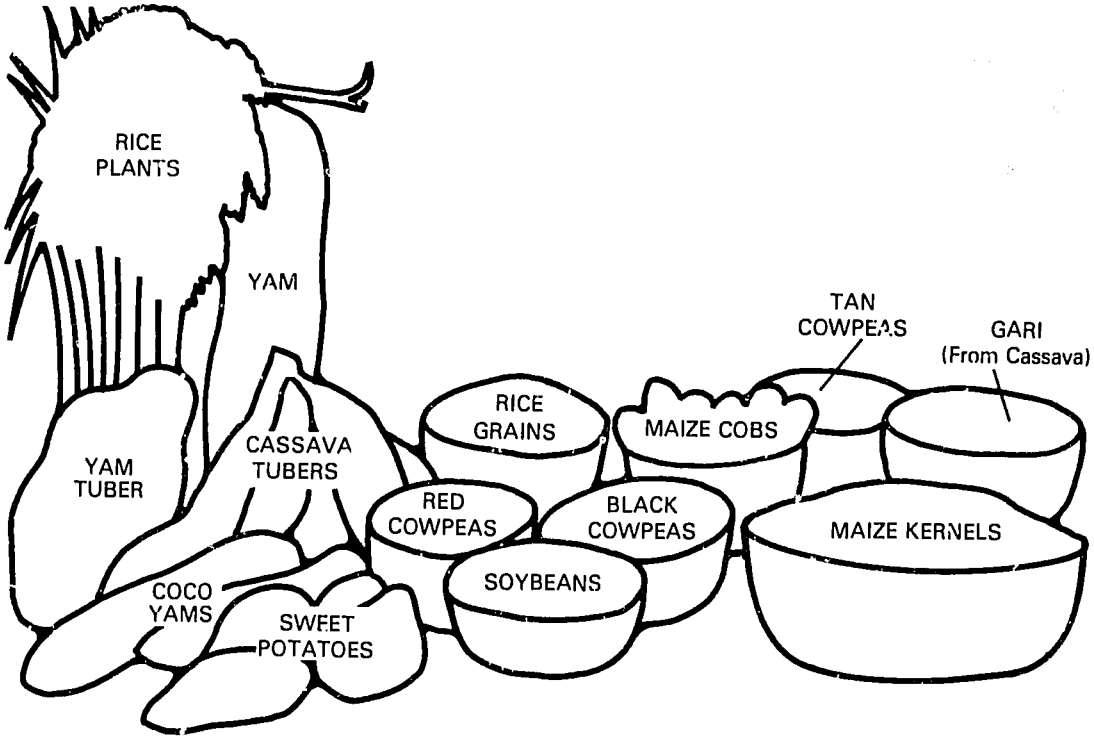
IITA Annual Report and Research Highlights 1985



International Institute of Tropical Agriculture

Front and back covers: Food products from IITA "mandated" crops.



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An aerial view of IITA's 1,000 hectare headquarters at Ibadan, Nigeria; the main campus on the right with laboratories, offices, and housing is surrounded by the experimental farms; on the left across the lake (the Institute's water supply) are research plots cleared from forest land.

Introduction to IITA

Established in July 1967 as the first major African link in an integrated network of international research and training centers located throughout the developing regions of the world, the International Institute of Tropical Agriculture (IITA) is an autonomous, nonprofit corporation with headquarters on a 1,000-hectare experimental farm at Ibadan, Nigeria in close proximity to the University of Ibadan. Its location facilitates research in three ecological zones of Nigeria — humid forest, transitional, and savanna — and these zones are representative of climate and soil conditions in many areas of Africa. In addition, research is conducted in many areas of Africa in cooperation with regional and national programs.

Funding for IITA came initially from the Ford and Rockefeller foundations, and the land for the experimental farm was allotted by the Government of the Federal Republic of Nigeria. The Institute is governed by a Board of Trustees comprised of 14 members, including eminent scientists and representatives from the host country, African tropical areas, and other regions of the world. (The names and affiliations of Board members are listed on page *134*.)

Mandate and Objectives: The "geographic mandate" of IITA includes the humid and subhumid tropical regions of the world, but the Institute concentrates its research and training activities primarily on the needs of sub-Saharan African countries. The central objective, in cooperation with national programs, is to undertake research which will make it possible to increase food production, employment, and income in those countries. A food crisis in many of them has been building up over the years as rapid population growth, drought, and lagging agricultural production have brought about a chronic food deficit.

Four out of five of the research programs of IITA are crop centered: Grain Legume Improvement, Maize Research, Rice Research, and Root and Tuber Improvement. The fifth is the Farming Systems Program. Specifically, the objectives of these and other segments of the Institute are to:

- Develop farming systems, including soil and crop management practices, that will provide viable, stable, and sustainable alternatives to traditional systems of shifting cultivation in Africa; the major emphasis centers on increasing the productivity of fragile tropical soils while still maintaining effective conservation in ecologically balanced environments.
- Fulfill a worldwide responsibility to develop and implement research programs which will lead to improved varieties of cowpeas, yams, and sweet potatoes.
- Conduct specific research in Africa in cooperation with other international centers and national institutes, to develop and improve cassava, maize, rice, soybeans, plantain, and cocoyams; here the practical emphasis is on the distribution of improved plant materials to national research programs to assist them with their plant breeding work and the adaptation of improved varieties to fit local conditions.
- Transfer new technologies and skills, through training, to scientists, technicians, and extension workers from developing countries.

- Arrange and conduct conferences, symposia, seminars, and workshops to review new research, consider current problems, and discuss needs for the future.
- Publish and widely disseminate research findings to scientists, policy makers, national research programs, development and extension personnel, and others.
- Provide an information center and library with a comprehensive collection of world literature on tropical agriculture for use by scientists and scholars.

Funding: Principal financing of the Institute is arranged through CGIAR – Consultative Group on International Agricultural Research. (See information on CGIAR beginning on page *9.*) Finance and support during 1985 for IITA's research and training was provided by the following international agencies, foundations, and national governments: Canadian International Development Agency (CIDA), United States Agency for International Development (USAID), World Bank, Ford Foundation, Rockefeller Foundation, Overseas Development Administration of the United Kingdom (ODA), Australia, Belgium, Denmark, Federal Republic of Germany, France, India, Italy, Japan, Netherlands, Nigeria, Norway, and Sweden. In addition, other donors provide funds to IITA to support specific research projects or training programs.

Staff: The Institute has nearly 200 principal staff members who come from more than 40 countries. IITA also employs over 1,000 support staff, most of whom are from Nigeria. The majority of the Institute's scientists are located at headquarters but some have been assigned to IITA substations at Onne, (Nigeria) and at Cotonou (Republic of Benin) and to projects in collaboration with regional and national programs. (See the Annual Report Executive Summary of the International Cooperation and Training Program beginning on page *123.*)

What is the Consultative Group on International Agricultural Research (CGIAR)?

At the initiative of the World Bank, the United Nations Food and Agriculture Organization (FAO), and the United Nations Development Programme (UNDP), an informal association of governments, international and regional organizations, and private foundations was set up in 1971 dedicated to supporting a system of agricultural research centers around the world. It was named the Consultative Group on International Agricultural Research (CGIAR). The purpose of the research effort of 13 centers (including IITA) now in the CGIAR system is to improve the quantity and quality of food production and the standard of living of people in developing countries (Figure 1). They focus their research efforts on crops and animals which provide a large part of the food supply of their respective regions.

The international centers have a variety of research interests. Eight concentrate on plant breeding for one or more crops. Nine are involved in agronomic research, two deal with livestock, and two include major programs aimed at improving pastures and forage crops. One center, IBPGR, devotes itself exclusively to the collection and conservation of genetic material; another, ISNAR, works with agricultural research agencies in developing countries to provide advice to governments on ways to strengthen agricultural research, and a third, IFPRI, studies the economics of food production to offer recommendations concerning policy changes needed to promote adequate and sustained growth.

All the centers work closely with national agencies. The linkage is vital to keep the work at centers oriented to the needs of the farming communities they are intended to serve. In fact, the gains made by scientists at the centers will get translated into actual food output only when the national agencies take up the results, adapt them to local conditions, and carry them to their farmers. This is why great importance is attached to training programs. To date, the centers have trained more than 18,000 persons, mainly from developing countries.

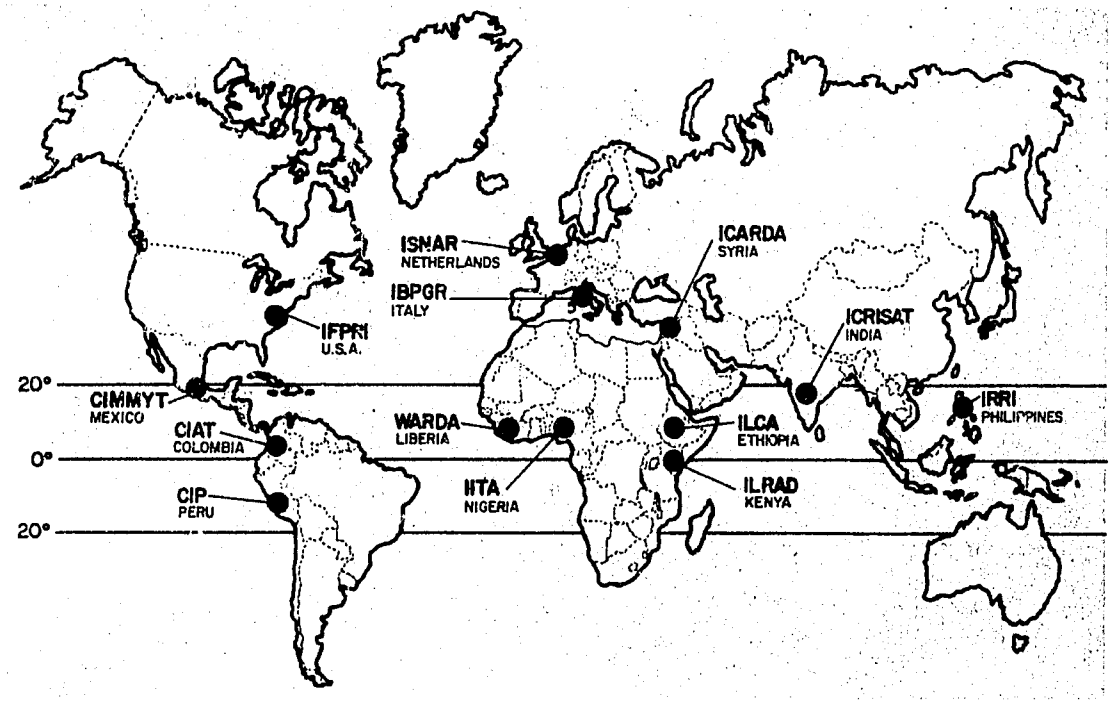
Each CGIAR-affiliated center is autonomous and run by an independent Board of Trustees on which members, chosen for their experience and expertise, serve in individual capacities. The board determines the direction of the center's research, but this is done in the framework of international consultations on two levels — one scientific and the other financial and administrative.

The CGIAR, which has an executive secretariat provided by the World Bank, meets twice a year to take decisions based on consensus. The meetings have before them recommendations from a Technical Advisory Committee (TAC) comprising a chairman and 12 distinguished scientists drawn equally from developed and developing countries. TAC is supported by a secretariat provided by the three co-sponsors of CGIAR and located in Rome at FAO headquarters. Also available to the semi-annual meetings are reports from centers, supporting bodies, and ad hoc committees that are set up from time to time to address specific issues.

Raising of funds to support the work of the centers is coordinated by the CGIAR secretariat based in Washington. Funds are not pooled but go directly to individual centers. The bulk of the funding is not task-specific, although some grants are earmarked for specific programs and activities within the broad framework defined by the CGIAR at its meetings. The CGIAR secretariat monitors the management performance of the centers, in keeping with the concept of accountability to donors, and provides overall administrative and management support. TAC monitors the scientific performance of the centers and reviews center budgets in the light of defined research priorities.

CGIAR started operations with 15 donor members but by the beginning of 1985 that number had increased to 43 countries, international and regional agencies, and private foundations. They pledged approximately U.S.$ 180 million to support the research and training programs of the 13 centers in 1985.

*Figure 1. Global location of the 13 CGIAR-supported international research and training centers (1985).**



**Centro Internacional de Agricultura Tropical (CIAT); Centro Internacional de la Papa (CIP); Centro Internacional de Mejoramiento de Maiz y Trigo (CIMMYT); International Board for Plant Genetic Resources (IBPGR); International Center for Agricultural Research in the Dry Areas (ICARDA); International Crops Research Institute for the Semi-Arid Tropics (ICRISAT); International Food Policy Research Institute (IFPRI); International Institute of Tropical Agriculture (IITA); International Laboratory for Research on Animal Diseases (ILRAD); International Livestock Centre for Africa (ILCA); International Rice Research Institute (IRRI); International Service for National Agricultural Research (ISNAR); West Africa Rice Development Association (WARDA).*

Director General's Report*

I am privileged to have the opportunity to lead IITA at this moment in its history. The eyes of the world are focused on Africa with its profound problems of burgeoning population, hunger, and malnutrition. Although IITA's "geographic mandate" within the CGIAR network of international agricultural research institutes covers the humid and subhumid zones of the world, its primary responsibility rests in sub-Saharan Africa, the region of the world where the need is most acute.

Despite the seemingly overwhelming difficulties that must be overcome to improve the situation, there exists at IITA an optimism and encouraging realism about the nature of the challenge. No one should advance misleading hope that Africa will experience a "green revolution" similar to the one so widely publicized in Asia. Africa's traditional agriculture is much more complex. The dramatic breakthroughs in Asia with rice and wheat were based on a backlog of basic knowledge in the plant sciences that is not so readily applied to important African crops (such as cassava, yams, sweet potatoes, and various food legumes) which are spread across a wide diversity of ecosystems.

What is encouraging is that IITA, in partnership with national programs, is generating a stream of technologies based on research which is laying the foundation for what I call a "quiet revolution" in the villages and on the small farms of Africa. They may have an even greater effect in the long run than the highly publicized "green revolution."

IITA scientists from 45 nations have been tackling some of the most difficult problems in international agriculture, and their accomplishments are substantial. There is evidence that IITA research, developed during the tenure of my predecessor, Dr. E.H. Hartmans, is paying dividends: new improved varieties developed by our scientists have been tested by national programs and released to farmers in many countries. As a result, yields of several important food crops have increased and become more stable. Moreover, improved farming systems that integrate traditional and modern emerging technologies are gradually being developed and tested in on-farm trials.

I call your attention to several articles in this volume: the development of drought tolerant, disease and insect resistant varieties of various crops; the progress in alley farming as one of the alternatives to the centuries-old shifting cultivation with its related bush-fallow rotations; new extra-early maturing maize varieties for the Forest and Sudan Savanna of West Africa that can fill the food shortage during the "hungry gap" between the tailend of food stocks of the previous season and the harvest of the later maturing food crops; performance of high-yielding rice varieties adapted to various African ecologies; and the development of an efficient means to produce yam plants in *in vitro* tissue culture for international distribution. These and other examples described briefly in this publication represent only a portion of IITA's accomplishments.

IITA's resources are precious in relation to the enormity of the challenge in Africa. Our funding comes primarily from the taxpayers of the industrialized countries to serve the needs of the poor in the developing countries. As IITA approaches its 20th year, we have a heavy

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**Dr. Stifel assumed responsibility as Director General in October 1985.*

responsibility to assure that these resources are sharply focused on the most urgent tasks.

We know the problems of the future will be different from the problems of today. For example, demographers project African population growing from its present share of 10 percent of world population to about 25 percent before global population stabilizes sometime in the 21st century. This will place extraordinary population pressure upon arable land in many parts of Africa. IITA is one of the few institutions with the scientific expertise, knowledge of the local environment, and commitment to sustain research on the agricultural problems of the 21st century.

Strategic Planning Study

As we develop future plans for IITA, it is essential that we establish clearly defined priorities and strategic directions for the future. This is particularly important for IITA because it has an extremely broad formal program "mandate", and it is dealing with very complex and difficult agroecologies. For this reason, IITA Trustees in November 1985 authorized management to undertake a Strategic Planning Study in 1986.

The purposes of the Strategic Planning Study are to help provide answers to two overriding questions: What are the possibilities of producing scientific and technical advances if resources are allocated to research on a particular problem or commodity? What will be the value to society of the new technology if the research effort is successful?

The Strategic Planning Study will be based on a critical assessment of IITA's substantial strengths and capacities vis-a-vis other international and national institutions. The objectives are to sharpen IITA's institutional mission and to provide a coherent framework for the allocation of scarce resources within and across its range of program activities. Finally, the Study should lead to a vision of IITA's future and goals by which to measure progress.

Small Study Groups, consisting of distinguished scientists, have been set up for each program to work with us in defining the issues, catalyzing discussion, and helping to think through priorities. The Study Groups for the commodity programs are guided by the following terms of reference: 1) assess the present and future significance of the commodity, 2) identify researchable issues, 3) assess IITA's comparative advantage, 4) determine appropriate research methodology, 5) estimate the resources needed to achieve research results and adoption within the expected time frame, 6) define the linkages between research on the commodity and Africa farming systems, and 7) assess priorities within and across researchable issues at varying funding levels.

Early in our deliberations on the structure and scope of the Study, we made two assumptions of fundamental importance: First, the Study should be concerned primarily with research relevant to small family farms in Africa. Second, the primary geographic area of focus for the Study should be the lowland humid and subhumid regions of Africa. These two assumptions, endorsed by the Board of Trustees in April 1986, warrant amplification here.

Generation of Technology for Small Family Farms

As a matter of policy, IITA's research objective will be to increase the productivity and income of the small African farmer. Our ultimate targets are progressive farm families which are committed to improved management practices and which have sufficient land and resources to produce a surplus for the market. These are the farmers who, by increasing

commercialization of their operations, can adopt the improved technologies that will be the driving force for agricultural change.

IITA can do little directly to improve the welfare of farmers unable to adopt improved management practices. Our best instrument for reducing their poverty is increasing agricultural productivity of the small-scale progressive farmers in the region and, thereby, demonstrating innovations and stimulating employment and higher incomes for all.

Given the rapid population growth and its ever increasing effect upon the degradation of fragile African soils, increasing the productivity of family farms must be at the heart of improving African agriculture and food production. But there are powerful biases that discriminate against the family farmer: 1) national policies and programs that squeeze them in favor of large-scale commercial enterprises, and 2) research institutes that design modern technologies that are not appropriate for traditional, African family farming systems.

The contribution of research to greater food production during the coming decade must come largely from improved varieties developed by commodity research programs. But there will be no payoff unless these varieties are productive in the real world of the African farmer. A greatly strengthened farming systems orientation throughout IITA will be required to assure that the technology we generate is within the management capability of the family farmer. Farming systems research is, in a sense, just the servant of the commodity programs; but its close involvement is essential.

The Strategic Planning Study will illuminate areas in which there is an economic trade-off between investment in technology for small versus large-scale farmers. In making program decisions, we will give preference to those strategies that are aimed at improving the productivity of the small family farm.

Africa Focus

For purposes of the Strategic Planning Study, we assume that IITA should place special emphasis on improving the productivity of farming systems in the lowland humid and subhumid tropics of Africa. IITA has almost 20 years of experience dealing with these ecologies, and falling per capita food production makes them areas of great concern. These ecologies, roughly congruent with West and Central Africa, contain half the population of sub-Saharan Africa. This enormous, diverse and complex region can fully challenge IITA's scientific capabilities.

This interpretation of our formal mandate in no way conflicts with the international character of IITA. We have broader responsibilities in Africa and other continents that we will continue to respect. We will actively promote those commodities for which we have a wider mandate in all of sub-Saharan Africa, but beyond Africa we will normally share technology and knowledge only by means of germplasm exchange, publications, and training.

Within the special target African ecologies, IITA expects to take the lead in research on all its crops. Core resources will be used to carry out the full range of research, training and outreach activities here. We will intensify efforts to understand the farming systems of these ecologies in order to improve the productivity of our crop improvement programs and to contribute through more basic research to better resource management and conservation.

In response to the crisis of African agriculture, many international agricultural research centers are developing new programs for Africa. This is admirable, but the generality of the

centers' mandates creates potential for misunderstanding, confusion to the leaders of national research systems, and possibly wasteful competition. IITA is centrally positioned to encourage evolution of the centers toward a coherent system with consistent programs in Africa. But IITA can play this role in intercenter cooperation only if we first delineate our own priorities in a way that is clear, realistic, and workable.

Conclusions

We enter 1986 constrained by a budget lower in real terms than in 1985 and the prospect for financial stringency through the end of 1987. Nevertheless, we are optimistic about the future. We are instituting major improvements in management control and financial planning systems for the Institute. The tight budget reinforces the process of program consolidation and priority-setting under way. As a consequence of the Strategic Planning Study, IITA should emerge as a stronger and more effective organization.

Moreover, a vision of the future is emerging that includes emphasis upon the small family farmer, increased focus on ecologies where IITA has a comparative advantage, orientation of IITA commodity programs toward the farming systems of these ecologies, and commitment to cooperation with other international centers and national agricultural research systems. IITA is a scientific enterprise animated by a high social purpose. The above elements suggest a philosophy and set of values that can be the basis for moving vigorously ahead on our challenging mission.

In conclusion, I must mention that our Board of Trustees has been strengthened by the addition of two new members, Mr. John D. Edozien, Permanent Secretary of the Federal Ministry of Agriculture, Water Resources and Rural Development in Nigeria, and Dr. Mayra Buvinic, Director of the International Center for Research on Women in Washington D.C. As a woman and social scientist, Dr. Buvinic will bring long-needed perspectives to the deliberations of our Board. At the same time, IITA lost the services of four dedicated and valued Trustees whose terms of service ended: Mr. Dominic E. Iyamabo, Vice-Chairman of the Board; Dr. Robert C. McGinnis, Chairman of the Program Committee; Dr. Hidetsugu Ishikura and Mr. Papoola. The Board of Trustees gratefully acknowledges their enduring contributions to the work of the Institute, and I am sure that we will continue to look to them for wise counsel in future years.

Laurence D. Stifel

Laurence D. Stifel
Director General

April 19,1986

IITA farming systems research teams experiment with alley cropping to assess its long-term effects for managing fragile tropical soils and sustaining crop yields.

Annual Report Executive Summary
Farming Systems Program

A multi-disciplinary effort, farming systems research is aimed at developing appropriate technological innovations to increase and sustain production of food crops designated in IITA's mandate. Its scientists study the biological, physical and socio-economic factors that affect the agricultural production of small-scale farms in the humid and sub-humid tropical regions of sub-Saharan Africa.

During 1985, the program at headquarters consisted of 16 core-funded scientists working in four research teams and one special unit: upland production systems, wetland production systems, agroforestry and plantain research, on farm research, and the socio-economic unit.

Upland Production Systems: The upland research team focused on soil and crop management systems based on cassava, yams, sweet potatoes, maize, upland rice, cowpeas, and soybeans.

In the forest zone, the emphasis was on root crop based systems, savanna areas on cereal/legume based systems. High priority was assigned to soil conservation and biological improvement of soil productivity. Thus, studies on cover crops and planted fallow and their effects on nutrient recycling, soil erosion control, biological nitrogen fixation, and soil biomass activity continued to be a major thrust.

For the non-acid or high base status Alfisols and Inceptisols in the sub-humid and humid zones, research results have shown that the no-till maize-cowpea-*mucuna* rotation system and alley farming with *Leucaena* are able to sustain high levels of maize and cowpea yields over a long period without reverting the land to varying periods of natural or planted fallow.

On the coarse-textured, well-drained acidic Ultisols in the high rainfall region of southern Nigeria, results from cassava tillage experiments indicated that a no-till system with chemical weed control produced tuber yields equal to those of conventional and strip-tillage methods.

In mixed cropping trials of cassava/maize and cassava/cowpeas conducted on an Alfisol at Ibadan, Nigeria, the size of cassava populations had no adverse effects on maize yields, but a high population of spreading-type maize reduced cassava yield. The most desirable planting pattern for cassava/cowpea mixture was to plant both crops in the same row.

Research on weed management for upland crops emphasized tillage methods and live mulch. Weed biomass in maize had an inverse relationship with intensity of tillage operations. Herbicide efficacy declined with reduction of tillage intensity. Weed control was less effective with low rates of herbicide application in no-till cowpeas and soybeans than in conventionally tilled treatments. In a long-term live mulch trial at Ibadan, plots where live mulch (i.e. *Psophocarpus palustris*) was grown for the past five years yielded more maize than the continuously cultivated no-till or plowed plots. This was attributed to less weed infestation and higher soil organic matter and biomass activities in the live mulch plots. Research on control of the noxious weed *Imperata cylindrica* in a sub-humid ecology was initiated in 1985.

Microbiology studies conducted during the year included biological nitrogen fixation in cowpeas, *mucuna* and sweet potatoes, mycorrhizal infections of sweet potatoes in different soil types, and changes in microbial populations and activities following forest clearance and cultivation.

Results from the biological nitrogen fixation study showed that nitrogen yield of early maturing cowpeas was less than late maturing indeterminate varieties. Cowpeas do not contribute nitrogen to maize intercropped with cowpeas.

In agricultural engineering, on-farm evaluation of improved tools and implements for small farms continued. These include rolling injection planter, fertilizer applicator, maize thinner, and row marker. Results from a tillage experiment at Ibadan showed that paraplow once a year produced significantly higher maize yield than continuous no-till and conventional tillage treatments. This was related to low penetrometer resistance, high water infiltration, and low incidence of wilting during dry spells.

Wetland Production Systems: Sub-Saharan Africa has over 30 million hectares of potentially arable wetlands, some of which are sources of various products traditionally gathered from the wild, yam/and or cocoyam cultivation on large mounds, and dry season vegetable production; approximately 3 million hectares of the wetlands are presently under rainfed lowland rice cultivation and less than 500,000 hectares are under irrigated paddies.

Research on small inland valleys is aimed at developing both upland and valley bottom as a whole farm unit. Because of the lack of appropriate soil and water management technologies in the valley bottom (wetland), many farmers have allocated more labor and resources to the production of crops in the upland. In large wetland areas, such as large river flood plains and coastal deltas where rainfed or irrigated lowland rice predominate, research priority is accorded to soil fertility management and land preparation for rainfed and irrigated lowland rice, and for post-harvest engineering.

During 1985, research on small valley development was started near Bida, Nigeria and Makenni, Sierra Leone in collaboration with the International Land Reclamation Institute (ILRI) in the Netherlands, Land and Water Development Division (LWDD) in Sierra Leone, National Cereals Research Institute (NCRI), and Bida Agricultural Development Project (BADP) in Nigeria. Hydrological studies were initiated in four benchmark valleys in both countries and on-farm agronomic trials conducted in several inland valleys near Bida on maize/sorghum intercropping in the upland and rice in the valley bottom. Preliminary results indicate that farmers liked the improved short maize variety (TZESR-W) because of its early maturity, resistance to streak virus, and resistance to lodging during heavy rain storms.

Results of 10 on-farm trials on rice (farmer managed) in the valley bottoms showed that with contour bunding, fertilizer, and weed control, both the late maturing local variety and the improved early maturing varieties (ITA 306 and FARO 29) gave comparable paddy yield of about 4 t/ha in the sandy hydromorphic soils.

Introduction of simple harvesting and threshing tools such as the serrated sickle and the manual rice thresher was readily accepted by local farmers. However, motor-driven implements (such as the turtle plow) will have to overcome many socio-economic constraints before they can be adopted by local farmers.

Agroforestry and Plantain Research: Agroforestry is an important component in farming systems in the humid tropics not only in terms of nutrient recycling and soil conservation but also in supplying food and firewood to small farmers and ensuring overall sustainability of production. Thus, agroforestry research at IITA focuses on alley cropping and the improvement of multi-story compound (homestead) farms.

The *Leucaena* and *Gliricidia* alley cropping systems on non-acid soils (Alfisols) developed at IITA have gained increasing acceptance by national researchers.

On the strongly acidic Ultisol (Typic Paleudult) at IITA's high rainfall station at Onne, Nigeria, several shrub species were evaluated in association with cassava. Preliminary results indicated that *Cassia siamea* planted in 8 m alleys gave the highest cassava yield. Cassava growth and yield were depressed when alley cropped with *Gmelina*.

During 1985, both farmer-and-researcher-managed alley cropping on-farm trials with *Leucaena leucocephala* and *Gliricidia sepium* were established in collaboration with ILCA and national research institutions in Nigeria and in several West and Central African countries.

This year plantain/banana research became one of the core activities in the Farming Systems Program. Major activities were centered around increasing productivity of low input production systems and increasing the supply of planting material to aid expansion of production. The major part of the research was done in national research institutions through the West African Regional Cooperative for Research on Plantain. A summary of the research results: (1) Small farm production was more profitable than medium or large-scale; (2) none of the plantain cultivars screened were resistant to black sigatoka—the disease threatening plantain production in West Africa; (3) plantain grown with coffee was not severely infested with the banana weevil; and (4) *in vitro*-produced plants appeared more vigorous than others.

Most plantain cultivars did not lose morphogenetic potential after six cycles of multiplication in meristem culture, and the multiplication potential of some exceeded 100 million in one year. The new technique for rapid multiplication of plantain in the field is a significant improvement over current practices. Tests for aberrations in plants from meristem culture multiplication showed less than 1% abnormality. Therefore, this technique can be safely used.

On-Farm Research: Development of research methods and testing of IITA technologies were conducted in three pilot areas in different ecologies in Nigeria in cooperation with national institutions. One full year of on-farm testing was completed in the savanna and transitional zones with a range of technologies, including varieties of the traditionally grown food crops, fertilizer use, and alley cropping. The pilot area in the forest zone was identified and surveyed in 1985.

Socio-Economic Unit: Staff members of this unit provided socio-economic inputs into the research activities of the crop improvement programs, expanded the socio-economic assessment for on-farm research to facilitate the transfer of improved technologies, initiated new projects on food crops utilization and nutrition (particularly on soybeans), and completed an exploratory study on compound farms.

A task force developed an integrated pilot program with the Kersey Children's Home at Ogbomosho, Nigeria on soybean production and utilization as a nutrition intervention strategy for health improvement. A socio-economic survey among 386 of its clientele showed that 88% of the children fell below the 50th percentile of the weight and height minimum for age, and at least 30% suffered from severe malnutrition. A soybean demonstration plot was established at Ogbomosho to test yields and systematically introduce women to production techniques. A Kersey staff member was seconded to the Socio-Economic Unit to work full time on soybean utilization with national collaborators from government ministries.

A multi-disciplinary team undertook an exploratory survey of compound (homestead) farms in eastern Nigeria. It was designed and implemented in collaboration with the University of Nigeria at Nsukka, the Forestry Commission at Enugu, Michael Okpara College of Agriculture at Umuagwo, and Imo State Accelerated Development Area Project. The study listed all plant species, documented the important nutritional value of foods and trees in the compounds, and prepared a model describing five types of compound farms and plant distributions according to ecology and population density.

A systematic effort was made during the year to increase the number of women in IITA's production training and post-graduate research and strengthen collaboration with national socio-economists.

Conferences, Workshops, and Training Courses: The Farming Systems Program collaborated with national centers in organizing three international conferences and/or workshops on: land clearing and development held in Indonesia, wetland utilization for rice production in tropical Africa held at IITA's headquarters, and plantain and cooking bananas multiplication and utilization held in Ivory Coast.

Five training courses were conducted in 1985 for national research and extension workers in Africa: soil/water conservation and tillage systems, weed management, alley cropping, soil and plant analysis, and on-farm research methods.

In the following pages, a few notable research highlights during the year are briefly described. More complete information on these topics and those mentioned in this Executive Summary can be obtained by requesting the Annual Report of the Farming Systems Program.

Fallow Management for Soil Fertility Restoration and Fodder Production in Rwanda

Because of a severe shortage of arable land in Rwanda, fallow periods between cultivation phases have been progressively reduced to one year or less. Consequently, better fallow management practices are needed to help restore soil fertility in a short time, and one means is to plant suitable leguminous and other species that can provide green manure, soil cover mulch, and fodder for animals.

Scientists in the farming systems research project at Karama have evaluated several leguminous species for biomass production, soil surface protection, ability to survive during the dry season (June–September), and ease of establishment and blending of harvested tops as green manure into the soil. Trials with four species — *Crotalaria* sp (sunn hemp), *Mucuna pruriens* var. *utilis*, *Cajanus cajan* (pigeonpea), and *Sesbania sesban* showed that they are about equal in biomass production (Table 1).

Significant increases in grain yield of succeeding crops were obtained due to incorporation of green material from two leguminous cover crops in comparison with the traditional practice of natural fallow. Also, plots previously planted to sweet potatoes (tuber yield 7.5 t/ha) gave a relatively high grain yield of subsequent soybean/maize intercrop (Table 2).

Fast development of vegetative cover is necessary to protect the soil surface from erosion. Sunn hemp (*Crotalaria* sp) rated as the best species for early ground cover (Table 3). *Sesbania sesban* was very slow growing and took much longer to cover the soil. Maintenance of ground cover during the dry season and at the beginning of rains in October is essential to

Visitors to the farming systems experiments at Karama, Rwanda see different leguminous species (including sunn hemp and mucuna) being evaluated for their ability to protect the soil surface, survive during the dry period, and provide fodder for animals.

reduce soil erosion. *Cajanus cajan* (pigeonpea) was the most drought resistant during the dry season; sunn hemp rated second. *Mucuna* sheds all its leaves during the early dry season.

Mixing 50% sunn hemp with 50% grasses improved the quality of fodder and increased the liveweight gain of goats. Both 6-month old and 18-month old goats gained 2 kg in 16 days when fed the mixture compared with only ½ kg for the 100% grass ration.

Traditionally, the majority of animals raised in stalls are fed grasses, and there is an acute shortage of this feed and other fodders throughout the country. This shortage can be eased by planting leguminous species on fallow land and using them to supplement the grasses for animal feed. However, when the fallow species are cut and used for this purpose, about half of the nitrogen fixed biologically will be exported from the field, thereby reducing the extent of rejuvenation of the soil and fertility restoration. This can be offset by the manure from the stall-fed animals being returned to the same field.

	Months after planting	
	3½	6½
Leguminous species	(Yield (kg/ha)	
		(Range)
Crotalaria sp	2.6	4.3 – 4.9
Mucuna pruriens var. utilis	5.7	4.7 – 7.1
Cajanus cajan	2.1	2.8 – 9.4
Mix of 1 + 2 + 3		6.2

Dry weight multiplied by 5 = approximate fresh weight of harvested materials.

Table 1. Dry weight of biomass produced by three leguminous species in the poor plateau soils of test sites at Kagasa and Dihiro, Rwanda.

Previous treatment	Green manure added (t/ha)	Yield (kg/ha)	
		Soybeans	Maize
Natural fallow	n.d.*	405	920
Sweet potato	n.d.	750	1,236
Crotalaria sp	9.0	768	1,619
Mucuna pruriens var. utilis	37.5	756	1,683

**n.d. not determined*

Table 2. Effect of planted fallows on the grain yields of succeeding soybean/maize intercrops at Kagasa Rwanda.

Leguminous species	Ground cover (%)
Crotalaria sp	87.7
Mucuna pruriens var. utilis	61.3
Cajanus cajan	52.5
Sesbania sesban	16.3

Table 3. Percentage of ground cover by different leguminous species at 50 days after planting.

Role of Animal-Powered Implements for Making Tied Ridges to Improve Crop Production in Burkina Faso

In semi-arid environments with limited rainfall and high soil water losses through runoff, cultural practices that reduce this runoff are essential for more stable yields. Tied ridges, introduced a few years ago in Burkina Faso (formerly Upper Volta) by IITA/SAFGRAD scientists, help meet this need. (See *Research Highlights* 1981.) They reduce runoff, improve soil water reserves, and markedly increase grain yields of several crops, including maize and cowpeas.

Tied ridges are either earthed-up rows or ridges with lateral ties built to connect the rows (on which the crops are grown. Although those made by hand can still be economically profitable, farmers indicated that a mechanical implement adapted to animal traction would make them even more attractive and less tedious to construct. The use of animals for field work is increasing in Burkina Faso, and donkeys, oxen, and horses are expected to be one of the most significant factors in implementing soil and water conservation techniques vital to a sustainable agriculture in the region.

With the help and expertise of a U.S. Peace Corps volunteer working with the IITA/SAFGRAD program, two versions of the tie-ridging implement were designed — one for donkey power, the other for oxen. The design is based on a "tripping shovel device" by Lyle and Dixon. It has four flat shovels that roll on an axis. The rolling is controlled by a catch mechanism that is activated by a bicycle break lever on the handle of the ridger. When the device is attached behind a ridger, one of the shovels pulls loose soil along the furrow until the operator releases the catch mechanism. When he does this, the next shovel rolls over and the process begins again.

The donkey model which weighs 11 kg has 40 cm wide shovels at the base, tapering to 16 cm at the outside. (Comparable figures for the oxen model: 17 kg, 55 cm, and 20 cm, respectively.) Production costs are estimated at 14,000 and 16,000 CFA.

The Centre Nationale d'Equipement Agricole manufactured 75 donkey and 60 oxen models for the cost of materials and labor. Several research institutions (ICRISAT, FSR-SAFGRAD, IRAT-CIRAD, and the World Bank Pilot Project for Agricultural Development) are conducting independent research and testing with 36 donkey and 41 oxen models, and seven development organizations are testing 30 donkey and seven oxen models in cooperation with farmers from 15 villages within a 60 km radius of Ouagadougou. A majority of the participating farmers are in the Project de Valorisation des Sites Anti-Erosifs conducted by Fonds de l'Eau et Equipement Rurale (FEER).

Preliminary tests showed that the donkey model could make 13 cm deep tied ridges in rows 50 cm apart and the oxen model 16 cm deep tied ridges in rows 70–80 cm apart. Once the ridges are made, it takes the farmer about 72 man-hours per hectare to prepare ties by hand. This time is reduced to 32 man-hours by using the donkey ridge-tier model.

In interviews, farmers said that making the ridges with the donkey model caused them no fatigue problems and that the donkey often tired out before the operator. When asked how many hours per day their donkey could make and tie ridges their answers ranged from 1½ to

Farmers attend a field day to see a demonstration of a donkey-powered tied ridging implement developed by the IITA-SAFGRAD research program in Burkina Faso.

3 hours. They pointed out that the combined activities of ridging and joining them with ties were too much work for their donkeys to do on a regular basis. Therefore, they would separate the two activities if they were to continue this cultural practice.

Full evaluation of the tests conducted in 1985 had not been completed at this writing, but preliminary conclusions indicate that animal power can be used for making tied ridges. The major limitations of the equipment are related to the weight and length (particularly in the case of the oxen model) and to the hand tripping mechanism (adjustments and cable life). Both devices will be modified and it is expected that the testing of improved models will continue.

A farmer-managed on-farm trial of lowland rice in a small inland valley (fadama) near Bida, Nigeria.

On-Farm Research in Small Inland Valleys in Central Nigeria

Increased demands for rice as a staple food in sub-Saharan Africa requires more intensive use of suitable wetlands for rice production. West Africa has over 30 million hectares of wetlands with about one-third of this area occupied by small inland (or stream flow) valleys. The rest is classified mainly into deltas, river floodplains, and overflow valleys.

In collaboration with the Bida Agricultural Development Project (BADP) and National Cereals Research Institute (NCRI) in Nigeria, Land and Water Development Division (LWDD) in Sierra Leone, and International Institute of Land Reclamation (ILRI) in the Netherlands, IITA initiated the West African Wetland Utilization Research Project. Its main objective is to develop low input soil, water, and crop management technologies that will enable small farmers to cultivate the valleys more intensively.

Two inland valleys near Bida in the sub-humid region of Nigeria were selected as

benchmark research sites and initial field work started in late 1984. Major activities in 1985 focused first on the characterization of the sites in terms of soil, water, cropping systems, and socio-economic environment; then preliminary studies of water balance and on-farm testing of improved crop varieties, soil management practices, and small farm tools and implements. Farmers in the area cultivate both the upland and valley bottom as components of a whole farm unit.

In the valley bottoms, rice grows in the rainy season where the soil is normally saturated or flooded. In the dry season, sweet potatoes, early maturing cassava and vegetables grow on mounds in the valley bottom where soil moisture is still available. In the uplands, farmers plant sorghum, millet, groundnuts, maize, and melons often under intercrop systems. Rainfall distribution and a farmers' crop calendar are shown in Figure 2.

Crop production practices in the two valleys depend entirely on hand labor and the use of small tools – a major handicap to increased cropping intensity and productivity. Also, there is usually a labor shortage during peak periods of land preparation, planting, weeding, and harvesting. Low yields of major food crops can be attributed to several constraints: in rice production, poor or no water control, inefficient land preparation, weeds, iron toxicity from seepage water, poor soil fertility, low crop density, and low yielding varieties; in the upland cropping systems, poor soil fertility,

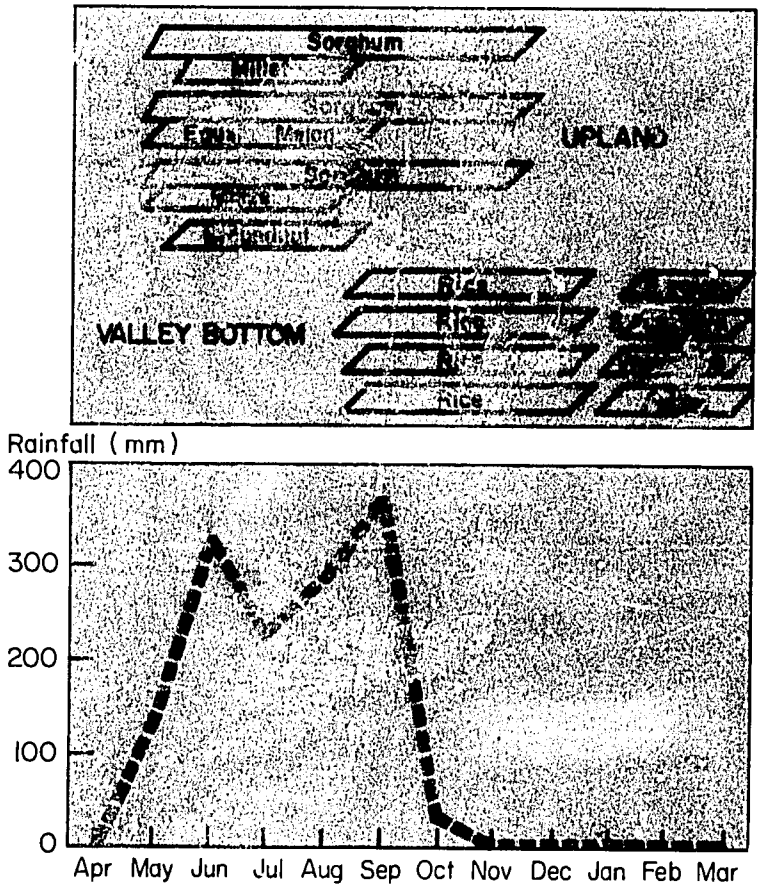


Figure 2. Major cropping systems in rainfed areas near Bida, Nigeria plotted against 1985 monthly rainfall.

erratic rainfall, drought stress, infestation of sorghum or maize by *Striga* (a parasitic weed), cassava mosaic disease, and low yielding varieties.

Farming activities in the upland result in rice planting delays in the valley bottom. Farmers plant their rice in August or September when there are few activities in the upland. Also, planting of second season crops after rice in the valley bottom is delayed because farmers allocate much of their labor to post-harvest activities. These constraints are being addressed in the design and testing of technologies for farm adoption, including the introduction of new early rice varieties in the lowland that mature before sorghum is harvested in the upland.

Results of 10 on-farm trials in the lowland during 1985 showed that under farmers' traditional management (transplanting and bunding) the improved rice variety ITA 306 gave higher yield than another improved variety (FARO 29) and the local check variety (Table 4). The local check is a mixture of several improved varieties from previous introductions. Under improved management (transplanting, bunding, chemical weed control, and fertilizer), the three varieties produced about the same yield.

Farmers responded favorably to the improved variety ITA 306 mainly because of its early maturity — 106 days after planting compared with 123 days for the local check. However, other qualities of improved rice varieties will be evaluated for seed multiplication and distribution.

Variety	Traditional management*	Improved management**	Mean
ITA 306	3,370	3,531	3,451
FARO 29	2,592	3,899	3,246
Local	2,327	3,755	3,041

** Bunding and transplanting.*
*** Bunding, transplanting, chemical weed control (BASAGRAN), and fertilizer NPK 90-60-45 kg/ha.*

Table 4. Average grain yields (kg/ha) of two improved lowland rice varieties and one local variety under traditional and improved management from 10 on-farm trials in small inland valleys near Bida, Nigeria (1985).

Performance of Woody Species in Alley Cropping with Food Crops

Four woody species – *Acioa barteri* (Chrysobalanaceae), *Alchornea cordifolia* (Euphorbiaceae), *Gliricidia sepium* (Papilionoideae), and *Leucaena leucocephala* (Mimosoideae) – were evaluated for their performance in alley cropping on degraded land at IITA. Despite a heavy pruning regime – five each year since 1982 – all four species still showed vigorous coppicing after pruning and produced substantial amounts of dry matter and nutrient yield (Table 5).

Acioa and *Alchornea* are indigenous woody species commonly planted or selectively retained by the traditional farmers in bush fallows in the humid zone of Nigeria. *Gliricidia sepium* introduced into the African continent a long time ago as a nurse crop for cocoa is also widely grown by traditional farmers for soil fertility improvement and for yam staking. The giant *Leucaena leucocephala* variety K-28 used in the trials was introduced from Hawaii during the early 1970s.

Hedgerows of these woody species, planted 4 m apart on an eroded Alfisol, were pruned back to a height of 75 cm to provide mulch and green manure for the companion food crops and at the same time prevent shading: cropping sequence used consisted of maize followed by cowpeas.

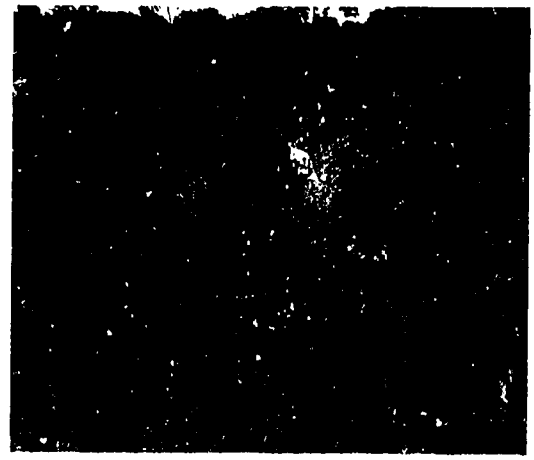
Long-term alley cropping had a positive effect on maize grain yield. With or without nitrogen application maize yield in the fifth cropping year grown under no tillage was higher than in the control treatment (Figure 3). In the control plot, maize yield peaked with an application of 90 kg N/ha. The yield with *Leucaena* alley cropping was significantly higher with half the application of nitrogen. This indicates that not only supply of nitrogen but also other improvements in the soil through alley cropping may play a more important role in ensuring higher maize yields on a degraded Alfisol.

Alley cropping demonstrations and on farm trials using *Leucaena leucocephala* and *Gliricidia sepium* were also carried out on degraded Entisols in the derived savannah of southern

Table 5. Dry matter (prunings) and nutrient yields in young tops of four woody species with five prunings in a year (1985).

Species	Dry matter prunings (t/ha/year)	Nutrient yield (kg/ha/year) N	P	K	Ca	Mg
Acioa barterii	3.0	40.5	3.6	20.4	14.7	5.4
Alchornea cordifolia	4.0	84.8	6.4	48.0	41.6	8.0
Gliricidia sepium	5.5	169.4	11.0	149.1	66.0	17.6
Leucaena leucocephala	7.4	247.2	19.9	185.0	98.4	16.3

Nigeria. Hedgerows were successfully established by transplanting 2½ month-old seedlings from plots where they were grown in association with maize and cowpeas on sandy and degraded land infested with the noxious weed *Imperata cylindrica*.



Alley cropping with two woody species Leucaena and Gliricidia and cowpeas on a degraded Entisol in the derived savanna of southern Nigeria.

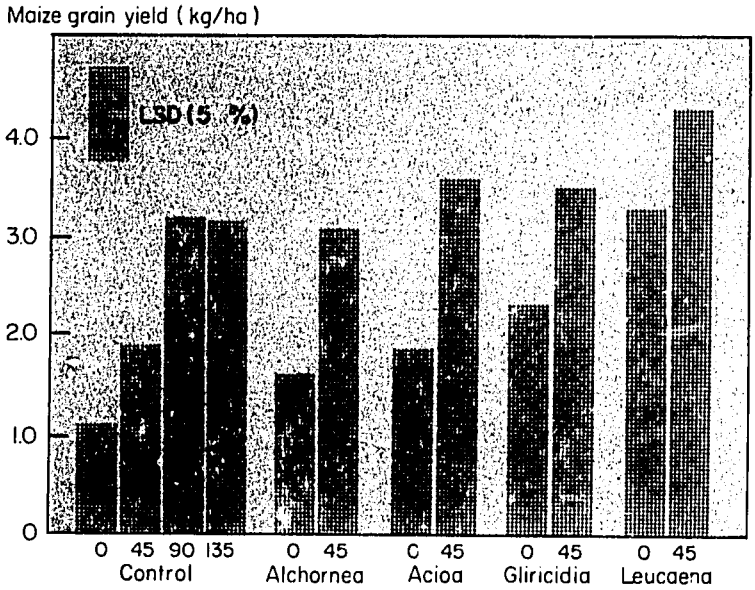


Figure 3. Effect of long-term alley cropping with four weedy species and nitrogen rates on grain yield of maize variety TZPB grown under no tillage in degraded Alfisol; fifth cropping year.

Exploratory Survey of Compound Farms

Compound (homestead) farms in several countries of tropical Africa have become an increasingly important sub-system of traditional farming systems. Encompassing the immediate area surrounding the household, they contain multi-use plant species – field crops, trees and other woody species – and small livestock, all of which play strategic nutritional roles.

In association with the other field systems (Figure 4), compound farms, which are fairly stable agroecosystems of varying complexity, help to minimize seasonal periods of food shortage. At the same time, they ensure reasonable levels of productivity for a range of foodstuffs with very little or no risk of crop failure. The complex agroecosystems of compound farms in tropical Africa have hardly been studied so as to understand their composition, structure, interactions among components, nutritional, economic, and overall socio-cultural importance. It is only through studying and understanding them that it will be possible to make worthwhile improvements.

A two-state exploratory survey of 84 compound farms in Imo and Anambra States of Nigeria by the Socio-Economic Unit of the IITA Farming Systems Program was undertaken in collaboration with national institutions, consisting of the University of Nigeria at Nsukka, Forestry Commission at Enugu, Michael Okpara College of Agriculture at Umuagwo, and Imo State Accelerated Development Area Project in Owerri. The multi-disciplinary team surveyed 54 households in Anambra State and 30 in Imo State. A plant species inventory was developed as the first step in the exploratory study – a total of 170 plants encountered were cited in Latin, Ibo, and English. Information on their uses was also gathered.

Among the initial findings of the survey:

- Compound farm plants provide essential nutrients complementary to staple food crops and vegetables in outlying fields.
- The compound farm size in Imo State ranged from one quarter to slightly less than two hectares. The size of the compound tended to cluster around 20% of the total cultivated farm area.
- Farms surveyed in the two states had a total of 146 various plant species in the compound. The number of plant species identified on any one compound ranged from 18 to 57; a core of about 25 species were encountered at high frequencies on the majority of farms.
- Because of extensive male out-migration in the Imo State areas surveyed, women remaining in the villages outnumbered men and many acted as heads of households in the absence of men.
- A high degree of soil fertility is maintained because household and animal wastes are used on the compound land. Small ruminants and poultry are integrated in varying degrees with crop production on the compound farm.

The results form the basis for a project to support national institutions in conducting longer term studies on: (1) labor, income, and nutritional factors of the compound; (2) physical components of the compound, including soil fertility and plant symbiosis in a multi-storied regime; (3) collection and maintenance of plant and tree species, some of

which are nearing extinction; (4) training materials and courses on the economic and nutritional value of the compound and potential improvement; and (5) interventions with plant materials which can intensify and sustain this vital farming system.

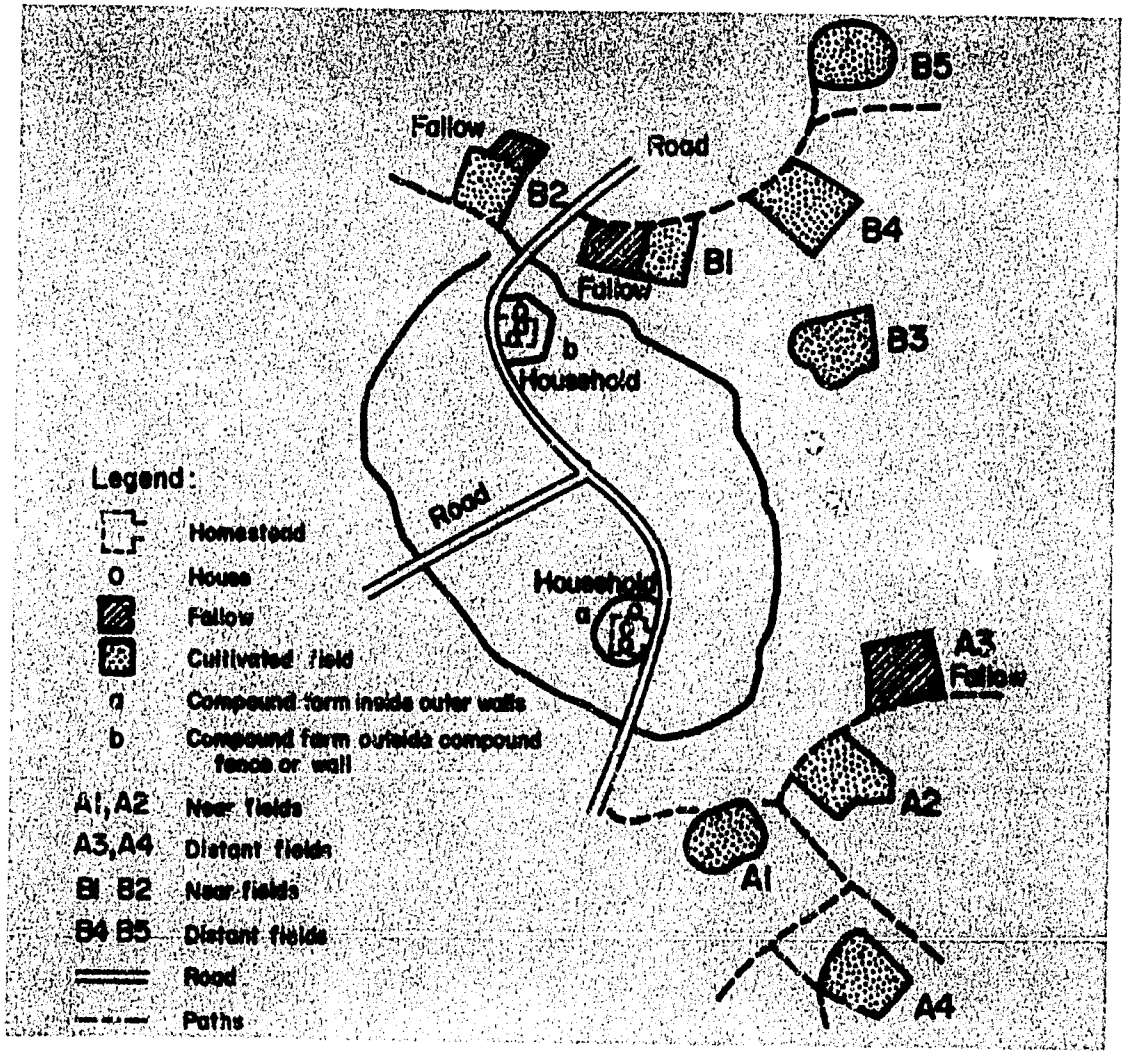


Figure 4. Schematic diagram of compound farms in relation to associated fields in traditional farming systems of the humid tropics of West Africa. (Source: FAO 1984.)

Soybean Production and Utilization: a Nutrition Intervention Model in an African Rural Area

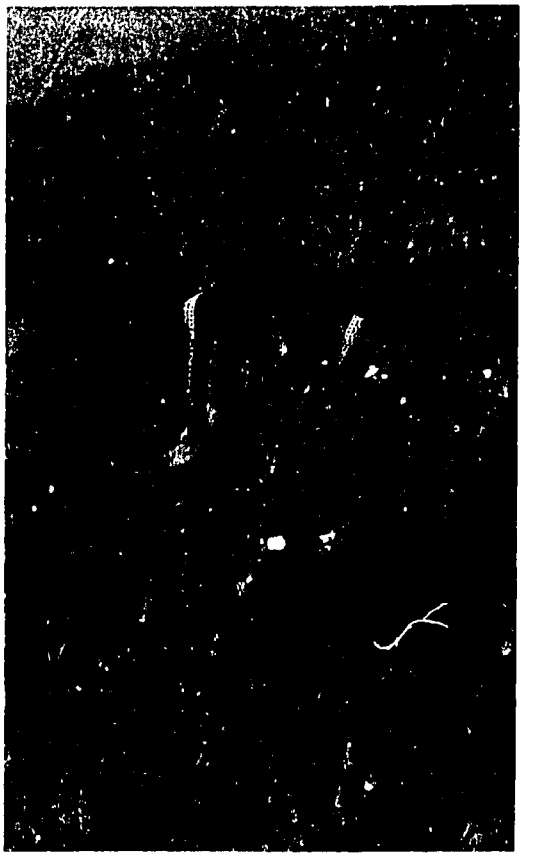
Protein malnutrition (kwarshiokor) has become a serious problem not only in famine areas in Africa, but also in some poorer rural areas where farmers may grow enough total food to feed their families but cannot afford to buy expensive protein to meet their nutritional needs. IITA's farming systems and grain legume programs have been studying one such area in southwest Nigeria (Ogbomosho) at Kersey Children's Home – a rural clinic specializing in childhood ailments, particularly those related to malnutrition.

During 1985, the clinic maintained an in-patient population of 40 to 60 children and received about 22,000 outpatient visits. More than three-fourths of the patients were children under two years old brought to the clinic for immunization and childhood ailments. But many of them suffered from diseases related to protein malnutrition.

Approximately 88% of the children attending the clinic fell below the 50th percentile of the weight and height minimum for age, and almost one-third of them were severely malnourished. In many traditional African families, adult males eat first followed by adult females. By the time the children come to eat, there may not be enough soup that contains fish, meat, or another protein source, and the children get only the starchy foods.

Major findings of a 1984-85 socio-economic survey of 386 outpatients of the clinic at Ogbomosho included:

- The most recurrent malnutrition factor was whether the child was being cared for by his or her mother. If cared for by a guardian, the chances of malnutrition were higher.
- Young girls faced greater degrees of malnutrition than boys.
- Women who were farmers lost more children – two out of every nine born, women with occupations other than farming two out of every ten; 60% of women farmers lost



Because of serious protein malnutrition among many African children, soybean production and utilization is receiving more attention and action, especially from women in rural areas.

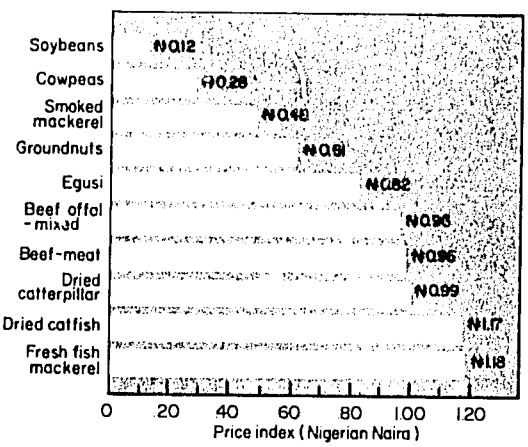
children compared with 40% in the rest of the sample.

- Polygamy alone was not a significant factor in child loss or malnourishment.

Staff members of the clinic started using soybeans in 1984 as the major source of protein in treating cases of protein malnutrition. Also, they began to promote the use of soybeans by teaching mothers and guardians of small children who attend the clinic how to prepare soybean milk and use soybeans in local dishes. See *Research Highlights* 1984. The staff recommends 120 grams of dry soybeans per child per day to substantially add required protein with the usual meals.

AT N1.00/kg (U.S. $1.05), soybeans are the least expensive source of quality protein (Figure 5). With about 40% protein and 20% fat, soybeans provide a highly nutritious food which can be used as a milk substitute. About 40% of the malnourished children treated are allergic to cow's milk. Also, soybeans are added to cereal weaning food, adapted to local dishes, and fermented and used as a soup flavoring.

Figure 5. Histogram showing prices at Ogbomosho, Nigeria on Friday, September 20, 1985 compared with costs of alternative foods with a protein value equivalent to that of a daily intake of 120 grams of whole soybeans (40.4 g protein).



Soybean paste made in the house with whole beans forms the basis for many recipes used at the clinic.

Soybean production technology matches the resources of small-scale farmers in the area with the principal inputs being good seed of an adapted variety and useful information.

Clinic and IITA staff members worked together during 1985 with these results: (1) land cleared and a demonstration plot of soybeans planted at the clinic with planting times staggered so the mothers of patients could see the crop at different stages; (2) illustrated pamphlet prepared in the local language and given to people in the area; and (3) soybean seed sold to farmers at a reduced price.

A member of the clinic staff worked nearly full time to explain the cultural practices necessary to grow soybeans. A number of farmers (both men and women) are now growing the crop and soybeans are sold in local markets.

The results obtained during the past two years in the Ogbomosho area indicate that this production and utilization model has possibilities elsewhere in Nigeria and in much of sub-Saharan Africa.

On-Farm Research with Early-Maturing Green Maize in Southwestern Nigeria

In southwestern Nigeria, as well as in many other parts of Africa, people face a food shortage at the beginning of the rainy season. The food shortage occurs because for various reasons insufficient supplies are carried over from the previous season or fungi insects and other pests have devastated the food reserves. Maize – normally the first crop which can be harvested – reduces the length and severity of this shortage when it is harvested green and eaten off the cob as roasted or boiled ears. Further reduction could be achieved by farmer adoption of earlier maturing maize varieties.

Development of earlier maturing maize varieties for this and other purposes has been an important goal for the past eight years. A physiological drawback of earlier maturity is that, since the vegetative period is shorter, all the plant parts including the ear are smaller than later maturing maize. To obtain more information about the market for fresh ears of maize and determine the agronomic and economic impact of earlier maturing maize varieties, studies were undertaken during 1985 in villages near IITA headquarters.

The on-farm research compared local late-maturing maize vs improved early maturing maize (TZESR-W) intercropped with a local cassava variety. Superimposed on the farmer management of this comparison were different levels of researcher-applied fertilizer. Four farmers completed the trials. The total number of ears harvested was greater for TZESR-W which is a reflection of the better plant stand achieved with IITA-supplied seed (Table 6). Because of later maturity, the local variety had larger ears and thus a higher percentage of marketable ears. Fertilizer increased the number and percentage of marketable ears.

The key factor in an economic analysis of green maize production is the value of the ears which is subject to marked fluctuation as the season progresses (Figure 6). It was difficult to establish a price for green maize before June and after September because the volume on the market was small and supply irregular. Prices in early June are very high because of the

15-15-15 Fertilizer	0 kg/ha		300 kg/ha	
Variety	TZESR-W	Local	TZESR-W	Local
Total ears	31,500	21,300	33,200	25,700
Marketable ears	19,300	16,800	22,000	18,100
Marketable %	62	69	66	71
Value/ear	.08	.065	.08	.065
Gross benefit	1,550	1,090	1,760	1,180
Seed and fertilizer costs	50	20	115	85
Net benefit	1,500	1,070	1,645	1,093

** The partial budget includes only those costs which differ by treatment. Values are in Nigerian Naira/ha.*

Table 6. On-farm trials for green maize production. Agronomic results and a partial budget analysis for improved early (TZESR-W) and local late maturing maize varieties grown under two fertilizer levels*.

severity of the food shortage.

As more farmers begin to harvest their green maize ears, the price declines rapidly, and in mid-July the market is flooded. After the first maize crop has been harvested, the price of maize again increases. The late season price increase, when more supplies of other food crops are available, is based on two factors: a reduced supply due to the agronomic difficulties of growing a late-planted maize crop and the demand for tasty maize ears.

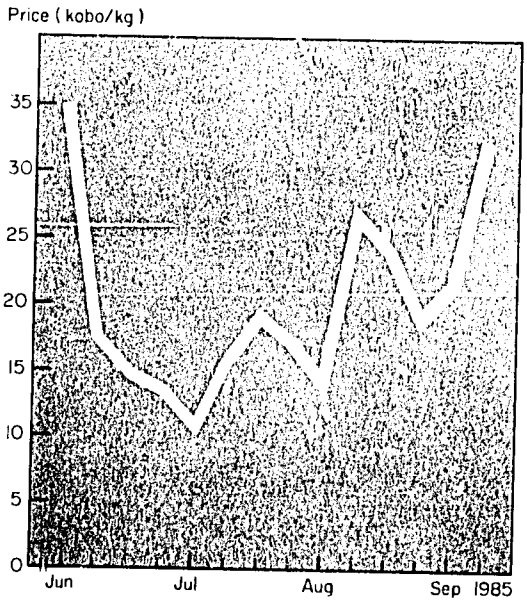
In the on-farm trials, TZESR-W was harvested 70 days after planting and the local variety two weeks later. TZESR-W was harvested before the sharp price decline; therefore, it had a higher value per ear even though the ears were smaller (Table 6). The value per ear is the major factor determining net benefit in the partial budget analysis. The partial budget does not include all the costs of production, but it can be used to determine marginal rates of return. The return for application of 300 kg/ha of 15-15-15 fertilizer was 234% for TZESR-W and 34% for the local variety. TZESR-W clearly responded to improved management, but an additional 45 kg/ha of nitrogen was not economical. The cost of fertilizer application is included in these analyses.

Assuming a rate of 40% as necessary for technology adoption, the farmer's present practice of not fertilizing the local variety is rational, but the application of fertilizer (300 kg/ha 15-15-15) pays if TZESR-W is planted. Moreover, the partial budget does not include all the benefits. The cassava which was intercropped in this trial is yet to be harvested, and cassava yields are expected to be higher in association with TZESR-W because of the reduced competition of the shorter, earlier maturing maize.

Farmer's reaction to growing early maturing maize were favorable. They preferred the sweeter taste of TZESR-W over their local varieties, and one farmer said if he had known how much money he could make, he would have planted a lot more.

One of the most important aspects of on-farm research is feedback to the "on-station" scientist. Some of the questions raised by this research are: (1) if seed of TZESR-W had been stored under the farmers' conditions, would the variety have performed well? (2) can breeders increase the percentage of marketable ears in TZESR-W?, and (3) is it possible to develop technologies which will allow a farmer to capture the high price of green maize later in the season? Research to answer these important questions is underway.

Figure 6. Fluctuations in green maize prices from June through September 1985 at the Ijaiye market near Ibadan, Nigeria. Availability of green maize is limited before June or after September.



Ecology of a Tropical Rain Forest and the Effects of Changes in Landuse

A long-term project, started in 1984, is designed to better understand the magnitude and trends in alterations of soil, hydrology, micro-climate, and biotic environments by deforestation and different landuse systems and agricultural practices. The existing vegetation, a high forest southeast of Benin City, Nigeria with a tree density of from 1,300 to 2,100 per hectare, was cleared in early 1985 using a front-mounted shear blade on a track-type tractor; 28 hectares were cleared in 301 hours. (See *Research Highlights* 1984.)

The different landuse treatments are listed in Table 7. The control (undisturbed forest) and traditional farming (manual clearing and growing mixed crops of yams, tomatoes, etc.) are compared with six other landuses for their bio-physical environments and production. Each of the eight treatments is imposed on a one-hectare plot and replicated three times. All of the 24 plots are equipped with an H-flume and water level recorder to monitor runoff rate and sediment loss. One replicate of all eight treatments has a monolith lysimeter installed to monitor evapotranspiration, seepage, and leaching losses of plant nutrients. In addition to hydrologic properties, other factors studied by IITA scientists include soil bulk density, infiltration rate, runoff and soil erosion, micro-climate, inter-flow and base-flow, soil fauna, nematode infestation, vegetation succession, and agronomic aspects of crop production.

Soil bulk density increased by deforestation, although the relative increase was more with mechanical than manual methods (Figure 7). Effect of deforestation on the increase in soil bulk density was observed down to a depth of 45 cm with machine clearing and 35 cm depth in manual clearing with forested control. But machine and manual methods of deforestation increased soil bulk density by 19.9 and 17.6% for 5 cm depth, 29.5 and 17.9% for 15 cm depth, and 13.3 and 7.0% for 25 cm depth. At a 35 cm depth, only the bulk density of the mechanically cleared plot was increased by about 4.5% as compared with forested control.

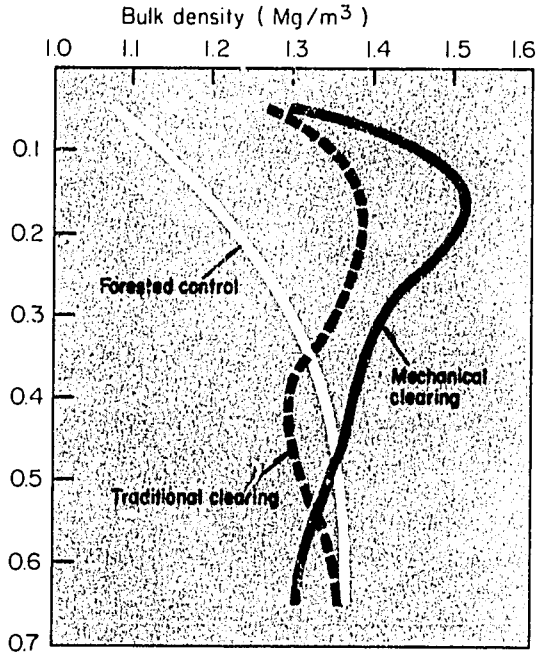
As a result of the increase in soil bulk density, the equilibrium infiltration rate decreased on all cleared plots. The equilibrium infiltration rate was 79.5 cm/hr for the forested control, 73.0 cm/hr for traditional farming, and 22.0 cm/hr for mechanically cleared plots (Figure 8).

Evapotranspiration on cleared land with different landuses was more than that on forested control by a factor of 8 to 10 (Table 3).

Treatment	Description
1.	Forested control
2.	Traditional farming
3.	Alley cropping of upland rice with *Gliricidia*
4.	Improved forestry
5.	Oil palm (with maize)
6.	Pastures (with coconuts)
7.	Plantain
8.	Cassava

Table 7. Treatments imposed in a long-term deforestation and landuse project in southern Nigeria.

Figure 7. Land clearing method and soil bulk density one year after clearing. (Each datum point is an average of eight measurements except for mechanical clearing where 16 points were considered.)



Treatment	Percolation	Soil profile water use	Evapotranspiration
	mm		mm/day
1. Forested control	350.1	40.9	0.3
2. Cassava	313.9	110.0	2.8
3. Oil palm	282.9	73.3	2.8
4. Upland rice	219.7	35.3	3.0
5. Plantain	273.6	73.3	2.9
6. Pasture + coconut	282.0	35.3	2.4
7. Improved forestry	231.6	111.9	2.3
8. Traditional farming*	291.8	73.0	2.7

* *Yam was planted in the lysimeter.*

The low evapotranspiration in forested control is due to the fact that no trees were grown in the forested lysimeter, hence the low transpiration. This situation will change with the establishment and growth of young seedlings already taking root. Among different landuse treatments, the maximum evapotranspiration rate was higher in improved forestry and rice than in other treatments.

Water runoff and soil erosion varied among different landuse treatments. As expected, the least runoff and erosion were observed in forested control (Table 9). Both runoff and erosion were low under traditional farming and cassava but relatively high under perennial crops (e.g. oil palm, improved forestry, coconuts, and plantain) because of slow growth rate and low canopy cover.

Growth of rice, maize, plantain, pastures, and tree crops was influenced by deforestation-induced changes in soil properties. Upland rice growth and yields were superior in windrows where dried woods were burned after clearing. Variations in rice grain and straw yields among four varieties are shown in Table 10. The maize crop (TSESR) showed extremely poor growth and failed to produce any significant grain yield because of poor soil fertility, no fertilizer application, and high soil acidity.

Principal collaborator and financial supporter in this long-term project is the United Nations University. The Okomu Oil Palm Company Ltd. provided the land.

Table 8. Percolation, profile water use, and average evapotranspiration calculated from lysimetric data for the eight treatments for 90 days from September to December 3, 1985. In this period, rainfall was 458.5 mm and throughfall 340 mm.

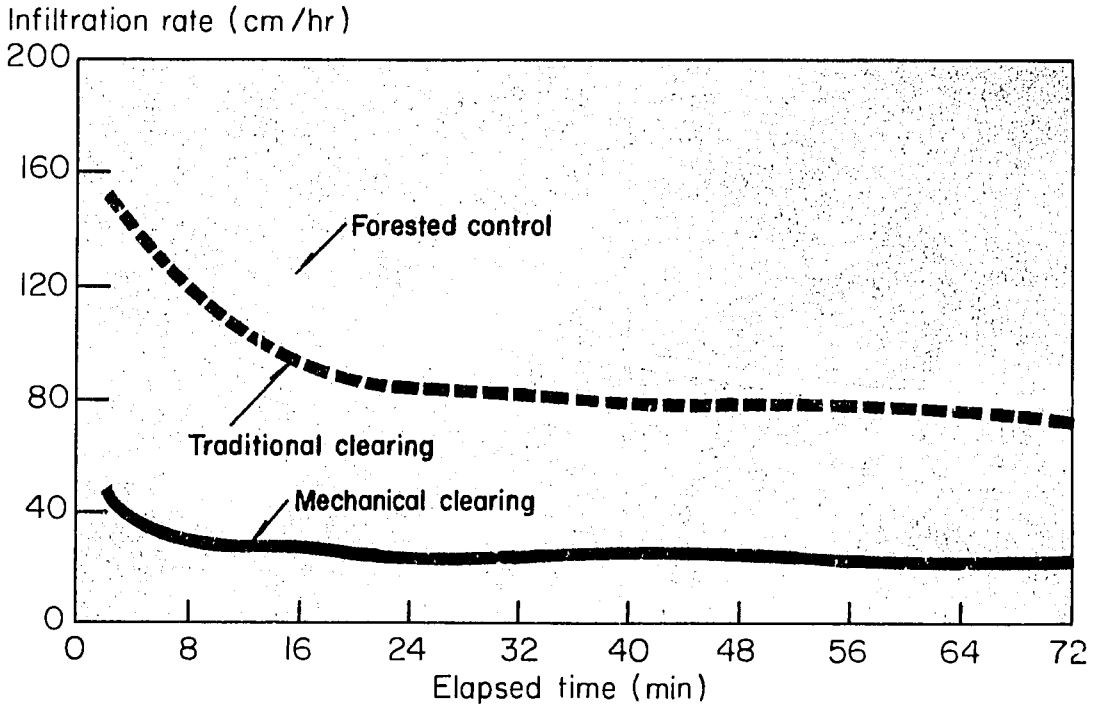
Treatment	Runoff (mm)	Soil erosion (kg/ha)
1. Forested	0.3	0.3
2. Cassava	13.2	29.5
3. Oil palm + maize	66.4	170.1
4. Traditional farming	0.3	32.0
5. Rice in alleys	28.3	94.2
6. Plantain	33.3	157.3
7. Pasture + coconut	39.1	183.1
8. Improved forestry	39.8	172.1

Table 9. Runoff and soil erosion in different treatments in the second half of 1985. (July to December 1985; total rainfall 1284.6 mm).

Rice variety	Soil treatment	Yield (t/ha) Grain (at 14% moisture)	Yield (t/ha) Straw (oven dry)
UPL-Ri-5	Not burned	2.0	4.2
	Burned	3.9	4.7
ISA 6	Not burned	2.0	3.3
	Burned	2.6	3.8
ITA 118	Not burned	1.5	2.6
IR 52	Not burned	0.5	2.6

Table 10. Harvest yields of alleycropped upland rice (first year) for the 1985 season.

Figure 8. Land clearing method and infiltration rate one year after clearing. (Each datum point is an average of 16 measurements; the i_s is the steady-state infiltration rate.)



Tropical rain forest in Nigeria cleared for a long-term project to study the effects of changes in land use.

Live Mulch: Long-Term Effects on Crop Yields, Weed Infestation, and Soil Organic Matter

Scientists continue to search for land management systems that cause the least damage to the environment and make it possible to intensively cultivate tropical soils without the traditional long bush fallow periods. One of many phases of this search involves an assessment of two legumes as live mulch ground covers – centro (*Centrosema pubescéns*) and psopho (*Psophorcarpus palustris*).

Research on the use of the tropical legumes as live mulches has shown that weed interference with crop plants can be minimized, and, if soil moisture is not limiting, crop yields in the live mulch system are superior to those in conventional or no-tillage systems at low levels of inorganic nitrogen fertilizer. Also, these studies have shown that there is more

The live mulch cover Psophorcarpus palustris controls weeds and contributes nitrogen to the soil, resulting in high maize yields. No nitrogen was applied in this field trial.

earthworm activity in the live mulch plots than in the conventional and no-tillage system plots.

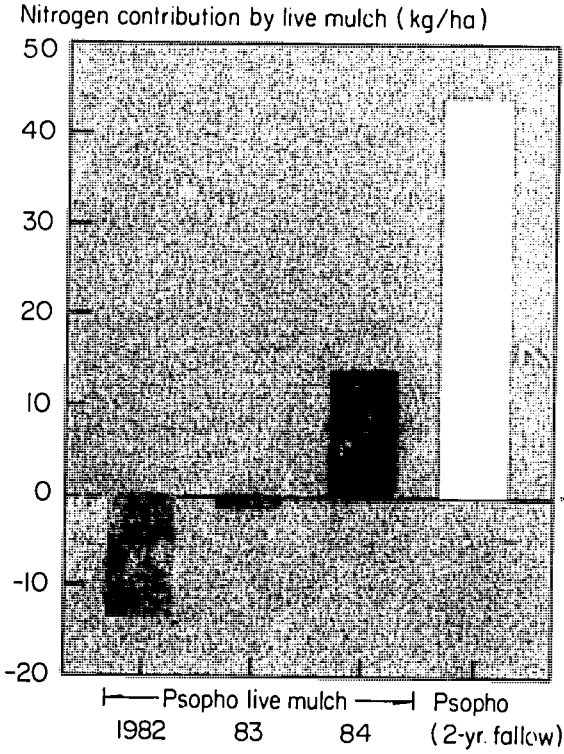
Another beneficial effect of live mulches is the addition of nitrogen to the soil for use by a food crop. Research results show that although psopho interplanted with maize competed with the crop for nitrogen during the first two years, it began to supply about 14 kg N/ha after that. A two-year psopho fallow supplied over 40 kg N/ha to a maize crop in its first year of use as a live mulch (Figure 9 left).

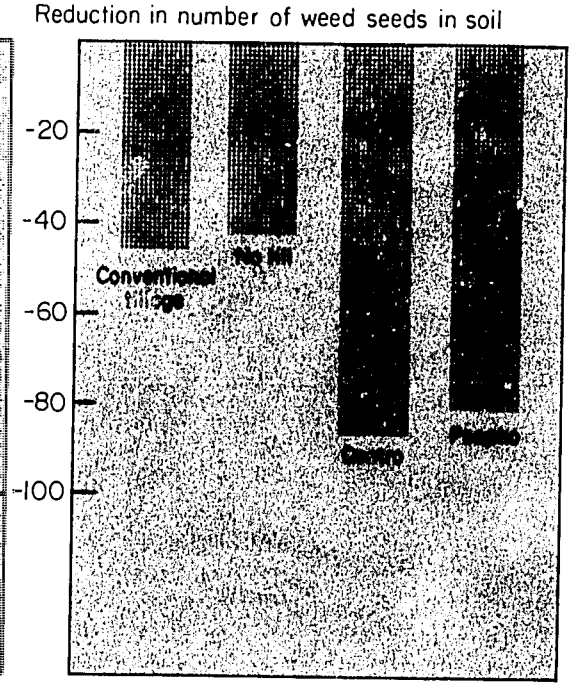
One of the undesirable side effects of intensive cultivation in the tropics is the increase in weed pressure caused by short bush fallow periods of two to three years.

The population of weed seeds in the soil after four years of tillage and live mulch was compared with the original seed population at the beginning of the study. Results show that after four years of maize production (two crops per year), weed seeds in the soil decreased by over 80% in the live mulch plots because they rotted. The decrease in the conventional and no tillage plots was only 45% (Figure 9 right). The live mulch depleted weed seeds in a manner similar to cropland subjected to a long period of bush fallow.

Effect of live mulch on soil fertility

Figure 9 (Left). Effect of psopho legume on nitrogen contribution to a maize crop in a live mulch management system; Figure 9 (right). Effect of live mulches and tillage systems on weed seeds in the soil after four years of continuous cropping at IITA.





restoration was investigated on a site with a previous history of intensive land use. After four years of cropping, the organic carbon content of soil in the live mulch plots approached the level in newly cleared tropical forests while that in the no-tillage and conventional tillage sites remained relatively low. This demonstrates the effectiveness of tropical legumes in adding organic matter to the soil and improving other soil properties at low input levels without a long period of bush fallow. However, management practices associated with the use of these legumes as ground covers need to be refined in order to increase the intensity of land use in the tropics at low weed pressure.

After five years of continuous maize production involving 10 crops of maize, yields in live mulch plots that received no nitrogen were consistently better than in the no-tillage and conventional tillage maize grown without nitrogen. To check the residual effects of live mulch and tillage systems on crop growth, maize was planted on the experimental site without the application of nitrogen fertilizer. Results show that maize yields in the live mulch plots were significantly higher than those in the conventional and no-tillage plots (Table 11).

Table 11. Effect of ground cover on maize grain yields in a continuously cropped Alfisol (after 10 consecutive maize crops). No nitrogen fertilizer was applied to this crop.

Land management system	Nitrogen applied in previous years (kg/ha)			
	0	60	120	Mean
	Maize yield (t/ha)			
Conventional tillage without maize stover mulch	1.8	1.7	1.4	1.6
No-tillage without maize stover mulch	1.9	2.5	1.8	2.1
Conventional tillage with maize stover mulch	2.4	2.7	2.3	2.5
Centro	3.5	3.2	3.0	3.2
Psopho	2.8	2.8	3.3	3.0
Mean	2.4	2.6	2.3	

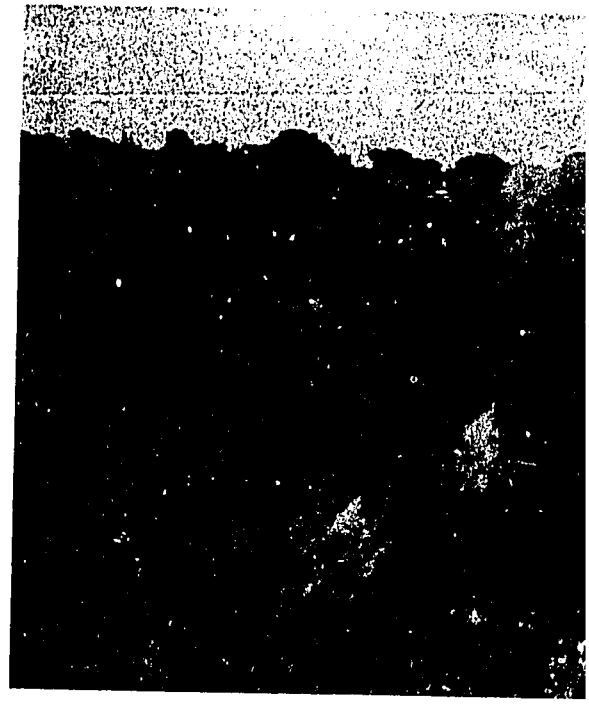
LSD (5%) for comparing ground cover means = 0.9 tons.

Role of Mucuna Mulch in Mechanized Farming Operations

The history of mechanized farming in the humid and sub-humid tropics of Africa is fraught with failure mainly because of rapid soil erosion and degradation, despite the use of conventional soil conservation measures. Smallholder farmers in these regions, however, do not face such problems because they normally clear small areas of land manually (one to two hectares), and the land is cropped for two or three years and then returned to forest fallow. A rapid increase in the pressure on land in recent years has led many researchers and planners to seek effective ways and means for land clearing and continuous cultivation.

New clearing practices with the shear blade and subsequent soil management practices (such as no-till planting) minimize soil erosion and help retain valuable top soil. Even with these new practices, several years of cropping can result in soil compaction. This is caused by tractors and other equipment used for planting, spraying, and harvesting operations. Mulching with plant residue helps to minimize soil compaction, runoff, and erosion, but, because of certain mulch management problems, it has not been possible to extend the benefit of mulching to the larger mechanized operations.

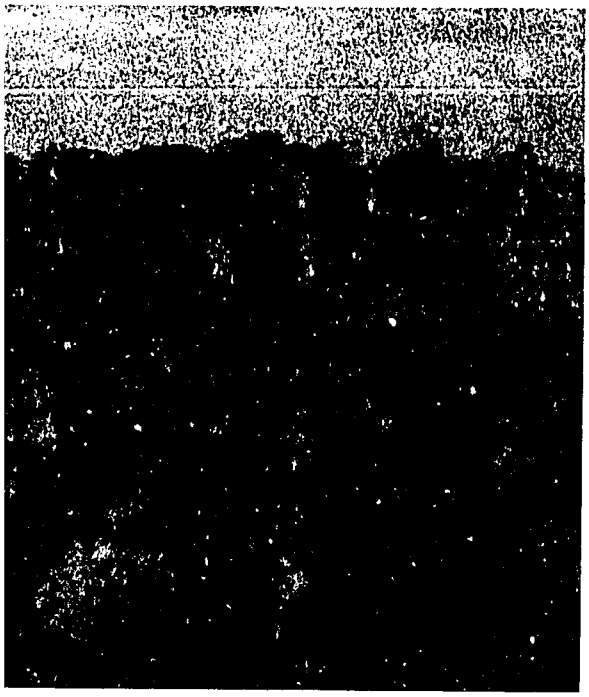
In situ mulch produced from the residue of a cover crop which occupied the land during fallow has been found most suitable for no-till maize and grain legume production, but not all cover crops produce residue or mulch compatible with mechanized no-till planting. Of those tested at IITA, mucuna (*Mucuna utilis*



syn. *Stizolobium deeringianum*), a leguminous cover crop, has been found to be the most compatible with existing no-till planting equipment. It is a fast growing creeping leguminous vine that fixes atmospheric nitrogen in the soil, and its residue mulch contributes to soil moisture retention, lower soil temperature, and a build-up of organic matter, all of which stimulate activity of earthworms.

The use of mucuna as a source for *in situ* mulch has been restricted to small-scale manual operations because the seeds may become weeds during cropping in the following rainy season. In small-scale operations, the fairly large seeds are hand harvested, but this is not feasible for large-scale harvesting as machines are not available for this purpose.

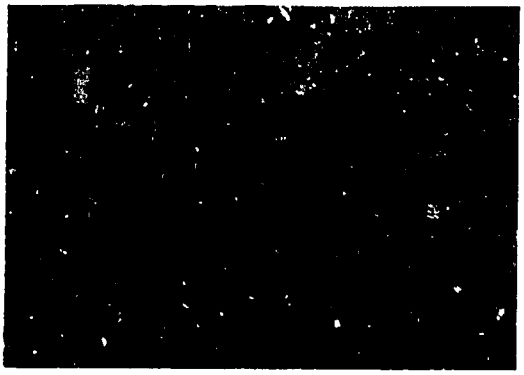
However, recent trials at IITA show that killing the mucuna plant and the seeds before seed maturity with machines is an effective method to prevent the seeds from becoming weeds in the succeeding crop. Of the several types of mowing machines tested at IITA, the



A leguminous cover crop of mucuna (left) has been found to be the most compatible with existing no-till planting equipment.

flail mower always gave the most satisfactory results. Mucuna was planted at the beginning of the rains in May and flail mowed during the dry season in December. The thick, even cover provided a good mulch for no-till planted maize.

Extending this *in situ* technique to mechanized grain production in the tropics should help eliminate rapid soil deterioration and minimize yield-reducing soil compaction. It permits a more stable production system for both small and large-scale farmers.



Upper photo: The flail mower produced the most satisfactory results; lower photo: a thick, even cover of mucuna provided a good in situ mulch for no-till planted maize.

"False Decapitation" of Plantain: an Improved Field Technique for Rapid Multiplication

Production of plantain – a major carbohydrate staple food in the wetter parts of the humid tropics – has not kept pace with demand from a fast growing urban population and prices are rising. Shortage of planting material stands out as a major constraint to expansion of the crop.

Of the many techniques developed to increase the multiplication rate, the two most common are decapitation with destruction of the apical meristem and *in vitro* multiplication with meristem tissue. The latter gives a high multiplication rate but it is too sophisticated for most farmers of developing countries in which plantain is important. The former has been used successfully, but this technique destroys the photosynthetic organs at the time of apical dominance suppression. This causes the new buds that sprout to produce new suckers that depend solely on food reserves of the parent plant for development. Consequently, sucker development is slow and the suckers produced are not as numerous and vigorous as desired.

To overcome the shortcomings of this technique, scientists have devised a method for destroying the apical meristem and eliminating apical dominance without destroying the photosynthetic organs. They call it "false decapitation." With this technique which is recommended for small farmers specializing in sucker production, a small cut is made near the ground in the base of the mother plant (Figure 10). A knife or similar instrument is inserted through it deep enough to destroy the meristem. Except for a small hole, the pseudostem and leaves are uninjured and continue to function for about three months after the operation.

The new technique that destroys the meristem but not the foliage produces significantly more sturdy suckers than the older technique in which the foliage was removed (Table 12). Furthermore, being able to produce viable suckers on four-month-old plants is a major improvement, and the older technique was not recommended for plants under six months.

Mounding soil around the base of the plant – another method suggested for stimulation of suckers – had no significant effect when combined with either of the techniques.

The new technique is undergoing further evaluation in on-farm trials.

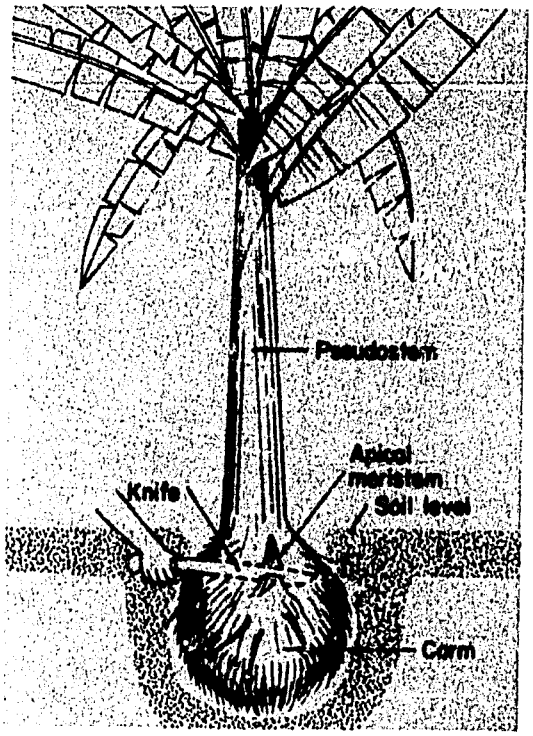


Figure 10. A new technique that destroys the meristem but not the foliage. It produces more sturdy plantain suckers than the older technique in which the foliage was removed. The new method is especially suited for small farmers specializing in sucker production.

Treatment	Time of treatment (Months after planting)		
	4	5	6
	Number of plantain suckers		
A	5	6	7
B	4	6	7
C	9	11	11
D	12	12	12

A: apical meristem and foliage destroyed.
B: same as A but with mounding soil.
C: apical meristem destroyed but foliage retained.
D: same as C but with mounding soil.

Table 12. Number of plantain suckers produced per stool in response to different treatments.

Harvesting cowpea breeding lines for the Grain Legume Improvement Program.

Annual Report Executive Summary

Grain Legume Improvement Program

Cowpeas and soybeans, primarily grown in different ecologies, complement each other as grain legume crops. Cowpeas are traditionally cultivated in diverse ecologies in association with millet, sorghum, maize, rice, cassava, yams, and cotton while soybeans are best suited as an alternate crop to maize but also grown as a mixed crop with cereals and other crops.

Production constraints for these two grain legume crops vary and are definitely location specific. Recently they have received more attention by national research programs than in the past, and improvements are starting to be made in traditional farm varieties and production technologies.

During 1985, scientists in the Grain Legume Improvement Program continued to develop stable, high-yielding lines suitable for the different ecologies and cropping systems with the principal aim of improving the income and nutrition of farm families. They have developed varieties which make cowpeas less risky for cultivation by small farmers. Most African farmers, for example, consider cowpeas a high risk crop because of pest and disease problems. Attention continued to be focused on new insect, disease, and drought resistant varieties. But the development of early maturing cowpea varieties, which is one of the drought escape mechanisms, also received a high priority during the year as another strategy for reducing risk of crop failure.

New soybean lines with free nodulation and good seed longevity also show promise for small farm cultivation. These varieties do not need rhizobium inoculum or nitrogen fertilizer and seeds can be stored under ambient conditions.

The overall strategy of the program is not only to continue to develop these lines but also to aggressively test the improved lines (genotypes) in various ecologies and cropping systems. Those found suitable can be used directly by national programs in certain areas for cultivation while other lines can serve as an important source of improved germplasm for national breeding programs.

To achieve this and other objectives, staff both at headquarters in Ibadan, Nigeria and locations in other countries interact closely with national scientists. Some of the key "outreach" locations and their principal research thrusts are:

- Burkina Faso — Cowpeas resistant to *Striga* (a noxious parasitic weed) and to drought.
- Niger — Dual purpose cowpeas for grain and fodder with minimum inputs for the Sahel region.
- Zimbabwe — "Promiscuous" soybeans which can yield well without inoculation and seeds with superior longevity for small farmers; cowpeas with resistance to drought for southern African countries.
- Kenya — Cowpeas and soybeans for mid-altitude and cold tolerance; also dual purpose cowpeas where leaves are consumed as a vegetable.
- Philippines — Cowpeas and soybean lines suitable for rice-based cropping systems in southeast Asia.

- Brazil — Resistance to potyvirus in cowpeas and improved soybean germplasm for Latin America.

Scientists have started to stratify IITA material for specific regions and to incorporate local adaptability in new lines for national breeding programs. Also, plans are being made to introduce regional coordinated trials. In the past, a large number of advanced nurseries have been set up as international trials throughout the world. In most cases, these trials were not location specific, but under the new proposed system, IITA should more effectively serve the national programs and assist them in developing improved lines in a much shorter period. Stronger regional breeding programs should also help solve some of the regional constraints. Furthermore, varieties developed under this system have the potential to be stable for a longer period, thereby reducing long-term research costs.

Research has been started on the development of dual purpose cowpeas for both grain and fodder suitable for the Sahel with minimum inputs. There is a critical shortage of fodder for animal feed in most semi-arid Sahelian countries in Africa.

An additional grain legume program dimension was added during 1985 to our soybean research — soybean utilization and processing for home consumption. Although in its infancy, this project is proving to be of much interest to national authorities, nutritionists, and rural women.

Scientists from many countries attended the Tropical Soybean Workshop on Research, Production and Utilization held at IITA in October 1985. One of the significant results of a World Cowpea Conference at the Institute the previous November was the publication of the proceedings in a book entitled, *Cowpea Research, Production and Utilization*. Proof of the worldwide interest in the conference sponsored jointly by IITA and Bean/Cowpea CRSP was the number of scientists, extension personnel, government officials and others who attended — 203 persons representing 34 countries in Africa, Asia, North and South America, and Europe.

The training program received special attention during the year, with soybean/cowpea production training increasing four-fold. In the past, one training course was offered each year at IITA but no regional courses. During 1985, two courses were held at IITA headquarters and two offsite in southeast Asia and Latin America. In addition a special intensive training course series was initiated for 12 national scientists from 11 countries during periods ranging from one to three months. Degree-related training was also expanded, and 12 graduate students from nine African countries participated in grain legume research for theses required by their universities.

In the following pages, notable research highlights during the year are briefly described. More complete information on these topics and those mentioned in this Executive Summary can be obtained by requesting the Annual Report of the Grain Legume Improvement Program.

Drought Tolerant Cowpea Varieties for West Africa

Drought – a serious problem in the semi-arid regions of West Africa – can occur at any time during a crop season, but the damage to cowpeas is more pronounced when it coincides either with flowering or pod filling. Very few known varieties can produce reasonable yields under low and erratic rainfall, high soil and atmospheric temperatures, and sand winds, particularly in the Sahel areas. Also, some of the varieties that do survive under these conditions lack certain other desirable traits such as good seed quality and resistance to diseases.

Scientists in Burkina Faso are engaged in developing improved cowpea varieties for drought-prone regions. Last year they tested three new varieties across a wide range of environments in collaboration with national

One of three new cowpea varieties developed for drought prone areas; tested across a wide range of environments.

Cowpea varieties	Yield 1984* (kg/ha)	Yield 1985** (kg/ha)	Seed color, texture	100 Seed weight (g)
New varieties				
KVx 30-305-3G	995	1,592	White rough	21
KVx 30-170-3G	963	1,404	White rough	21
KVx 30-309-6G	925	1,159	White rough	20
Others				
SUVITA-2	809	1,465	Brown rough	18
TN 88-63	793	1,283	White smooth	12
TVx 3236	715	1,305	White brown rough	13

* *Mean of 11 locations in West Africa.*
** *Mean of 4 locations in Burkina Faso.*

Table 13. Yield and seed characteristics of new drought tolerant cowpea varieties compared with others available in West Africa.

programs in West Africa. In spite of a serious widespread drought in 1984, these varieties produced mean yields ranging from 925 to 995 kg/ha—slightly higher than three other known drought tolerant varieties (Table 13). In the more favorable rainfall year of 1985, mean yields of four locations in Burkina Faso ranged from 1,404 to 1,592 kg/ha.

These new varieties with preferred seed characters are also capable of producing enough plant growth to make them useful for forage. A limited quantity of seed is available from the IITA/SAFGRAD Project.

A cowpea crop severely damaged by drought in Burkina Faso.

Root Systems of Cowpeas and Their Relationship to Drought Tolerance

During the past two years, scientists have examined the genetic variability for root characteristics in cowpeas, and their preliminary results show significant differences among several IITA-improved varieties for root length and mass within four weeks after planting. In the semi-arid regions of the tropics where farmers normally plant the crop, fast growing, deep, and dense root systems are desirable because they can increase resistance to drought.

In cowpea production areas, rainfall may exceed crop-water use during part of the rainy season. Since most of the water in the surface layer is lost by evapotranspiration, part of the excess water is only available deep down in the soil profile. Here it is accessible only to varieties with deep, extensive root systems. Also, better

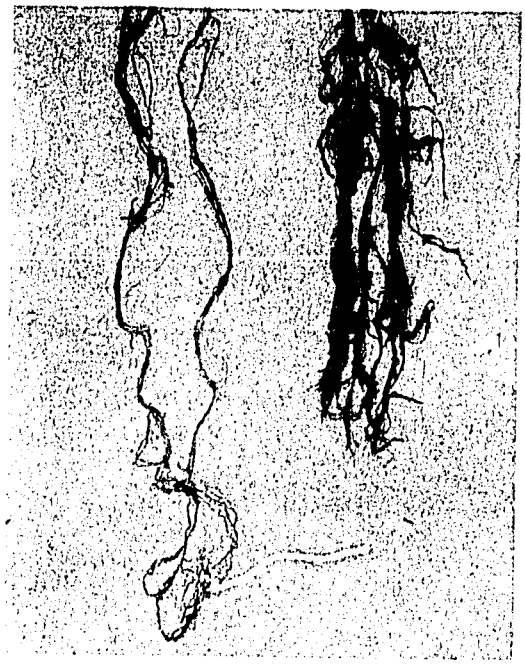
Cowpea variety	Root length* (cm)	Root dry weight* per plant (g)
IT 82E-60	91.9	1.6
IT 81D-1020	93.5	0.7
IT 81D-812	92.8	1.0
VITA-7	84.3	1.1
IT 82D-716	71.8	1.1
VITA-3	70.5	1.2
TVx 3236	66.5	1.9
LSD (5%)	21.7	0.7

**Four weeks after planting.*

Table 14. Root characteristics of IITA-improved cowpea varieties.

root growth can be particularly useful in soils that offer considerable resistance to root development. A "Dior" soil in the semi-arid zone of Senegal is an example.

Trials at IITA showed that varieties IT 82E-60, IT 81D-1020, and IT 82D-812 had faster root growth and IT 82E-60, TVx 3236, and IT 81D-716 relatively more root mass compared with other varieties (Table 14). Variety trials in Sahelian environments have shown TVx 3236 and VITA-3 to be drought tolerant. Further studies are underway to clarify the relationship between root characteristics and drought tolerance.



Left, a cowpea variety (IT81D-1020) with a fast root growth and right, one with more root mass (VITA-3) which is drought tolerant in Sahelian environments.

Performance and Prospects of Dual Purpose Cowpeas for West African Farmers

In the Sudan Savanna and Sahel ecologies of West Africa, fodder obtained from cowpeas is as important to many farmers as the grain. Nearly every household has domestic animals and a severe shortage of feed is the normal situation in the dry season.

Essentially, a good dual purpose variety should produce a reasonably fair grain yield (600 to 800 kg/ha) while retaining its foliage until the end of the season when the vines and leaves are harvested for fodder, sun-dried, and stacked away for livestock feed in the dry months when pasture is not available. Both grain and fodder attract almost equal market prices in times of scarcity.

Local long-maturing varieties (100–140 days) produce good fodder but very low grain yields (100–200 kg/ha), and several new varieties average 1,500 kg/ha of grain in 55 to 75 days but cannot be used for fodder because they shed their leaves at maturity. In-between these two groups are varieties which, if properly managed, can serve the dual purpose usage. To meet this requirement, IITA and national program scientists in Kano, Nigeria and Niamey, Niger Republic evaluated some medium maturing cowpeas for their suitability as grain and fodder varieties.

Preliminary results from Kano in 1983 indicated that TVx 4659-03E — a multiple disease resistant variety — could be suitable as a dual purpose cowpea. It gave higher grain (1.7 t/ha) and fodder (4.5 t/ha) yields than either IAR 341 (1.6 t/ha of grain and 3.5 t/ha of fodder) or IT 82E-60 (1.1 t/ha of grain and 0.8 t/ha of fodder).

A multilocation trial involving local and improved varieties carried out at research stations and farmers' fields in Kano and Niamey areas in 1984 confirmed the superior qualities of TVx 4659-03E as a dual purpose cowpea. Yields obtained for this variety in Nigeria ranged from 1.3 t/ha of grain and 5.2 t/ha of fodder in areas which received about 850 mm of annual rainfall (Kadawa, for example) to 1.0 t/ha of grain and 2.6 t/ha of fodder in drier zones (Mallam Maduri, for example) with approximately 400 mm of rainfall. Corresponding yields for this variety in Niamey (260 mm rainfall) were 1.0 t/ha for grain and 0.8 t/ha for forage.

In the 1985 cropping season, other varieties which combine high grain yield with pest and disease resistance and good consumer appeal were included in the trials both in Nigeria and Niger Republic. At Samaru, Nigeria, the varieties were planted once weekly starting from July 29 to August 12, but only one planting was done in Niamey, Niger Republic. There was a progressive drop in both grain and forage yields of all test varieties with each week delay in planting. The largest reduction was suffered by the early-maturing variety IT82E-60, but TVx 4659-03E consistently gave over a 4 t/ha fodder yield for all three planting dates. It also gave the highest grain yield (1.6 t/ha) and a modest 2.1 t/ha forage yield in Niamey (Table 15).

Research is continuing to identify dual purpose lines that will perform well when intercropped with cereals and under minimum protection inputs.

Cowpea fodder for livestock put on top of houses to dry in a village near Kano, Nigeria; in addition to the fodder, the dual purpose cowpea produced a fair grain yield.

Cowpea lines	Samaru Grain (kg/ha)	Samaru Forage (kg/ha)	Niamey Grain (kg/ha)	Niamey Forage (kg/ha)
IT 81D-994	518	2,647	215	2,012
TVx 4659-03E	674	4,592	1,600	2,078
Local (checks)*	124	1,252	**	3,531

**Sam Booth White Early in Samaru; Local Sadore in Niamey.*
***Not included in analysis for grain yield.*

Table 15. Performance of dual purpose cowpea lines at Samaru, Nigeria and Niamey, Niger Republic (1985).

Cowpea Lines Resistant to New Strains of Two Common Viruses

Among the several viruses known to infect cowpeas in Africa, the aphid-borne mosaic virus (CAbMV) ranks as the most important in all areas where farmers grow the crop. In second place is the beetle-transmitted cowpea yellow mosaic virus (CYMV).

In surveys for cowpea viruses in Nigeria over the past two years, isolates of CAbMV were obtained which exhibited considerable pathogenic variation on the basis of their symptoms (type and severity) on some selected test plants and cowpea varieties such as Ife Brown and IT28E-10. A new isolate ("IT-16") seems to represent a different strain of CAbMV than the "Onne" isolate used so far in resistance screening.

In 1985, a new strain of CYMV (CYMV-K) was identified. The isolate representing this strain was found in a farmer's field in Nigeria's Kano State. In initial tests, it infected the cowpea line IT 82E-10 which was found to be immune to CYMV, the standard isolate used so far for resistance screening.

Because of the pathogenic variation of both CAbMV and CYMV, scientists are updating available information on resistance to these strains and screening several advanced cowpea breeding lines for resistance to the new isolates. They tested 176 breeding lines with CAbMV and 59 cowlea lines with CYMV. One-week-old seedlings were inoculated on the primary leaves with a second inoculation three days later to avoid any escapes. The plants were scored for reaction 10, 20, and 30 days after the second inoculation and graded on a scale of 1 (no symptoms) to 5 (severe symptoms).

Evaluation of the symptoms in the 176 breeding lines inoculated with the isolates "Onne" and "IT-16" of CAbMV showed that the advanced breeding lines IT 82E-889, IT 82E-60 and IT 82D-885 are highly resistant to both isolates (Table 16). The breeding line IT 82E-16 was resistant to the "Onne" isolate but susceptible to the "IT-16" isolate.

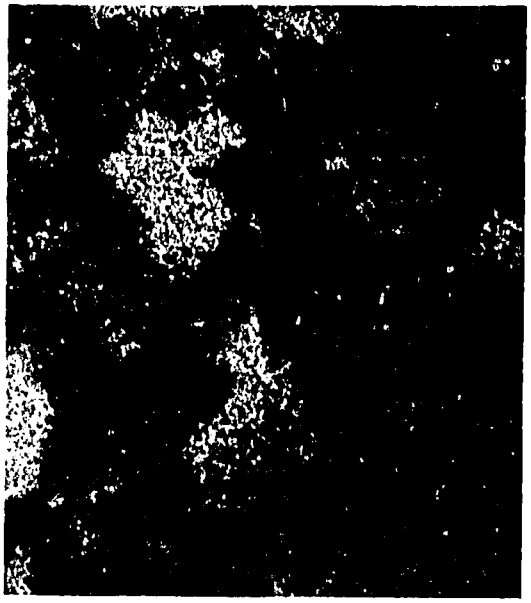
The screening of 59 cowpea lines to the new isolate of CYMV ("K") revealed that Vita-1, Vita-3, and IT 82E-16 are also highly resistant to the new isolate (Table 17). Cowpea lines IT 82E-10 and TVu 410, which are immune to the standard isolate CYMV-6, showed a susceptible reaction to the CYMV-K strain.

Breeding line	Reaction rating* Onne isolate	IT-16 isolate
Ife Brown (TVu-3629)	5	5
IT 82E-10	1	5
IT 82E-889	1	1
IT 82E-60	1	1
IT 82E-16	1-2	4
IT 82D-885	1	1
IT 82D-716	2	1
IT 82D-789	4	5
IT 82E-18	2	4

*1 = no symptoms, 5 = severe symptoms.

Table 16. Reaction of selected cowpea lines to two isolates of aphid-borne mosaic virus (CAbMV) in Nigeria.

Particles of cowpea aphid-borne mosaic virus magnified 57,000 times.



Particles of cowpea yellow mosaic virus magnified 112,000 times.

Results obtained in this study demonstrate that some breeding lines found earlier to be resistant to the standard isolates of CAbMV and CYMV are susceptible to the new isolates. However, the majority of lines used so far in screening at IITA which have resistance to the standard isolates of the viruses also possess resistance to the new isolates. Nevertheless, potential breeding parents are being screened for resistance to all known types of the viruses.

Breeding lines	Reaction rating* CYMV-6 isolate	CYMV-K isolate
IT 82E-10	1	4
IT 82E-16	1	1
VITA-1	1	1
VITA-3	1	1
TVu 410	1	3

*1 = no symptoms, 5 = severe symptoms.

Table 17. Reaction of selected cowpea lines to two isolates of yellow mosaic virus (CYMV) in Nigeria.

Left, a tan-seeded cowpea line, (CNCx 252-1E) with combined resistance to potyvirus complex and cowpea severe mosaic virus; right, a virus susceptible variety VITA 7.

Virus Resistant Cowpeas for Latin America

Although a majority of Latin Americans prefer dry beans, cowpeas play an important role by providing inexpensive vegetable protein. In northeastern Brazil, for example, average annual per capita consumption has reached 40 kg. Furthermore, from a production standpoint, cowpeas in a tropical lowland ecology have several advantages over dry beans – fewer diseases and insect pests and greater tolerance to drought, waterlogging, infertile soils, and acid stress.

But cowpea production has some constraints to overcome, including yield losses caused by the cowpea severe mosaic virus (CSMV) and the potyvirus complex. The former is specific to the Americas and strains of the latter appear to be different from cowpea aphid-borne virus (CAbMV) in Africa. To help reduce the yield losses caused by these viruses, Brazilian and IITA scientists are incorporating resistance into improved germplasm.

CNC 0434 – a white-seed variety released in 1985 – carries the gene for immunity to CSMV. It was selected in Brazil from a population sent from IITA's headquarters in Nigeria and has now been recommended by several states in that country. BR 1-Poty – a tan-seeded variety – carries field-level resistance to the potyvirus complex and was released in Brazil in 1984. (IITA's germplasm line TVu 410 was the donor of the resistance genes.) Both varieties were sent by the IITA/EMBRAPA Latin American Regional Legume Program in 1985 to approximately 20 sites outside of Brazil.

Several tan-seeded breeding lines have now been developed that combine resistance to both viruses. CNCx 187-22D-2, tested in an Advanced Yield Trial in 1985, demonstrated good yield potential (Table 18). Performance of another tan-seeded line with combined resistance – CNCx 252-1E – is shown in Table 19. Both of these lines are now being used as parental material in the crossing program. Because many countries prefer large seed varieties, CNCx 187-22D-2 is a particularly

useful parent due to its combined virus resistance and acceptable seed size.

Out of 17 improved cowpea varieties released by various states in Brazil since 1981, seven are directly from IITA germplasm and four from crosses involving IITA germplasm.

Although it is not possible at this time to document the total area occupied by the new cowpea varieties derived directly from IITA germplasm, farmers in many Brazilian states have planted them. For example, at least 6,000 hectares of EPACE 1 are now grown in Ceara State, and it is popular also in Piaui and Rio Grande do Norte. EPACE 6 has shown promise in intercropping with sugar cane in Ceara State and with cotton in Paraiba, and Manaus is

Table 18. Performance of cowpea line CNCx 187-22D-2 with virus resistance in Advanced Trials at Goiania and Serra Talhada, Brazil (1985).

Cowpea lines	Virus scores*		Trial locations		Seed Weight
	Poty-virus	Severe mosaic	Goiania	Serra Talhada	
			Yield (kg/ha)		(g/100)
CNCx 187-22D-2	2.0	1	1,041	925	17
Checks					
Pitiuba (local)	3.0	4	421	850	20
CNC 0434	3.5	1	697	605	14
BR 1-Poty	2.0	5	837	925	13
Trial X (25 entries)			855	762	
CV (%)			21	29	
LSD (5%)			256	328	

** 1 = highly resistant, 5 = very susceptible ; scores from inoculated trial.*

Table 19. Performance of cowpea line CNCx 252-1E with virus resistance in Preliminary Trials at Goiania and Quixada, Brazil, (1985).

Cowpea lines	Virus scores*		Trial locations		Seed weight
	Poty-virus	Severe mosaic	Goiania	Quixada	
			Yield (kg/ha)		(g/100)
CNCx 252-1E	1.0	1	767	737	14
Checks					
Serido (local)	3.0	4	268	440	19
CNC 0434	3.5	1	592	720	14
BR 1-Poty	2.0	5	554	731	13
Trial X (49 entries)	-	-	494	478	
CV (%)		-	17	37	-
LSD (5%)			146	280	

** 1 = highly resistant, 5 = very susceptible ; scores from inoculated trial.*

widely grown in the humid north in the states of Amazonas, Rodonia, Acre, and Roraima. CNC 0434 and BR 1-Poty are being multiplied in several states because of their resistance to virus diseases.

A white-seeded cowpea variety (CNC 0434), which carries the gene for immunity to cowpea severe mosaic virus, was released in Brazil in 1985. It is being multiplied for farmer use.

Improved Aphid Resistant Cowpeas

Aphids (*Aphis craccivora*), a major problem in all cowpea growing countries, not only cause direct damage by feeding on the plants but also transmit virus diseases. To help counteract this production constraint without resorting to repeated insecticide sprays, IITA scientists identified several sources of aphid resistance. Then, through a systematic breeding program over the past four years, they developed improved varieties which combine aphid resistance with multiple disease resistance and high yield potential. These were first evaluated for yield in 1984 and retested in 1985.

Specific sprays are sometimes needed to control aphids only, particularly at the seedling stage in dry regions. With aphid resistant varieties, farmers could reduce the number of sprays. However, they may still have to use insecticides to control other insects during the growing season.

The general performance of six varieties during 1985 at four locations in Nigeria and one in Burkina Faso is shown in Table 20. In these multilocational tests, IT 83S-712-11 and IT 83S-728-5 had the two highest overall mean yields. They consistently performed well at all locations with good resistance to aphids. Seeds of these two lines have been multiplied and will be distributed to various national programs in 1986 in an international trial.

Two cowpea breeding lines resistant to aphids (left and right) compared with a susceptible line in the middle.

Table 20. Yield performance of aphid resistant cowpea varieties at five locations (1985).

Cowpea variety	Locations: Kamboinse B. Faso	Samaru Nigeria	Ibadan Nigeria	Kano Nigeria	Mokwa Nigeria	Overall Mean	Days to maturity Ibadan
	Grain yield kg/ha						
IT 83S-742-11	**1,357**	**1,346**	**1,461**	**1,816**	**1,300**	**1,456**	**63**
IT 83S-728-5	**1,328**	**1,451**	**1,271**	**1,555**	**1,404**	**1,402**	**63**
IT 83S-712-13	1,417	908	1,287	1,169	1,113	1,251	62
IT 83S-728-13	1,131	1,002	1,517	1,086	1,386	1,231	62
IT 83S-720-2	1,519	815	1,407		832	1,158	62
IT 83S-713-1	813	1,011	1,258	1,212	1,235	1,121	63
IT 81D-1137 Control	1,179		1,307	191	910	1,017	70
LSD 5%	150	151	317	727	309		
CV	21	39	17	17	20		

Potential for Soybean Production in High Altitude, Semi-Arid Regions of Rwanda

Although the soybean is a newly introduced crop in Rwanda, its cultivation is spreading fast as a complementary grain legume to beans and peas. Trials conducted by scientists in the ISAR/IITA farming systems research project during the past two years indicate that it has high potential in marginal areas such as Bugesera and Gisaka where the bean crop faces several constraints, including low rainfall (350–400 mm per season), poor soils (particularly on the plateau), and serious disease problems.

But the soybean also faces production problems in Rwanda, including poor nodulation with native rhizobium, rapid loss of seed viability when stored in a warm, humid environment, and poor germination under inadequate rainfall at the time of sowing or during a dry spell of 7 to 10 days immediately after sowing. To tackle these environmental constraints, scientists assembled a wide range of genetically diverse soybean genotypes from different sources for testing on the poor plateau soils.

More than 70 lines were evaluated at Kagasa during 1983–85 under multiple stress conditions such as low fertility, unpredictable dry spells, and disease pressure. Most adaptable lines selected from these initial trials were advanced to multilocational tests at different agro-ecological zones of the Burgesera-Gisaka-Migongo region. Grain yields of six promising early-maturing lines at two sites are shown in Table 21.

Yields at Dihiro, which represents the Buges zone characterized by low rainfall and poor soils, were generally low. Soybean line L2-3 gave the highest yield of 1125 kg/ha followed by L2-7 with a yield of 775 kg/ha. At Kibungo in the Buju zone with relatively fertile soils and better rainfall, yields were considerably higher. Based on mean yields, all the soybean varieties except Branton yielded more than 1,000 kg/ha. Farmers can plant these early-maturing lines during both seasons.

Days to maturity and grain yields of six medium-to-late maturing soybean lines which gave consistently good yields over two years are shown in Table 22. The medium maturing lines are well adapted to drought stress and low soil fertility. Based on other trials, the long duration lines showed a potential for use as a green manure cover and fodder crop. Furthermore, soybeans performed well in mixed cropping systems.

On-farm varietal evaluation of soybeans presently underway will identify appropriate and potentially productive varieties for different agro-ecological zones.

"Promiscuous" and "non-promiscuous" soybeans developed for high altitudes. ("Promiscuous" lines nodulate with rhizobia indigenous in African soils and yield well without innoculation.)

Soybean line/ variety	Days to maturity	Yield (kg/ha)		
		Dihiro	Kibungo	Mean
Branton	100	477	1,125	786
Palmetto	105	631	1,518	1,074
L2-3	**115**	**1,122**	**1,687**	**1,404**
L2-7	**115**	**775**	**2,079**	**1,427**
PK 7394	100	688	1,406	1,047

Table 21. Performance of five early soybean lines at Dihiro and Kibungo, Rwanda during October–January 1984–85.

Soybean line	Days to maturity	Yield (kg/ha)
TGx 711-01D	180	1,270
TGx 573-6E	180	1,234
TGx 297-35c	180	1,201
TGx 533-65c	140	1,132
TGx 536-100cy	140	1,091
TGx 422-02D	130	1,013

Table 22. Growth cycle and mean grain yields of six promising late soybean lines for the Burgesera-Gisaka-Migongo region in Rwanda.

Relationship between Populations and Row Spacing to Soybean Yield

As soybeans become more popular in Africa with both smallholders and large-scale commercial growers, improved management as well as better varieties can contribute to higher yield. Scientists conducted a trial at IITA during 1985 to see how yield varied with changes in varieties, distance between rows, space between plants within rows, and population.

The most notable effect in the trial was the difference in yield with varying distance between rows (Figure 11). Two of the lines used (TGx 930-9C and TGx 814-26D) tend to be erect with upright branches. These two lines showed a clear linear relationship between yield and distance between rows. As the distance decreased from 75 to 60 to 45 to 30 cm, the yields of these lines increased. The third line tested (TGx 306-036C) tends to be bushy with spreading branches. The relationship between spacing and yield is not so clear as with the other lines. It had the highest yield with the closest spacing, but yields were nearly the same for the other three row spacings.

Soybeans in this trial were planted in densities from 66,000 to 666,000 plants/ha and analysis relating yield directly to populations (ignoring the arrangement in the field) showed no obvious trends. The soybean plants were insensitive also to different spacing between plants in the same row and yield did not change significantly with spacings of 5, 10, or 20 cm between plants.

This study has implications for farmers in the Nigerian savanna and other areas where local farmers plant on fixed ridges. In this system, the farmer each year makes ridges on the previous year's furrows, and these ridges are usually 90–110 cm apart. They can be changed only with much manual labor or with animal or tractor drawn implements to level the field and create narrower furrows between ridges. Planting on ridges is practiced in parts of the savanna to avoid moisture stress in the peak rainy periods and to hold moisture during dry spells.

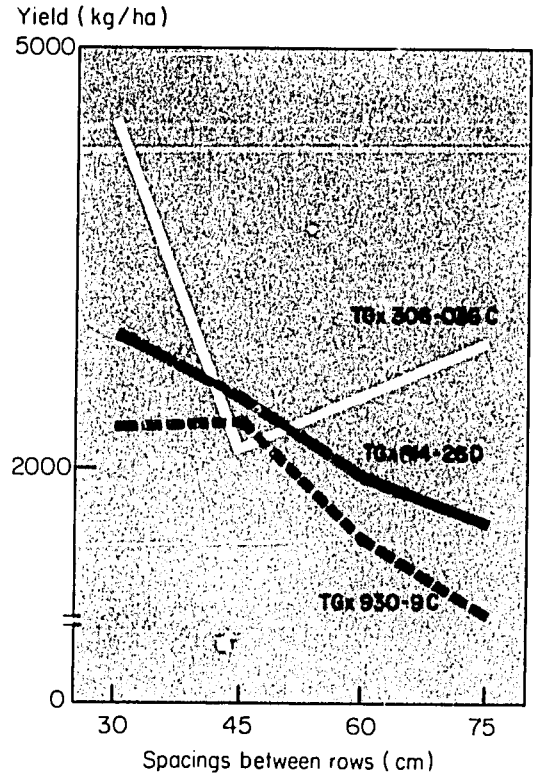


Figure 11. Soybean varietal yield responses to changes between row spacings.

Findings of this research suggest that soybeans can compensate for a lower population and fill in gaps resulting from poor stand establishment with more vigorous growth. But the research also indicates that the farmer can achieve greater yield by planting in closer rows. The dilemma and challenge for further research may be to find how the farmer can change the pattern of rigidly fixed wide ridges using available tools and methods.

Soybeans planted by a farmer and his family under high population in an intercrop situation.

Testing Tropically Adapted Soybeans for Resistance to Soybean Mosaic Virus

Soybean mosaic virus (SMV) is found in many parts of the world and can cause serious yield losses when it is epidemic. So far, in Nigeria and other areas of West and Central Africa, SMV becomes a serious problem only in the dry season but because the disease is often seed-borne it can spread from one season to the next. Infected plants may be stunted and less productive, leaves tend to be narrower, leaf margins turn down, and blades become severely ruffled along the edge of the main veins.

Soybean lines resistant to SMV were tested in 1985 for yield and agronomic characters, and lines with tropical adaptation, high yield, and desirable agronomic characteristics now incorporate SMV resistance (Table 23).

The work represents a cooperative effort between the soybean breeders and virologists at IITA and with the International Soybean Center (INTSOY) in the United States.

Realizing the potential problem of SMV, scientists crossed tropically adapted lines with soybean introductions from the U.S. known to be resistant to this virus. Segregating F_3 populations from these crosses were grown at IITA headquarters in the 1983–84 dry season with a susceptible control variety, each plant in the population was inoculated with SMV isolate "Micro-A" – a highly virulent strain of

Entry	Yield (kg/ha)	Shattering* 1–5	Lodging** 1–5	Height (cm)	Maturity days	Greenhouse screening of SMV*** Micro A	SMV-10
5642-1	2,709	3.5	1.7	70	97	1&2 (segr.)	1
TGx 1035-27D	2,593	2.0	1.7	78	98	1	1
TGx 1035-26D	2,505	3.3	2.7	73	97	1	1
TGx 1035-28D	2,394	3.5	2.4	108	100	1	2
5631-2	2,392	1.7	1.9	71	98	1	1
TGx 536-02D (control)	1,860	3.5	1.3	61	97	4	1&4 (segr.)
Trial mean	1,825	3.3	2.3	74	100		
Standard error	245	0.4	0.4	7	1		
CV (%)	23	19.8	32.9	17	2		

*Shattering rating: 1 = no pods shattered; 2 = < 25% shattered; 3 = 25–50%; 4 = 50–75%; 5 = > 75% shattered.
**Lodging rating: 1 = all plants erect; 2 = some plants leaning or lodged; 3 = most plants leaning, some lodged; 4 = most plants lodged; 5 = all plants lodged.
***Soybean mosaic virus ratings (1–5 scale): 1 = no symptoms, 5 = severe symptoms.

Table 23. Mean yield and agronomic characteristics of promising soybean lines with resistance to soybean mosaic virus (SMV) grown at Mokwa, Nigeria (1985).

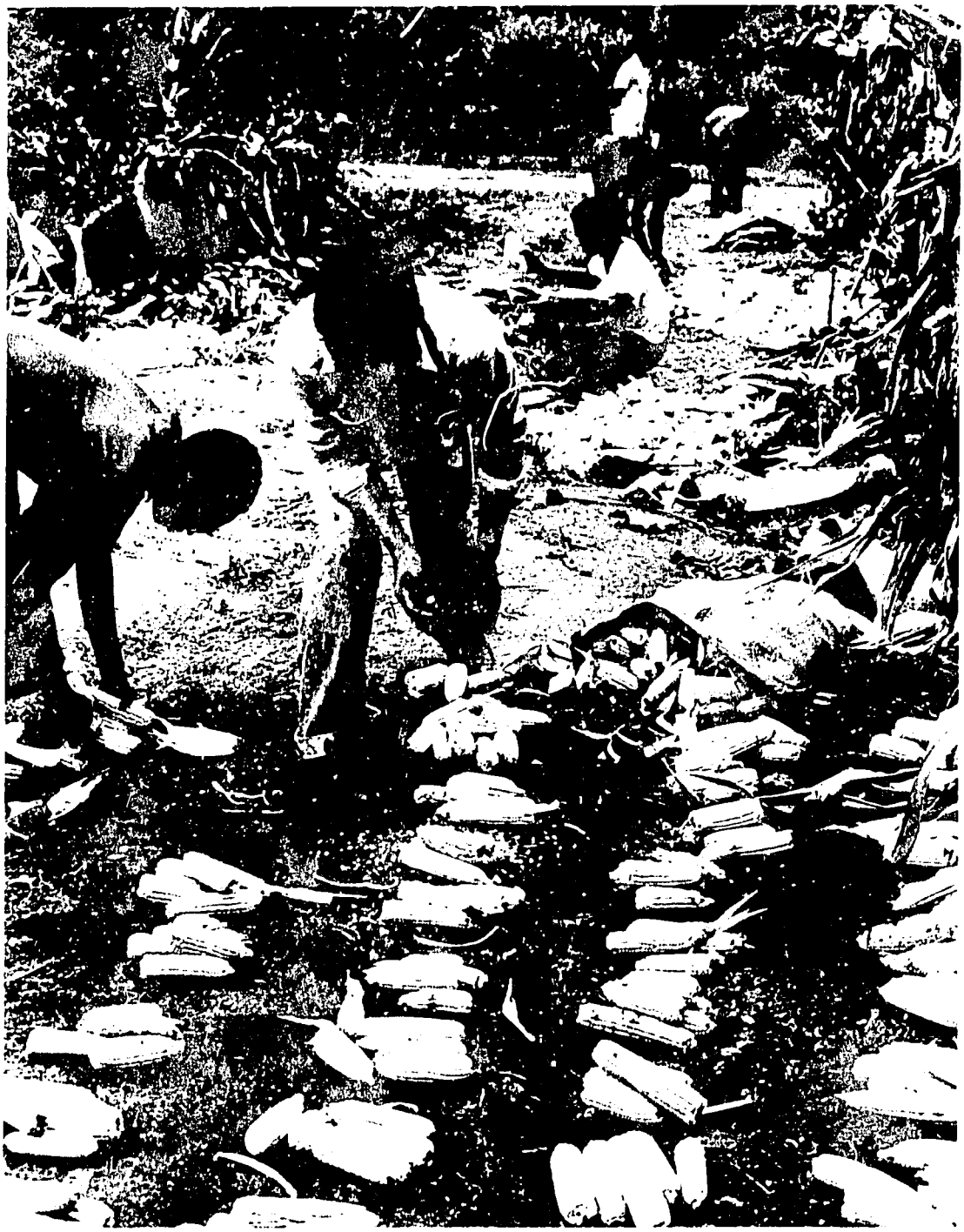
the virus which causes severe symptoms. Plants showing SMV symptoms were pulled and the remaining plants harvested individually.

A few seeds from each plant were tested for resistance to SMV and the remaining seed shown in progeny rows in the 1984 rainy season. About half of the plants that showed no symptoms after inoculation in the field the previous dry season had symptoms after inoculation with the same isolate in the greenhouse. Single plants were selected in the field in 1984 from progeny rows of the lines that showed no reaction in the greenhouse. These plants were grown in progeny rows in the 1984–85 dry season where they were tested for free nodulation, seed storability, and shattering. The plants acceptable for these traits were harvested and used in a yield trial at Mokwa, Nigeria in 1985.

At the most recent stage of testing, seed from each entry in the field trial was again sown in the greenhouse and tested with SMV-"Micro A" and with another isolate (SMV-10) which is less virulent, though typical of the virus found in the field. So far, lines resistant to "Micro A" are generally resistant to common forms of the virus. Lines showing no symptoms of SMV in the greenhouse are tested to a susceptible variety as well as by serological means. If both back tests are negative, it is assumed that the line is resistant to SMV as it occurs in Nigeria.

Some of the lines shown in Table 23 do not have adequate resistance to shattering and lodging, and they have not yet been tested for their reaction to other diseases. All the lines listed in the table represent early-maturing types. They will be crossed with other tropically adapted lines to bring in other resistance if necessary and to incorporate SMV resistance into lines in other maturity groups. Work has begun to test other populations of crosses between adapted parents and SMV resistant lines from Zimbabwe and the U.S.

Soybean mosaic virus: Symptoms of a common mild type (left) and a severe type rarely found in Nigeria (right).



Scientists develop improved maize varieties for important African ecologies where the crop is grown.

Annual Report Executive Summary
Maize Research Program

Recognizing the need to strengthen research for increased maize production in Africa, avoid duplication of efforts, and improve coordination of the international testing programs, IITA and CIMMYT established a joint program for Africa in 1985. The most significant undertaking of this program during the year was the establishment of the mid-altitude germplasm development site in cooperation with the University of Zimbabwe. Initially, two scientists — a breeder and an entomologist — were posted in that country and other scientists will be assigned to the project later. Its major aim is to develop stable, high yielding, and disease-resistant maize germplasm adapted to the mid-altitude ecology in Africa.

In addition to Harare, Zimbabwe, the joint program operates presently in two other major sites: Ibadan, Nigeria and Ouagadougou, Burkina Faso. The three represent all the important ecologies where maize is grown in Africa except high altitude — over 1800 m above sea level. Scientists at each of these sites are concentrating on the improvement of maize germplasm for the national programs in Africa. Another new dimension in IITA's Maize Research Program was the posting of a breeder with the national program in Zaire.

Ten years of research and breeding for resistance to maize streak-virus (MSV) — an African endemic disease — was completed in 1985. It is one of the most economically important diseases in sub-Saharan Africa and widely distributed across the continent. It can be insignificant in some years or areas but then strikes with devastating crop losses in other years or places. For example, a severe MSV epidemic occurred in 1983 and 1984 in all the savanna zones of West Africa, and a severe outbreak was reported recently from Zambia, Angola, Mozambique, and some other southern African countries.

The Institute's work on streak resistance is a classical example of a well focussed and targeted breeding program aimed at solving a serious constraint to production of maize in Africa. Involved in this research were IITA breeders, entomologists, virologists, and pathologists, one or two CIMMYT maize breeders beginning in 1980, and scientists from many African national programs. The latter also participated in the international progeny testing and the selection of the families that later constituted the experimental varieties. As a result of these efforts, there are now streak resistant varieties and hybrids available to cover all the relevant ecologies in Africa and with different maturity ranges, grain color, and texture to meet the preferences of African farmers in various countries.

Streak resistant variety trials were sent upon request to most of the African countries, and the "feedback" indicates that the resistance is stable across the continent. Many requests for additional seeds of selected varieties have been received and dispatched. Streak resistant varieties are already commercially grown in at least six countries — Nigeria, Ghana, Benin Republic, Togo, Sao-Tome and Zambia — and probably others. If available varieties were to be adequately used by all national programs, the problem of streak in Africa would be solved.

Part of the work in the streak resistance breeding program was devoted to conversion of selected non-streak resistant varieties to resistant varieties by backcrossing. The varieties were selected based on their performance in several African countries. Converted varieties were included in the streak resistance variety trials in the last few years with encouraging results.

While emphasizing streak resistance work, scientists were not neglecting other constraints to maize production in Africa. Drought was particularly serious during *1983 and 1984*. The IITA/SAFGRAD team based in Ouagadougou, Burkina Faso concentrates its research work on the development of technology to minimize the effect of drought stress. Tied-ridges, introduced in Burkina Faso by the IITA/SAFGRAD Agronomy Program, have helped to reduce runoff, increase soil water reserves, and markedly increase grain yields of maize and other crops in the predominate soils of that country. An implement adapted to animal traction and designed for tie-ridging was farm tested on a large scale during 1985. Preliminary reports indicate that it has possibilities to make ridging less laborious and more attractive to farmers.

Early maturing varieties, even though potentially lower yielding, have an obvious advantage in short rainy seasons. Breeding early varieties with 90–95 days to maturity was emphasized in the past in the Maize Research Program. However, experience in the past few years has shown that in drought years a closer fit between the effective length of the growing season and the varietal time of maturity is required. Farmers in the Sudan Savanna may be better off planting even earlier maturing varieties at least in part of their fields. Two very early-maturing local varieties with acceptable yield potential were identified by the team in Burkina Faso. Efforts continue to further improve yield potential, agronomic characteristics, and adaptability of these varieties.

Areas cultivated with maize in the Northern Guinea Savanna zone (900–1200 mm rainfall) have increased dramatically in the past two decades. But as the maize spread so did *Striga* – a parasitic weed. A 1984–85 survey completed in Nigeria, Benin, and Togo showed that under severe infestation farmers abandon their fields because of complete crop failure. Even in well managed, highly fertilized experimental fields yield reduction of susceptible varieties was as high as 90%.

The maize program initiated screening work for *Striga* resistance three years ago under natural field infestation, and several inbred lines and hybrids were developed showing tolerance and reduced damage under *Striga* infestation. Unfortunately, because natural field infestation is not uniform and sometimes unpredictable, it does not permit efficient breeding programs. Therefore, attempts are presently underway to develop more reliable screening methodology in the field, greenhouse and laboratory.

Work has continued to screen for resistance to stem borers, particularly *Sesamia calamistis* which is one of five different species causing significant yield losses in Africa. Progress so far is only marginal. Therefore, we are intensifying efforts to develop artificial mass rearing facilities for maize borers and reliable field infestation techniques.

Although stalk rot usually does not reach epidemic proportions, it causes from 10 to 15% yield losses in farmers' fields due to premature death of the maize plants and or lodging. Artificial field infestation techniques have been adapted to the tropical environment at Ibadan for three causal organisms, and they are being used to screen for resistance to stalk rot.

The techniques are reliable and uniform and being widely used by maize breeders in population improvements, as well as in inbred lines and hybrid development.

Storage insects also account for a share of the losses suffered by farmers. But our scientists believe they can develop maize varieties in the future which will be resistant or tolerant to weevils. Observations during 1985 showed great variability among maize varieties and hybrids in response to long-term storage under normal room temperature conditions.

Research in the hybrid maize project, supported largely by the Government of Nigeria, was intensified in 1985 with emphasis on development of three-way cross hybrids to enable production of cheaper seeds and obtain more stable seed production. On-farm demonstration trials were conducted in almost all the states in Nigeria. Agronomic trials were also carried out in the different agro-ecological zones of the country. Two private seed companies (one formed in early 1985) produced enough hybrid seeds to plant about 40,000 ha in 1986 compared with only 6,000 ha in 1985.

Some people believe that hybrids have a narrower adaptational range and that their potential can be realized only under good growing conditions and management. Results obtained for two of the hybrids does not support this belief. These hybrids were found to perform well across different ecological zones in Nigeria and also under stress conditions such as drought and *Striga* infestation.

In the following pages, a few 1985 research highlights are briefly described. More complete information on these topics and those mentioned in this Executive Summary can be obtained by requesting the Annual Report of the Maize Research Program.

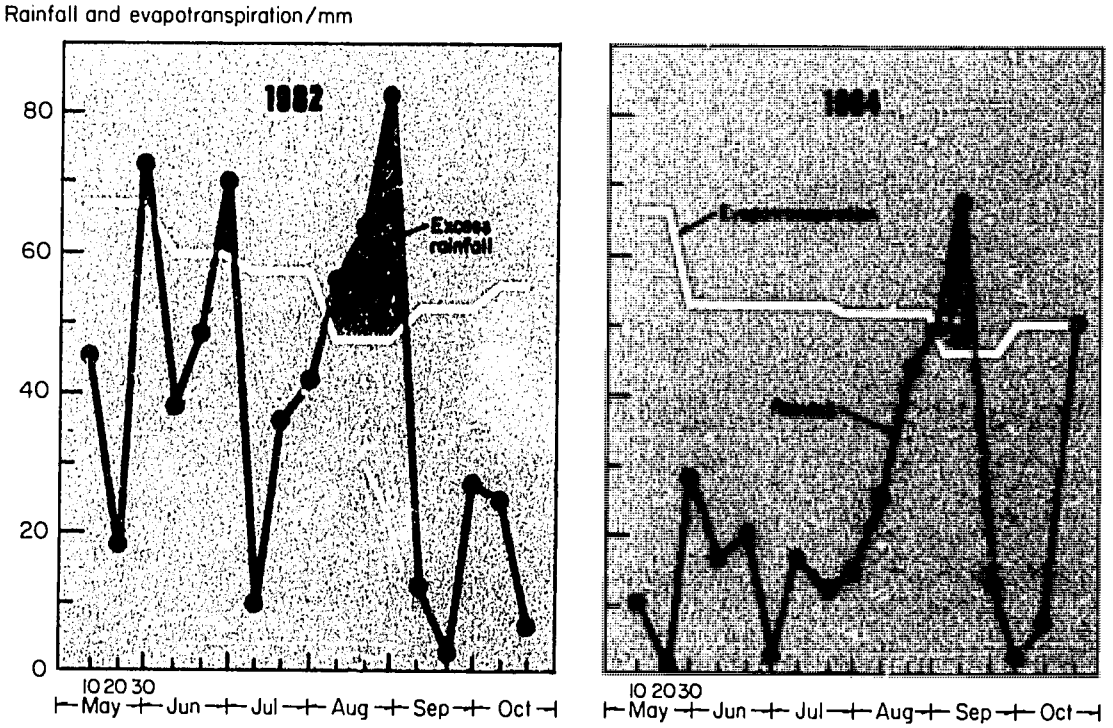
Development of Extra-Early Maize Varieties

In "bad years" when the rains start too late or cease too soon, extra-early maturing maize varieties can play an important role in the Sudan Savanna of semi-arid West Africa. Farmers can minimize the risk of crop failures by planting varieties that reach 50% silking within 42 or 43 days. If a farmer is not able to plant until July 20 because of weather and/or soil conditions, extra-early maturing varieties could make it but not later maturing ones.

Limited rainfall and the low water-holding capacity of the predominant soils impose limitations between the effective length of the growing season and the variety cycle (Figure 12). In toposequence trials at Kamboinse, Burkina Faso in 1984 – a "bad year" – earliness was the key factor determining maize grain yield. Only 227.4 mm of rain fell between planting time and harvest.

The earliest maturing and best yielding varieties were Raytiri local and Koudougou local among six varieties tested. Their mean yields across five positions along the toposequence ranging from top to bottom were 365 kg/ha and 340 kg/ha, respectively, as compared with 119 kg/ha for SAFITA-2 and 165 kg/ha for Kamboinse local – both later maturing varieties. Many of the experimental plots and the

Figure 12. Rainfall and potential evapotranspiration in 10-day periods at Kamboinse, Burkina Faso in 1982 (a "good" year) and 1984 (a "bad" year).



varieties that normally flower after 50 days never reached 50% silking, even in hydromorphic soil.

However, in average or better rainfall years early or medium maturing varieties produce higher yields than the extra-early. Even so, the latter are still acceptable in "good years" and with breeding can be further improved. In 1985 trials in Burkina Faso, three varieties Bursanga Tollo, (Gue 314 × Mex 497) F_1, and CJP which silked in 42-43 days had mean grain yields across three locations (Kamboinse, Gampela, and Saria) ranging from 2,444 to 2,985 kg/ha. Comparable mean yields for varieties which silked in 50 to 54 days ranged from 3,641 to 4,126 kg/ha. But because no one can accurately predict a "good" or "bad" rainfall season, planting extra-early maize along with other varieties improves the farmer's chances of harvesting something.

In the "bad" rainfall year of 1984, the best yielding extra-early local maize variety in trials at Kamboinse, Burkina Faso was Raytiri.

Many people in the Sudan Savanna of semi-arid West Africa count on maize to fill the food gap during the "hunger period" between the tailend of food stocks of the previous season and the harvest of the late local sorghums and millets. This food gap sets in earlier following a "bad year" which emphasizes the need to grow very early catch crops such as extra-early maize which can be harvested and eaten before maturity. A variety of 70 days to maturity can be harvested and eaten as green maize off-the-cob 60 days after planting.

Scientists are collecting and selecting additional germplasm from different parts of the world to improve presently available material.

Selected upland maize varieties developed by IITA have shown yield superiority under different management and stress conditions.

Hybrid Maize: Stable across Environments and Different Management and Stress Conditions?

Is hybrid maize in the tropics less stable than open-pollinated varieties as commonly believed? Based on IITA scientists' experience in West Africa, the answer is "sometimes" but not "always." They have observed the performance of hybrid maize across different environments (forest vs savanna), management (good vs poor) and stress (drought, streak virus, and *Striga*) conditions in Nigeria and a few neighboring countries.

The hybrid variety 8322-13 developed by IITA has shown wide adaptation and stress tolerance. In the severe drought year of 1983, it was tested against the two best yielding open-pollinated varieties (TZB and Poza Rica 7843) across six locations in Nigeria (one forest and five savanna). The hybrid yielded an average of 8 t/ha compared with 5.5 and 5.1 t/ha for the two open-pollinated varieties.

Similar wide adaptation and yield stability of this hybrid were observed again in the 1984 and 1985 cropping seasons in Nigeria and some other West African countries. For example, in three out of four test locations in Cameroon, hybrid 8322-13 significantly outyielded (by 39%) the top yielding check variety Poza Rica 7822-SR.

Stability of the hybrid 8322-13 was also tested under two different stress conditions — streak virus and *Striga hermonthica*. Under artificial streak pressure, it produced 45% more grain than the streak resistant Poza Rica 7843-SR used as a control. The yield increase of this hybrid under natural *Striga* infestation at Mokwa, Nigeria was 270% more than the top yielding open-pollinated variety. This shows

some advantage of line development resistant breeding in maize in the tropics where various stresses have affected yields.

Results of 1985 hybrid maize on-farm demonstration trials conducted by farmers in two ecological zones of Nigeria (forest and savanna) show the yield superiority of selected hybrids such as 8322-13 and 8428-19 under different management conditions. With recommended good management, the two hybrids yielded 32% more in both the forest and savanna zones than the open-pollinated TZSR-W-1 or 6.5 t/ha and 7.4 t/ha respectively (Table 24). Average yields of the two hybrids under poor management were 3.7 t/ha (37% higher) in the forest zone and 3.0 t/ha (54% higher) in the savanna zone.

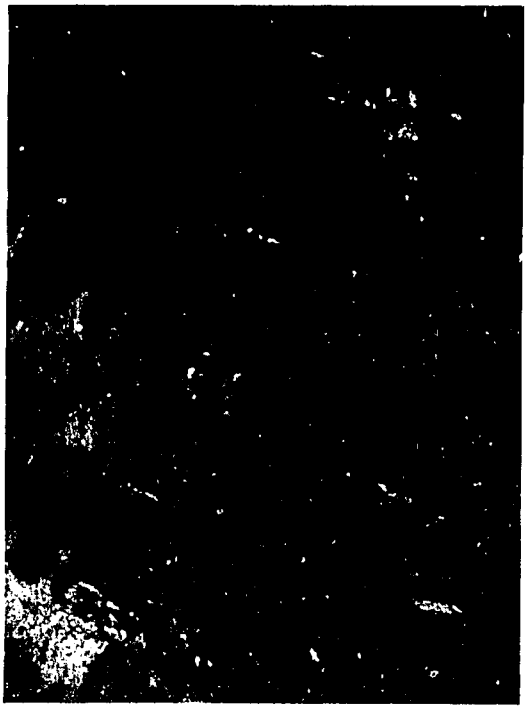
Approximately 6,000 hectares of hybrid maize were grown commercially in Nigeria in 1985, but it is estimated that 40,000 hectares will be planted in 1986. The success story of hybrid maize in parts of East Africa, North America, and Europe could be repeated in West Africa in the future.

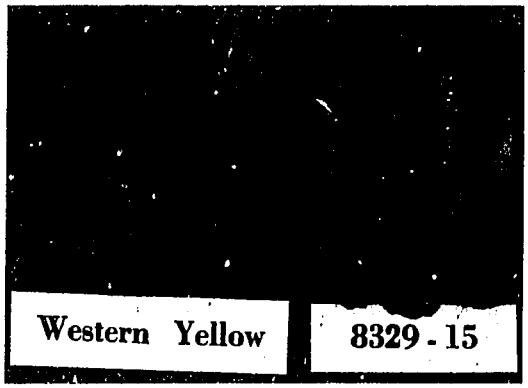
Hybrid maize variety	Good management*		Poor management**	
	Average	Range	Average	Range
Forest				
8322-13	6.3	6.0–6.6	3.9	2.5–6.0
8428-19	6.6	5.0–8.2	3.5	2.4–5.1
TZSR-W-1 (O.P.)	4.9	3.6–5.8	2.7	1.0–4.4
Local (O.P.)	2.2	1.4–3.2	1.6	0.5–3.3
Savanna				
8322-13	7.5	5.4–8.7	3.0	1.7–4.0
8428-19	7.3	6.7–7.7	3.8	3.6–4.0
TZSR-W-1 (O.P.)	5.6	3.7–6.7	2.2	1.1–3.8
Local (O.P.)	2.3	2.2–4.6	0.9	1.0–1.3

* *Fertilizer (kg/ha) 120 N, 60 P_2O_5, and weed control.*

** *Less than 50% of recommended fertilizer applied, poor weed control, or maize grown under poor soil conditions.*

Table 24. Grain yield (t/ha) of hybrid maize for on-farm demonstrations in Nigeria (1985).





Left, an enlarged close-up of weevil attacking maize ears in storage; a weevil-susceptible variety, Western Yellow (above), suffered 70% kernel damage compared with less than 10% for the resistant yellow flint-dent hybrid 8329-15.

Weevil Damage: a Comparison of Different Maize Varieties

African maize farmers suffer heavy losses because of grain deterioration during storage, and *Sitophilus* weevils are among the worst pests that reduce eating quality and seed viability. To determine the susceptibility of 22 maize hybrids and open-pollinated varieties to weevil attack under long-term storage at room temperature conditions, scientists conducted preliminary tests during 1985. Also, they examined seed viability every month through germination tests.

Several maize varieties showed low levels of weevil damage after five months in storage (Table 25). A yellow flint-dent hybrid (8329-15) suffered less than 10% kernel damage compared with 70% for a locally grown variety (Western Yellow). Among the white maize hybrids, 8321-18 ranked the best with less than 20% damage compared with 80% for 8338-1.

Although seed viability for all materials tested differed little after three months of storage, significant differences were observed after four months. Seed viability remained high (over 90%) for 8329-15, 8425-10, and Sekou 81 TZSR-W-1 but was reduced to very low levels (< 40%) for some others (Table 25). Two of the widely grown open-pollinated varieties in West

Africa – EV 8443-SR and Western Yellow – are highly susceptible to weevil attack. The former, a streak resistant variety developed from CIMMYT's tropical population La Posta, is presently grown in Ghana and Republic of Benin. Western Yellow was developed by the Nigerian Institute of Agricultural Research and Training. Also, studies show that there is wide genetic diversity in IITA's maize germplasm in relation to susceptibility to weevil attack.

Several factors are known to influence susceptibility of maize to weevil attack: a tight husk cover helps reduce infestation in the field, and kernel hardness may interfere with oviposition and feeding. More detailed genetic and entomological studies are underway to confirm these findings and determine more precisely the mechanism of resistance.

Table 25. Damage to various maize varieties by** Sitophilus **weevils.

Maize varieties	Grain color and texture*	Origin	Weevil damage (1–10)**	Seed germination*** (%)	Husk cover rating (1–5)****
8329-15	Y/FD	(Tzi8xTzi30)	1.0	95	1.0
8425-10	Y/F	(Tzi8xTzi28)	1.0	95	1.4
8425-9	Y/FD	(Tzi8xTzi32)	1.3	70	1.2
Sekou 81 TZSR-W-1	W/FD	Open-pollinated	1.8	96	2.0
8321-18	W/FD	(Tzi3xTzi15)	2.0	78	1.5
8322-13	Y/FD	(Tzi3xTzi12)	2.0	81	1.8
IK 81 TZSR-Y-1	Y/DF	Open-pollinated	2.5	73	2.0
EV 8428-SR	W/D	Open-pollinated	7.0	46	2.5
Western Yellow	Y/D	Open-pollinated	7.5	35	2.0
EV 8443-SR	W/D	Open-pollinated	8.0	16	2.5
8338-1	W/DF	(Tzi9xTzi10)	8.7	8	3.5

*W = *White*, Y = *Yellow*, D = *Dent*, F = *Flint*.

**Mean of three samples taken after five months in storage; 1 = 1 – 10%, 10 = 91 – 100% kernel damage.*

***Mean of three samples taken after four months in storage.*

****1 = tight, 5 = loose.*

Conversion of Maize Varieties to Streak Resistance

Although a number of maize varieties developed in the past by CIMMYT and IITA were identified as superior germplasm, they lacked resistance to maize streak virus disease. Therefore, to increase the scope of their adaptation and adoption by African farmers and increase the diversity of maize germplasm available to them, joint efforts between the two international research centers was initiated five years ago to introduce streak resistance into these varieties. (The seriousness of this disease in Africa is described in the Executive Summary).

Fourteen maize varieties and populations (mostly from CIMMYT) were selected for a conversion program for streak resistance using the backcross procedure (Table 26). These varieties represented different maturity groups, grain types and color, protein quality characteristics, and ecological adaptation. Streak resistance populations developed at IITA were used as the source of resistance and the selected varieties as recurrent parents. During the course of conversion, artificial infestation with leafhoppers carrying maize streak virus was performed at every stage of the procedure to ensure the transmission of resistant genes to the recurrent parents. Eleven varieties at the end of 1985 had reached the BC_1 or BC_2 stages considered as adequate recovery of the preferred varieties' genotypes.

The more advanced converted varieties were included in the streak resistant variety trials distributed by IITA in Africa with encouraging results; 28 entries including streak resistance donors, recurrent parents, and BC_2 and BC_1 generations were tested in four locations in

Left, a maize variety susceptible to streak disease used as a recurrent parent in a backcross with a resistant donor to produce the resistant variety on the right.

Nigeria. At IITA the trial was conducted under artificial infestation to induce streak epidemics.

Streak resistance levels of BC_2 and BC_4 generations (Table 27) were similar to the donor populations, indicating that the backcross method was an efficient procedure for transmitting streak resistance genes. Under non-streak conditions, both BC_2 and BC_4 generations had similar yields as their recurrent parents. In many cases, however, BC_4 generations showed higher yield and better uniformity in plant and ear characteristics than the BC_2 generations.

The converted varieties are now available to national programs in Africa and represent a significant contribution to efforts to minimize yield losses due to maize streak virus in Africa.

Table 26. Maize varieties and parental populations being converted to streak resistance.

Name of SR maize variety	Parental population name	Description	Backcross generation
Maracay 7921-SR	21 Tuxpeno-1	Late white dent	BC5
EV 8422-SR	22 Mezcla tropical blanca	Late white semi-dent	BC4
Pop 25-SR	25 Blanco cristalino-3	Late white flint	BC2
EV 9428-SR	28 Amarillo dentado	Late yellow dent	BC4
EV 8429-SR	29 Tuxpeño caribe	Late white dent	BC4
EV 8430-SR	30 Blanco cristalino-2	Early white flint	BC4
EV 8431-SR	31 Amarillo cristalino-2	Early yellow flint	BC4
EV 8435-SR	35 Antigua-Rep Dominicana	Intermediate yellow dent	BC4
EV 8443-SR	43 La posta	Late white dent	BC4
EV 8444-SR	44 AED-Tuxpeño	Subtropical white dent	BC4
Ikenne (1) 8149-SR*	49 Blanco dentado-2	Intermediate white dent	BC4
EV 8540-SR	40 White QPM**	White flint QPM	BC5
Pop 66-SR	66 Yellow QPM	Yellow dent QPM	BC3
TZB Gusau-SR	TZB	Late white flint	BC3

**Short plant type.*
***QPM = quality protein maize.*

Table 27. Yield and streak resistance level of four maize streak resistant (SR) materials (1985).

Maize group	Entry name	Description	Yield (t/ha) Streak free*	Yield (t/ha) Under streak**	Streak resistance***
Late white	TZSR-W-1	Donor population	4.2	5.1	1.5
	Ferke (1) 8129	Recurrent parent	5.1	0.3	4.7
	Across 7729-SR	BC2	4.6	5.9	1.7
	EV 8429-SR	BC4	5.3	5.8	2.0
Late yellow	TZSR-Y-1	Donor population	4.8	5.6	1.2
	Ferke (1) 8128	Recurrent parent	4.7	1.1	4.0
	Across 7728-SR	BC2	4.5	5.4	2.0
	EV 8428-SR	BC4	5.4	5.8	1.2
Early white	TZESR-W	Donor population	4.0	4.4	1.2
	Comayagua 8130	Recurrent parent	4.1	0.6	5.0
	EV 8330-SR	BC2	3.7	4.2	1.5
	EV 8430-SR	BC4	4.1	4.9	1.7
Early yellow	TZESR-Y	Donor population	3.9	4.0	2.7
	La Molina 8131	Recurrent parent	3.9	0.2	5.0
	EV 8331-SR	BC2	3.2	4.3	1.5
	EV 8431-SR	BC4	4.0	4.5	2.0

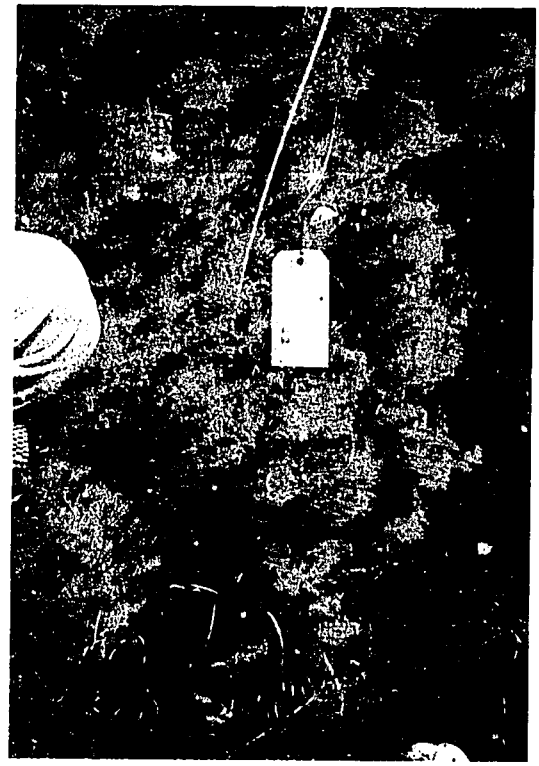
** Mean of three Nigerian locations: Ikenne, Ilorin, and Samaru.*
*** Under artificial infestation of leafhoppers carrying maize streak virus (MSV).*
**** 1 = excellent, 5 = very poor.*

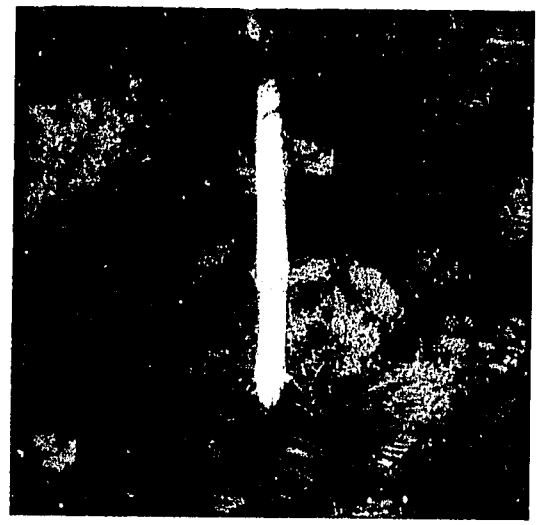
Labor-Saving Technique to Screen Maize for Resistance to Stalk Rots

Wherever maize is cultivated stalk rots are common diseases, and in the tropics fields are infested at a range of 5 to 40%. They usually develop during the grain-filling period, cause premature death, and, as a result, light and undersized cobs. Affected plants also lodge and the ears become prone to rot damage. Major causal agents in the lowlands of Africa are *Fusarium moniliforme*, *Botryodiplodia theobromae*, and *Macrophomina phaseoli*. Other species are prevalent in the cooler environment that characterizes the mid-altitude and highland ecologies.

In their efforts to develop stable high-yielding maize germplasm, IITA scientists have developed a modified efficient artificial inoculation technique. This enables the plant breeders to identify and select stalk rot-resistant maize genotypes. The pathogens are isolated from infected maize stalks and/or seeds using Potato Dextrose Agar (PDA) as a culture medium. Later the fungi are cultured on white maize grains under optimal conditions for three weeks.

For inoculation, spore suspension is prepared with approximately 2.5×10^6 spores/ml. The first elongated internode from the soil level is inoculated one week after mid-silk. The modified inoculation method combines drilling and inoculation simultaneously by utilizing a 1 cm^2 sponge attached to the needle of a syringe. The needle with the small sponge is dipped into the inoculation. As the plant is drilled, inoculation is squeezed into the plants. This method reduces the labor involved by half compared with separate drilling and inoculation.





Top photo: A new innoculation procedure using three pathogens to determine susceptibility or resistance to stalk rots in maize. Lower photo: Two maize stalks split to show a resistant variety (left) and a susceptible one (right).

Eleven inbred lines, developed at IITA and planted in the 1985 second season, were inoculated with spore suspension of the three pathogens, separately, and with a mixture of three. The stalks were split longitudinally for rot infestation evaluation four weeks after inoculation. Disease reaction was evaluated on the basis of the rate of rot spread from the point of inoculation using a 1–6 scale (1 = less than one-fourth of the inoculated internode rotten and 6 = rot spreading to two or more internodes).

The inbred lines showed a range of reaction against the pathogens (Table 28). *Fusarium* was consistently the most virulent. Inbreds 1368, 2096, and 9091 were resistant across all the pathogens while inbred 9490 was susceptible to all. On the other hand, some inbreds showed differential reaction to the pathogens. For instance, 9450 is susceptible to *Fusarium* but resistant to *Botryodiplodia* and *Macrophomina*. Therefore, even though it would appear that the pathogen mixture does not give higher rot scores than inoculating only with *Fusarium*, the scientists use the pathogen mixture for their routine germplasm evaluation.

This technique of stalk rot resistance screening is being used in the IITA hybrid maize program. Similarly, the following maize populations/pools are currently being subjected to improvement for stalk rot resistance: TZESR-W, Pool 16, TZPB-SR, and Back-up LSR-W.

Maize inbreds	Pathogens			Mixture
	Fusarium	*Botryodiplodia*	*Macrophomina*	
1368	1.8*	1.5	1.4	1.4
2096	2.0	1.5	1.6	2.0
5068	3.0	2.2	2.8	3.4
9091	2.0	1.7	1.7	2.3
9450	4.1	1.6	2.2	4.3
9490	5.6	4.3	4.2	5.0
	S.E.	LSD (5%)	CV(%)	
Pathogen mean	0.04	0.13	9.5	
Inbred mean	0.16	0.45	23.6	

Table 28. Stalk rot scores* of six maize inbred lines inoculated with *Fusarium moniliforme*, *Botryodiplodia theobromae*, *Macrophomina phaseoli*, **and a mixture of the three pathogens.**

**On a scale of 1–6 where 1 = 25%, 2 = 50%, 3 = 75% and 4 = 100% of the inoculated internode rotten, 5 = rot spreading to adjacent internode and 6 = rot spreading to two or more internodes and killing the plant prematurely.*

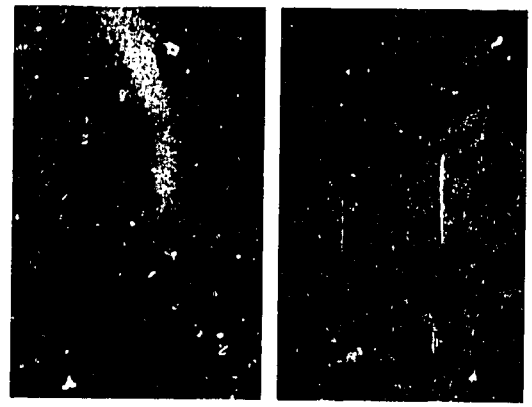
Screening Techniques for *Striga* Resistance in Maize

Crop infestation by the parasitic weed *Striga* continues to pose a serious threat to maize production in Africa. The solution to the problem of damage caused by pests and pathogens in maize adopted at IITA is to identify and develop varieties with broad spectrum stable resistance. The backbone of an effective breeding program for resistance to a pathogen is efficient and reliable screening techniques.

Screening for *Striga* resistance is conducted in three stages with the objective of identifying germplasm resistance embracing the mechanisms involved in the host/parasite interaction. *Striga* seeds will germinate only in response to chemical stimulants present in root exudate from a susceptible host.

To identify non- or low-stimulant maize genotypes, *Striga* seeds are sterilized and preconditioned for seven days on moist fibre glass filter paper in Petri dishes or plastic growth bags before pre-germinated maize seeds are introduced. Germinated *Striga* seeds could be observed within three days. The growth bag technique is more efficient because it is easier to handle, and germination can be examined using a hand lens as opposed to looking in the Petri dishes under the stereoscopic microscope. This makes it possible to examine more materials in a relatively shorter time. Screening in the greenhouse is complementary to observations made in the laboratory. Maize genotypes are observed for non- or low-stimulant producers over a longer period of crop growth in vermiculite. Seeds of the parasite on filter paper at the bottom of the pot are examined for germination. In addition, lines which support *Striga* attachment and emergence may be identified.

The screenhouse method has been modified to make it more efficient and faster to evaluate a large number of maize germplasm. The method involves the use of jiffy pots (6 cm cardboard pots) with vermiculite replacing soil. The looseness of the vermiculite pellets makes it easier to



Left, germination of Striga seeds in response to maize root exudate; right, reaction of maize leaves to Striga toxic extract: one on left susceptible, center resistant. (Control on the right injected with buffer.)

Red flowered Striga (S. asiatica) has killed these maize plants in the field.

uproot the maize plant to observe *Striga* attachment, and time is saved because the roots do not need to be washed. Also, the nature of the medium resulted in earlier emergence of the parasite. By using both Petri dishes in the laboratory and jiffy pots in the greenhouse, four inbred lines and two hybrids with known reaction to *Striga* under natural field conditions were tested for stimulant production. Significant differences in germination of *Striga* seeds were observed. The differences are well correlated with the field observation (Table 29).

Early symptoms of *Striga* infection in the field indicate the possible action of toxins in the disease etiology. A technique using crude *Striga* extract injected into maize plants three weeks after planting resulted in varietal differences between susceptible and tolerant host varieties. This methodology after refinement appears promising for application in large scale field screening at IITA where the organism is absent. It will also permit testing germplasm for tolerance to other *Striga* species of economic importance. Through these processes only desirable materials will be screened under field conditions at various testing sites.

Field screening under heavy *Striga* pressure is the final evaluation stage. Since 1985, this was conducted under natural infestation which unfortunately is not uniform. A method of artificial inoculation in the field was tried with little success. The technique will be modified in 1986 to aim at predictable and uniform levels of *Striga* infestation in the field.

Inbred lines and hybrid maize varieties	Germination of *Striga* seeds (%)		Field observation rating*
	Pots	Petri dishes	
5057	39.8	25.6	4.6
1368	40.9	30.7	4.0
9071	16.2	20.0	1.9
9848	8.2	7.1	2.0
8322-13	12.2	9.0	1.5
8338-1	25.1	19.0	4.3
LSD (5%)	1.7	2.5	
CV	8.0	15.8	

** 1 = resistant, 5 = highly susceptible.*

Table 29. Summary of Striga seeds germination by susceptible and tolerant inbred lines and hybrid maize varieties and corresponding field rating.

An IRTP-Africa (International Rice Testing Program) monitoring tour in a key rice testing location in Liberia.

Annual Report Executive Summary
Rice Research Program

Breeding superior rice lines and devising appropriate management practices for the major rice-growing ecologies of Africa continue to be the main thrust of this research program. Rice is mainly grown in rainfed upland, rainfed lowland (hydromorphic), and lowland/swamp ecologies in 31 rice growing countries in sub-Saharan Africa. In some countries the per capita consumption is estimated at more than 100 kg/year. Demand for rice is increasing and greater production is needed to feed more people and reduce costly imports. A few countries (Nigeria, for example) have banned rice imports as a means of encouraging local production.

More than half of the rice in Africa is grown under upland conditions, and, in high rainfall areas where drought stress is of minor concern, rice production could be increased substantially. IITA's rice breeding work at Onne in southeast Nigeria is developing superior upland varieties tolerant to soil acidity and diseases associated with a high rainfall, humid forest ecology. Most successful lines in this ecology combine tolerance derived from traditional African upland parents with the shorter straw and higher tillering capacity of modern semi-dwarfs.

For the third consecutive year, the variety ITA 307 yielded 60% more than the local check OS 6 when reasonable improved cultural practices were adopted. Varieties like ITA 116, ITA 117, ITA 118, and ITA 307 will have a major impact if used with good management in the coastal rice belt in countries such as Guinea, Liberia, Sierra Leone, and Ivory Coast where rice is the dietary staple and upland ecologies predominate. Such varieties are free from the local stress of grain discoloration and blast. In cooperation with the national program of Liberia, tests are being carried out with several late maturing selections for the high rainfall, upland conditions there.

Under lower rainfall conditions (less than 1500 mm/year), early-maturing lines with drought and blast resistance have shown promise. ITA 257 and ITA 235 have drought tolerance, and the former variety possesses durable resistance for blast. Because such areas are prone to drought, the emphasis is on breeding an early variety to fit into the short growing season with resistance to drought, leaf and neck blast, and grain discoloration.

The rainfed lowland (hydromorphic) ecology also offers a great potential for increased rice production in Africa because the rice plant has adequate moisture in the root zone for at least a major portion of the growing cycle. Also, vast areas of such lands are available for rice cultivation (about 20 million hectares). However, varieties with tolerance to a constantly fluctuating water regime are required. A new breeding program has been initiated to develop superior and high yielding lines for such an ecology. Scientists are working on the development of rice lines with early vigor to withstand seedling drought, intermediate stature to compete with weeds, adaptability to grow under stagnant and sometimes iron-toxic water, and tolerance to a changing level of nutrient supply.

Lines such as ITA 306 are well adapted for such ecologies, and, if grown under optimal management, can yield as much as 4 t/ha. Also, a second crop such as 60-day cowpeas or vegetables can be grown after rice on the residual soil moisture. This increases the intensity of land and water use efficiency and reduces the weed problem for the succeeding rice crop.

Another rice growing ecology that receives research attention — inland valley swamps — is characterized by patchy areas of iron toxicity where susceptible varieties fail to do well. ITA 249 — one of iron tolerant varieties — has performed better than the traditional tolerant variety (Suakoko 8) in Liberia where iron-toxic soils limit rice production. As a further step in varietal improvement for this ecology, rice lines with a wide range of growth duration and better level of resistance to neck blast have been generated at IITA. These are being evaluated in iron-toxic soils at Suakoko in collaboration with the Central Agricultural Research Institute, (CARI) and the West Africa Rice Development Association (WARDA).

Unquestionably, rice yields are highest where assured irrigation is possible and several elite varieties are available for irrigated conditions where there are no Africa-specific stresses such as the rice yellow mottle virus disease (RYMV). During the past year, field tests have shown the superiority of ITA 212, ITA 222, and ITA 306 in a number of stress-free locations in Cameroon, Nigeria, and Ghana. Preliminary results from the Republic of Chad also indicate that ITA 306 has high yield potential there. These varieties have yielded an average of 5 t/ha under moderate management, and the latter two have had stable yields during the past three years in Nigeria and Cameroon.

Further progress was made during 1985 in identifying several lines tolerant to RYMV and field tested in endemic areas in the Republic of Niger. The better lines are being reinforced with desirable agronomic traits to produce RYMV-tolerant, high-yielding rice lines for several countries where the disease occurs. The varietal improvement is backed up by a sensitive serological test for identifying the most resistant line. In addition to drawing resistance from *O. sativa* varieties, plant breeders are also looking at the African rice, *O. glaberrima*, as possible donors.

Similarly, African-specific insect pests such as *Diopsis* (thoracica) *macrophalma*, gall midge, and several species of borers and grain sucking bugs are constraints to rice production. Specifically designed screening procedures have enabled scientists to identify resistant lines, and they are using resistant donors for *Diopsis* and gall midge in their breeding programs. Priority attention is being given to an integrated approach to pest management, including not only resistant varieties but also chemical, cultural, and biological control.

For higher altitudes, IITA's breeding program has identified superior lines for cold and blast tolerance at Dschang, Mbo, and Ndop plains of Cameroon, sites which expose the test lines to different regimes of low temperature and associated stresses such as blast and sheath rot diseases. Low temperature is a serious constraint to rice production in the mid-altitude zones of east, south, and central African countries and also at higher latitudes during the second crop season (November–February). IR 7167-33-2-3, tested over the past three years at Ndop Plain, is being grown over large areas because of its superior performance.

During 1985, the rice quality laboratory continued to provide the necessary backstopping to the breeding program by screening rice lines from IITA's large germplasm collection and from several African countries to gather information on quality preferences of consumers. Preferences for cooking and eating qualities often differ from country to country. IITA has a wide range of varieties to suit the taste or quality preference of many African nations (*Research Highlights 1984*).

Requests for seeds of elite rice varieties from IITA continue to increase. In 1983, nearly 860 kg of seeds were sent to several national programs for experimental purposes and as initial seed stock for further multiplication. In 1984 and 1985, the supply was 1183 and 1442 kg, respectively. Because of the increasing demand, IITA's capability to produce good quality seed for national programs is being stepped up.

To improve the efficiency of rice technology transfer in Africa, an international testing network began to function in 1985. Called the International Rice Testing Program for Africa (IRTP-Africa), it is a cooperative program involving IRRI, WARDA, and IITA. This network distributes specific rice nurseries for target ecologies and brings rice scientists together from several national programs to interact and participate in the assessment of test lines.

During 1985, six trials with several hundred entries were sent to 186 locations in 29 countries south of the Sahara, and an expanded program with new trials will be formed under this network during 1986. Fifteen rice scientists from several national programs were involved in monitoring tours to key test locations in four West African countries. This interaction resulting in specific recommendations helps both national and IITA rice scientists improve their strategies for higher rice production.

In the following pages, several research highlights during the year are briefly described. More complete information on these topics and those mentioned in this Executive Summary can be obtained by requesting the Annual Report of the Rice Research Program.

Performance of High Yielding Rice Varieties in Three African Countries

According to reports from Cameroon, Ghana, and Nigeria, selected rice varieties developed by IITA for irrigated lowlands have shown superior performance in extensive tests at experiment stations and in farmers' fields. ITA 222 and ITA 306 not only produced high yields but also showed a wide range of adaptability. Both varieties were heavy tillering and produced long grains with acceptable physicochemical characteristics.

Over a three-year period (1983–85), grain yields of the two varieties at IITA averaged more than 6 t/ha (Table 30). ITA 222 matured in 123 days after planting and reached a height of about one meter. This variety in trials conducted under the auspices of the National Cereals Research Institute in eight locations in Nigeria had an average yield of 5.3 t/ha (Table 31). It also matured earlier and was less prone to lodging than other varieties.

In Cameroon, ITA 222 outyielded Tainan V (a widely grown variety) by approximately 20% in trials by researchers in the National Cereals Research and Extension Project (Table 32). Multilocation trials in farmers' fields in the country confirmed this result.

Right, rice variety ITA 306 performs well under hydromorphic and irrigated soil conditions; now undergoing large-scale testing in Cameroon.

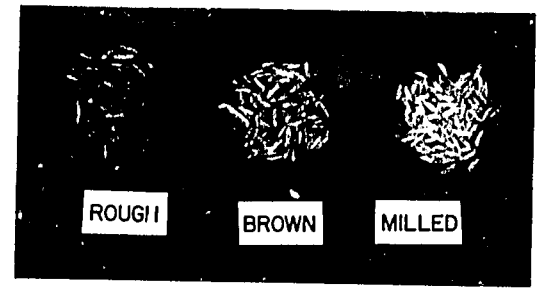
Table 30. Average yield, days to maturity, and plant height of two IITA rice varieties ITA 222 and ITA 306 at IITA (1983–85).

Rice variety	Yield (t/ha)*				Days to maturity	Plant height (cm)
	1983	1984	1985	Mean		
ITA 222	6.1	6.5	6.2	6.3	123	103
ITA 306	6.5	6.9	7.1	6.8	120	106

* *Mean of the varieties from trials conducted during the year.*

Long slender grains, resistance to blast, and the ability to perform well under irrigated and hydromorphic soil conditions are the main attributes of ITA 306. This variety — now undergoing large-scale testing in Cameroon — fits well into rice-based cropping systems with cowpeas following rice. In Ghana, it yielded 7.8 t/ha, and is being increasingly grown on farms in various parts of the country.

ITA 222 is a selection from the progeny of the cross Mahsuri/IET 1444 and ITA 306 from TOx 494 Sel/TOx 711/BG 6832. The parent varieties in these crosses, namely Mahsuri, IET 1444, and BG 6832 show different favorable traits, the combinations of which have resulted in the superior performance of ITA 222 and ITA 306 under African lowland conditions. TOx 494 Sel and TOx 711 are IITA lines.



Long slender grains of the high-yielding rice variety ITA 306.

Rice entry	Yield (t/ha)	Days to flowering	Plant height (cm)
IR 8192-166-2-2-3	5.4	114	98
ITA 222	5.3	106	88
FARO 29	5.2	116	94

*Source: National Cereals Research Institute, 1985.

Table 31. Entries with the highest yields in the Coordinated Rice Evaluation Trial conducted at eight locations in Nigeria.*

Rice entry	Yield (t/ha)			Days to flowering	Field reaction to blast*	
	1983	1984	Mean		Leaf	Neck
ITA 222	7.5	5.4	6.4	105	R	R
Tainan V (check)	6.1	3.5	4.8	95	MR	R

*R = resistant, MR = moderately resistant.

Table 32. Performance of rice variety ITA 222 compared with Tainan V in Mbo Plain, Cameroon (1983–84).

Problems and Potential for Rice Production in Hydromorphic Lands

Proper use of at least 20 million hectares of hydromorphic land presently available in West Africa for rice cultivation could substantially increase production. The yield potential of this land is close to that of the lowlands and higher than the uplands (Figure 13). But serious problems need to be solved before such a potential can materialize.

Hydromorphic lands are usually on the heel of a slope bordering a valley, and, based on the physiological requirements of rice plants, can be classified into these two categories: lower

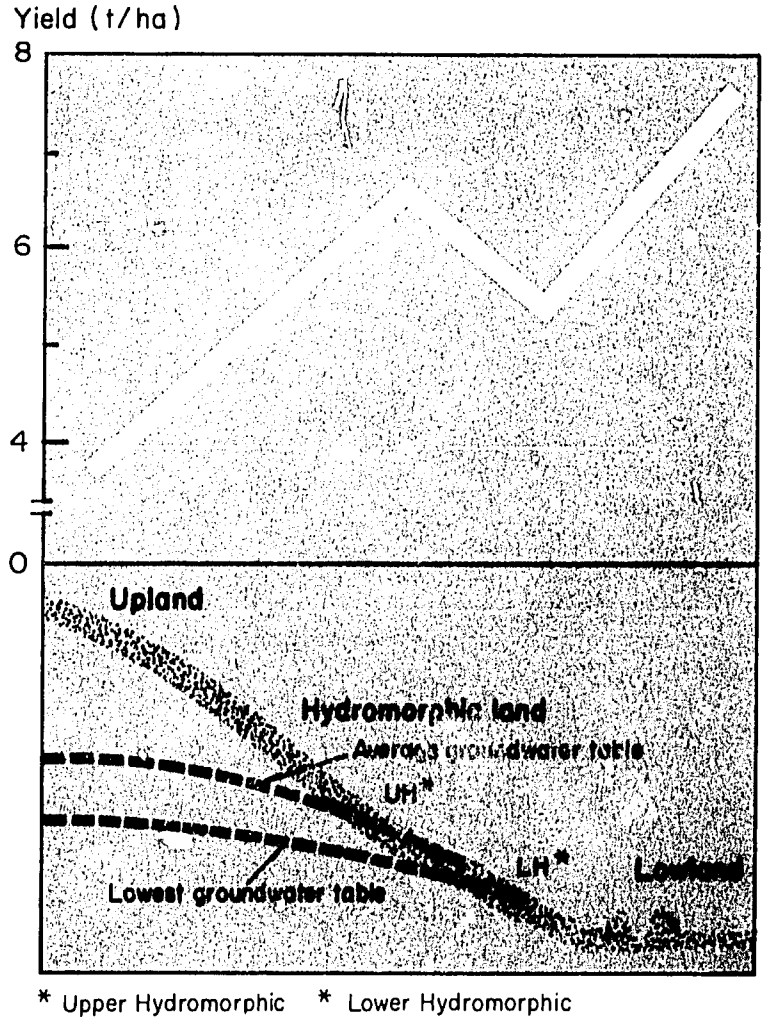


Figure 13. Mean rice yield at different sites in a hydromorphic valley at IITA in 1985. (The value is the mean of eight rice lines; experiment conducted without fertilizer.)

One of the basic problems affecting rice production in lower hydromorphic lands: oxidized iron (red color) in seepage water.

hydromorphic land with seepage water during the growing season and upper hydromorphic land with a fluctuating groundwater table within reach of the rice roots. Rice yields tend to be higher in the latter.

The basic problems affecting rice production in the lower hydromorphic lands are adverse soil conditions — a deficiency of potassium and iron toxicity, both of which reduce yields. The latter is a widespread problem where seepage flows contain a high concentration of ferrous iron (Fe^{++}). Studies conducted in 1985 showed that the iron toxicity problem is related to and worsened by potassium deficiency. Rice and soil scientists are working together to develop a field methodology for testing rice varieties for tolerance to iron toxicity. Several varieties have been developed. (see *Research Highlights 1983*).

Another problem is weed infestation which is more serious than in upland and lowland areas because of uncontrolled water conditions and less leaf area of the rice plants. Research is underway to breed rice lines which can compete with weeds in hydromorphic areas.

In a yield trial with eight promising lines in both upper and lower hydromorphic lands (Figure 14), ITA 306 had the highest yield 8 and 7.4 t/ha, respectively — which was attributed to high total dry matter production and harvest index. This variety is the most promising developed so far by ITA scientists for these lands.

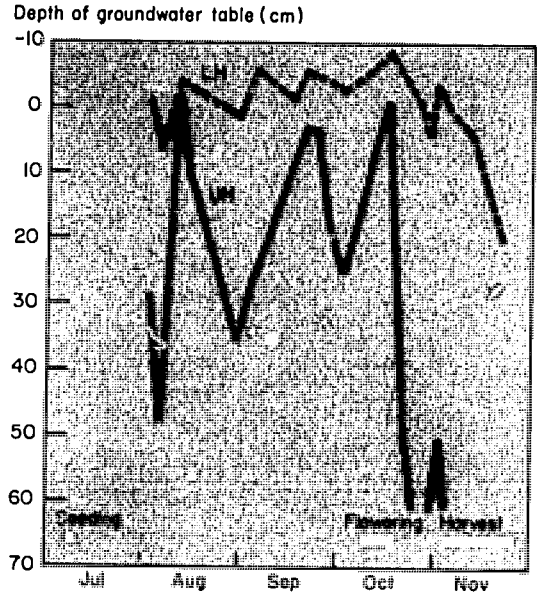


Figure 14. Fluctuation of the groundwater table at upper (UH) and lower (LH) hydromorphic lands at different phases of rice growth.

Clean-Grained, High-Yielding Rice Lines for Upland Humid Tropics

Vast areas in parts of Nigeria, Ivory Coast, Sierra Leone, Liberia, and Guinea grow rice under upland situations with an annual rainfall of more than 2,000 mm and where high humidity, overcast skies, and soil nutritional imbalances often lead to discolored grains – a major constraint in rice production. If not completely filled, these grains lower yields, and, even if fully filled, they may have discolored kernels with poor milling quality.

Several fungi are incriminated in this syndrome, the most common ones being species of *Sarocladium*, *Curvularia*, and *Fusarium*. Grain-sucking insects are also known to predispose the grains for infection by these organisms.

To identify sources of resistance to this disease problem, IITA scientists tested several thousand exotic and many local rice varieties from Africa in the Institute's high rainfall station at Onne in Rivers State, Nigeria. Screening of progeny or crosses of breeding materials under severe disease pressure there showed that many progenies found resistant came from crosses where rice lines 63-83, OS 6, and LAC 23 were involved as parents.

In trials over the past few years by IITA at several upland experimental sites and by the National Accelerated Food Production Program (NAFPP) of Nigeria, three elite lines ITA 116, ITA 117 and ITA 118 have shown promise for clean grains, good milling quality, blast resistance, and high yields. Compared with the local variety, OS 6, they were distinctly superior in yield and at least equal in their level of resistance to grain discoloration (Table 33).

Rice line	Average yield (t/ha)	Height (cm)	Maturity days
ITA 116	2.0	120	115
ITA 117	2.6	115	120
ITA 118	2.8	120	120
OS 6 (check)	1.5	130	125

**All resistant to grain discoloration and blast.*

Table 33. Performance of superior rice lines for humid uplands.

Left, a rice variety with severe grain discoloration vs ITA 117 with clean grains (right).

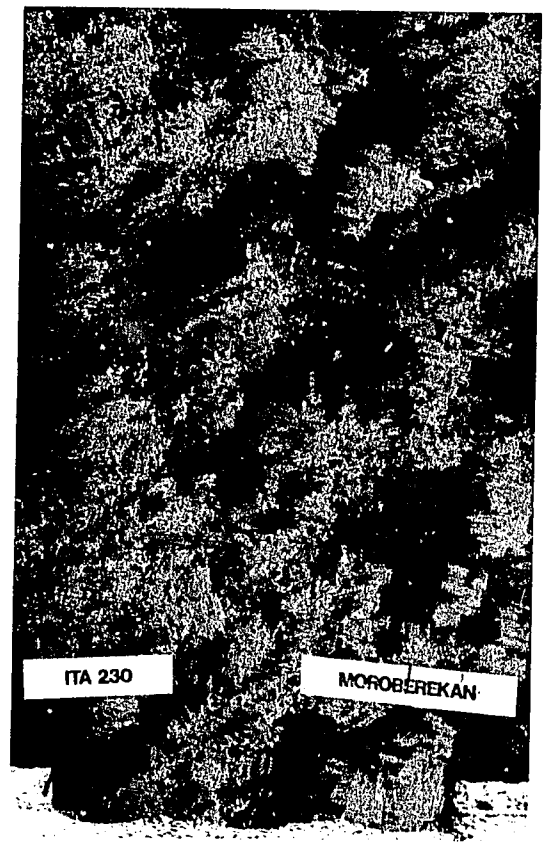
Strategies to Combat Yellow Mottle Virus Disease in Upland and Lowland Rice

Until 1985, the potentially devastating rice yellow mottle virus (RYMV) disease was reported mainly in lowland rice in East, Central, and West Africa, but a joint survey conducted by WARDA and IITA in Ivory Coast has revealed that it also occurs in susceptible exotic varieties under upland conditions. Therefore, IITA's scientists have been devising strategies to combat this disease in upland as well as in lowland rice.

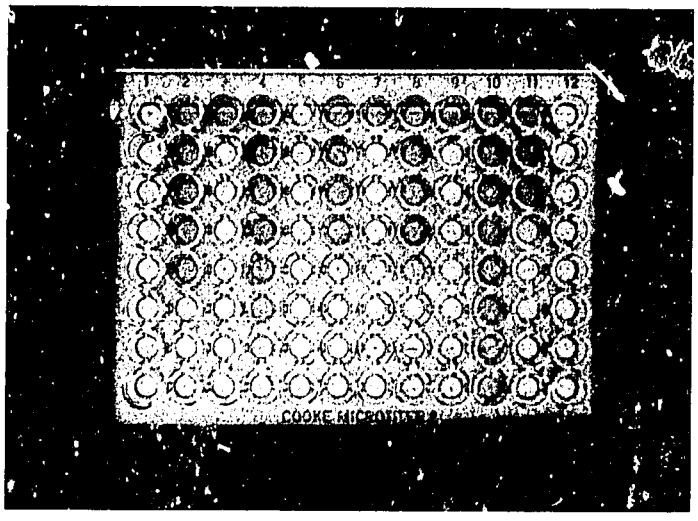
The virus causes yellowing and stunting of rice plants leading to incomplete emergence of panicles with sterile grains. Yellow mottle can be transmitted to healthy plants by sap inoculation and by insects, but no seed transmission has been observed in experiments with over 5,000 seeds from infected plants. Also, the virus has been purified at IITA and a high titre antiserum prepared. Various serological techniques, including the sensitive Enzyme-linked Immunosorbent Assay (ELISA), have been successfully applied with this antiserum.

A combination of a visual assessment of symptoms and relative virus antigen concentration in tissues as determined by ELISA have proven useful to differentiate resistant/tolerant lines. With the former method, scientists have eliminated highly susceptible lines such as BG 90-2, IR 5, IR 8, and IR 20. LAC 23, Moroberekan, and OS 6 were highly tolerant but contained the virus as determined by ELISA. Among these rice varieties, LAC23 had the least amount of virus antigen. None of the *O. sativa* lines tested were immune.

In the development of virus-free lines, the scientists have found it difficult to obtain desirable genotypes from crosses involving *O. glaberrima* and *O. sativa*. Also, *O. glaberrima* and *O. barthii* have many undesirable characters that result in low yields. Recognizing the case of transferring the gene s for resistance from *O. sativa* as an immediate goal, they intensified



RYMV-tolerant donor Moroberkan and the semi-dwarf IITA 230 which is susceptible to the virus but high yielding if not infected; the middle plant – a cross between the two – has tolerance plus vigor. All three were artificially innoculated with the virus at the seedling stage.



A sensitive serological technique (ELISA) for identifying rice lines with resistance to RYMV. Fewer yellow wells vertically mean higher resistance to the virus.

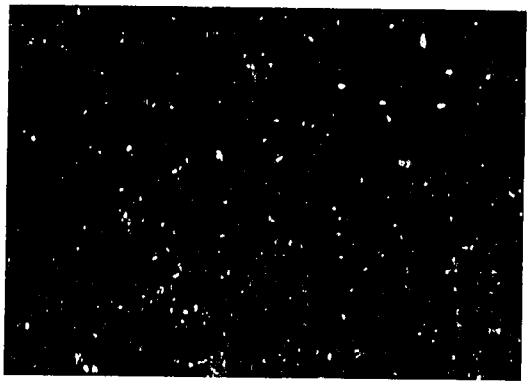
their efforts to incorporate tolerance to the virus from *O. sativa* into breeding lines intended for irrigated, hydromorphic, and shallow swamp ecologies. Varieties identified in earlier screening trials as tolerant were used as donors.

From crosses made in early 1984, an initial set of F_4 lines were established in 1985 and screened for tolerance to the disease and for better plant type. A total of 450 lines were screened in RYMV endemic fields in the Republic of Niger in field tests and at IITA in screenhouse evaluation. Out of these, 21 were found to combine tolerance and good plant type characteristics. Individual plant selections were made for further yield evaluation and possible refinement in plant type and resistance.

IITA scientists are continuing to widen their source for resistance to RYMV and have made initial crosses to explore the possibility of transferring the high level of resistance of *O. glaberrima* (TOg 5674 and TOg 5681) to *O. sativa*.

Response of Lowland Rice to Applications of *Sesbania rostrata* Cuttings

High yielding rice varieties respond well when an additional supply of nitrogen is added to soil, but the high price of inorganic nitrogen fertilizers and their scarcity at the farm level at the right time are major constraints for small rice farmers in various parts of Africa. Therefore, the identification of cheap and readily available sources of nitrogen has been one of the major objectives of researchers at IITA.



Sesbania rostrata – a fast growing African-originated leguminous shrub – is a potential nitrogen supplier for lowland rice. (Shown here at an early growth stage in a flooded rice crop.)

They have identified an African-originated shrub (*Sesbania rostrata*) as a potential nitrogen supplier to rice crops grown on hydromorphic land. Also, field tests have shown that it can thrive well under flooded conditions. When planted with rice in a spacing of 200 cm × 40 cm, *S. rostrata* yielded 2,465 kg/ha of fresh matter or 431 kg/ha of dry matter with a nitrogen concentration of 2.6%.

The 1985 field experiments showed a substantial yield increase in lowland rice when *S. rostrata* cuttings (but no nitrogen fertilizer) were added to the soil – as much as 42.1 and 60.3% with the application of two and four tons of *S. rostrata* cuttings, respectively, at four weeks after transplanting (Table 34). This contribution of *S. rostrata* to the rice yield, however, was not significant when soil fertility was high with the addition of 60 kg N/ha.

Sesbania cuttings (t/ha)	No nitrogen: Grain yield (kg/ha)	No nitrogen: Yield increase (%)	60 kg N/ha: Grain yield (kg/ha)	60 kg N/ha: Yield increase (%)
0	3,045		4,830	
2	4,327	42.1	4,645	3.80
4	4,881	60.3	5,368	11.14

Table 34. Grain yield of rice variety ITA 306 treated with different levels of Sesbania rostrata cuttings under field conditions at IITA (1985).

The Root and Tuber Program gave cassava the Number One priority during 1985. (Cassava, shown here in an African market, has been fermented, pee'ed, and dried.)

Annual Report Executive Summary
Root and Tuber Improvement Program

Cassava, yams, sweet potatoes, and aroids – major sources of food energy for millions of people in the humid and subhumid tropics – received priority attention in that order during 1985. Scientists concentrated their efforts in four directions: (1) improving lines and populations of these root and tuber crops to obtain high stable yields, resistance to major diseases and pests, and product quality acceptable to principally African consumers; (2) controlling cassava mealybug (CM) and green spider mite (CGM) through biological control; (3) cooperating closely with national programs and transferring improved technologies to them; and (4) training national scientists.

Much of the research involves a multi-disciplinary team approach by scientists in plant breeding, pathology, entomology, nematology, virology, biochemistry, food technology, physiology, and tissue culture. Scientists interact with staff members of other programs (such as the Farming Systems Program) in the improvement of cultural practices and in conducting on-farm trials and the Virology Unit in studies on viruses and virus indexing. Also, IITA cooperates with the International Center for Tropical Agriculture (CIAT) in Colombia, South America in cassava improvement and biological control, and the Asian Vegetable Research and Development Center (AVRDC) in Taiwan in sweet potato improvement through exchange of material, technical information, and interaction of staff members.

During the year, scientists tested their selected and improved materials under specific environmental conditions in cooperation with national programs, including Program National Manioc (PRONAM) in Zaire, Cameroon National Root Crop Improvement Program (CNRCIP), Rwandan National Root Crop Improvement Program (RNRCIP), and Jamaica National Root Crop Improvement Program (JNRCIP).

The Program National Manioc marked its tenth anniversary and 10 years of IITA's involvement in cassava improvement in Zaire. Major improvements made in 1985 include electrification, installation of a water system, and construction of a training center at PRONAM's headquarters in M'Vuazi. PRONAM has become one of the best national programs working solely on cassava with more than 10 national scientific staff holding M.Sc. degrees and three holding Ph.D. degrees. Several more staff are undergoing M.Sc. and Ph.D. courses.

Significant progress was made in 1985 to develop improved cassava varieties that are high yielding and resistant to green spider mite. A high yielding and non-sweet variety of sweet potato and 61 other non-sweet types preferred by many consumers in Africa were identified. New promising clones of both white yam (*D. rotundata*) and water yam (*D. alata*) were produced, and researchers identified several clones of cocoyam (*Xanthosoma* spp.) in Cameroon which are resistant to the root rot complex.

Cassava mealybug populations were significantly reduced in the areas where the most promising natural enemy, *Epidinocarsis lopezi*, was successfully established. These areas included parts of Nigeria, Benin, Togo, Zaire, Congo, and Ghana. Exploration activities continued to be pursued on the CM and CGM fronts. One new CM parasitoid (*Allotropa* sp.) has been introduced and is undergoing bionomics studies. Experimental releases with this species have been made in Nigeria, Zaire, and Sierra Leone. New stocks of all previously introduced natural enemies have been received to renew the genetical base of IITA cultures. Also, new CM and CGM natural enemy species have been found and are currently being processed in the CIBC quarantine laboratory in London.

Mass rearing techniques for the CM and its natural enemies have been developed and are now in the production phase. Up to 15,000 *E. lopezi* can be produced daily in the automated insect production system. Appropriate rearing technologies for use by national programs have been designed and built and are in the experimental phase. National biological control programs have been started in Guinea Bissau, Ivory Coast, Ghana, Nigeria, Rwanda, Zambia, and Malawi. They received technical and financial assistance from IITA, and many of their staff members were trained in IITA/FAO/OAU-STRC courses.

A 1985 field survey of the impact of IITA improved cassava varieties in Nigeria's Oyo State showed that these varieties account for about 20% of all cassava grown there. They are also spreading in other Nigerian states and in Zaire, Ghana, Benin, Cameroon, Sierra Leone, Liberia, and Rwanda.

IITA-improved sweet potato varieties performed well in Sudan, Malawi, Rwanda, Sierra Leone, Ghana, Cameroon and Solomon Islands. IITA varieties showed early bulking and high yields under high altitude (1,300 m) conditions in Rwanda.

Both cassava mosaic disease (CMD) susceptible and resistant varieties that were freed from the disease through meristem culture and rigorous virus indexing were planted in the field. It was demonstrated that a cassava variety susceptible to CMD became readily infected with the virus only two months after planting, while a resistant variety showed no disease symptoms from planting time up to nine months and maintained low disease incidence.

Reciprocal grafting of low and high cyanide cassava varieties showed that cyanide is synthesized in the leaves and translocated into the tubers.

New seed yam production technology using pre-sprouted minisetts and plastic mulch was adopted by many seed yam growers in Nigeria. Use of plastic mulch for ware yam production without plant staking showed a 30% yield increase over conventional production systems with staking. Further studies may show the possibility of complete elimination of staking for ware yam production in the high rainfall forest zones. Experiments demonstrated that 80,000 to 100,000 seed yams per hectare (about 250 grams each) can be produced under plastic mulch and without staking. More than 100 Nigerian farmers adopted the improved seed yam production system on 120 hectares and found it profitable.

Water yam (*Dioscorea alata*) breeding has not been successful so far in producing genotypes with acceptable tuber shapes, but 12 very promising new clones with acceptable tuber shapes and yields have been produced from hybrid seeds for the first time since yam breeding work began at IITA a decade ago.

Sweet potato weevils are very destructive pests of sweet potatoes in the tropics. Individual control techniques, such as moderately weevil resistant varieties and some cultural practices, have shown some promise but to a limited degree. Integration of these control measures gave the best overall results.

In the following pages, notable research highlights during the year are briefly described. More complete information on these topics and those mentioned in this Executive Summary can be obtained by requesting the Annual Report of the Root and Tuber Improvement Program.

Distribution of improved cassava planting material is increasing but the demand for plantable stem cuttings far exceeds the supply.

Impact of IITA Cassava Varieties

Farmers in Oyo State – one of 19 states in Nigeria – grow cassava on slightly more than half of their cultivated land and IITA cassava varieties now cover from 30,000 to 40,000 hectares or about one-fifth of the land planted to this crop. These figures are based on a 1985 survey of farmer acceptance of IITA varieties in the state over the past decade (Figure 15).

Trends in the adoption of these improved varieties reflect an increasing supply of plantable stem cuttings and the gradual replacement of a least 40 traditional varieties. The National Seed Service of Nigeria, Oyo State Ministry of Agriculture, and TEXAGRI farms at Opeji are the main sources of plantable stems for farmers. Farmer-to-farmer gift or sale of stems is another major contribution to the pattern of spread, but the main obstacle is the shortage of stems.

Root yields of IITA types on farms ranged from 6 to 19 t/ha compared with 3 to 8 t/ha for local varieties. Farmers in the survey reported that the improved varieties matured earlier (some called them "six-month cassava"), smothered weeds with a better canopy formation, and increased their farm income. Delay of root harvest beyond 15 months leads to root rot, increase in fibre, or reduced dry matter content.

IITA variety TMS 30572 – the mainstay of

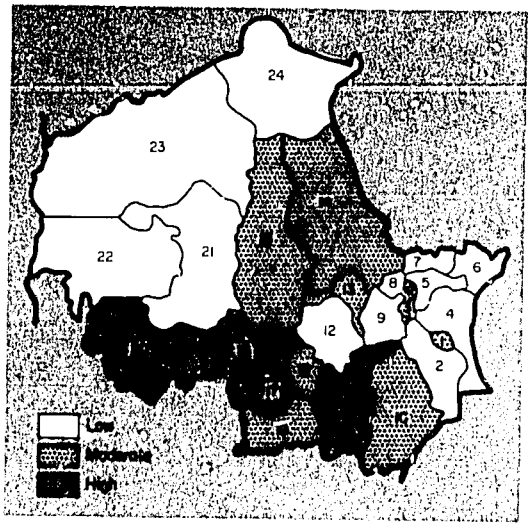


Figure 15. Local government areas in Oyo State, Nigeria showing cultivation intensity of IITA cassava varieties in 1985.

large cassava farms that support gari processing factories scattered over the state – received a particularly high rating in the survey. It and other IITA varieties are most suitable for gari – the most widespread food preparation from cassava in Nigeria.

Besides Oyo State of Nigeria, IITA varieties are also prevalent in Ogun, Bendel, Ondo, Rivers, Lagos, and Imo states where cassava is a major food. Similarly, with the technical cooperation of IITA, viable cassava programs now exist in Zaire, Sierra Leone, Liberia, Ghana, Gabon, Cameroon, Rwanda, Burundi, Tanzania, Seychelles, and Sudan. About a dozen high yielding and farmer accepted varieties derived from IITA tissue culture and breeder seed materials have been released in these countries. These varieties have also spread from Nigeria to the Republic of Benin, from Gabon to Congo, Equatorial Guinea, and Sao Tome by farmer-to-farmer distribution.

Mass Rearing of Natural Enemies of the Cassava Mealybug: Advanced and Appropriate Technologies

Two systems of mass rearing of natural enemies of the cassava mealybug now in use at IITA involve different levels of technology according to the specific purposes for which they were designed. The first system uses advanced technology for a continuously high and stable production of clean natural enemy populations, as well as for scientific research in rearing techniques at IITA.

In each of eight stainless steel units, 600 sprouted cassava cuttings can be fixed in trays holding a nutrient solution and moving around a centrally located light source. Within two weeks the plants reach a height of 25 cm with five or six leaves per plant. Then they are artificially infested with approximately 1.2 million first instar mealybugs ("crawlers") i.e. about 2,000/cutting.

As soon as the "crawlers" have developed into the third instar (thereby stopping the plant growth) approximately 5,000 female *E. lopezi* are introduced into the unit and allowed to lay their eggs into the mealybugs. After two weeks of incubation, about 100,000 *E. lopezi* (the cassava mealybug's natural enemy) can be collected from the unit over a seven-day period. If a unit is loaded with cuttings every week, a continuous production of 20,000 parasitoids per day can be achieved. This system is less labor intensive than the classical insectary where plants, host insects, and natural enemies are reared separately.

An alternate, less complicated, and lower-cost system built entirely from locally available materials has been designed for use in national biocontrol projects where electric power supply may be irregular or unavailable and technical "know-how" and funds are limited (Figure 16). In this system, 200 cassava cuttings are inserted into a vertical pipe. The roots which start to grow immediately into the substrate (sawdust, palmkernel shaft, and Styrofoam) held by the pipe are irrigated twice daily with a nutrient solution from an overhead tank. The resulting so-called "cassava tree" is covered by a fine nylon screen. This keeps out unwanted insects but allows enough light transmission and ventilation for growth of cassava plants to the desired size in two weeks.

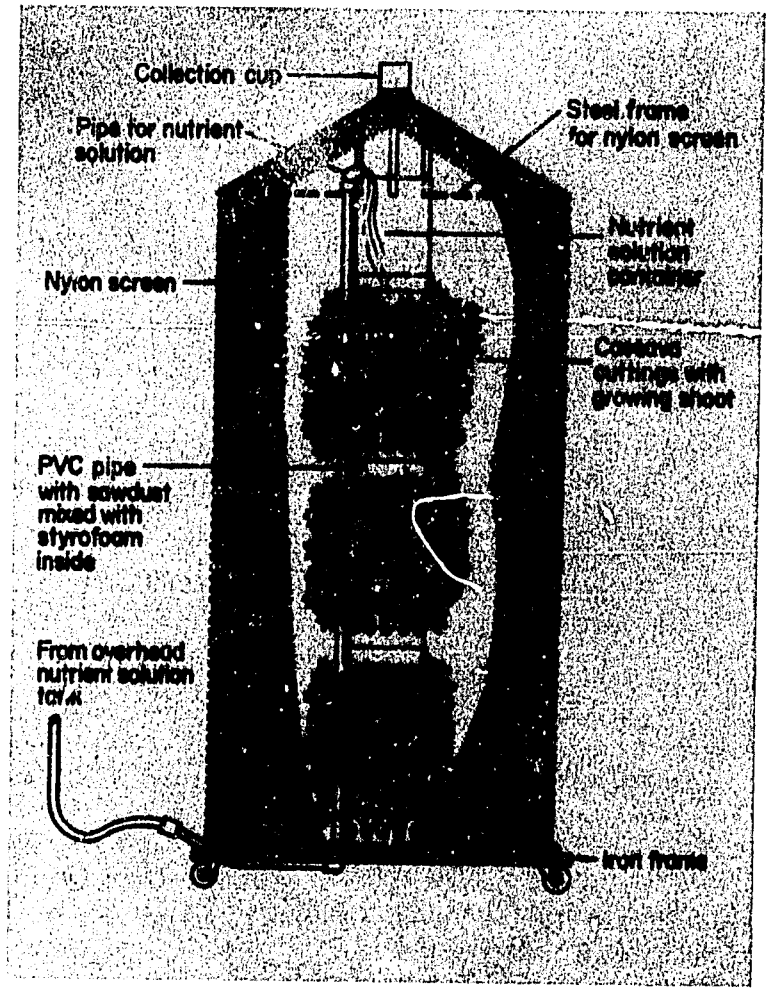
Advanced technology for a high and stable production of natural enemies of the cassava mealybug.

The cassava plants are artificially infested with mealybug "crawlers" and inoculated with *E. lopezi* in the same way as in the first system. Seven weeks after planting, about 10,000 parasitoids can be collected at the top of the unit. The "cassava trees" are placed outdoors in a

place of unrestricted air movement but protected against rain by a transparent polyethylene roof sheet. For the mealybug and parasitoid phase of the cycle, the "trees" have to be moved into a shaded portion of the shelter.

Under this low-cost, labor-intensive system, mealybugs and natural enemies are reared without airconditioning in tropical climatic conditions. Therefore, compared with the more sophisticated system, it is less efficient in terms of production and the output of natural enemies cannot be accurately predicted.

Figure 16. A low-cost unit for mass rearing of natural enemies of the cassava mealybug. (Designed for use by national biological control projects where electrical power may be irregular or unavailable.)



The simplified mass rearing equipment in operation.

Role of Indigenous Hyperparasitoids in Biological Control of Cassava Mealybug in Africa

Among the natural enemies imported from South America for control of the cassava mealybug (*Phenacoccus manihoti*), the parasitic wasp *Epidinocarsis lopezi* has proven to be particularly successful over the past three years. (See *Research Highlights* 1982–84.) It has now been released and established in 13 countries over 650,000 square kilometers in Africa.

During these releases, no hyperparasitoids were brought from South America. Because their host is another parasitoid, they are considered to be harmful to the biological control program. One of the main functions of the strict quarantine control therefore is to screen the field-collected material for hyperparasitoids and to remove known species of this habit. For the Africa-wide Biological Control Project (ABCP), quarantine is assured by the Commonwealth Institute of Biological Control (CIBC) and approved by the Nigerian Plant Quarantine and the Inter-African Phytosanitary Council.

But *E. lopezi* is now attacked by 10 indigenous species of hyperparasitoids which have been recovered from every African country in which the wasp was established and where extensive monitoring could be done: Cameroon, Congo, Gambia, Ghana, Guinea-Bissau, Nigeria, Rwanda, Togo, and Zaire. Several species were also recovered from other countries (including Senegal) before the establishment of *E. lopezi* and in Gabon where the wasp has not yet been released. These hyperparasitoids are indigenous African insects attacking parasitoids, mainly of the genus *Anagyrus*, which themselves develop in other mealybugs, like the closely related *Phenacoccus madeirensis*. Because hyperparasitoids, in general, are not strictly host-specific, they were able to adopt the freshly introduced *E. lopezi* as a new host.

This adaptation to the newly introduced parasitoid proved to be very fast. On numerous occasions hyperparasitoids were already present in the first sample taken one to a few months after the release of *E. lopezi*. At TEXAGRI farm near Abeokuta, Nigeria, hyperparasitoids reached 52.1% four months after the release (Figure 17). Farther away from the release site, *E. lopezi* arrived later and by March 1983 hyperparasitoids had not yet built up their populations to the same high level as on TEXAGRI farm. Hyperparasitism did not prevent rapid dispersal of *E. lopezi* and efficient biological control of the cassava mealybug in the area. (See *Research Highlights* 1984.)

But would the percentage hyperparasitism continue to grow in the future? The answer is "no" based on the results of four large-scale surveys from March 1983 to December 1984 in southwestern Nigeria. The mean percentage hyperparasitism fell dramatically (Table 35 and Figure 18). For each group of insects (parasitoids, hyperparasitoids, various predators, etc.), the scientists determined the mean number of insects per bunch top and the percentage of fields with bunch tops which yielded the particular insects. These figures were used to calculate the number of insects per 100 randomly collected cassava tips. Table 35 shows the reduction in bunch top density and the accompanying change in the abundance of *E. lopezi*.

Because of the diminishing parasitoid densities, the hyperparasitoids were unable to maintain their percentage hyperparasitism between March 1983 and December 1984.

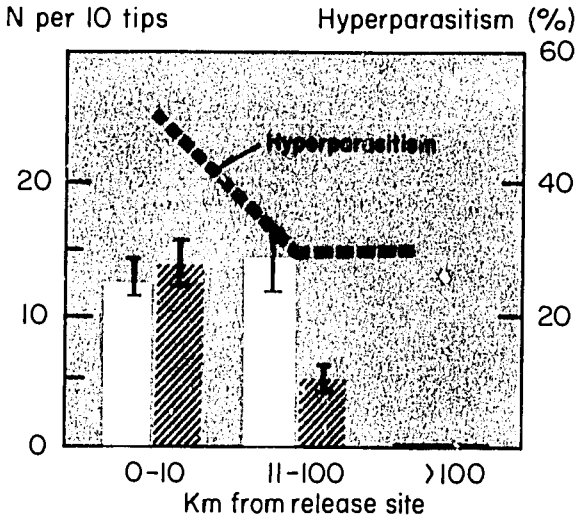
The result demonstrates a positive density-dependent relationship in time between hyperparasitoid and *E. lopezi* populations.

The same result was obtained when the percentage hyperparasitism of one sampling period (March 1983) was registered separately for different *E. lopezi* densities in different localities (Figure 19). The higher the number of *E. lopezi* emerging from a given sample of 10 bunch tops from one field, the higher the percentage hyperparasitism. Only at the highest host densities were the hyperparasitoids unable to catch up with their host. The conclusion? In a given period, the hyperparasitoids react in a positive density-dependent way to host population in different localities.

Where *E. lopezi* succeeds in keeping cassava mealybug populations low, its own populations do not reach the same high levels they often had shortly after establishment. In view of their density-dependent behavior, hyperparasitoids are expected to play a less important role now than during the establishment phase of *E. lopezi*. Based on field observations so far, IITA scientists do not expect them to pose a danger to the future progress of the African biological control program.

Table 35 also shows the very marked collapse of the indigenous predators and especially the coccinellid populations. Like coccinellids on many other crop pests, these beetles are mainly active on high host densities. Because *E. lopezi* reduced their food supply, their members became reduced. All other predators are much less common and have a limited impact.

Figure 17 (Left): Mean number of Epidinocarsis lopezi (white column) and its hyperparasitoids (grey) (· SE) reared from 10 bunch tops and percentage hyperparasitism at different distances from the release site. (Samples taken in March 1983.) Figure 18 (Right): Mean percentage hyperparasitism in southwestern Nigeria during four survey periods.



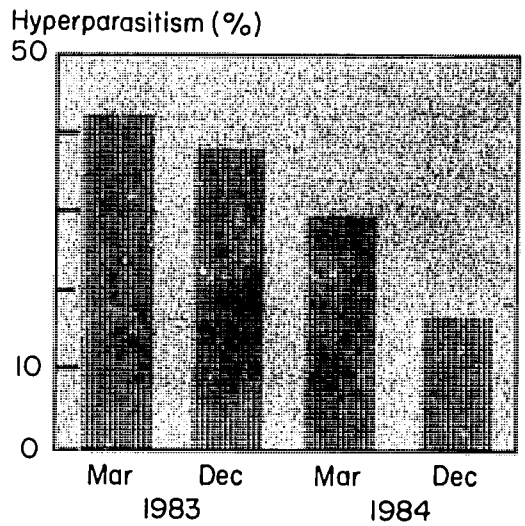


Figure 19. Percentage hyperparasitism in relation to the population density of Epidinocarsis lopezi in different localities in March, 1983. (x^2 45.20, significant)

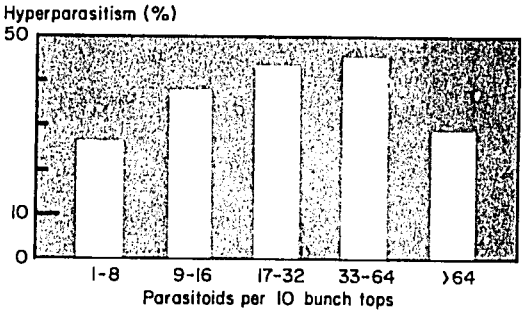


Table 35. Cassava mealybug damage and population densities of Epidinocarsis lopezi, its hyperparasitoids, and competitors in southwestern Nigeria during four survey periods.

	Survey periods				
	1983		1984		
	March*				
	> 100 km	< 100 km	Dec.**	March**	Dec.**
Total no. of fields	27	112	154	115	271
% fields with any bunch top	85.2	99.1	53.3	87.0	53.1
Mean % bunch tops per infested field	78.4	93.4	6.3	26.9	4.1
Calculated no. per 100 tips***					
Epidinocarsis lopezi	2.2	125.8	6.9	19.8	4.6
Hyperparasitoids	1.0	88.6	4.1	7.9	0.9
Coccinellids	191.0	160.3	2.2	13.1	0.3
Other predators	12.2	10.1	0.3	5.5	0.3

* > *100 km distance from release site: almost no* E. lopezi *yet.*
< *100 km distance from release site:* E. lopezi *in 82.9% of all fields.*
**E. lopezi *present in most fields.*
****Calculated as insects per bunch top × % fields with this insect × mean % bunch tops per field × % fields with CM × 100.*

Use of Tissue Culture for Screening Cassava Germplasm for Tolerance to Acid Soil

Under most circumstances, screening crop germplasm for tolerance to environmental stress makes special demands on land or glasshouse space, labor, expensive equipment, and the time of scientists and technicians. However, experiments indicate that the tissue culture method can be used for the first step in screening of cassava germplasm for tolerance to acid soil. This could assist plant breeders by eliminating a large portion of susceptible germplasm before field or glasshouse screening takes place.

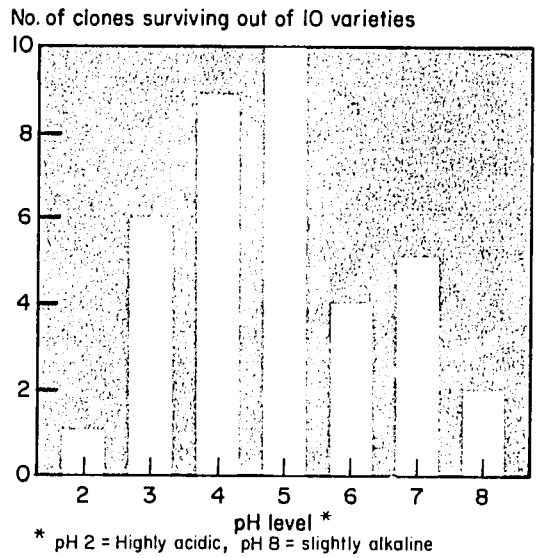
In the experiments, scientists used nodal cuttings of 10 selected cassava varieties obtained from meristem-cultured plantlets. The nodal cuttings were transferred onto liquid culture media which contained different pH levels (from pH 2 for highly acidic to pH 8 for slightly alkaline). The composition of the culture media for all treatments was essentially the same.

The percentage survival rate of nodal cuttings that exhibited notable growth was recorded weekly, and the lengths of the shoots that developed from the buds were measured on the third and fifth weeks after inoculation. Among the 10 varieties, there were varietal differences in optimal pH for the highest percent explant survival rate, but all cassava varieties tested had more than a 40% survival rate at pH 5 (Figure 20). The number of varieties that exhibited more than this decreased with the increase or decrease in pH above or below 5.

Only one variety (TMS 633397) had more than a 40% survival rate at the two extremes pH 2 and pH 8; variety TMS 60444 also survived at pH 8. The mean shoot lengths of the 10 varieties increased with time at all pH levels with the highest mean shoot length recorded at pH 4 and the lowest at pH 2. This indicated that high acidity adversely affected plant growth substantially.

The tissue culture technique may also be used in screening for tolerance to other stresses such as salinity and tolerance to chemicals. Further studies are underway to evaluate the practical application of this technique.

Figure 20. Number of cassava clones among 10 varieties that had more than a 40% survival rate at different pH levels in the culture medium (five weeks after inoculation).



Infection Rate of Selected Cassava Varieties by Cassava Mosaic Virus

Will a cassava variety susceptible to African cassava mosaic disease (CMV) but "clean" (disease-free) when planted in the field likely become infected soon thereafter? The answer is "yes" if the whitefly (*Bemisia tabaci*) which transmits this virus disease is present and disease pressure (inoculum) is high in the field. Depending on the susceptibility of the variety, cassava yield losses can range from 20 to 90%.

Using a meristem culture technique and rigorous virus indexing, IITA researchers selected three virus-free varieties: TMS 60444 (susceptible), TMS 4(2)1425 (moderately susceptible), and TMS 30001 (resistant). These varieties were then planted in IITA experimental fields with whitefly presence.

As shown in Figure 21, the susceptible variety became readily infected with the virus only two months after planting (scored 2.5), and within four months the infection score was rated as severe (3.7). Scores were determined at 2- to 3-month intervals using a scale from 1 (no symptoms) to 5 (severe infestation symptoms).

The moderately resistant variety picked up the infection gradually, scoring 1.2 at two months after planting. It remained stable for six months, and then the score increased slightly to 1.9 when the next rainy season began (12 months after planting). The resistant variety showed no cassava disease symptoms from planting time up to nine months. When the next rainy season started, the score climbed slightly to 1.6. (New growth encourages an increase in whitefly activity).

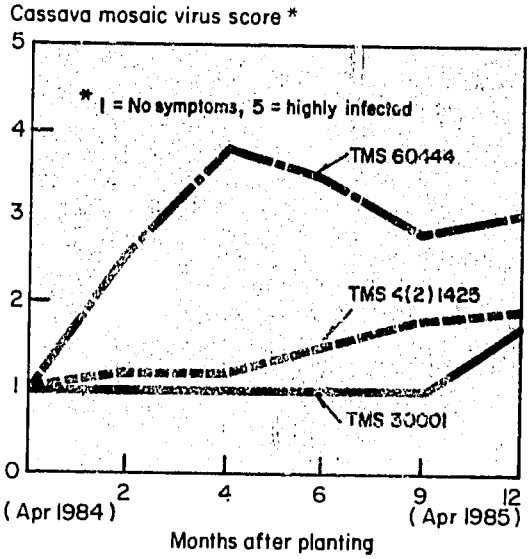


Figure 21. Cassava mosaic virus (CMV) score of three cassava varieties two to 12 months after planting.

New Methodology for Selecting Low Cyanide (HCN) Cassava

Research on cyanide transport from cassava leaves where it is synthesized to the edible storage roots has been hampered by the difficulties of linking what happens in the leaves in early generations to what is observed in the edible roots in advanced generations. A recent experiment at IITA appears to provide one of the necessary links.

Low cyanide (HCN) is generally desired, and three key factors account for the amount found in cassava roots: (1) leaf cyanide production, (2) leaf cyanide export to other plant parts, and (3) root cyanide accumulation. Knowledge of the relationship between these factors will help researchers identify suitable varieties. The practices of selecting low cyanide cassava varieties principally based on imprecise leaf cyanide assay is useful but inefficient.

In a field experiment, scientists tested combinations of reciprocal stem grafts among scions and stocks of the three cassava varieties – TMS 30001, TMS 30572, and TMS 50395 – that contain low, medium, and high cyanide. Despite a low cyanide production in stocks of TMS 30001 and 30572, the scion of TMS 50395 was consistently associated with high root cyanide content. Conversely, the high cyanide production stock of TMS 50395 was associated with low root cyanide when grafted to low cyanide scions of TMS 30001 and 30572 – proof that HCN is transported from leaves to roots. Larger differences among scions than among stocks (Table 36) also imply that scions exert a stronger influence on root cyanide content.

Further trials are underway to confirm these results, but it is clear that the basis for selecting low root cyanide in cassava improvement should include a more accurate measurement of cyanide levels in roots and leaves in early generations.

	Scion			
Stock	TMS 30001	TMS 30572	TMS 50395	Mean
TMS 30001	3.2 (4.0)*	3.2	6.3	4.2
TMS 30572	4.6	3.3 (5.2)*	7.7	5.2
TMS 50395	4.1	4.3	7.5 (10.6)*	5.3
Mean	4.0	3.6	7.3	

*Unpaired.

Table 36. Mean root cyanide in cassava stem grafts (mg HCN/100 g fresh weight).

Yam Micro Tuber Production in Tissue Culture for International Distribution

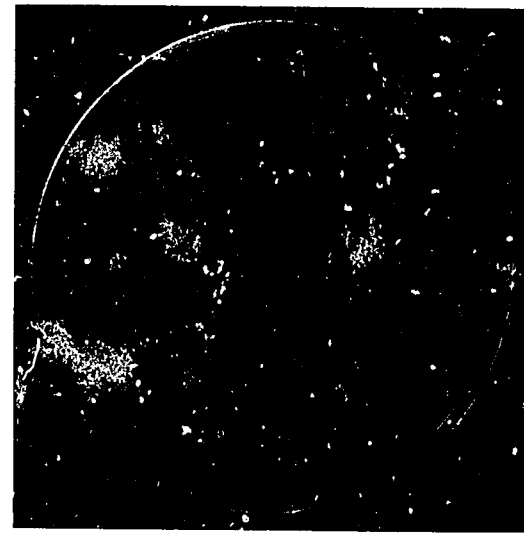
Hand-carrying tissue culture materials – the usual method of distribution of virus-free yam plantlets from IITA to scientists in national programs – often results in a very low survival rate because the plantlets deteriorate if kept in the dark for prolonged periods of time. Furthermore, this distribution method has created two other problems for the tissue culture laboratories: the plant materials have to be ready and in sufficient quantity at any time, and it is impossible to target the quantity needed and the date of delivery of the materials.

Yam micro tubers produced in tissue culture offer solutions to these problems. They can be sent by mail which has not been possible before. Also, they are easier to handle when planting, and, compared with plantlets, more of them survive. Scientists produce the micro tubers by culturing node cuttings of the virus-free plants. Because they are virus-free, quarantine authorities approve them for international distribution.

Tubers of different shapes and sizes have been obtained at IITA from a number of varieties of both *D. rotundata* (white yam) and *D. alata* (water yam) plantlets grown in culture media for four months. Technicians remove the plantlets from the culture containers aseptically and detach the micro tubers from the mother plant for storage. The nodal cuttings of the plantlets are transferred to fresh culture media for further multiplication.

The micro tubers stored in the culture media sprouted three to four months after storage but those stored without culture media and under dark conditions sprouted after six to seven months. The storage duration is much longer than required to reach most destinations by mail.

The tuberization of yams *in vitro* was influenced by the sucrose concentration in the culture media and was highest with a 5% sucrose concentration. Sucrose concentrations higher or lower than 5% decreased the frequency of tuberization, indicating that tuberization can be manipulated by this technique under *in vitro* conditions.



White yam plantlets with mini tubers grown in a tissue culture medium.

Planting Density for Yam Microsetts

Growing pre-germinated 5 to 10 gram microsetts under plastic mulch can reduce the yam tonnage used as planting material as well as increase the multiplication rate tenfold over conventional systems. The use of microsetts – small pieces of yam cut from "mother" seed yams – does not only substantially cut the farmer's cost for traditional planting materials but also saves an enormous amount of yams for food in Africa.

How many yam microsetts can be planted per hectare with satisfactory results 50,000, 80,000, 100,000? To find out, scientists conducted spacing experiments with 7-gram microsetts of the white yam variety TDr 131. The results showed that as the number of tubers per hectare increased, the average tuber weight decreased, but yield per hectare increased as planting density of microsetts was increased (Figure 22).

The relationship between the number of tubers per hectare and tuber weight showed that a tuber weight of about 280 or 240 grams can be obtained when plant density is 60,000 and 80,000 per hectare, respectively. Researchers estimate that tuber weight will be about 225 grams at a plant density of 100,000 per hectare. This means that an adequate seed yam weight might be achieved even at a planting density of 100,000 per hectare.

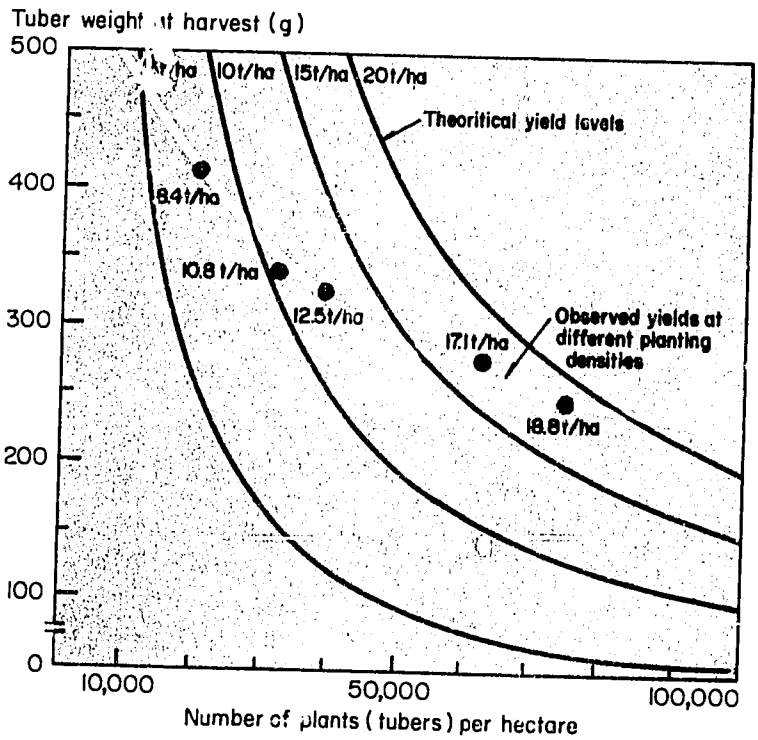
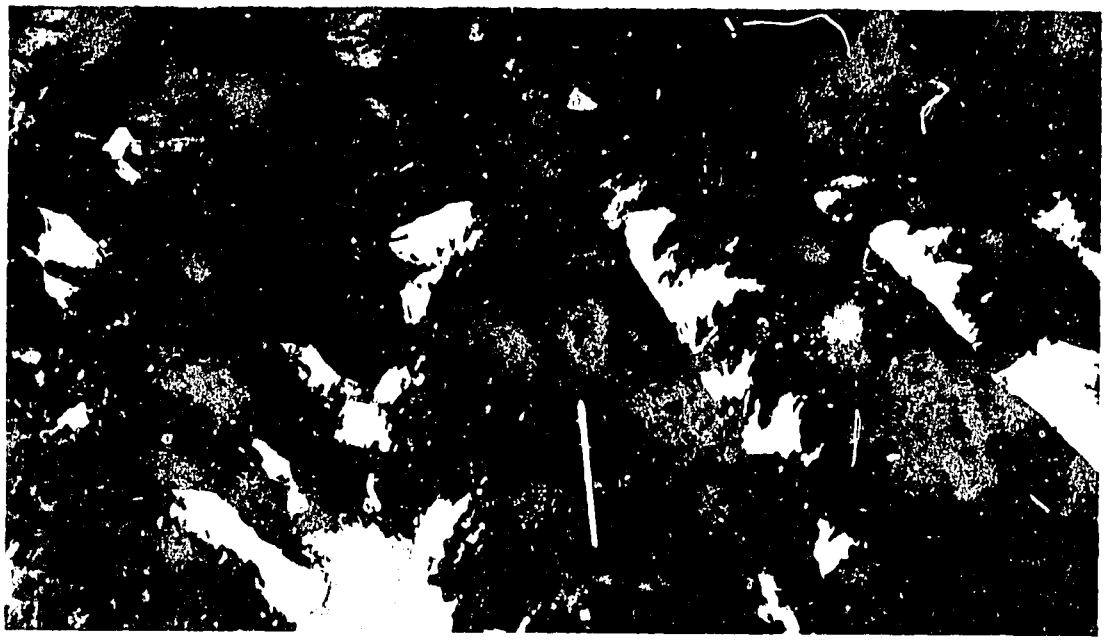


Figure 22. Relationship between number of 7-gram white yam microsetts per hectare, tuber weight, and tuber yield (t/ha).



White plastic mulch used with white yam minisetts helped to produce healthier and faster growing plants compared with black plastic mulch.

Effects of Different Mulching Materials and Plant Population on Seed Yam Production

Continuing their research to help ensure that farmers who adopt the new minisett technology achieve high and reliable yields, IITA scientists investigated the effects of different mulching practices and plant populations on white yam (*Dioscorea rotundata*) seed production. The technology involves cutting the "mother" seed yam into small pieces called minisetts. They are treated in a fungicide/insecticide suspension, planted in a nursery bed to sprout, and then transplanted into the field on ridges covered with plastic mulch. (*Research Highlights* 1984.)

The scientists used these six treatments in their 1985 experiments: (1) black and white polyethylene plastic with the black surface up; (2) black and white polyethylene plastic with the white surface up; (3) lighter black polyethylene plastic; (4) rice straw mulch; (5) no mulch but plants staked; and (6) no mulch and no staking.

In the first trial with yam variety TDr 131, polyethylene plastic with the white surface up was superior to any other treatments both in terms of the mean tuber size (606 grams/tuber) and the overall yield at the end of the seasons (22 t/ha). These figures are 50% higher than those achieved from the traditional staking

method and more than double those obtained from the no staking-no mulch situation (Table 37). The second best treatment was rice straw mulch with 500 grams/tuber and an overall yield equivalent to 18 t/ha.

In the second trial, TDr 131 and a second variety TDr 179 were examined under polyethylene plastic (with the white surface up) and a no mulch situation. Each variety was grown at four plant populations ranging from 20,000 to 80,000 plants per hectare. At any given plant population both the average size of the tubers and the total tuber yield per unit area was more than 50% higher in the polyethylene treatment.

The superiority of the white plastic surface is probably due to a larger leaf area index and longer leaf area duration which result in a higher bulking rate over a comparatively longer period. Also, it may have improved the light interception pattern of the plants. Whatever the reasons, two things seem clear: Under tropical conditions, farmers can get better yields per hectare if they use white polyethylene plastic mulch and increase the plant density of the minisetts.

Treatment	No. of tubers/ha	Wt/tuber grams	Tuber yield t/ha	LAI*
Polyethylene plastic Black surface up	36,050	425.0	15.5	1.1
Polyethylene plastic (White surface up)	**37,330**	**605.8**	**22.2**	**2.3**
Lighter black Polyethylene plastic	33,790	415.5	14.2	1.3
Traditional staking	37,160	399.9	14.9	0.6
No stakes, no mulch	31,150	312.9	10.7	0.5
Rice straw	31,300	517.8	17.9	1.3

**Mean of the last two samplings.*

Table 37. Effect of different mulching materials, staking, and type of polyethylene mulch on white yam (*Dioscorea rotundata*) minisetts.

First New Water Yam Clones from Seeds

Since yam breeding work began at IITA a decade ago, selection of new promising water yam cultivars from seedlings of limited amounts of true seeds have not been sucessful in producing genotypes with acceptable tuber shapes. But sustained efforts at sexual seed production and improved nursery evaluation are beginning to pay off.

Water yam (*Dioscorea alata*) comes after white and yellow yams in terms of spatial spread, intensity of cultivation, and preferences in consumption. Previous breeding efforts with this important food yam species have been constrained by:

- Poor synchronization of flowering periods of early male and late female plants, plus a generally low intensity of flowering among parental clones.
- A long vegetative phase from seed germination to flowering coupled with a long seed formation period so that the seeds had to mature under unfavorably dry season conditions.
- Breeding clones largely susceptible to leaf necrosis, resulting in complete die back before flowering.

Mature seeds from crosses between numerous water yam parental clones were grown in nursery beds in the 1984 season, and resulting tubers replanted in the field in 1985. Of 56 clones tested there, 12 with acceptable tuber shapes and yields were selected. When scored for disease reaction to the most important pathogens of water yam (shoot necrosis and virus) their performance was promising.

With further genetic recombination from crosses using these new clones from seeds, there is now a greater potential for water yam improvement by incorporating necrosis resistance and profuse flowering characters. Also, these achievements will permit international exchange of water yam genetic stocks in seed form — an opportunity which did not exist before.

Water yam breeding clones with desirable tuber conformation.

Plastic Mulch for Increased Ware Yam Production

Although previous experiments showed that plastic mulching can help eliminate staking for seed yams, the possible advantages of using it for ware yam production were not known. (Ware yams are large yams for marketing and consumption). Therefore, during 1984–85, IITA scientists used plastic mulch with or without staking and whole seed yam tubers (400 grams) for ware yam production. They compared these treatments with the traditional system which uses staking but not plastic mulch.

Results? Plastic mulch gave 68 to 80% larger tuber yields compared with no mulching (Table 38). Staking yam vines increased the yield by 20% compared with no staking, but the increase for plastic mulch alone was 39% more than the traditional system (Table 39).

An economic assessment shows that each additional Nigerian Naira spent in changing from traditional yam farming to a mulched and staked operation can earn a 3.70 Naira return. On the other hand, each additional Naira spent in changing from traditional practice to the plastic mulch operation without staking can earn 4.23 (Table 39). When plastic mulch was used, the additional yield benefits from adding stakes did not offset the cost of staking.

Contrary to the common belief that yam yield is low when started later than February, the yields from the plastic mulch plots in these experiments were always higher than those from the unmulched plots regardless of the planting dates in April, May, June, and July, and the yields were not decreased until June (Table 38).

These results should encourage the use of plastic mulch and quality seed yam to help extend the planting season. Other advantages include reduced labor for ridge/mound preparation because of rain softened soil and better labor distribution because the time of weeding can be adjusted to periods when the demand for labor is less.

	Time of planting			
	April	May	June	July
Treatment	yam yield (t/ha)*			
Plastic mulch	**15.5**	**15.0**	**17.6**	**8.9**
No mulch	9.2	8.6	9.8	5.1
Yield increase from mulch (%)	68	74	80	75

*Average of 16 replications.

Table 38. Ware yam yield with and without plastic mulch; different times of planting and November harvest.

Large ware yams in a Nigerian market.

Table 39. Ware yam production using alternative management methods: costs and income (Nigerian Naira).

Items	Treatments			
	Traditional yam farming	Mulched and staked	**Mulched and unstaked**	Unmulched and unstaked
Benefits				
Yield (kg/ha)	9,300.00	15,600.00	**12,900.00**	7,000.00
Gross income	4,464.00	7,488.00	**6,192.00**	3,360.00
Land preparation	312.00	312.00	**312.00**	312.00
Cost of planting material	3,000.00	3,000.00	**3,000.00**	3,000.00
Total labor cost	774.00	822.00	**504.00**	468.00
Cost of plastic mulch		600.00	**600.00**	
Total variable cost	4,086.00	4,734.00	**4,416.00**	3,780.00
Net income	378.00	2,754.00	**1,776.00**	-420.00
Benefit-cost ratio	1.09	1.58	**1.40**	0.89
Ratio of change in income to change in expenses between traditional and experimental treatments*		3.67	**4.23**	N.A

** The ratio shows the additional income generated by each additional Naira outlay to change from the traditional system to the experimental treatments.*

Early, High Yielding and Stable Sweet Potato Lines for Rwanda

Sweet potatoes – the second most important sources of carbohydrates as a dietary staple in Rwanda – account for about half of the total root crops produced. But production is not keeping pace with demands from an expanding population.

Because local varieties grown by farmers are late bulking and susceptible to sweet potato virus complex and anthracnose, IITA and national scientists have tested and selected lines that are early bulking and adapted to varied agro-ecologies where the crop is grown. In a recent survey, farmers in Rwanda reported that earliness was by far the most preferred characteristic for sweet potato lines, followed by adaptability to the soil, high yield, good taste, and resistance to weevils and drought. A common comment heard in Rwanda is "late bulking lines are for the rich because only they can afford to wait."

Field tests were conducted in 1985 in six different experiment station environments and at seven off-station sites representing a wide spectrum of sweet potato production areas ranging from lowland acid soils to high altitude.

The line DV 16/820 was the best with a mean yield of 12.8 t/ha and with good adaptation to a wide range of environments. It and the other high yielding early lines at the six stations (Table 40) consistently remained the high yielders in the other test areas. They are being multiplied for distribution to farmers and collaborative projects.

The elite sweet potato line DV 16/820 (right foreground) had the highest yields in field tests in six different environments in Rwanda; TIS 2544 (left) was second.

Line	Mean yield t/ha	Regression coefficient
DV 16/820	**12.8**	**1.28**
TIS 2544	9.6	1.37
Serura	9.3	1.02
Rutambira	9.2	.96
Bukarasa 812	9.1	1.00
Wadada	7.6	.91
Resenya (local check)	6.3	.71
Nyiramujuna	5.1	.71
Mean	8.6	
SE	2.3	

Table 40. Mean yield and stability index of elite sweet potato lines tested in six environments in Rwanda.

Evaluating Sweet Potato Lines in IITA's Germplasm Collection for Less Sweetness

Consumers in West Africa consider the sweet taste in sweet potatoes an undesirable characteristic and prefer non-sweet varieties called staple sweet potatoes. Staple lines in IITA's germplasm collection, consisting of almost 600 clones, have been selected by determining total soluble sugar and reducing sugar concentrations in the flour prepared from raw and baked tubers.

Among the sweet potato lines tested for yield at IITA in 1985, three had low total sugar concentration even after baking (Table 41). The sugar concentration increased very little after baking due to low concentration and/or activity of the amylase enzymes which convert starch to sugars during the initial period of cooking.

Fifty-one more lines in the collection were identified as non-sweet. A few, such as TIS 8267 and TIS 9191, did not show an increase in sugar concentration after baking, suggesting absence of amylase activity. In a preliminary taste panel evaluation of baked and boiled sweet potatoes, the line TIS 8504 with a fresh root yield of 23.6 t/ha was never rated sweet.

More breeding work using non-sweet lines to produce sweet potatoes similar to white yam in degree of sweetness, texture, and color will increase the potential of this tuber crop as a staple food in West Africa.

Sweet potato lines	Fresh root yield (t/ha)	Total soluble sugars (%) Raw tuber (wet basis)	Raw tuber flour (dry basis)	Baked tuber flour (dry basis)
Non-Sweet				
TIS 8504	23.6	3.4	14.6	18.6
TIS 84/0007	19.6	5.8	17.6	20.2
TIS 84/0026	13.3	7.4	22.0	19.8
Sweet				
TIb 4	18.7	5.0	19.4	48.8
TIS 2498	16.0	5.6	17.5	26.8
TIS 8250	32.8	4.7	27.2	24.8

Table 41. Yield and total soluble sugar concentration of six sweet potato lines (1985).

Integrated Management for Control of Sweet Potato Weevils

Experiments show that a combination of several methods are necessary if weevils (*Cylas* spp.) – the most destructive pests of sweet potatoes both in the field and in storage – are to be controlled effectively. No single method has accomplished this.

Studies of individual control techniques have shown that some improved sweet potato varieties sustain less weevil damage in the field than non-improved ones. Early planting and harvesting are also important because the weevils are dry season pests and their population builds up only during that period of the year. Furthermore, the weevils locate and damage the crop by following cracks in the soil around growing tubers. Earthing up the plants or placing an additional layer of soil on the ridge (re-ridging) makes it difficult for the weevils to locate the tubers.

After the harvest, putting the sweet potatoes in underground storage adversely affects weevil development, and putting plant materials with insecticidal or insect repellent properties in underground storage pits may further reduce weevil damage.

One phase of an experiment to collect data for the development of an integrated weevil management program involved two improved sweet potato lines with moderate resistance to the weevils (TIS 2532 and TIS 70357) and a local susceptible one (TIb 11). They were planted in June (early planting) and September (late planting) and harvested in October and December. At harvest time records were kept of the number of plants with damaged tubers (hill

A combination of control measures are needed to reduce weevil damage to sweet potatoes; shown here is an enlarged close-up of the weevil and its damage.

infestation), weevil feeding holes on tubers, the number of weevils, and the number of tubers which would not be marketed because of weevil damage.

The percentage of unmarketable TIb 11 tubers planted and harvested late was as high as 42% compared with only 5% of the improved and moderately resistant line TIS 2532. However, preliminary results show that the integration of improved lines moderately resistant to weevils with early planting and harvesting and re-ridging produces the best overall results.

Annual Report Executive Summary

International Cooperation and Training Program

A major responsibility of IITA is to develop effective linkages with national and regional programs to ensure that the technologies developed through research reach the potential beneficiaries — farmers and consumers. Collaborative projects and comprehensive training programs are principal instruments to achieve this goal.

Current policy calls for an increasing number of research and training program activities to be conducted outside the Institute's headquarters in Ibadan, Nigeria so that local specific agricultural production problems can be adequately tackled. Among the actions taken was the establishment of a substation in the Republic of Benin and officially dedicated in September 1985.

During the year, IITA participated in collaborative project activities designed to strengthen national/regional research capabilities in nine other African countries: Cameroon, Ghana, Kenya, Niger, Rwanda, Sierra Leone, Tanzania, Zaire, and Zimbabwe.

Close linkages are fostered between personnel in IITA's International Cooperation and Training Program and representatives of national programs. (One group is shown here on a field trip.)

Primary assistance in Cameroon involved the generation and selection of germplasm of maize, rice, and root crops adapted to different ecological zones, and the testing of new varieties developed from this germplasm through the activities of the Testing and Liaison Unit. The Institute accepted the responsibility to continue to provide assistance to the National Cereals Research and Extension Project for five more years and to the Cameroon National Root Crops Improvement Program for another three years.

An expanded program in Zaire provides assistance to a project designed to integrate and sustain the research and technical manpower capabilities of that country to develop and transfer agricultural technologies with emphasis not only on cassava but also on maize and grain legumes. Previously, IITA involvement in Zaire was limited to cassava.

Assistance to Ghana in 1985 made it possible for scientists there to strengthen the existing legume breeding program for the development of specific high yielding varieties of cowpeas and soybeans.

Activities in Kenya were designed to strengthen collaboration with the International Centre for Insect Physiology and Ecology (ICIPE) and to complement its research efforts and those of IITA in the areas of cowpea improvement and integrated pest management.

IITA intensified its efforts in Niger in the identification, selection, and testing of cowpea cultivars suitable for millet-based cropping systems for the Sahelian region of Africa.

The scientific team in Rwanda is engaged in the selection of crops/varieties and the development and testing of cropping systems adaptable to the semi-arid conditions in certain areas of that country. In addition, assistance is provided for the development of a strong Rwandan national cassava and sweet potato improvement program.

In Sierra Leone, IITA initiated a program of assistance for the development of suitable technologies in soil and crop management for intensive utilization of inland valleys for rice-based farming systems by low resource farmers in West Africa. This activity is part of a West Africa-wide program for wetlands development. Similar activities are underway in the Bida area of Nigeria and planned for the Republic of Benin.

A program on the other side of Africa in Tanzania is designed to develop strong collaboration with Tanzanian national and other Eastern African research organizations for testing and evaluating cowpea production technologies. Also, it seeks to develop training programs for agricultural manpower development in the region.

IITA collaborates with CIMMYT in Zimbabwe in the development of a maize breeding program to generate germplasm adapted to mid-altitude areas which can be exchanged on an Africa-wide basis. The Institute is also involved in the development of a regional research program for grain legumes with major focus on varieties resistant or tolerant to local stresses and technologies for cropping systems suitable for countries in Southern Africa.

Research support continued for SAFGRAD's regional maize and cowpea improvement program for 26 countries in the semi-arid tropics of Africa stretching across the southern edge of the Sahara desert and down to the southern part of the continent.

Altogether, 42 IITA scientists have been assigned to country and regional programs in Africa, Southeast Asia, and Latin America to assist with the development of comprehensive programs for evaluation and adoption of improved germplasm for maize, rice, cowpeas, soybeans, cassava, sweet potato, yams, aroids and improved farming systems technology.

Current training strategy calls for a gradual shift from offering practically all training courses at IITA's headquarters to scheduling them in various countries with an emphasis on regional coverage. The Institute provides assistance in strengthening institutional capabilities within national/regional programs to enable their personnel to assume these responsibilities.

During the year, 28 group courses were conducted at IITA and in the Republic of Benin, Sierra Leone, Rwanda, Brazil, and the Philippines. Out of the 678 persons who attended them, 100 were participants in off-site training activities and the remainder in Ibadan-based courses. The major focus of these group courses was research and production technology for all crops in the Institute's mandate, plus specialized topics such as weed control, soil and plant analysis, soil and water conservation, and statistics in agricultural experimentation.

Through degree-related training programs, supervisory support was provided for 34 M.Sc and 28 Ph.D. candidates from 14 and 12 African countries, respectively. These graduate students are engaged in the thesis research component of their university degree work. This arrangement ensures that the young researchers benefit from the experience and expertise of IITA's senior research scientists. At the same time, it enables the scientists to expand their capacity for more in-depth research with the assistance of these young scientists.

In addition to providing training opportunities for 13 participants from five Portuguese-speaking African countries, the Institute provided a forum to further identify specific areas of need for agricultural training for nationals from Guinea Bissau, Angola, Mozambique, Sao Tome, and Cape Verde. As a result of the discussions at a roundtable at IITA headquarters, plans were developed for a comprehensive training program for Lusophone African countries.

Thirty-two agricultural technicians and students were trained through non-degree related and vacation student scholarship programs. Their programs were designed to respond to the demand to help improve the agricultural technology research and production skills of employees of departments and ministries of agriculture, international organizations, private agencies, and universities in Africa and elsewhere.

The overwhelming proportion of the 740 participants in all training program categories during 1985 were from Africa. For the first time, however, participants came from Cape Verde, Nepal, Ireland, the Bahamas, Bolivia, Ecuador, Mexico, Panama and Paraguay.

One of the most comprehensive and long-running training programs for assisting the development of national manpower capabilities is in Zaire. Over the past 10 years, IITA systematically organized and delivered training services that have ensured the establishment of a full-fledged Zaire National Cassava Program. A total of 153 Zaire nationals at various levels and in various disciplines received training. Notable among these are 19 M.Sc and 11

Ph.D. degree holders who have now assumed responsibilities for leadership in a major national thrust in cassava production.

More complete information on the topics mentioned in this Executive Summary can be obtained by requesting the Annual Report of the International Cooperation and Training Program.

Annual Report Executive Summary

Documentation, Information and Library Program

It was a year of consolidation for the relatively young Documentation, Information, and Library Program — the focal point for the information activities of the Institute. Its constituent units are: Conference and Visitors' Center, Interpretation and Translations, Library and Documentation Center, Public Affairs, and Publications, including graphics, audiovisuals, and printing.

Library automation was a major achievement in 1985. An integrated computerized library system was developed covering all acquisitions, cataloging, and circulation functions. All catalog records, circulation records, and "outstanding order" files were input into the

A computerized library system was developed during 1985.

online bibliographical database which was named ALISTRA. At the end of 1985, this database had about 40,000 records. The system has a large number of fields that can be searched online. These include authors, all keywords in the titles of publications, subject descriptors, publishers, corporate sources, publication dates, and keywords in abstracts.

Taking advantage of the automated system, library staff members now supply to scientists and senior management lists of new books and journal articles which match their specific interest profiles. This service, known as Selective Dissemination of Information (SDI), has proven to be useful to all concerned. Automation of the library also permits fast compilation of bibliographies on various subjects, whether broad or highly specialized, to meet the demands of scientists and trainees.

When IITA purchased the computer software package for the system (called BASIS), negotiations were completed so that other CGIAR centers could obtain this versatile database management system at a discount. Two centers (CIP and ICRISAT) decided to do so, and IITA will help the former install the system in 1986. The use of the same software package (BASIS) on the same VAX computer will facilitate collaboration and exchange of scientific information among the international centers.

During 1985, a new computerized mailing list was developed using BASIS. The old computer program was limited and clumsy to use. The new mailing list database can be searched via numerous categories: for example, by name, job title, discipline, organization, publication(s) required, language, and subjects of interest. All entries in the mailing list were individually checked and corrected as necessary. Although some addresses were dropped, there was a net increase of about 600 during 1985, bringing the total to 4,600. Most of the additions were libraries to facilitate the implementation of a Deposit Library Scheme in which libraries of key institutions in Africa and donor countries are designated IITA Deposit Libraries. They receive all IITA publications *gratis* and are requested to make them readily available to anyone seeking information about the Institute's work.

Publications produced during the year included: *IITA Annual Report 1984*; *IITA Research Highlights 1984*; *Le Point de la Recherche 1984*; *Varietal Improvement of Cowpea/L'amelioration varietale du niebe* (Crop Production Training Series No. 1); *Tropical Root Crops: Their Improvement and Utilization*; *A Bibliography of Yams in the Genus Dioscorea, vol. 2*, 1975–1983; *A Case Study of On-Farm Adaptive Research in Bida Agricultural Development Project* (OFR Bulletin No. 1); and *Report on Exploratory Survey of Ijaiye Imini Pilot Research Area, Oyo State, Nigeria* (OFR Bulletin No. 2). Reprints of the *Research Highlights* for 1981–1984 were compiled and published for each of the five research programs.

The audiovisual staff initiated video recordings of Institute activities and produced an entirely new 17-minute, three-projector audio/slide presentation giving an overview of the Institute's research and training activities. Mass media coverage of IITA's work (particularly through newspapers and magazines) was frequent and widespread during 1985. Research accomplishments were displayed at a week-long Farm Tech '85 Exhibition in Kingston, Jamaica. More than 20,000 visitors, including Jamaica's Prime Minister, toured the IITA exhibit. The Institute was also represented at both the Zimbabwe and Frankfurt Book Fairs.

Seminars were conducted for various audiences in Nigeria and at the University of Bonn in West Germany and the International Development Research Centre in Ottawa, Canada, and staff members collaborated with scientists to organize many field days "on-site," as well as at various locations off-campus. These field days attracted thousands of farmers, extension workers, government officials, and researchers of other institutions. Two open-house days held on the campus attracted members of the Nigerian Chamber of Commerce and individual prospective investors in agriculture.

Jamaica's Governor General (left) visits an IITA exhibit prepared by the staff of the Documentation, Information and Library Program.

Annual Report Executive Summary
Virology Unit

Virology research in 1985 focused on the etiology of unknown diseases, refining indexing techniques, resistance screening, studies on pathogenic variability, and ecology of viruses. To facilitate control of virus diseases causing economic losses in crops under investigation at IITA, virologists continued studies on virus diseases in cassava, yams, sweet potatoes, cocoyams, cowpeas, soybeans, rice, and maize. They collaborated with pathologists, breeders, and entomologists of crop improvement programs to screen for resistance against important virus diseases.

One of the virologists spent a year on sabbatical leave at the Asian Vegetable Research and Development Center (AVRDC) in Taiwan and at the Research Institute for Plant Protection (IPO) in the Netherlands to make an in-depth study of sweet potato viruses. A sound knowledge of various viruses present in different countries is considered essential to be able to develop indexing methods for the exchange of germplasm on a global scale.

Although various potyviruses have been isolated from sweet potatoes in Taiwan and other countries, very little is known with certainty regarding their role in the etiology of known virus diseases in this crop. In addition to the aphid-borne potyviruses, the occurrence of whitefly-borne viruses has been reported from various countries.

The aim of a more detailed study of the whitefly-borne 'leaf curl' disease in Taiwan was to isolate and purify the causal agent and/or to develop a reliable testing procedure for this virus, and to investigate its possible role in the etiology of (virus) diseases other than 'leaf curl' reportedly occurring in this crop in Taiwan and possibly other countries in the Southeast Asian region. By means of whitefly transmission to *Ipomoea setosa*, as well as to true seedlings of sweet potato, various virus isolates were obtained from plant samples taken from obviously virus-infected and symptom-showing sweet potato plants. Most of the isolates obtained in this manner only proved capable of inducing leaf curl-like symptoms of varying degrees of severity in sweet potato seedlings, whereas *I. setosa* proved highly susceptible to all isolates obtained in this manner, developing characteristic and severely stunted growth and yellowing symptoms. Thus, the indexing for this virus is very reliable by grafting to *I. setosa*.

Several aphid-borne and sap-transmitted virus isolates were obtained from diseased sweet potatoes and from the common weed species, *I. triloba* and *I. obscura*, showing various kinds of virus-like symptoms other than those of typical 'leaf-curl'. None of the aphid-borne and/or sap-transmitted isolates proved capable of inducing disease symptoms of the kind and severity observed in diseased plants of the same local varieties from which disease samples were originally taken.

Mutual, serological comparison of six sap-transmitted isolates from sweet potato obtained in *Nicotiana benthamiana* have shown that all are closely related and possibly identical (virus H).

Serological studies have also revealed that none of the virus isolates obtained from sweet potato through sap and aphid transmission, either in *N. benthamiana* or *I. setosa*, represent viruses which are serologically related either to FMV or SPV-N, the latter being a poty(?) virus which has so far been described from Taiwan only. Indexing for the newly isolated potyvirus (Virus II) may be done with the antiserum prepared for this new and possibly hitherto undescribed virus of sweet potato which was successfully purified from *N. benthamiana*.

New potyvirus isolates obtained from sweet potato in Nigeria were also purified and antisera produced. The virus isolates from Nigeria reacted with an antiserum against feathery mottle virus (FMV) from the United States. Similarly, diseased sweet potato samples from Nigeria when tested in ELISA using FMV antiserum gave a positive reaction. It is concluded that the aphid-transmitted component of the sweet potato virus complex from Nigeria is similar or identical to the FMV reported from the U.S. and other countries.

In Zaire, some of IITA's improved and CMD-tolerant cassava cultivars showed prominent symptoms of cassava mosaic. To identify this disease and compare the cassava mosaic disease from Nigeria with that from Zaire, comparative studies were initiated at IPO. Using the antiserum produced at IITA, samples from Zaire were compared in ELISA. Some samples from Zaire showed milder symptoms on *N. benthamiana* and proved serologically different. The knowledge of the different types of cassava mosaic virus and their distribution is considered essential for developing widely adapted and resistant cultivars. Further work on characterization of the isolates from Zaire is in progress.

Because cowpea aphid-borne mosaic virus (CAbMV) and cowpea yellow mosaic virus (CYMV) are economically important constraints, the research activities during 1985 included the collection and identification of different isolates and a study of the relative importance of various types as far as resistance is concerned.

For selecting better sources of resistance to rice yellow mottle virus (RYMV), scientists coupled visual assessment of symptomatology with comparative virus antigen concentration as determined by ELISA to differentiate resistant/tolerant lines. They found that some *Oryza glaberrima* and *O. barthii* accessions are immune from this virus.

A few viruses are reported to be seed-transmitted in cowpeas and soybeans. Therefore, information on seed transmission of several viruses has been updated. Extensive screenhouse and laboratory tests showed no seed transmission of cowpea yellow mosaic virus (CYMV) in cowpeas. This finding is contrary to previous reports. Similar results were obtained when seeds collected from cowpea mild mottle virus (CMMV) infected soybean plants (Malayan variety) were sown and the seedlings were tested in ELISA, but all proved to be negative. However, other soybean lines will be tested before concluding that there is likely to be no seed transmission of CMMV in soybeans.

In screening advanced soybean breeding lines, using the standard and a severe isolate of soybean mosaic virus (SMV), several lines were identified as resistant to this virus.

An outbreak of maize stripe virus at IITA fields was positively identified by transmission tests by *Peregrinus maidis* to the same maize lines which showed symptoms in the field. This was

again confirmed by serological tests using antisera from the U.S. Various parents used in the breeding program are being screened against maize stripe virus in collaboration with pathologists and plant breeders.

More complete information on the topics mentioned in this Executive Summary can be obtained by requesting the Annual Report of the Virology Unit.

Annual Report Executive Summary
Genetic Resources Unit

Plant exploration and acquisition activities continued during the year with 421 samples of seeds of cowpeas, rice, and other crops collected in the Central African Republic and added to IITA's large germplasm "bank." In this and other collection expeditions, the Institute seeks out both cultivated and wild species which become the source of genetic diversity used by scientists to develop new insect- and disease-resistant and high yielding varieties. National programs and IITA's researchers provided another 502 samples in 1985.

Part of the "bank's" stock – 12,497 samples – was sent to 29 countries for use in their plant breeding programs, and during the year several thousand germplasm accessions were grown at IITA's headquarters for seed increase or rejuvenation. The staff also documented data on morphological and agronomic characteristics and other factors for more than 3,000 accessions, and this process continues, as does updating of the germplasm information by computer. These data speed up the rate of scientists' finding of specific genetic materials they want for their research.

In collaboration with entomologists, 8,265 accessions of cowpea germplasm were evaluated for resistance to pod sucking bugs at Mokwa, Nigeria, and the best of these were selected for further screening. Also, in cooperation with virologists, 27 accessions of *Vigna vexillata* (a wild cowpea species) were screened for resistance to cowpea mottle virus. Almost all of them were immune. So far, scientists have not found good sources of resistance to this virus in cultivated crops. During 1985, crosses were made between cultivated and wild species, but these crosses were unsuccessful. Cross-pollinated flowers invariably aborted within two days after pollination. However, results obtained with hormones on flower buds were encouraging. Treatment with 6-benzyl amino purine (BAP) prolonged the development of young hybrid pods for up to 12 days after pollination; then they aborted. Studies on embryo culture to rescue the immature embryos from these crosses are continuing, as are long-term experiments on the effects of chemical treatments on cowpea seed longevity under different temperature and moisture conditions.

More complete information on the topics mentioned in this Executive Summary can be obtained by requesting the Annual Report of the Genetic Resources Unit.

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Prof. T.M. Wormer
Senior Agronomist, Royal Tropical Institute, Amsterdam, Netherlands.

*Replaced by Mr. John D. Edozien.

List of IITA Personnel

Administration

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E.H. Hartmans, Ph.D., director general*
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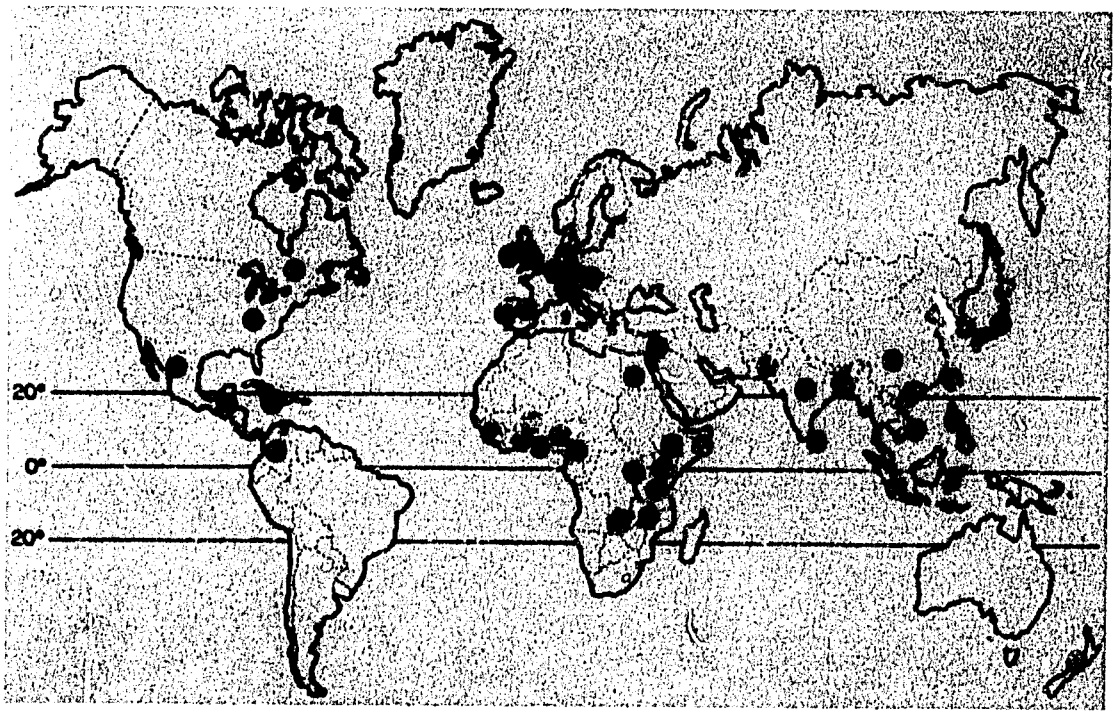
J.W. Pendleton, Ph.D., deputy director general (research)
M.A. Akintomide, B.S., director for administration
J.E. Haakansson, M.B.A., director of budget and finance*
D.N. McDonald, C.A. acting director of budget and finance
B.A. Adeola, ACIS, accountant
K.A. Aderogba, J.P., FCIS, principal administrative officer
T. Akintewe, M.R.C.P. (U.K.), medical officer
J.O. Badaki, B.A., M.B.A., human resources manager
C.A. Enahoro, administrative assistant to the director general
E. Ivars, B.S., manager, International House
L.J. McDonald, B.A., LL.B., computer manager
O.O. Ogundipe, M.D., senior medical officer
R.I. Olorode, security superintendent
M.E. Olusa, assistant to the director for administration
D.J. Sewell, manager, aircraft operations
R.O. Shoyinka, B.S., personnel manager
W.M. Steele, Ph.D., special assistant to the director general
S.J. Udoh, AMNIM, chief accountant
A. Yusuf, B.S., controller of stores

Figure 23. Nearly 200 principal staff members come from more than 40 countries.



Farming Systems Program

A.S.R. Juo, Ph.D., program director, soil scientist and coordinator of research on wetland production systems
I.O. Akobundu, Ph.D., weed scientist (sabbatic leave)
M. Ashraf, Ph.D., agricultural economist
E.A. Atayi, Ph.D., agricultural economist and chief of party, NCRE, Cameroon
P. Ay, Ph.D., socio-economist, Cameroon
V. Balasubramanian, Ph.D., agronomist, Rwanda
M. Bernard, Ir. Assoc. expert/soil physicist
Y.S. Chen, M.S., agronomist
A. Evers, Ir., water management engineer
H.C. Ezumah, Ph.D., agronomist
C. Garman, M.S., agricultural engineer
T. Gebremeskel, Ph.D., agricultural economist
B.S. Ghuman, Ph.D., soil scientist, Bendel State, Nigeria
H. Gunneweg, Ir., water management engineer, Benin
N.D. Hahn, Ph.D., head, socio-economics unit
N. Hulugalle, Ph.D., soil scientist, SAFGRAD, Burkina Faso
C.A.A. Huysmans, Ir., socio-economist, Bida
A. Huzing, Ir., assoc. expert/water management, Sierra Leone
B.T. Kang, Ph.D., soil scientist/agronomist
J. Kikafunda-Twine, Ph.D., agronomist, NCRE, Cameroon
R. Lal, Ph.D., soil physicist and coordinator of research on upland production systems
P. Lippold, Ph.D., USAID liaison scientist
D. McHugh, M.S., extension agronomist, NCRE, Cameroon
S.K. Mughogho, Ph.D., agronomist
K. Mulongoy, Ph.D., microbiologist
H.J.W. Mutsaers, Ph.D., agronomist and coordinator of on-farm research
N.C. Navasero, B.S., agricultural engineer
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O.A. Osiname, Ph.D., agronomist
M.C. Palada, Ph.D., agronomist
J.A. Poku, Ph.D., weed scientist
M. Price, Ph.D., agronomist and project manager, FSR/OFR, Rwanda
R. Swennen, Ph.D., agronomist, Onne
A.B.M. van der Kruijs, Ir., agronomist, Onne
A.H.S. Van Elslande, Ir., soil scientist*
W.O. Vogel, Ph.D., agricultural economist
D. Vuylsteke, Ir., plant physiologist, Onne
M. Weber, Ir., visiting soil scientist
G.F. Wilson, Ph.D., agronomist

Grain Legume Improvement Program

S.R. Singh, Ph.D., program director
A. Acosta-Carreon, Ph.D., training coordinator
V.D. Aggarwal, Ph.D., cowpea breeder, Burkina Faso
L. Akundabweni, Ph.D., cowpea breeder
A.M. Alghali, Ph.D., entomologist
R.A. Amable, Ph.D., agronomist, Tanzania
L.L. Bello, Ph.D., soybean breeder
H.S. Chiang, Ph.D., entomologist
K.E. Dashiell, Ph.D., soybean breeder
J. Ehlers, Ph.D., cowpea breeder, Kenya
P. Franks, M.S., entomologist
M.A. Hossain, Ph.D., cowpea breeder, Ghana
L.E.N. Jackai, Ph.D., entomologist
E.A. Kueneman, Ph.D., soybean breeder, Brazil
N. Muleba, Ph.D., cowpea agronomist, Burkina Faso
D.M. Naik, Ph.D., agronomist, Zimbabwe
B.R. Ntare, Ph.D., plant breeder, Niger
R.K. Pandey, Ph.D., regional coordinator for Southeast Asia, Philippines
W.R. Root, Ph.D., soybean breeder/agronomist
S.A. Shoyinka, Ph.D., cowpea breeder/pathologist
B.B. Singh, Ph.D., cowpea breeder
J.B. Suh, Ph.D., cowpea entomologist, Burkina Faso
E.E. Watt, Ph.D., cowpea breeder, Brazil
K. Weingartner, Ph.D., agronomist/utilization

Maize Research Program

Y. Efron, Ph.D., program director (sabbatic leave until September
M. Bjarnason, Ph.D., CIMMYT liaison scientist and acting program director*
D. Akibo-Betts, Ph.D., entomologist, Zimbabwe
N. Bosque-Perez, Ph.D., entomologist
Z.T. Dabrowski, Ph.D., entomologist
O.P. Dangi, Ph.D., plant breeder, Cameroon
A. Diallo, Ph.D., plant breeder, Burkina Faso
L.T. Empig, Ph.D., plant breeder, Cameroon
L. Everett, Ph.D., plant breeder, Cameroon
J.M. Fajemisin, Ph.D., pathologist/breeder
J.E. Iken, Ph.D., plant breeder (visiting scientist)
K. Johnson, Ph.D., plant breeder, Zaire
F.H. Khadr, Ph.D., plant breeder, Zaria, Nigeria
S.K. Kim, Ph.D., plant breeder
J. Kikafunda-Twine, Ph.D., agronomist, Cameroon
M.H. Lee, Ph.D., plant breeder
J.H. Mareck, Ph.D., plant breeder
H.I. Mohammed, Ph.D., agronomist (visiting scientist)
L.T. Ogunremi, Ph.D., agronomist
V.O. Parkinson, Ph.D., pathologist

M. Rodriguez, Ph.D., agronomist and team leader, SAFGRAD, Burkina Faso
C.Y. Tang, Ph.D., plant breeder
R. Ward, Ph.D., plant breeder, Zimbabwe

Rice Research Program

J.A. Lowe, Ph.D., program director
Kaung Zan, Ph.D., IRRI liaison scientist and acting director*
A.O. Abifarin, Ph.D., ITTA liaison scientist at WARDA, Liberia
D. Akibo-Betts, Ph.D., entomologist*
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D. Janakiram, Ph.D., plant breeder, Cameroon
V.T. John, Ph.D., pathologist
T.M. Masajo, Ph.D., plant breeder
E.P. Navasero, M.S., rice quality specialist
N.V. Ngun, Ph.D., agronomist
A.C. Roy, Ph.D., agronomist, Cameroon
M. Winslow, Ph.D., plant breeder, Onne, Nigeria
M. Yamauchi, Ph.D., physiologist
S.M.H. Zaman, Ph.D., IRRI liaison scientist

Root and Tuber Improvement Program

S.K. Hahn, Ph.D., program director
M.O. Akoroda, Ph.D., plant breeder of UNIBADAN (part-time)
A.M. Almazan, Ph.D., biochemist/food technologist
M.N. Alvarez, Ph.D., plant breeder, Rwanda
V.L. Asnani, Ph.D., plant breeder
F.E. Brockman, Ph.D., agronomist and project leader, PRONAM, Zaire
F.E. Caveness, Ph.D., nematologist
E.M. Chukwuma, research associate
D. Friese, Ph.D., entomologist
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Publications

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