IITA Annual Report and Research Highlights 1987/88

International Institute of Tropical Agriculture

Front cover: *A farmer harvests plantain—a major staple food for millions of people in Africa. More than 60% of the world's plantain (a cousin to the banana but must be cooked to be edible) is produced and consumed primarily by small farmers and their families in West and Central Africa. Black Sigatoka, a virulent fungal disease which causes large yield losses and threatens the food security in plantain growing regions, has spread to several African countries.*

Back cover: *IITA scientist Dr. R. Swennen checks on young* in vitro-*produced plantain plants growing in an experimental field at the Institute's sub-station at Onne, Nigeria. IITA has accepted the responsibility to breed plantains and cooking bananas for resistance to the black Sigatoka disease in Africa.* *(See article beginning on page 26.)*

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Introduction to IITA

The International Institute of Tropical Agriculture (IITA) was established in 1967 to increase the productivity of key food crops and to develop sustainable agricultural systems that could replace bush fallow or slash and burn cultivation in the humid and subhumid tropics. It was the first major African link in an integrated network of international research centers located throughout the developing world. The Federal Republic of Nigeria provided 1,000 hectares of land for the Institute's headquarters and experimental farm at Ibadan, Nigeria, and the Ford and Rockefeller foundations provided the initial financial support.

Research and training are conducted at the headquarters and in other areas of Africa in cooperation with regional and national programs. Although the "geographic mandate" of IITA includes the humid and subhumid tropical regions of the world, the Institute now places primary emphasis on improving

Airview of a portion of IITA's headquarters and experimental farm at Ibadan, Nigeria. Research is done here, at other sites in Nigeria, and in several other African countries in collaboration with national and regional programs and international centers.

the farming systems in the major agro-ecological zones of West and Central Africa. (See map on pages 22 and 23.) Four out of five of the principal research programs of IITA are crop centered: Grain Legume Improvement, Maize Research, Rice Research, and Root, Tuber, and Plantain Improvement. The fifth is the Resource and Crop Management program.

Research findings at IITA's headquarters and substations and in the selected agro-ecological zones have relevance for tropical zones elsewhere in Africa and in other continents, and IITA shares these findings through germplasm exchange, publications, and training.

The Institute works closely with national programs—a vital linkage. The gains made by its scientists will get translated into actual food output only when national programs take up the results, adapt them to local conditions, and carry them to their farmers.

Principal funding is arranged through the Consultative Group on International Agricultural Research (CGIAR). Financial support for IITA's core program during 1987 was provided by Austria, Belgium, Canada, China, Denmark, Federal Republic of Germany, The Ford Foundation, France, India, Italy, Japan, The Netherlands, Nigeria, Norway, Sweden, The Rockefeller Foundation, United Kingdom, United Nations Development Program, United States Agency for International Development, and World Bank.

In addition, the following organizations and governments also provided funds for special projects and specific training activities: African Development Bank, Austria, Belgium, Canada, Denmark, Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ), European Economic Community (EEC), Federal Republic of Germany, Food and Agriculture Organization of the United Nations (FAO), The Ford Foundation, Gatsby Charitable Foundation, International Development Research Center (IDRC), International Fund for Agricultural Development (IFAD), Italy, Nigeria, Norway, The Rockefeller Foundation, Switzerland, UNICEF, United Nations University, United States Agency for International Development (USAID), University of Hohenheim, and World Bank.

IITA is governed by a Board of Trustees which includes eminent scientists and representatives from African countries and other regions of the world. The Institute has about 200 principal staff members who come from more than 40 countries and it 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 in Africa.

Board of Trustees

(As of May 1988)

About the CGIAR

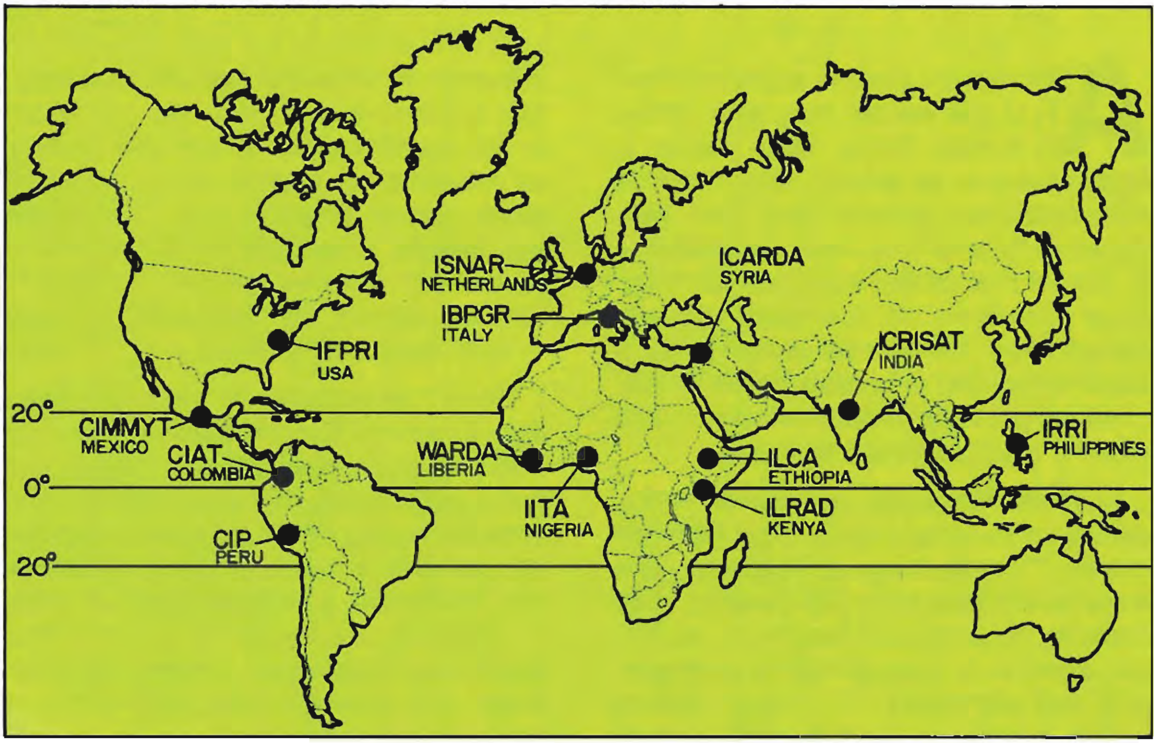
The Consultative Group on International Agricultural Research (CGIAR) is an informal association of countries, international organizations, and private institutions, cosponsored by the World Bank, the Food and Agriculture Organization of the United Nations (FAO), and the United Nations Development Programme (UNDP). The three cosponsors brought donors together in 1971 to get the international community to earmark a portion of its concessional aid for agriculture in the developing countries to support, on a sustained basis, a well-defined and closely monitored program of research on food commodities. CGIAR operates without a formal charter, relying on the consensus deriving from a sense of common purpose.

CGIAR started with a nucleus of four existing international agricultural research centers, including IITA. The number of centers has now increased to 13 (Figure 1), supported by 39 donor members and other contributors providing between US $240–$250 million in funding in 1987. Each CGIAR-affiliated center is independent and autonomous, with a particular structure, mandate, and objectives, and with oversight by its own board of trustees. Some centers focus on one or two commodities for which they have a global mandate, while others have a regional or ecological mandate for one or more commodities. Still others perform specialized functions in the fields of food policy research, genetic resources conservation, and strengthening national agricultural research in developing countries.

The CGIAR is serviced by an executive secretariat, located in Washington, D.C. and provided by the World Bank. A Technical Advisory Committee (TAC), comprising a chairman and 14 scientists drawn equally from developed and developing countries, makes recommendations on research programs and priorities and monitors performance through annual program and budget reviews and periodic external reviews by independent scientists invited to serve on specially constituted panels. TAC is supported by a secretariat provided by the three cosponsors of CGIAR and located at FAO headquarters in Rome.

CGIAR meets twice a year, once in Washington, D.C. in October/November and once elsewhere in May. The meetings receive and discuss recommendations to overall strategy, budgetary needs, and management issues pertaining to the centers as a group. Reports from individual centers, as well as independent external evaluations, are presented periodically at these meetings.

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



Centro Internacional de Agricultura Tropical (CIAT**); Centro Internacional de la Papa (**CIP**); Centro International 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 Center 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

Although the world is producing more food per person than ever before in human history, more people in Africa each year go to bed hungry, suffering malnutrition that prevents them from leading active, healthy lives. The silent presence of chronic malnutrition produces no newspaper headlines or television specials. Nevertheless, there is an urgent need to increase food for today's expanding population without undermining Africa's resource base for food production tomorrow.

The problem is stated clearly in the widely discussed Brundtland Report, *Our Common Future:* "The Challenge of increasing food production to keep pace with demand, while retaining the ecological integrity of production systems, is colossal both in its magnitude and complexity . . . These realities require agricultural systems that focus as much on people as they do on technology, as much on resources as on production, as much on the long term as on the short term. Only such systems can meet the challenge of the future."

Twenty years ago, long before sustainability became a burning issue, the founding fathers of IITA had a vision of a new institute in Africa. It was established to increase the productivity of key food crops and to develop sustainable agricultural systems that could replace bush fallow or slash and burn cultivation in the humid and subhumid tropics. IITA's mandate reflects both the essential difference and the critical link between the goals of feeding hungry people and developing sustainable systems.

Our founders recognized that the major advances in temperate agricultural technology in recent decades were not well suited to the resource-poor farmers and physical environments of tropical Africa. To serve these people, scientists had to recognize the diversity of farmers' conditions and to understand the crop production systems that had evolved with them over hundreds or even thousands of years.

When I joined IITA two and a half years ago, it seemed that the Institute could not realize its goal unless it sharpened program focus, set priorities, and developed a framework for dealing with the issues of malnutrition, poverty, and sustainability. We therefore conducted a strategic planning study in 1986–87, the results of which I shall summarize in this report. The full plan document, *IITA Strategic Plan 1989–2000*, is available upon request.

The major themes in the plan are focus, integration, and cooperation:

- **Focus** on the most important clients, geographic regions, ecological zones, commodities, and researchable issues to be addressed by the Institute.
- **Integration** of all the Institute's activities to achieve its goal of increasing sustainable food production.
- **Cooperation** and partnership with African national agricultural research systems, other international institutes of the CGIAR, and those many other organizations which share our mission.

Four Program Strategies

Four basic program strategies cut across all of the research programs, providing the means for integrating activities and focusing on the important elements.

(1) Geographic focus: IITA places primary emphasis on improving the farming systems of the lowland humid and subhumid tropics of West and Central Africa, a large region containing almost all of these lowland environments in Africa. This geographic focus is consistent with the international character of IITA. We believe that research findings in Africa have relevance for lowland tropical zones in other continents, and we share them through germplasm exchange, publications, and training. Having completed the strategic study, we are now entering the implementation stage. IITA clearly cannot do this job alone. We are working closely with partners, both in our sister centers and in national systems, to develop modes of collaboration that will best serve the interests of Africa. IITA is a link in a chain that stretches from the basic research laboratories of the developed countries through national agricultural research and extension agencies to our ultimate target, the African farmer. We depend on our sister international centers with global mandates because they have a comparative advantage in strategic upstream research and because of the breadth of their germplasm. We are currently engaged in positive collaboration with many centers, especially CIMMYT (which has had staff at IITA since 1980) and CIAT which will place a scientist at IITA in 1988. IITA's comparative advantage rests upon 20 years of experience with the farming systems of West and Central Africa, an enormous, complex region with over 40% of the population of sub-Saharan Africa. IITA has the infrastructure, program momentum, and long established, strong links with many of the national systems of the region. We are thus in an excellent position to facilitate intercenter cooperation and the evolution of a coherent CGIAR program to strengthen African national systems.

(2) Focus on the family farmer: IITA seeks to increase the productivity of the African smallholder or family farmer, as contrasted with the large-scale commercial enterprise. Small farms, usually under three hectares in size, remain the basic food production unit in West and Central Africa. They employ about 75% of the people of the region. Our focus increasingly will be to raise the productivity of the farmer rather than to maximize yields from his land. This means that farmers—both men and women—must be the center of our concern. Industrial or urban growth cannot absorb ever-growing rural populations. Most farm families have no employment alternatives. Increasing their productivity and income is an efficient means of producing more food; it is also a moral imperative that we cannot ignore. IITA distinguishes between two groups of smallholders as beneficiaries of our research. First, the resource-poor farmers largely ignored by conventional research. To break the subsistence pattern of their lives requires the following: technologies that optimize productivity from low levels of purchased inputs, consistent with the requirements of sustainability; varieties resistant to diseases and insect pests and tolerant of adverse environmental factors; biological approaches that reduce dependence on chemicals and that work with nature to solve farmers' problems; and management practices that save labor and raise productivity. We also focus on generating technologies for more advanced small farm families who already have some resources to produce surpluses for the market. These are the farmers who, by increasing commercialization of their operations, can adopt improved technologies that will become driving forces for change in Africa.

(3) Focus on key ecological zones: IITA will establish small research substations in the key ecological zones of the region. Decentralization of IITA's research is a logical stage in the evolution of the Institute. In the first stage of IITA's history, it was apparent that commodity research could make the greatest impact by developing germplasm resistant to major diseases for use by national systems. With access to genetically diverse germplasm and sophisticated research support, the commodity scientists could do this work most effectively at IITA headquarters. Moreover, they were notably successful in breeding resistance to major pathogens—cassava bacterial blight and African mosaic virus disease, diseases of maize such as lowland rust and blight and the streak virus diseases, rice blast, and numerous cowpea diseases. These successes now permit a significant decentralization of research from Ibadan headquarters to the zones where the commodities we study are most important. The major ecological distinction in lowland West and Central Africa is between the humid forest and the savanna. IITA is situated in the narrow transition zone between these major environments (see map on pages 22–23). We plan to locate research stations in the humid forest zone for work on cassava and resource management, in the moist savanna to breed maize and cowpeas, and in an inland valley for rice research. We will staff these research stations with small teams of scientists who, because of their location, will be able to set research objectives based upon close study of the farming systems in the zone. With strong support from Ibadan headquarters, they will increase our ability to help national programs in the region.

(4) Focus on farming systems: We are inculcating a farming systems orientation throughout IITA to assure that the technology we generate will be productive in the real world of the African farmer. Interdisciplinary cooperation is needed to integrate research on improved varieties with work on management practices. After considering various organizational alternatives for promoting multidisciplinary collaboration, we adopted the simple innovation of inter-program, commodity-based working groups. This is a crucial new mechanism because it integrates the work of IITA's commodity improvement scientists and its resource management scientists. These working groups are already functioning, and there is encouraging evidence that they are leading to a profound reorientation in the way we think about our research at IITA. (See the *Focus* article in this report, *Improved Integration of IITA's Research Programs*, beginning on page 21.)

Resource Management Research

Research at IITA is conducted on three

interrelated topics, with feedback at all levels:

(1) Systems of natural resource management.

(2) Improved crop varieties that can stabilize and increase production with minimal damage to the environment.

(3) The products of the first two sets of research converge in the common goal of the Institute as a whole, the development of sustainable and productive cropping systems compatible with the resources and objectives of the family farmer.

The first of these research components is natural resource management. This involves the search for sustainable alternatives to shifting cultivation. This task, fundamental to African agricultural development, is an enormously complex and long-term undertaking, a problem that will grow in intensity in the 21st century. The renaming of the former Farming Systems Program as the Resource and Crop Management Program is explicit recognition of both the close link and the important distinction between the two facets of farming systems research at IITA: sustaining resource potential and increasing crop production.

Growing population densities and increased intensity of land use have caused the bush fallows of traditional shifting cultivation systems to be significantly shortened in many areas, resulting in sharply declining soil productivity. The process has especially acute consequences in the humid forest zones of Africa where the deeply weathered, acidic soils lose fertility rapidly under repeated cultivation. Here there is an irreducible need for fallow periods to restore productivity. Some of the most densely populated areas in Africa are in this humid forest zone.

IITA's resource management research will follow a conceptual model consisting of three phases:

Phase I. Base Data Analyses: Analyzing and understanding the biophysical and socioeconomic determinants of stability and degradation in the resource base.

Phase II. Technology Development: Improving existing practices and devising new resource management technologies, mainly through research station experiments.

Phase III. On-farm Testing and Validation: Synthesizing innovations into systems and evaluating their agronomic, socioeconomic, and ecological viability on farms.

IITA has accumulated data and information from almost two decades of research on the subhumid, non-acid soil environment of the transition zone where our headquarters are located. First priority is the synthesis of technologies developed here into systems and on-farm testing by IITA working groups and collaborating national scientists.

We will also launch an integrated resource management program for the acid soil environment at a new station in the forest zone. Drawing upon experience at Ibadan, we expect to progress more rapidly through the phases of base data analysis and technology development to the on-farm testing of new systems.

We believe that alley farming, a form of agroforestry, is the most promising and exciting sustainable system to emerge from our resource management research to date. Alley farming involves the growing of food crops in the alleys between rows of nitrogen-fixing shrubs or trees. It is promising because it mimics farmer practices, because it is based on principles of natural regeneration, and because its flexibility permits a wide range of adaptations, including the integration of small animal production into the system.

In setting priorities for the future, IITA has had to decide the appropriate allocation of funds between research on resource management and on commodity improvement, recognizing that they both depend on the crops-based systems working groups to link them in research on farming systems. There are significant differences between research on resource management and research on commodity improvement.

There are differences in research complexity and time horizon. The *CGIAR Impact Study* estimated that an international center should be able to develop and test a new crop variety in 6–15 years. There are no models, however, for creating resource management innovations.

There are differences in extension potential. New varieties are relatively simple to integrate into existing farming systems. Resource management innovations require changes in existing practices and the benefits are usually more delayed in time. Thus it is more difficult for family farmers with limited resources to adopt them.

There are differences in ecological focus. The zone within IITA's region of primary focus with the highest potential for producing marketable surpluses in the short run is believed to be the forest savanna transition and the moist savanna of West Africa. The most profound problem, and one that IITA is uniquely positioned to handle, is the need for sustainable and productive systems to support the population that will be living in the more humid zones in the 21st century.

There is no conceptually correct or optimal balance between these two components of IITA's program. But we considered both opportunities and needs in reaching a policy decision to increase gradually the relative level of funding for resource management as a percentage of the total research budget. This will permit us to expand research in the less favored forest environment where soil degradation is increasing poverty and, in a vicious circle, poverty is accelerating soil degradation. Although this research may have limited impact in the short run, IITA feels responsible as trustee for this mandate in the CGIAR system to assist future generations who must cultivate these lands in the future.

Commodity Improvement Research

As a result of the strategic plan IITA now has three major commodity improvement programs: cassava, maize, and cowpeas. Within each of these programs, we will have more highly focused research agendas described below. We terminated research on cocoyams and transferred IITA's global mandate for sweet potatoes to CIP. IITA's rice improvement responsibility will be gradually shifted to WARDA. We are continuing small, focused improvement programs for three commodities: sustained breeding of soybeans and the application of biotechnology to yams and plantains—crops of special importance in the humid tropics.

Cassava Research Program

IITA has a continental mandate for cassava in Africa. The CGIAR system can take great credit for promoting research at CIAT and IITA on this neglected crop since the early 1970s. In all the debate about famine in Africa, one seldom hears of cassava. Perhaps this is because it is the great famine reserve in the broad cassava belt across Africa. It is the poor man's crop, adapted to marginal soils, simple to plant and to manage, and with tubers that can be stored in the ground until needed. IITA has been successful in developing improved varieties and breeding populations for Africa that are high yielding, resistant to two devastating diseases, low in cyanide, and widely accepted for the preparation of gari, a popular African food.

In the strategy for the future, highest priority will be given to breeding cassava for local adaptation to diverse environments and cropping systems, with increased emphasis on the humid forest zone where a research station will be established. We shall also begin work on the crop in Eastern and Southern Africa and the drier zones of West Africa.

We are also increasing research on postharvest technology and utilization of cassava. The processing of cassava, largely by women, is onerous and requires more labor than production of the tubers. Dr. Natalie Hahn, IITA scientist, was recently installed as a Chief in a traditional Nigerian ceremony in honor of her work on utilization with village women. With appropriate processing, cassava has a great potential as a source of cheap food for urban populations.

In cooperation with CIAT and ICIPE, we are also using biological approaches to decrease the losses of cassava caused by two introduced insect pests. IITA's project for the biological control of two insect pests of cassava, which were accidentally introduced from Latin America, was reviewed by a team headed by TAC member, Michael Arnold. Efforts to locate the natural enemies of the cassava mealybug in Latin America and to establish them in the cassava belt of Africa was judged to be an outstanding success. Because cassava is the greatest source of food energy in Africa, control of this devastating pest has enormous impact. The Arnold team estimated that benefits over the life of the project will exceed three billion dollars!

This is pioneering research, the first of its kind ever to apply biological control on a continental scale. The project demonstrates what a creative and dedicated group of scientists can accomplish for the benefit of resource-poor farmers by working with nature to reduce dependence on expensive chemical inputs.

The campaign to control the cassava mealybug will be completed in a few years, and we will merge biological control into an integrated pest management program. The feasibility of using biological control of additional pests of cassava and other food crops of the humid tropics will be explored, and we will invite scientists concerned with other commodities to work as visiting scientists at our biological control unit in the Republic of Benin.

Maize Research Program

The success of IITA's Maize Research Program has been widely recognized. It won the 1986 King Baudouin Award for International Agricultural Research for a research breakthrough that solved the problem of maize streak virus—a highly damaging disease found only in Africa. African farmers know they face a high probability of failure if their maize is infected by it. Resistant materials reduce the risk of loss and encourage farmers to practice good husbandry and apply fertilizer to increase production. We are receiving requests for streak-resistant maize from national programs, seed companies, and farmers all over Africa. The National Seed Service of Nigeria is multiplying streak-resistant varieties and predicts that most of the maize land in the country will be seeded with them within three years.

The maize program was also honored with an award for developing the first high-yielding hybrids with combined resistance to the major maize diseases of Africa. We launched the hybrid project at the request of and with financial support from the Nigerian government. This research stimulated the formation of two Nigerian private seed companies, and hybrid maize is now spreading in the savanna of the country.

We are continuing a full-scale commodity improvement program for maize because of its importance as a source of food and feed, its high labor productivity, and the potential for rapid impact. TAC has approved funding for the maize research station in the West African moist savanna, an area where maize is replacing sorghum and where production is expected to grow most rapidly. A major research objective there will be breeding resistance to *Striga*, a parasitic weed that attacks traditional crops in this ecological zone.

Cowpea Research Program

The third major commodity is cowpeas for which we have global responsibility. The future strategy is to focus more sharply on tropical Africa. We are shifting from breeding varieties suitable for sole crop production to those adapted to the cereal intercropping systems of the savanna where at least 80% of African cowpeas are produced.

The overriding biological constraint to cowpea grain production in African farming systems is the damage caused by post-flowering insect pests. Resistance breeding at IITA will involve collaborative upstream research with advanced institutes in the developed countries.

Other Commodities

IITA will continue small, focused improvement programs on three additional commodities: soybeans, yams, and plantains. The Institute's plant breeders removed two serious obstacles to soybean production in Africa: poor seed longevity and the need for artificial inoculation with rhizobial bacteria. This gives the resource-poor farmer the means to produce a high-protein food crop with minimal investment. The principal constraint to increased production is the low level of demand. IITA will support a single breeder to sustain our capability to expand the program rapidly if the level of demand increases, as we hope it will.

Established methods of commodity improvement are not readily applicable to yams and plantains. We expect that our planned new capability in biotechnology will give us comparative advantage in improving these two crops, as well as cassava, for the humid tropics. In the case of plantains, the critical issue is the appearance in West and Central Africa of black Sigatoka disease which is discussed in the *Focus* article starting on page 26.

In summary, IITA's commodity improvement research is linked to research on resource management by the crop-based systems working groups, an important innovation at IITA. Their objective is to ensure that new commodity technologies are consistent with resource management innovations leading to improved and sustainable cropping systems—the Institute's overall research goal.

International Cooperation

The goal of international cooperation activities is to strengthen the capability of national agricultural research systems to use and generate agricultural technology in order to satisfy their own needs. IITA has the largest portfolio of special projects to develop partnerships with national programs in the CGIAR system. This has enabled us to engage in a wide range of collaborative activities that extend technologies to specific agro-ecological zones and contribute to national systems throughout Africa. Since 1971, IITA has trained more than 5,000 Africans, mostly technicians in group courses, but 10% have been scientists receiving research training for postgraduate degrees. The Institute's scientists work with IITA alumni who are rapidly moving into key positions of responsibility in African national systems.

Nevertheless, we recognize that national agricultural research systems have had less impact in Africa than in other developing regions. This is partly explained by the diversity of African environments, poorly developed infrastructure, government policies that have been biased against agriculture, and the small size of many national systems; over half the countries of West and Central Africa spend under $3 million annually on agricultural research.

Since our technology is of little value for countries lacking the capacity for effective collaboration, IITA has a responsibility to assist in building such capacity to the extent that we have a comparative advantage and that such activity does not weaken our vitality as a research institute. This requires us to operate more downstream toward adaptive research than is customary for an international center.

The Institute distinguishes the requirements of national systems at different stages of their institutional development. There is a model on page 143 that illustrates how IITA mechanisms for collaboration evolve as national systems grow in strength. This conceptual framework does not imply linear progress nor any moral judgment. It merely emphasizes the dynamic relationship that is necessary if IITA is to meet countries' strategic needs over time.

Our Strategic Plan provides for new and revised mechanisms for promoting partnerships with national systems: training, visiting scientists, research liaison scientists, information services, and resident scientist teams.

Research Liaison Scientists: We place high priority on deepening our understanding of the institutions, scientists, and needs of the highly diverse national systems of West and Central Africa. Therefore, a small number of research liaison scientists will be appointed, each to serve a group of countries by studying their requirements and linking them to IITA and other sources of technology and assistance. In the conduct of their research, all IITA scientists will continue their direct association with national scientists. The liaison scientist will be responsible for coordinating these activities in each country of the region. His or her responsibilities will include identifying training opportunities, facilitating communication with scientists at IITA and elsewhere, encouraging collaborative research projects, developing research networks, and arranging for screening and testing of improved varieties. The goal is to assure that IITA partnerships with national systems are responsive to their strategic needs and genuine concerns.

Training: In the long run, training may be IITA's most enduring contribution to the solution of Africa's food problems, and it will receive higher priority in the future. Like other international centers, IITA has a unique comparative advantage in training because of its role in applied and adaptive agriculture research. Regional studies suggest that an enormous number of agricultural scientists trained in African agriculture will be required: 5,000 people by the year 2000 for West Africa alone. Clearly, IITA can meet no more than a small proportion of Africa's requirements for agricultural scientists. Therefore, it has been necessary to work with national scientists to establish clear priorities for the future. IITA is making five significant changes:

(1) Devoting more of its "core" or permanent resources to training in order to increase control over the basic decisions on training priorities.

(2) Increasingly decentralizing group training to national institutions in response to their request for more "in country" training. This will permit an increase in the numbers trained, reduced costs, and ensure more relevance to national problems.

(3) Shifting emphasis at Ibadan from group training to individual research training, especially of Africans at the M.Sc. and the Ph.D. levels. There is an important need to apply IITA's substantial research resources to training advanced researchers who will be able to address African problems in and through African national institutions.

(4) Improving the planning and design of training materials.

(5) Seeking effective means to increase the proportion of women participants at all lev-

els. The record of the past four years shows that only about 7% of African trainees at IITA were women. Given the important role women play in African agriculture, this record is clearly unsatisfactory. IITA is developing an affirmative action program to identify and encourage women to apply for training opportunities.

Resident Scientist Teams: IITA has a comparative advantage in directly assisting countries to strengthen their research systems by its appointment of resident scientists to work together with national scientists. Over the last decade, IITA has invested over 300 scientist years working within national systems of the region, and much has been learned in the process. The objectives of its resident scientists are to conduct adaptive research, drawing upon the technologies of the international centers, and to institutionalize the capability of national programs to sustain such research without external assistance. In the past, these activities have been conducted by a special cadre of many scientists supported by project funding. In the future, we will form a small group of mature, permanent scientists to continue this as an essential service to national systems. ISNAR strongly supports this emphasis on building capacity for adaptive research as a complement to its own role in improving the management of research systems.

Resident scientists will be assigned in teams of two or three, if feasible in association with scientists from other centers, to countries whose research systems are at an early stage of development. The number will be deliberately small to avoid distortion of our principal research mission. Building research capacity is a long-term process. Nevertheless, by the year 2000 (end of the Strategic Plan period), we expect that numerous weak national systems, with the assistance from IITA, will be progressing to more advanced stages of institutional development.

The significance of international cooperation at IITA was elevated in 1987 with the creation of a new position of Deputy Director General (International Cooperation).

Conclusion

Since I arrived at IITA two and a half years ago, we have made significant changes in order to be cost-effective in carrying out our ambitious agenda of research and international cooperation. We conducted an exacting review that has significantly increased our program focus and set our program strategy for Africa to the year 2000, trimmed the size of our staff, restructured the organization, and installed new systems of communication and financial controls. In addition, we have successfully rebuilt IITA's top management team: John H. Davies as Deputy Director General (Management), Kenneth S. Fischer as Deputy Director General (Research), Jacques P. Eckebil as Deputy Director General (International Cooperation), and Roger A. Smith as Director of Budget and Finance. Each person is superbly qualified, and collectively they constitute the outstanding team needed for IITA's challenging mission.

I am pleased to report that in 1987 IITA made major contributions to two sister centers in the CGIAR system: Dr. Klaus J. Lampe resigned from our Board of Trustees to become Director General of IRRI and Dr. Eugene R. Terry resigned from his position as Director of International Cooperation to become Director General of WARDA. We look forward to particularly constructive collaboration with these two institutions in the future.

Finally, IITA's Board of Trustees was strengthened by the recent election of two new Trustees: Dr. Gerardo Perlasca and Dr. Robert K. Cunningham, agricultural consultants with deep experience in private sector research and international agricultural research, respectively.

Our vision of the future involves a balance between short-term impact from food crops with long-term commitment to sustainability, a balance between strategic basic or upstream research with downstream assistance to national systems, and a balance between research and international cooperation. We do not promise a green revolution, but we are optimistic that the stream of technologies based on research at IITA and other CGIAR centers, in partnership with national systems, will cumulatively raise food production and income to the extent that there will be a "quiet revolution" in the villages and on the small farms of Africa.

Laurence D. Stifel

Laurence D. Stifel
Director General

April 10, 1988

Improved Integration of IITA's Research Program

The purpose of this section is to explain how IITA's diverse research activities are integrated to achieve the overarching objective of the Institute: to develop sustainable food production systems that are appropriate for and acceptable to the smallholder family farms of tropical Africa.

Ecological diversity in Africa was a major factor in the development of IITA's Strategic Plan for the period 1989–2000. (See Figure 2: West and Central Africa Agro-Ecological Zones.) The importance which IITA attaches to this diversity is reflected in the ecological focus of the Institute's plans for research and in the strategic decision to decentralize research to substations in the key ecological zones of Africa for which the Institute has a mandate. Furthermore, it provides the orientation for a research framework that will promote the integration of resource management research, commodity improvement, and farming systems research to achieve the objective of sustainable food production systems.

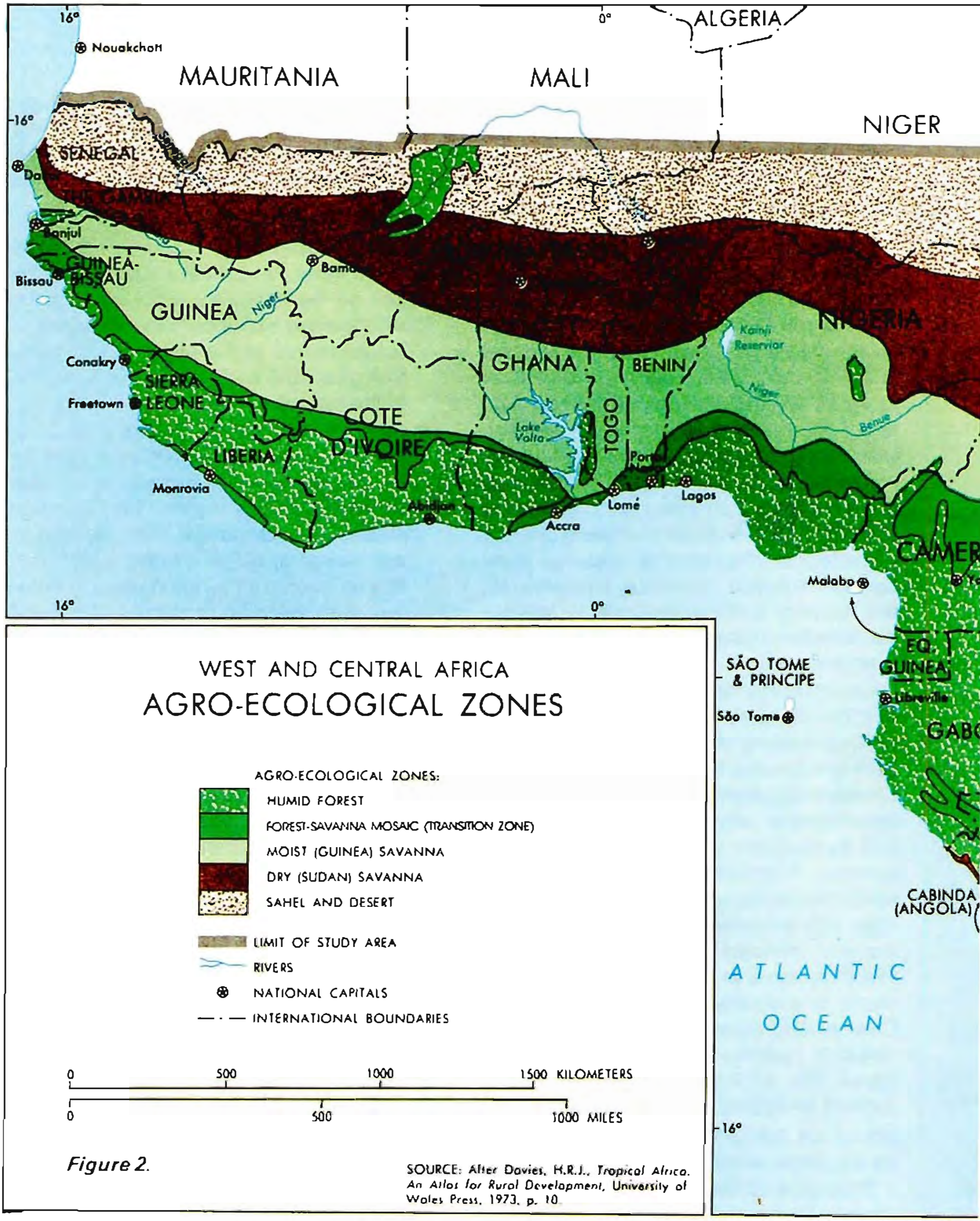
Central to this framework is the integrative function of newly established crop-based systems working groups which ensures linkages and feedback between resource management and commodity scientists as they work together with economists in the study and improvement of smallholder production systems. Furthermore, several initiatives have been taken to strengthen existing linkages with the scientists of Africa's national research systems, for it is through them that IITA reacts to the needs of its ultimate clients in a continent so diverse as Africa. Chief among these initiatives are the IITA research liaison scientists and country teams, the visiting scientists from African national programs, and the increased emphasis on postgraduate research training for the future leaders of national systems.

Resource management research: IITA's strategy for resource management research to develop sustainable production systems involves three conceptual stages which are based on the Institute's experience in the forest/savanna transition zone at Ibadan:

- Measurement of the physical, chemical, biological, and socio-economic elements of the natural resource base.
- Analysis of the determinants of stability and degradation of the resource base by studying the dynamic interactions of these elements. This includes, for example, studies of transport and storage of water and nutrients; of soil erosion; and of fertility as measured by the physical, chemical, and biological properties of the soil and their effects on biomass production.
- Designing resource management systems. The principles identified by the analysis of the determinants of stability and degradation are used to modify existing resource management practices, or to design new ones which are capable of stabilizing or increasing output while avoiding degradation of the resource base.

Recommendations arising from resource management research generally call for changes in the cultural practices currently in use by African smallholders. The socio-economic viability of new technologies or changes to existing practices needs to be determined on these farms. This is done, along with testing improved commodity components, by IITA's crop-based systems working groups.

Commodity improvement: IITA presently has four commodity improvement pro-

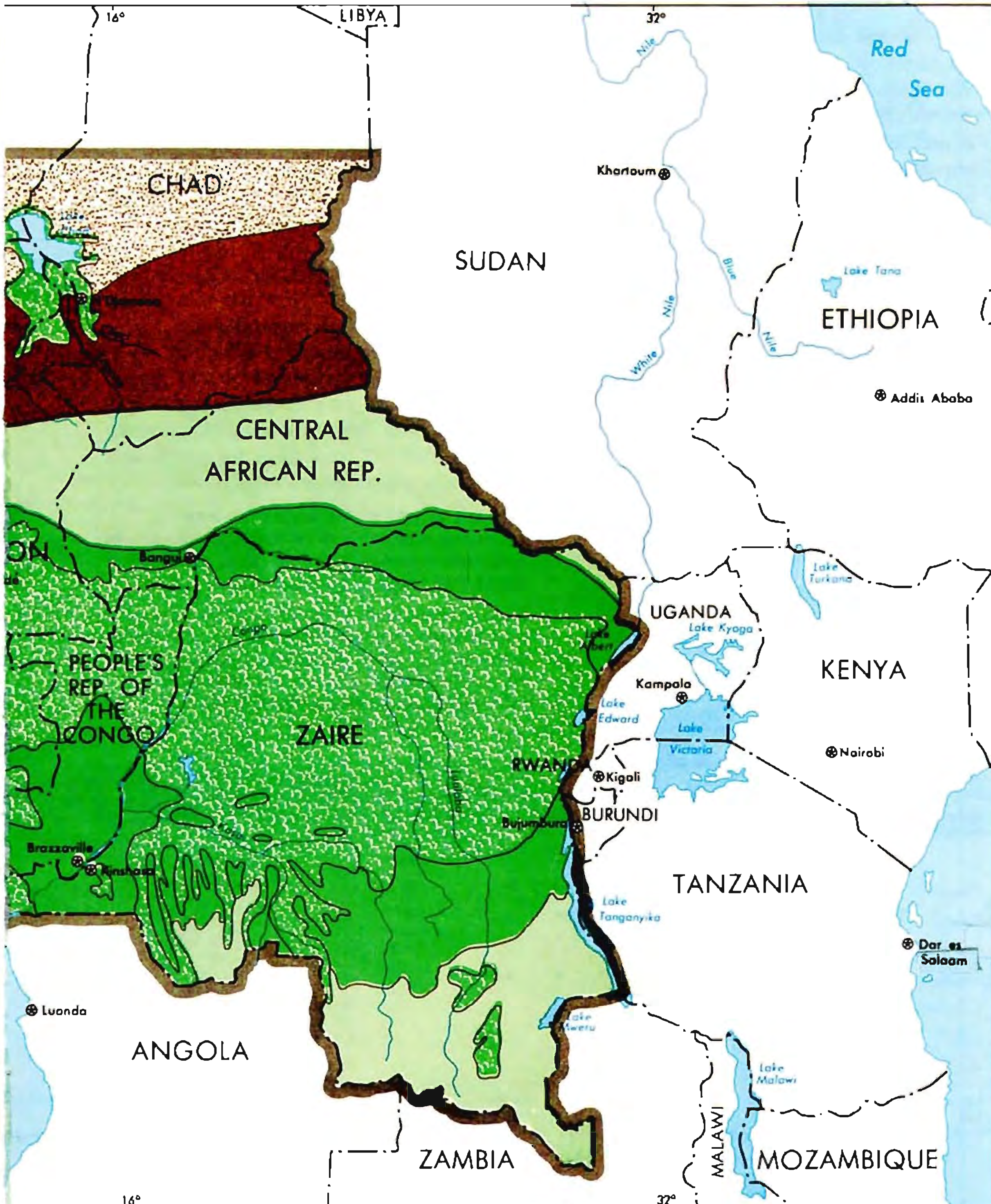


WEST AND CENTRAL AFRICA

AGRO-ECOLOGICAL ZONES

Figure 2.

SOURCE: After Davies, H.R.J., *Tropical Africa. An Atlas for Rural Development*, University of Wales Press, 1973, p. 10.


LIBYA
16°
32°
Red Sea
Khartoum
CHAD
SUDAN
ETHIOPIA
Lake Tana
Blue Nile
White Nile
Nile
Addis Ababa
CENTRAL AFRICAN REP.
Bangui
Lake Turkana
UGANDA
Lake Kyoga
KENYA
Lake Albert
PEOPLE'S REP. OF THE CONGO
Kampala
Lake Edward
Lake Victoria
ZAIRE
Nairobi
RWANDA
Kigali
BURUNDI
Bujumbura
Brazzaville
Kinshasa
TANZANIA
Lake Tanganyika
Dar es Salaam
Luanda
Lake Mweru
ANGOLA
Lake Malawi
MALAWI
ZAMBIA
MOZAMBIQUE
16°
32°

grams, whose activities are integrated at three levels:

- Within the Institute by the participation of commodity scientists in the on-farm research of the crop-based systems working groups. By this means they obtain first-hand experience of the smallholders' environment and problems as they work in teams with resource management scientists, agronomists, and agricultural economists.
- Within the West and Central African region by the Institute's work in partnership with the scientists of national commodity improvement programs, which goes beyond the exchange and testing of improved germplasm. IITA's commodity scientists have frequent opportunities to exchange views with, and to learn from their counterparts in national programs through visits and monitoring tours, at occasional workshops and conferences, and through participation in regional commodity improvement networks.
- Within the context of the CGIAR by collaboration with other international centers whose global concerns are relevant to IITA's commodity improvement objectives. Such collaboration brings to Africa the benefits of the global centers' germplasm and of their basic research. Examples are the collaboration between IITA, CIMMYT, and CIAT for maize and cassava improvement in all Africa.

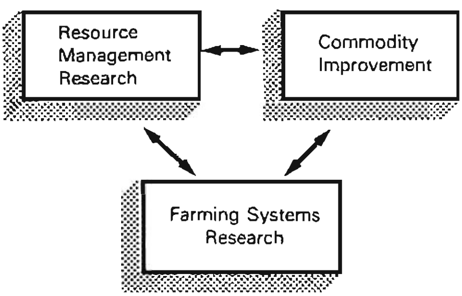


Figure 3A (left). IITA's organizational mechanism to achieve essential linkages and feedback between resource management and commodity improvement research.

Figure 3B (below). Integration of IITA crop and resource management research in major agro-ecological zones of West and Central Africa. (The dots indicate the importance of IITA-mandated crops in each zone.)

Crop Management Research	Resource Management Research				
Crops	**Agro-ecological Zones**				
	Humid Forest	Transition	Savanna: Moist	Savanna: Dry	Inland Valley*
Cassava	●●●	●●	●●	●	●
Maize	●	●●	●●●	●	●
Rice*					●●●
Cowpea		●	●	●●●	●
Soybean**					
Plantain	●●	●			
Yam	●●	●●	●●●		●
System base	Cassava	Cassava Maize	Maize	Sorghum/ Millet***	Rice

* IITA will work on rice only in the inland valley ecosystem which occurs in all zones.

** Soybeans are not a significant component of any West or Central African farming systems at this time. Nonetheless, research into their potential will be undertaken in the transition and moist savanna zones and the inland valleys.

*** IITA cowpea breeders will collaborate with ICRISAT farming systems scientists in this zone.

Farming sytems research: On-farm research by agronomists, economists, and other scientists in collaboration with the scientists of national programs has always been a part of IITA's program. While this has included testing improved varieties, as well as other innovations, it has proved difficult to integrate these on-farm studies with the work of the commodity improvement scientists. There has been insufficient feedback from on-farm research to the commodity improvement programs; and it had also at times been difficult to integrate the shorter-term research on crop improvement with resource management research done by soil and other physical scientists. To conduct multidisciplinary farming systems research there was need for an organizational mechanism to achieve the essential linkages and feedbacks between resource management and commodity improvement research in each ecological zone (Figure 3A).

These linkages are provided by multidisciplinary working groups which have been established for cassava-based, maize-based, and rice-based farming systems, named after the predominant IITA-mandated crop in the forest and moist savanna zones, and the inland valley ecosystem (Figure 3B). Each group includes a full-time agronomist and agricultural economist as well as breeders for the system's major and secondary crops (e.g. grain legumes). A soil scientist, weed scientist, entomologist and/or pathologist, and a post-harvest technologist are also regular group members, depending on the particular issues being explored.

The general goals of each group are to examine the constraints and potentials of these crop-based systems and to devise appropriate research agendas for farming systems improvement. They have three functions:

- A service function involving on-farm screening, testing, and evaluation of technologies generated by experiment station research.
- An adaptive research function involving the adjustment or adaptation of existing technology to a particular set of environmental conditions, either agro-ecological or socio-economic, through on-farm research.
- A feedback function providing relevant information from farm-level characterization, diagnosis, and/or adaptive research to scientists developing resource management technologies or breeding improved varieties at research stations.

The three working groups conduct diagnostic surveys and further base data collection to identify key production constraints, determine the distribution and impact of improved crop varieties, analyze the agricultural potential of the region(s), and identify the main opportunities for improvement. Because commodity improvement scientists participate actively in each group, their farming systems orientation is strengthened, and their enhanced knowledge of the ultimate client improves their ability to define appropriate breeding objectives. Furthermore, the working groups offer excellent opportunities for cooperation with the scientists of national programs.

Although IITA cannot focus on all the variations of ecological conditions and farming systems even in its primary area of focus, the Institute can work with national programs to develop methodologies for cropping systems research and can produce prototype systems. National program scientists can then refine and adapt them for use in their own countries. Moreover, the contributions of national scientists are extremely important in assuring that the methodologies and prototype systems coincide effectively with the resources and capacities of existing institutions. Recent activities of two crop-based systems working groups are described in this report.

Food Security in Plantain Regions Endangered:

Over 60% of the world's plantain is produced and consumed in West and Central Africa and about 60 million people whose average consumption is 200 or more calories per day depend on this crop as a staple food. But reports of the presence of a virulent fungal disease—black Sigatoka —in various parts of Africa are causing alarm and scientists are being asked to help alleviate the problem both on a short-term and long-term basis.

The disease causes yield losses estimated at between 30 and 50%. This is especially significant because the bulk of plantain production is in the hands of small farmers whose families consume at least a portion of the crop and sell any surplus on the local market.

IITA has accepted the responsibility to breed plantains and cooking bananas for resistance to black Sigatoka in Africa.

In some regions of Cameroon, Gabon, Congo, and Zaire, plantain ranks first among the principal food crops, and trends in Nigeria and other West African countries indicate that the demand for plantain is on the increase.

Traditionally, plantains are cultivated near the homestead where they generally receive ample supplies of organic matter from household refuse. Within the shifting cultivation system, they are usually planted first among other food crops after the fallow period to ensure maximum benefit of the organic matter and nutrients and are often intercropped with maize, cocoyam, cassava, yam, vegetables, and maize. In some cases, plantain is also associated with cocoa and coffee because it provides shade for the young seedlings.

Millions of people in Africa depend on plantain as a staple food. In some regions it ranks first among the principal food crops.

Plantains are among the most conservative of crops in terms of ecosystem degradation in areas of very high rainfall, and labor productivity in growing them is very high. In the first year of cultivation, yields as large as 20 t/ha can be obtained with a labor input of 100 man-days. But plantains are faced with many problems: attacks by black Sigatoka disease, lack of disease-free planting material, rapid yield decline, high stemborer and nematode susceptibility, slow suckering, lodging, seasonality of productivity, and low storage life.

A Campaign to Control Black Sigatoka Disease

The black Sigatoka disease, with the fungus *Mycosphaerella fijiensis* as causal agent, has become the overriding constraint to plantain and banana production worldwide. It causes leaf necrosis either partially or entirely, resulting in reduced foliage area and seriously reduced yields depending on the extent of the disease in the crop. First identified in 1963 in Fiji, black Sigatoka was found in several other Pacific Islands, Papua New Guinea, Philippines, Taiwan, and Malaysia by 1969. Its presence in Central America was first noted in Honduras in 1972, but has now reached most of the plantain and banana growing areas of Central and South America.

In Africa, it was reported for the first time in 1973 in Zambia and in Gabon in 1979. From there it spread into Congo and Cameroon (1984) and reached Nigeria two years later. Recent reports show it has also spread to other West African countries and into East Africa. Since no plantains with resistance or tolerance to black Sigatoka have yet been identified, food security in the plantain growing regions is endangered.

The short-term strategy to help alleviate this serious situation is to multiply and distribute black Sigatoka-resistant cooking bananas as substitutes for plantain. IITA introduced cooking bananas (ABB genomic constitution) and East African (highland) cooking bananas (AAA). Three cooking banana cultivars (all of the ABB group) showed high levels of resistance, namely Nzizi, Fougamou 1 and Pelipita 1. The former two cultivars were obtained from the Institute for Research on Fruits and Citrus (IRFA) in Côte d'Ivoire and Gabon, respectively; the latter from the Tropical Agricultural Research and Training Center (CATIE) in Costa Rica.

Symptoms of black Sigatoka disease of plantain which is spreading across Africa. Scientists are attempting to breed plantains resistant to this disease which causes yield losses estimated at between 30 and 50%.

Only a few plants of each cultivar were collected. To obtain several thousand of these plants with the conventional propagation technique in the field would take too much time because of the low multiplication rate. This constraint was overcome by using *in vitro* micropropagation techniques for both bananas and plantains.

The International Network for Improvement of Banana and Plantain (INIBAP) supported a project in 1987 for the rapid *in vitro* multiplication of cooking bananas (ABB) with high levels of black Sigatoka resistance. Tiny shoot tips are dissected from buds and cultured on a defined medium under aseptic conditions. Massive proliferation of new miniature buds and shoots is obtained by high cytokinin levels in the medium. Lower cytokinin concentration, along with auxin addition, induces shoot elongation and rooting. *In vitro* multiplication rates are several orders of magnitude higher than in conventional propagation. Plant production *in vitro* is then only limited by the number of skilled laboratory technicians who can aseptically handle large numbers of shoot tip cultures.

Another significant advantage of *in vitro* plants is that they are disease and pest-free and thus grow vigorously following establishment in the field. Plant production by shoot tip culture of many different *Musa* species and cultivars is a routine procedure carried out in the tissue culture laboratory at IITA's Onne Substation. Starting from only two to four cultures of each cultivar, more than 1,000 cultures were obtained in six months. Several thousand plants have been produced from these *in vitro* cultures and will be distributed in 1988 in Nigeria through the national program.

In vitro culture techniques also play a major role in the introduction and exchange of banana and plantain germplasm. Unlike conventional propagules, shoot tip cultures are less bulky and disease-free. However, because viruses may persist in these cultures, all germplasm passes through an INIBAP Transit Centre at K.U. Leuven (Belgium) or Montpellier (France), where screening for disease symptoms is carried out for at least six months. From there it is sent to the Nigerian Plant Quarantine Services. By this route, IITA has over the past two years introduced more than 100 new *Musa* species and cultivars in meristem culture form. Recently, more banana and cooking banana cultivars with known resistance to black Sigatoka were introduced. These will also be multiplied *in vitro* and distributed to national programs.

Although black Sigatoka can be controlled by fungicides at high cost, the only long-term solution to the disease in plantain is the development of resistant clones. IITA has accepted the responsibility not only to breed plantains but also cooking/starchy bananas for resistance to black Sigatoka in Africa. Two prerequisites are needed for the development of an efficient plantain breeding program: female fertile plantains and black Sigatoka-resistant improved male diploids.

IITA now has 227 accessions of *Musa* in its genebank at the Onne substation. Among these accessions, the wide variability in plantain is represented by 79 different cultivars. (Another 28 await evaluation.) Among the 79 plantain cultivars, all medium and small French plantains were screened for female fertility. Four were found to produce seeds and several black Sigatoka-resistant diploids have been identified. After rapid multiplication, they will be used in breeding schemes. Contacts have been made with the Honduran Foundation for Agricultural Research (FHIA) to obtain black Sigatoka-resistant improved male diploids. Initial breeding efforts are based on crosses with nine diploid and triploid accessions showing high levels of resistance to black

Sigatoka. Embryo culture is applied to improve the low germination of the obtained *Musa* seed.

In their efforts to find resistance to the black Sigatoka disease of plantains, scientists use* in vitro *micropropagation techniques (right) to produce thousands of plants for breeding programs; below, examples of* in vitro*-produced plantings in a field at IITA's substation at Onne, Nigeria.

Working with Nature: Progress in Biological Control of Cassava Pests in sub-Saharan Africa

A few years ago, a global newspaper, the *International Herald Tribune*, reported that "a small bug is eating the heart out of Africa" and its long-term impact on food production in this huge continent could be "far worse" than the much publicized droughts causing starvation in several countries. The article pointed out that droughts do not go on forever, "but unless stopped by man's intervention, the cassava mealybug will endlessly ravage the continent right across its tropical midbelt."

Not only does cassava mealybug (*Phenacoccus manihoti*) cause substantial yield losses of a basic food for millions of Africans but another pest—cassava green mite (*Mononychellus tanajoa*)—adds its big share to the damage. Together they can cause yield losses as high as 80%, with an average 30% considered a conservative figure.

Any sizable loss can be catastrophic because cassava (*Manihot esculenta*) grown on an estimated 10 million ha, is a staple food for approximately 200 million people in sub-Saharan Africa. It is a prime source of carbohydrates from the underground roots and proteins and vitamins from the leaves. Of all the food crops in tropical Africa, cassava—a drought tolerant crop—is the greatest source of food energy.

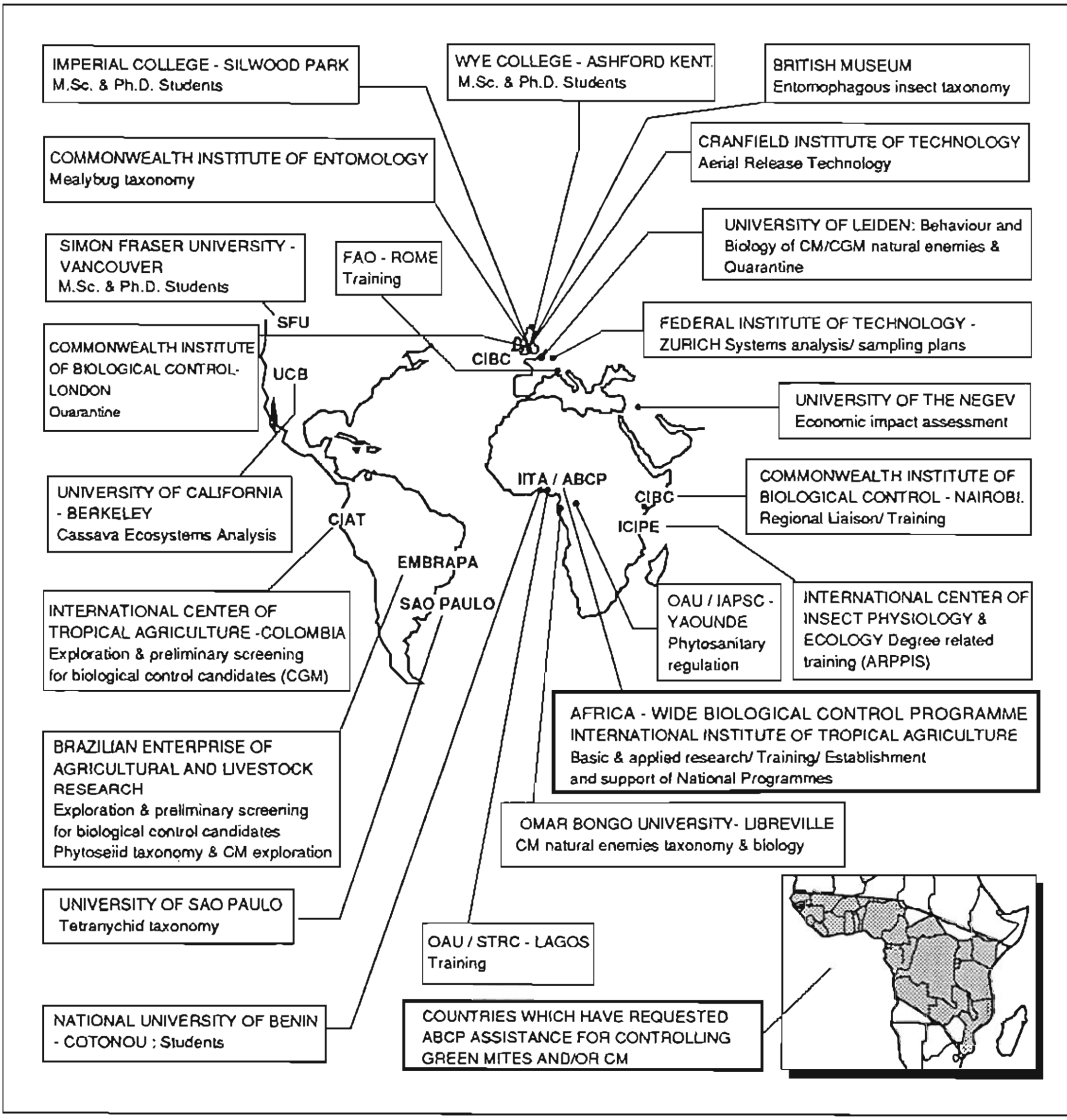
Fortunately, man did intervene and a two-pronged attack, which has become the world's largest biological pest control program, was launched against the two cassava pests by IITA with help of many collaborators and donors in Africa and in other parts of the world (Figures 4 and 5).

The size of the threat demanded a rapid solution over an area larger than the United States. The biological control option using natural enemies for control of the two pests was chosen as the fastest, safest, and most appropriate method and a special Africa-wide Biological Control Program (ABCP) was established in 1980. (In the meantime, plant breeders were identifying source of resistance to the pests and incorporating this characteristic in improved cassava cultivars. Some of them have shown moderate resistance to the pests in varietal trials over the past four years and this high priority research continues.)

Analyses from several sources illustrate the advantages of working with nature. Checks and balances have evolved in natural systems that keep the proportions of species within narrow ranges during any given period. Cassava came to Africa from South America about 300 years ago without the mealybug. When the mealybug did arrive (first discovered in Congo/Zaire in 1973), it came without its natural enemies. The resulting damage that occurred as the mealybug multiplied in the absence of natural enemies emphasizes their value.

Although the cassava mealybug (CM) and the cassava green mite (CGM) can be controlled with frequent applications of highly toxic pesticides, this approach is both ecologically and socially unsound, as well as too expensive. Also, delegates from the Third World at a 1987 meeting of the ruling council of FAO voiced their worries about the safe use of pesticides in developing countries. The UN estimates that perhaps 40,000 people are killed each year by pesticides and a further 2 million injured.

Successful results with biological control of CM using the parasitic wasp *Epidino-*

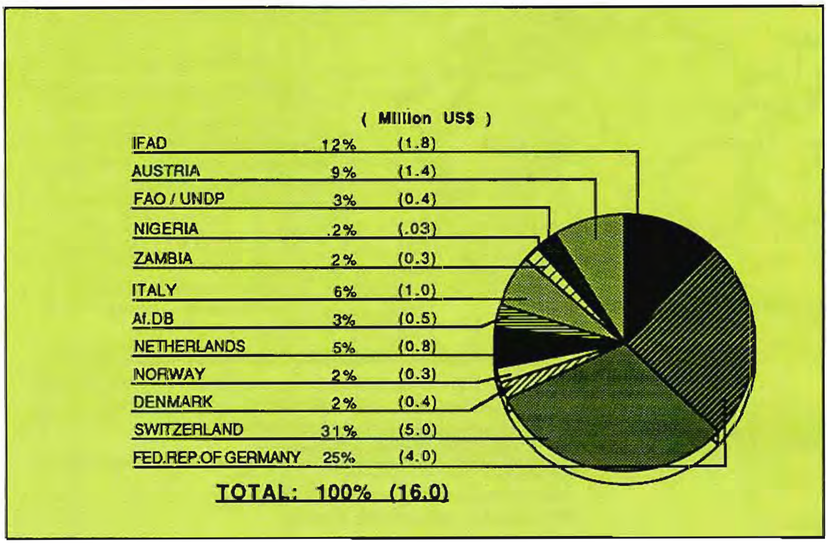


carsis lopezi show this environmental-conscious approach to be a meaningful strategy for control of the mealybug, especially in sub-Saharan Africa agriculture that is oriented towards low-input, sustainable production of food crops and the maintenance and protection of agro-ecological zones devoid of widespread use of pesticides.

Figure 4. World-wide collaborative research and training network of the Africa-wide Biological Control Program (ABCP). It has become the world's largest biological pest control program.

By the end of 1987, the two pests had spread to 31 of the 35 countries in the African cassava belt (Figures 6 and 7). They are found together in 24 countries and will probably cover all cassava-growing areas within the next two or three years. Originally the CM was considered to be the more important of the two pests, causing devastating damage in Central and West Africa. It has recently moved over the Rift Valley into East and Southern Africa causing great concern. But in the past three years the CGM has been reported as an increasingly serious problem.

Biological control of the CGM—first observed in Uganda in 1971—is proving to be more difficult and may require consistent, long-term efforts. The complex of efficient



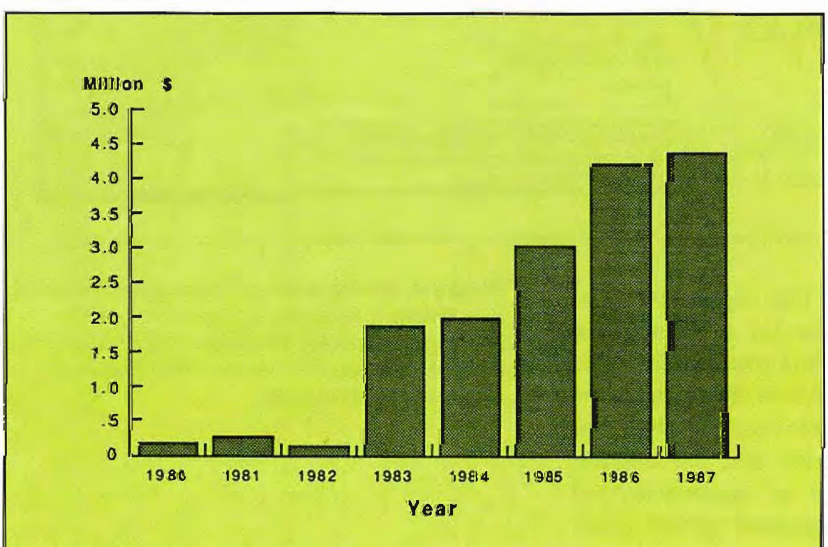


Figure 5. Top, distribution and total funds received from donors since the Africa-wide Biological Control Program was started in 1980; below, annual donor contributions for the program.

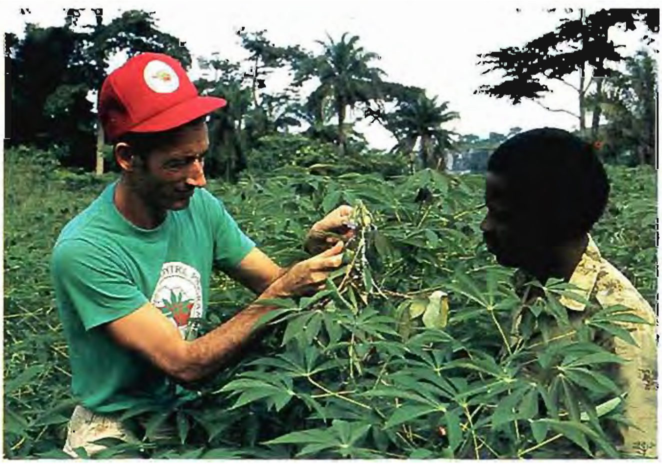
natural enemies of the green mite is almost restricted to predatory mites. Because of different behavior and ecological needs of these biological control agents, the introduction of predatory mites from South America and their establishment in African countries appears to be more difficult than that of mealybug antagonists.

Because cassava—the main natural host of CM in Africa—was introduced from South America and the genera *Manihot* and *Phenacoccus* are particularly rich in species in that part of the world, the search for natural enemies started there in 1980 as a follow-up of the efforts initiated by the CAB International Institute of Biological Control (CIBC/England). The exploration over thousands of square kilometers during the past seven years with the support of the International Center for Tropical Agriculture (CIAT/Columbia), International Development Research Center (IDRC/Canada), German Agency for Technical Cooperation (GTZ/West Germany), and IITA has resulted in the identification of more than 60 natural enemies of the two pests, 14 of which have been released in Africa.

However, to date only one parasitoid—*E. lopezi*—has proven to be effective against the mealybug using both aerial and ground releases in many ecological situations. This parasitic wasp has been established in 18 countries over areas of about 1.5 million km^2. It is estimated that cassava crop losses due to the CM in these areas have already been reduced by half and both IITA and national scientists expect that losses will continue to decrease since *E. lopezi* is known to keep CM population low only after the second year following its establishment.

On the other hand, none of the releases of cassava green mite predators has led to proven establishment. Therefore, CGM research, including rearing of host mites for natural enemies, mass rearing the natural enemies, and experimental releases, is being stepped up. Also, a three-year contract

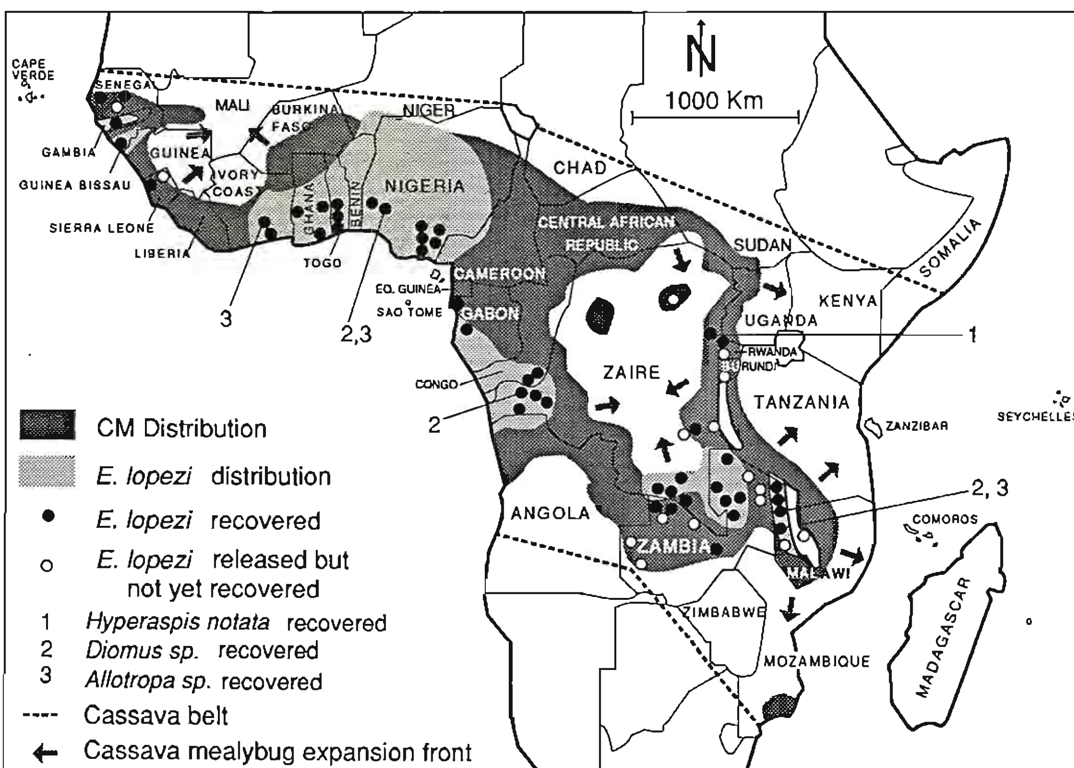
Left, an enlargement of the parasitic wasp *Epidinocarsis lopezi*—***a successful natural enemy of the cassava mealybug; thousands have been released in selected cassava fields in African areas via aircraft in remote, hard-to-reach sites and by persons on the ground (right).***



with CIAT covers further explorations for natural enemies in Central and South America and the Caribbean, as well as biology, taxonomy, and field ecology studies.

Why has biological control of the cassava mealybug been successful? According to a May 1987 report by a review team of five scientists from outside IITA, the establishment of *E. lopezi* for the control of cassava mealybug in Africa "represents an ideal investment in technological change and the project has been unusually cost-effective". Among the reasons given by the team were these: *E. lopezi* was discovered quickly and inexpensively, could be mass-reared by techniques developed by research, appears to be capable of permanent establishment over nearly all (if not all) of the cassava belt, disperses effectively and rapidly, and provides good control under a wide variety of conditions. Furthermore, farmers do not have to decide to adopt the technology and it requires neither investment nor maintenance by them. The total net benefit of about $3.0 billion and a benefit/cost ratio of 178:1 calculated by the team was admittedly high and it is stressed that the figures should be interpreted with caution. The analysis took into account only the mealybug part of the program. An article prepared by Prof. R. B. Norgaard of the University of California at Berkeley and accepted for publication in the *American Journal of Agricultural Economics* (May 1988) uses a benefit/cost

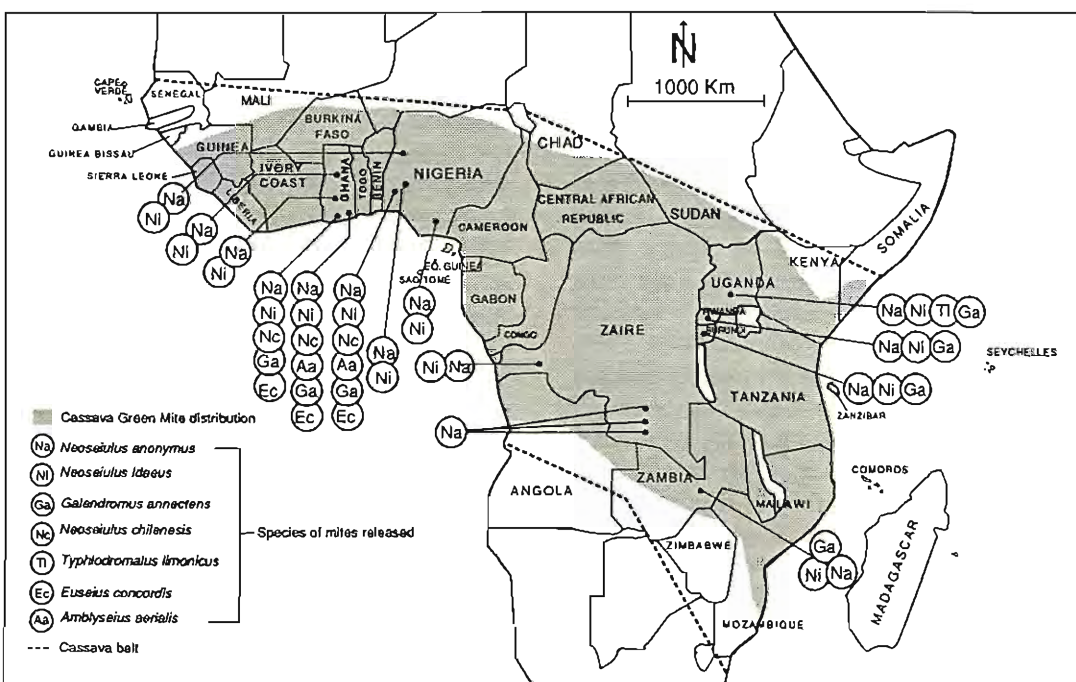
Figure 6. Cassava mealybug (*Phenacoccus manihoti*) and exotic natural enemies distribution in Africa.



ratio of 149:1. The Expert Advisory Committee to the Sponsoring Group for the Africa-wide Biological Control Program, meeting at IITA in July 1987, pointed out that as with all cost benefit analyses some of the assumptions and values used to determine them are open to argument. Nevertheless, it still appears there is likely to be an extraordinarily high benefit to cost ratio. Most economists would regard a benefit to cost of 1.2:1 to be very good. Meanwhile, in field studies by the ABCP in Ghana and Côte d'Ivoire in areas with and without *E. lopezi*, tuber yield loss and plant growth reduction caused by the CM were measured in different ecological zones and the reduction of this damage due to *E. lopezi* was quantified for different situations.

ABCP has used an integrated problem-solving approach that includes research, training, and development of national programs. Rather than being concentrated only on the pests and their natural enemies, research has included the plant and its environment. Through intensive field and laboratory studies and computer simulation, the cassava agro-ecosystem is analyzed and the impact of manipulations assessed. (Brief accounts of the results of this research are reported in IITA *Research Highlights* in 1982 through 1986 editions.) Training at the technical level develops the manpower required to fight the CM and CGM with the appropriate urgency. University level training is being given a high priority to develop the essential, long-term national biological control capability. National biological control programs are being established in 35 countries of the African cassava belt with assistance from ABCP and bilateral funds.

Figure 7. Cassava green mite (*Mononychellus tanajoa*) distribution in Africa.



The 19 already set up are staffed by ABCP-trained specialists and equipped to carry out surveys, releases, and monitoring activities.

Zambia is an example of a recently established national biological control program in the Plant Protection Section of the Ministry of Agriculture and Water Development. Both cassava pests have spread rapidly in the country and the plight of cassava-dependent subsistence farmers and their families became acute. Many of them have been living on the borderline of chronic malnutrition, and, in the most severely affected areas, the damage by the pests has brought near starvation. Introduction of natural enemies was initiated in 1984 with additional releases during the following three years (Figure 8). Field surveys in several areas confirm that *E. lopezi* has been established and mealybug damage to the cassava crop diminished.

The results of the Zambia operation proved the value of the delivery and release techniques used by ABCP in cooperation with national program personnel. For example, from July to October 1987, IITA provided nine shipments made up of more than 190,000 individuals of six species of CM enemies. These natural enemies, reared at the ABCP laboratories at IITA in Ibadan, Nigeria, were packaged and carried by courier on scheduled air flights from Lagos to Nairobi, Kenya. There they were met on arrival and transferred to the ABCP aircraft which flew them to Zambia. They were then released at 14 widely-spaced and often remote sites in five provinces. Of these releases, nine were made by aircraft and five on the ground. (The aircraft was used for the latter to deliver the insects to a nearby airport.) In most cases releases of the natural enemies took place, even in the most remote of these areas in Zambia, within 24 to 36 hours of them being packaged in Nigeria. The average mortality of the natural enemies at release was less than 30% overall.

Similar results were achieved in the much smaller cassava growing areas of Malawi where ground releases of ABCP-supplied natural enemies (mostly executed by national biological control program staff) resulted in widespread establishment of *E. lopezi*. Two years after the first releases in 1985, a central zone of 100 km length is now virtually free of CM. However, food aid by the government was still required in 1987 because of previous destruction of cassava and subsequent lack of planting material. In southern Shaba (Zaire) the situation was similar, and, following the CM outbreaks several years ago, cassava growing in the region is recovering only slowly.

As a result of the achievements so far, all countries in the cassava belt are well aware of the ABCP and most have sent technicians and scientists to attend courses or take degree-related training. Their requests for help, covering training, delivery of natural enemies, and technical assistance, have been met on most occasions but not always at the level required. This was due to manpower and production shortages caused by resource and space limitations at the present location of the ABCP at IITA headquarters in Ibadan, Nigeria. These constraints have been addressed in the planning of the 1988–1992 phase of the program. For example, new facilities for the program have been constructed at IITA's substation in Cotonou, Republic of Benin. Not only do they provide adequate laboratories for mass rearing of beneficial organisms and offices for IITA biological control staff but also some facilities for scientists from other organizations. The rearing chambers at Cotonou will provide a reliable central supply for starter cultures for national programs.

Because biological control is area-wide, it can spread from one country to another. Thus, there is a critical need for African countries sharing similar climatic conditions

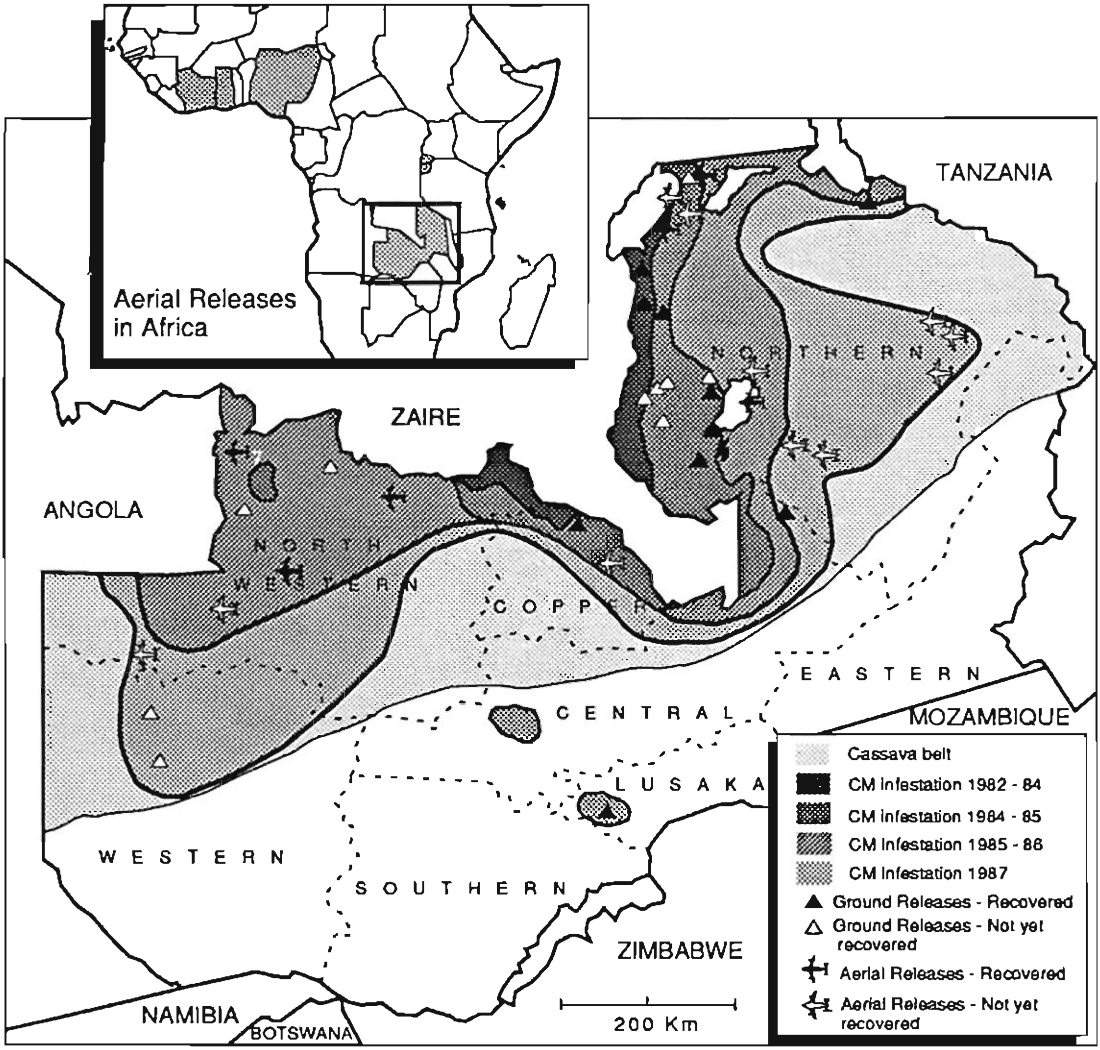


Figure 8. Cassava mealybugs spread rapidly in Zambia beginning in 1982 and the plight of cassava-dependent subsistence farmers and their families became acute. Both aerial and ground releases of the mealybugs' natural enemy *E. lopezi* ***from 1984 through 1987 have been successful in reducing mealybug damage to their cassava crops.***

and production systems to adopt a uniform set of regulations for the importation, quarantine, distribution, and field-release of biological control agents. The Expert Advisory Committee to the sponsoring group for the biological control program recommended in May 1987 that the establishment of such a framework be given urgent consideration by the Inter-African Phytosanitary Commission, FAO, and ABCP. In addition, it was emphasized that an authority responsible for the application of these regulations should be established.

The "cassava tree"—an inexpensive rearing unit for mealybug parasitoids designed for use by IITA and national programs. Based on hydroponic culture, the simplest version does not need electricity.

Institution-building for Cassava Research and Outreach in Zaire

Zaire is often called "the heart" of Africa and, in terms of experience since independence in 1960, it is a country that confronts many of the problems acknowledged to be at the heart of development throughout sub-Saharan Africa today. As Africa's third largest country, Zaire has a rapidly growing population currently estimated at 35 million. Agriculture is the major economic activity and the primary means of livelihood for three-fourths of the population who live in rural villages and rely on traditional, small-scale subsistence farming.

One of the major factors limiting economic development in this country since independence has been the low number of Zaireans highly trained in managerial and scientific disciplines. Nowhere has this need been more pressing than in agriculture—the most important sector of the national economy and the cornerstone of economic survival and development. Ironically, during the 30 years before independence, the then Belgian Congo had one of the best developed agricultural research systems, *Insti-*

Dr. N.M. Mahungu, director of PRONAM (left), and IITA scientist Dr. O. Osiname (right) inspect an improved cassava variety at the main reseach station in M'Vuazi, Bas-Zaire.

The importance and extent of cassava production in Zaire are illustrated here in a village in the Bandundu region: cassava is being sun dried in the white areas shown in this airview.

tut National, pour l'Etude Agronomique du Congo (INEAC), for export cash crops in the tropical world. With the departure of most scientists from INEAC after independence, Zaire had few national scientists to manage or conduct agricultural research, especially on food crops.

While a considerable physical research infrastructure with 22 research stations was part of the legacy of INEAC, critical shortages of finance and manpower made it impossible for its national successor—*Institut National pour l'Etude et al Recherche Agronomique* (INERA)—to maintain the scale or capability of the previous system on a nationwide basis. National research efforts were largely confined to activities such as the maintenance of germplasm of annual crops and limited rejuvenation and multiplication of seed and planting materials.

By the early 1970s, Zaire had little national research capability or an effective improvement program for cassava (*Manihot esculenta*)—the most important staple food crop in the country. Zaire was then, as now, Africa's largest cassava-producing country with one half of the total estimated cultivated land under this staple that provides 60% of the caloric needs of two-thirds of the population. Rapid population growth

An improved cassava variety named "Kinuani" (meaning "fighter" in the Kikongo language) has proven to be an outstanding performer in farmers' fields.

(2.5% per year) led to increased demand for cassava and other food crops and foreshadowed future shortages if steps were not taken to develop agriculture and increase production. The Government of Zaire (GOZ) recognized that external assistance was needed to develop national research and technical capabilities.

A serious disease—cassava bacterial blight (*Xanthomonas campestris*)—started to spread in epidemic proportions in the 1970s throughout Bas-Zaire and the two Kasai regions of the country. Many cassava fields were completely destroyed by the disease, and, as supplies of cassava tubers dwindled, prices went up as much as tenfold. In 1973, the Commissioner for Agriculture in Zaire and the USAID mission made an urgent request to IITA to send scientists to Zaire to assess the extent and seriousness of the disease and advise on methods of control. A major outcome was the government's decision to start a national research program for cassava, *Programme National Manioc* (PRONAM), and to involve IITA in its establishment and development. A Memorandum of Understanding between GOZ and IITA was signed in May 1974 under

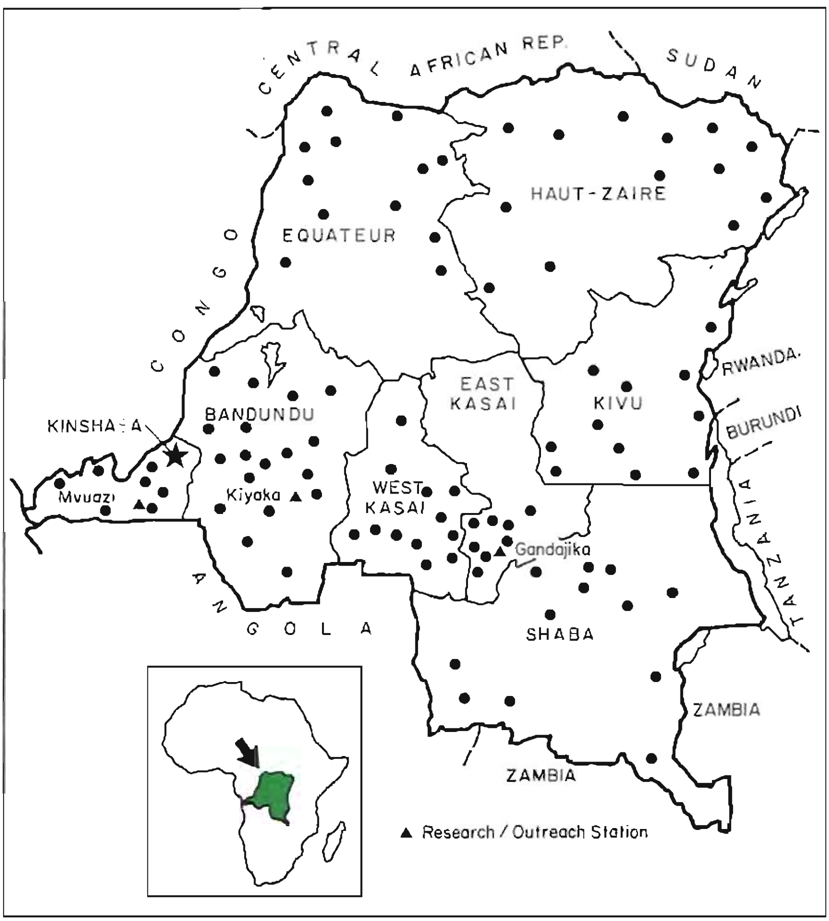


Figure 9. Locations of PRONAM research/outreach stations in Zaire and geographical distribution of cassava production. (Each dot = 1% of national production.)

which the international research institute would provide technical assistance with funds provided by the government. Later that year IITA put a plant breeder in Zaire and within three years it had stationed a complete research team there, including an agronomist, pathologist, and entomologist.

The first priority of the newly formed PRONAM in 1974 was to get a comprehensive breeding program underway at M'Vuazi in Bas-Zaire and to identify, test, and develop cassava lines and varieties that would be high-yielding, resistant to major diseases such as cassava bacterial blight (CBB), cassava mosaic virus (CMV), and cassava anthracnose disease (CAD). Varieties also needed to be adapted to a wide range of environmental conditions and suitable for the production of good quality cassava-based products such as fufu and chikwange.

Another important objective was to identify and train scientists to take responsibility for the management and operation of PRONAM at the earliest opportunity. IITA provided non-degree technical training for Zaireans and assisted in arranging training at advanced degree levels in African and American universities.

Meanwhile, at three main stations—M'Vuazi, Kiyaka, and Gandajika—PRONAM continued to develop varieties adapted to the most important cassava growing regions in Zaire: Bas-Zaire, Kinshasa and Bandundu, the southern areas of Kasai Oriental and Kasai Occidental, southern Kivu and the north Shaba regions (Figure 9). An intensive, multipurpose breeding program for cassava improvement is laborious and time consuming, taking up to eight years to develop fully-tested varieties for multiplication and release to farmers.

By 1983, PRONAM had developed a cassava variety named "Kinuani" (meaning "fighter" in the Kikongo language) that was recommended for general cultivation in Bas-Zaire. This variety, with good resistance to several diseases, provided yield stability in contrast to most local varieties that were relatively susceptible. The performance of Kinuani is evident from 135 on-farm demonstration trials carried out in collaboration over a three-year period with the National Fertilizer Program (PNE). On average, both with and without fertilizer application, Kinuani has given 35% higher yield than local varieties. Kinuani is also more responsive to fertilizer application and the high demand for this improved variety in Bas-Zaire has led to greater efforts to multiply and distribute it to farmers. PRONAM has cooperated actively with various local oganizations and agricultural development projects to distribute Kinuani to farmers and about 60 hectares are multiplied annually for distribution to them.

PRONAM is also evaluating improved IITA varieties such as TMS 30572 and 30555 which have been introduced in tissue culture form from the institute headquarters at Ibadan, Nigeria. Cassava varieties that have tolerance to acid soils and give good leaf yields are important in Zaire. (Leaves are a source of protein for many families.) The benefits of the research are now obvious to extension agents and farmers who have seen yields go from a range of 4 to 6 tons/ha to 7 to 12 tons/ha. Plant breeders continue to introduce and cross new materials with locally adapted varieties and two other varieties are at an advanced stage of development.

In its early years, PRONAM also had to respond to the cassava mealybug (CM) (*Phenacoccus manihoti*) which was discovered in 1973 around Kinshasa. CM spread rapidly throughout Bas-Zaire and caused severe damage and yield losses, especially in 1976 and 1977. With the assistance of the IITA Africa-wide Biological Control Project (ABCP), natural enemies of the cassava mealybug were identified and released in

1982 and 1983. An introduced parasitoid (*Epidinocarsis lopezi*) had spread over 60,000 km^2 within fourteen months after the first releases in Bas-Zaire and Bandundu regions. This parasitic wasp became established and mealybug populations declined. (See article on biological control in Africa on pages 30 to 38.) The training of PRONAM staff by the ABCP was a major factor in this success.

In parallel with the intensive breeding program and biological control programs for cassava in Zaire, PRONAM's research capability has also been developed through systematic training of personnel. This training was organized at two levels: (1) graduate training at M.Sc and Ph.D degree levels for Zairean scientists who would take over senior responsibilities with PRONAM in the future and (2) training for research technicians and extension personnel in cassava research and production technologies. (The scope of this training is shown in Figure 10.)

Today, cassava research in this huge African country is increasingly managed and conducted by Zairean scientists with IITA providing technical assistance to the national team when needed. With a national research capability virtually consolidated for cassava, PRONAM has become involved in a new project—Project de Recherche Agronomique Appliquee et Vulgarisation (RAV) which started in 1985 and includes research on maize and grain legumes as well as cassava.

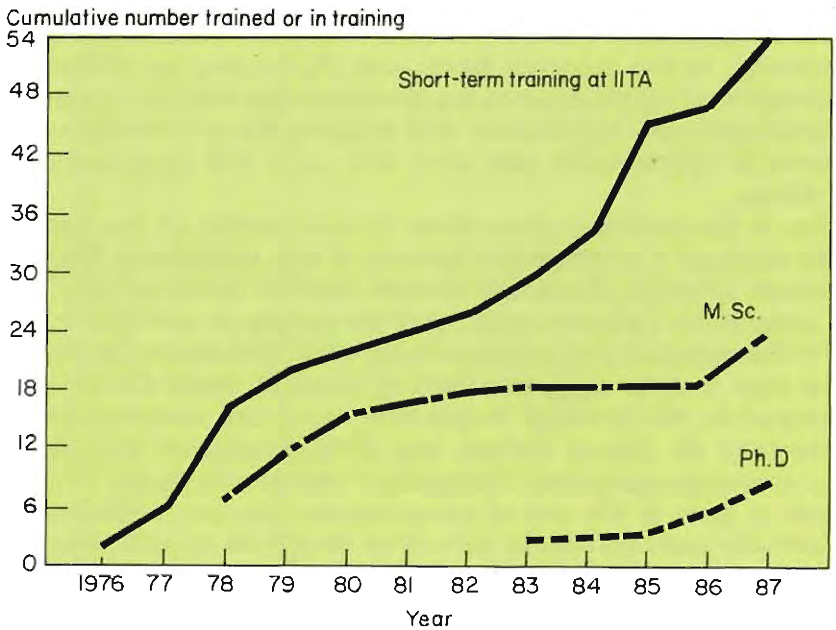


Figure 10. Training of Zairean national staff for PRONAM. (Three staff members now in the program have Ph.D. degrees and in 1987/88 five others were studying for their Ph.D. degrees.)

Annual Report Executive Summary

Resource and Crop Management Program

Dr. D.S.C. Spencer
Program Director

The overall goal of this program is to develop economically and ecologically viable farming systems for increased and sustainable production by small-scale farmers while conserving the natural resource base. The resources with which it is concerned are the soil, water, labor and other engergy sources, crops, fallow vegetation, and material inputs such as fertilizers and chemicals. Research during 1987 was conducted by scientists working in five research teams: resource management, cassava-based systems, maize-based systems, rice-based systems, and special studies.

Resource management: The conceptual framework and strategy for resource management research involves: (1) measurement of the physical, chemical, biological, and socio-economic elements of the smallholders natural resource base; (2) studying the dynamic interactions of these elements to quantify the determinants of stability and degradation of the resource base; and (3) devising or designing potential resource management systems using the principles identified by the study of the determinants of stability and degradation and adapting these innovations to specific farming systems in collaboration with other IITA units and programs and national scientists in Africa.

Alley farming studies in the transition zone where IITA is located on the use of nitrogen (N) show that although a considerable amount of N is released to the soil by the hedgerows through prunings, the actual amount used by maize is low. This is partly because of competition between maize and the hedgerow and partly because of poor timing in the application of prunings to the crop. Results of this year's studies show that the best time to apply prunings to maize is when the crop is seeded. Nitrogen released by the prunings at this time has a use efficiency comparable to 75 kg urea N/ha for *Cassia siamea* and *Gliricidia sepium* and about 50 kg urea N/ha for *Leucaena leucocephiala*. Competition between maize and hedgerows for light is severe in spite of the use of recommended pruning frequencies. Higher maize yield *Gliricidia* plots compared with other hedgerow species was attributed to a lower level of competition between *Gliricidia* and maize for climatic resources. Performance of hedgerow species in farmers' fields was affected by inherent soil fertility and the symbiotic effectiveness of native *Rhizobium* strains in the soil.

Evaluation of the potentials of selected hedgerow species for alley farming and their performance under farmers' production conditions continued. Alley farming with *Gliricidia* generally gave higher maize yields than with *Leucaena*. Small applications of P and Ca improved establishment, as well as initial growth of *Leucaena* in acid soils. Studies of long-term effects of alley farming on soil chemical properties show that soil organic C, extractible P, exchangeable K and Mg status in the surface soil was higher where the hedgerow species was *Leucaena* compared with *Gliricidia*, *Alchornes*, or *Aciao*. Soil pH was highest in *Alchornes* plots, Ca status highest in *Gliricidia* plots, and exchangeable K and Ca levels lowest in *Aciao* plots.

Studies on the effect of large-scale deforestation on hydrology and land productivity in a humid zone show that deforestation caused significant changes in soil physical and chemical properties. One of the problems of deforestation is handling of excess vegetation resulting from bush clearing. The smallholder's practice of *in situ* burning or even burning in small heaps is better than windrow burning used when large areas of forest are mechanically cleared.

Research on the effect of various methods of fallow management on weed infestation show that bush fallow is most effective in suppressing weeds. Weed pressure was most severe in continuously cultivated plots, especially where crop residue was removed. Fallowing with grass or *Leucaena* tended to reduce the population of annual weeds. The herbaceous legume, *Crotolaria retusa*, has potentials for weed suppression when interplanted with maize and can reduce weed pressure in subsequent crops.

Macroptilium artropurpureum, *M. Lathyroides*, *Echinochloa colona* and *Psophocarpus palustris* are good cover crops for the Sudan savanna. When these cover crops were combined with a minimum tillage system which does not disturb the plant residue on the soil surface, good soil conditions were maintained and this resulted in increased crop yields. Although the use of tied ridges in this ecology significantly improved physical, chemical, and hydrological properties of soil, the effect on crop yields was variable.

Cassava-based systems: Research was conducted at several sites in Nigeria, Cameroon, and Zaire in collaboration with national program scientists. In a cassava + maize intercropping trial at IITA's headquarters, the best land use efficiency was obtained with maize variety TZSR-W planted at 40,000 plants/ha and variety TZE at 80,000. The researchers obtained the best results when cassava and maize were planted at the same time or cassava was planted not later than 20 days after maize. Planting TZSR-W maize at 40,000 plants/ha in the same row, as an inter-row, or in alternative rows with cassava did not affect yields of either crop. In trials conducted with national scientists in three ecologies in Nigeria (humid, transition, and subhumid), it was revealed that the most economic rate of nitrogen fertilizer application for cassava intercropped with maize was 80 kg N/ha. Labor required for band fertilizer application in cassava + maize intercropping systems was over three times that needed for broadcasting. Although yields were slightly higher, the increase was not sufficient to compensate for the higher labor costs.

Based on a diagnostic survey of farming systems and practices in the Ohosu area (Nigeria), farmers on the average cultivate 0.8 hectares of cassava with yields of about 20 t/ha for improved varieties compared with 11 t/ha for traditional ones. In on-farm trials in acid Ultisols in Nigeria, the improved cassava variety TMS 30572 outyielded others by about 30%. Collaborative trials with the Nigerian Institute for Oil Palm Research (NIFOR) showed that interplanting of cassava in oil palm plantations before the canopy closes had no significant adverse effect on oil palm bunch yields but reduced the establishment cost of oil palm plantations by providing a return before the oil palms started to yield fruit.

Improved maize varieties intercropped with cassava in Cameroon yielded more than local varieties and responded to fertilizer application on both the fertile lower volcanic soils site and the less fertile Tiko plain soils of coastal lowlands. However, the fertilizer response was uneconomical at the former site. Diagnostic surveys conducted in the coastal lowlands of Cameroon, southwestern Zaire, and southern Nigeria revealed the following technical constraints to cassava production by small farmers: low soil fertility, use of unimproved varieties susceptible to diseases and pests, low end-product prices, and high production and processing labor requirements. In two villages in southwestern Nigeria which are heavily dependent on cassava consumption, children under 12 years suffered from inadequate intakes of protein, carbohydrates, iron, calcium, and other essential nutrients. This emphasized the need to incorporate more nutritional foods into the farming systems.

Maize-based systems: Research in two pilot areas in southwestern Nigeria concentrated on improvement of farmers' maize + cassava intercrop and options for second season cropping. Compared with other maize varieties, TZSR-W had a yield advantage regardless of growing conditions and inputs in the Alabata pilot area, but in Ayepe the yield advantage was only significant in the presence of fertilizer. An IITA hybrid maize did not show a yield advantage over the local variety under farmer management. Extreme yield variability among farmers was again observed and is being addressed more extensively. Maize was compared with soybeans and cowpeas in the second season trials. Findings: very low maize yields with the crop failing completely on many farms; soybeans proved to be an acceptable crop for home consumption but marketing remained erratic; and farmers were able to manage sprayed cowpeas but the main problem was availability of sprayers and insecticide.

A major survey in the highlands of western Cameroon (Ndop plain) established the importance of various cropping systems and quantified the labor needs for food crop growing. A stepwise on-farm trial with maize and groundnuts based on earlier factorial trials led to firm recommendations for farmers on land with medium to high yield potential. A program of station trials was started in northern Cameroon with a variety of crops, cropping systems, fertility and water management practices, and weed and pest control measures. The emphasis is on sorghum both as a dry season crop (grown on residual moisture in Vertisols) and as a rainfed crop.

In the Republic of Benin, on-farm research continued on the improvement of maize, groundnut, and cowpea production and station research on alley cropping, live mulch, and cover crops. Fertilizer on maize requires a grain yield increase of 750 kg/ha to be attractive in Benin—a criterion not met by most farmers in 1987. TZSR-W continued to show its good yield potential and hybrid 8428-19 outyielded the local maize variety in the second season by 130%, with or without fertilizer. Also, an improved cowpea package was successfully tested in a pre-extension trial.

On-farm research was initiated in 1987 in the Gandajika area of Zaire, plus a survey on current soybean growing and a preference test for cowpeas. Station research continued on fertilizer rates for soybeans and groundnuts, showing profitable responses to P and K and to P and N, respectively. Alley farming trials involved comparative testing of *Gliricidia sepium*, *Leucaena leucocephala* and two locally growing species of *Cassia*. On-farm research in the Lumumbashi area of Zaire started in the 1986/87 season with data collection on current farming practices. In the subhumid and semi-arid areas of Rwanda, station research focussed on screening of varieties of sorghum, maize, beans, groundnuts, and pigeon peas, and work on fertility showed the superiority of *Cassia spectabilis* as an alley farming species.

Rice-based systems: Scientists concentrated on the development of appropriate technologies for the improvement of farming systems in inland valley swamps (IVS) and hydromorphic soils. They conducted surveys aimed at describing and analyzing the existing farming systems, on-farm agronomic research, and research aimed at identifying the components of improved technologies in the area of soil and water management. These were conducted in two pilot areas in Bida, Nigeria (medium rainfall, Guinea savanna zone) and in Makeni, Sierra Leone (high rainfall, humid zone). The farm surveys confirmed that inland valley swamps are cultivated by small-scale family farmers who also plant crops in upland fields; in most cases, the lowland fields constitute less than one third of the total farm size. In inland valley swamps with high moisture levels, farmers grow various second season crops after rice; in those with low moisture, rice is followed by a fallow in the second season. Dry season cropping has expanded over the past 25 years and makes a significant contribution to the productivity of rice-based systems.

To develop prototype technologies which address the many constraints faced by farmers, scientists adopted a two-pronged strategy aimed at: (1) developing ways to alleviate the labor bottleneck during the peak rainy season, including the intensification of cropping activities during the slack labor demand period of the dry season and identifying high yielding, short-season crop varieties; and (2) conducting basic research to achieve sustainable and increased productivity.

In pursuit of the first strategy, farmer-managed on-farm tests have shown that IITA-improved rice varieties give superior yield and that their duration is comparable to that of farmer varieties; therefore, they can be easily fitted into farmers' existing cropping systems. Farmer-managed trials demonstrated that it is technically feasible to grow cowpeas during the second season. Yields of 500 to 1,000 kg/ha with two to three insecticide applications were obtained with three IITA-improved varieties which matured in 60 days. Other trials indicated that rice yields can be increased substantially: up to 150% by more timely weeding, 40% by better timing of fertilizer applications, and 70% by transplanting more vigorous seedlings. Also, the use of rice straw for mulching of second season cowpeas conserves the soil moisture and can increase yields up to 100%.

In the pursuit of the second strategy to develop more sustainable systems, water balance studies were undertaken to characterize the various field conditions in three classes of inland valleys in the Bida, Nigeria area: paddy fields with continuous flooding regimes of more than 130 days which could be planted to long-duration rice varieties, those with 100 to 130 days of continuous flooding which are more suitable for early maturing rice varieties, and paddies with less than 100 days of saturated soil moisture conditions that have a high risk of rice crop failure due to drought during the growing season. An improved paddy system was constructed in one of the swamps. Farmer-managed on-farm trials there verified that yields could be increased up to 100% for rice. However, because large capital and labor inputs are required to develop such a system, scientists are working on less costly technologies more suited to farmers' resources.

Special studies: A UNICEF-financed survey on the health and nutrition of rural households in Oyo State, Nigeria, conducted in collaboration with national program scientists, revealed that young children in cassava-consuming villages show severe protein energy malnutrition, and food consumption in the rural communities is generally below the FAO//WHO recommended dietary allowance. As part of the IITA/UNICEF collaborative household food security project, new food products have been developed for both cassava and soybeans and over 30,000 bundles of improved cassava varieties distributed in Oyo and Ondo States of Nigeria.

In an IDRC-funded survey in Oyo State, completed by an IITA socio-economist and three agricultural economists from the University of Ibadan, it was found that soybeans can be easily incorporated into existing diets without major changes in consumption patterns. In all soybean production operations, all the family members were involved. In most of the households, women completed most of the processing. Yields of over 640 kg/ha in the survey area were above the national average of 385 kg/ha.

(In the following pages, a few research highlights are briefly described. More complete infomation on these topics and those mentioned in this Executive Summary can be obtained by requesting the Annual Report of the Resource and Crop Management Program.)

Generating and Evaluating Cassava Production and Utilization Technologies

One of the three crop-based systems working groups recently created by IITA to link commodity improvement research with that on resource management has the assignment to develop and evaluate sustainable and economically viable systems of cassava production and its subsequent utilization that have positive values for smallholder farmers, distributors, and consumers in the humid and sub-humid ecological zones of West and Central Africa. This working group, consisting of scientists in seven different disciplines, conducts on-station research and uses the results for on-farm trials in cooperation with national programs. Recent results follow:

Spatial arrangement and population studies in cassava + maize intercropping system: A popular crop combination in West Africa's humid tropics is maize intercropped with cassava and/or yams. Early-harvested maize brings a premium price during periods of food scarcity (June–August) known as the "hungry period". But according to field survey data, maize population planted by farmers (especially under intercropping with cassava) is unusually low, ranging from 5000/ha to a high of 20,000/ha. Also, farmers' spatial arrangement for the intercrop is usually random.

Population per ha	Cassava root yield (t/ha)	Tubers per plant
Cassava		
10,000	11.9	4.7
20,000	12.2	5.2
40,000	12.5	5.8
SE (±)	1.08	0.23
CV (%)	22.7	19.8

Table 1. Effect of cassava population on the average cassava root yield and number of roots per plant under intercropping with maize at IITA. (Cassava harvested after 12 months.)

A two-year experiment was conducted at IITA to determine what happens to yields when two maize and two cassava cultivars of contrasting growth habits are interplanted at varying populations. Increasing cassava population from 10,000 to 40,000/ha had no effect on root yields but increased tuber numbers significantly (Table 1). Yield of early-maturing maize (TZE) increased with a greater maize population up to 80,000/ha, but the later-maturing, highly vegetative type (TZSR-W) peaked at 40,000/ha (Table 2). However, cassava root yield decreased as the maize population increased from 40,000 to 80,000/ha. The best total cassava and maize land-use efficiency, based on Land Equivalent Ratios (LER) were 1.96 (with TZSR-W at 40,000/ha) and 2.06 (with TZE at 80,000/ha).

A follow-up experiment showed that variety and not planting pattern significantly affected both maize and cassava yields. Cassava root yield was lower when intercropped with highly vegetative, later-maturing maize such as TZPB compared with short, early types such as Population 49 (Table 3).

In summary, these trials show that planting maize at 40,000/ha on the same row, as interrow, or on alternate row arrangements with cassava does not lower cassava root production (at 10,000/ha) or

Maize variety	Maize population	Yields (t/ha) Maize	Cassava	LER*
TZSR-W	20,000	1.58	12.4	1.49
	40,000	2.50	10.9	1.97
	80,000	2.20	9.1	1.66
TZE	20,000	0.94	12.8	1.44
	40,000	1.61	12.3	1.85
	80,000	1.85	11.0	2.06
SE (±)		0.44	2.41	
CV (%)		18.9	22.6	

**LER = Land Equivalent Ratio.*

Table 2. Effects of maize variety and maize population on maize and cassava (Cv Tms 30001) yields and productive efficiency of their intercrops at IITA.

maize yields in a tropical Alfisol in southwestern Nigeria. However, an intercropped maize population can be advantageously increased beyond 40,000 depending upon the maize growth habit—whether early or late maturing. Therefore, farmers have a wide range of spatial arrangements to use in their cassava production system with maize, especially where field equipment may compel them to adopt row-planting systems.

Response of cassava and maize intercrop to nitrogen in two year sequential cropping: Commonly observed cropping sequences in humid West Africa following land clearing include those in which nutrient-demanding crops such as maize and yam are followed by those less demanding such as cassava and cocoyams. Starting in 1985, a study of cassava-maize-fallow sequences in two year cycles was conducted in Nigeria to determine nitrogen response, sustainability, and monetary returns. The sites represented three areas: Warri (perhumid Ultisol soil), Okolu (humid Alfisol soil), and Mokwa (subhumid Alfisol soil). The most common nutrients limiting plant growth in these environments are usually N and K and sometimes P. Both P and K were applied at planting and the level kept constant at 60 kg/ha each.

In order to estimate the total response function, the N levels varied from 20 kg/ha to 320 kg/ha with half applied in the seedbed and the other half four weeks after planting. Three maize varieties—TZESR-W, TZSR-W, and a hybrid (8321 × 181)—were intercropped with cassava variety TMS 30572. Cassava and maize were planted in alternating rows: cassava spacing at 1 m × 1 m and maize at 1 m × 0.25 m for 10,000 and 40,000 plants per ha, respectively.

Maize variety	Maize grain (t/ha)	Cassava root (t/ha)
TZPB	4.12	17.1
TZSR-W	3.39	18.5
TZSESR-W	2.00	22.5
Poza Rica 7729	3.51	20.8
Pirsabak (1) 0.7930	2.57	23.0
Ferke (1) 7035	2.71	20.2
New Modified br$_2$	2.71	19.0
Population 49	2.41	24.5
SE (±)	0.37	1.09
CV (%)	18.2	21.4

Table 3. Effects of maize variety on intercropped maize grain and cassava root yields averaged over three planting patterns and two years, IITA (1985–86).

Hybrid maize yielded more than the other varieties, especially in the subhumid zone. Irrespective of zone, the highest maize yield under intercropping with cassava was obtained between 80 kg and 160 kg/ha N level (Figure 11). However, there was a reverse effect of the N rates on cassava root yield, particularly in the perhumid area.

Economic returns: A comparison of economic returns (Table 4) based on total costs of production (i.e. unsubsidized fertilizer costs, plus land clearing and plot preparation, weeding, harvesting, etc.) shows that it is more beneficial to intercrop cassava and maize at 80 kg N/ha in all the areas studied; also, returns from hybrid maize compared with the open pollinated composite (TZSR-W) were about the same but higher than from the early maturing composite maize (TZESR-W).

Farm performance of improved cassava varieties: How do IITA's improved cassava varieties perform when compared with local ones under real farm conditions? To find out, a survey was conducted in 1987 in a predominantly cassava producing area (Ohosu) in Bendel State, Nigeria. It is within the rainforest vegetation zone with a mean annual rainfall of about 2,000 mm and an "Acid Sands" soil type.

The main features of the farmers' cropping pattern included multiple cropping and land fallow: cassava intercropping with maize and vegetables; intercropping with plantain, maize, and vegetables; and intercropping with trees, plantain, maize, and vegetables. The introduction of the improved cassava varieties did not induce a change in the cropping pattern.

Three improved varieties—TMS 30572, TMS 30211, and TMS 30555—harvested at 12 months yielded a 75% larger root weight than the local ones. The yield advantage of the improved varieties declined to 30% at 18 months harvest. Since number of plants, shoot fresh weight, and number of roots per ha are not significantly different between the improved and the local varieties, the difference in root yield is attributed to higher bulking capacity by the improved

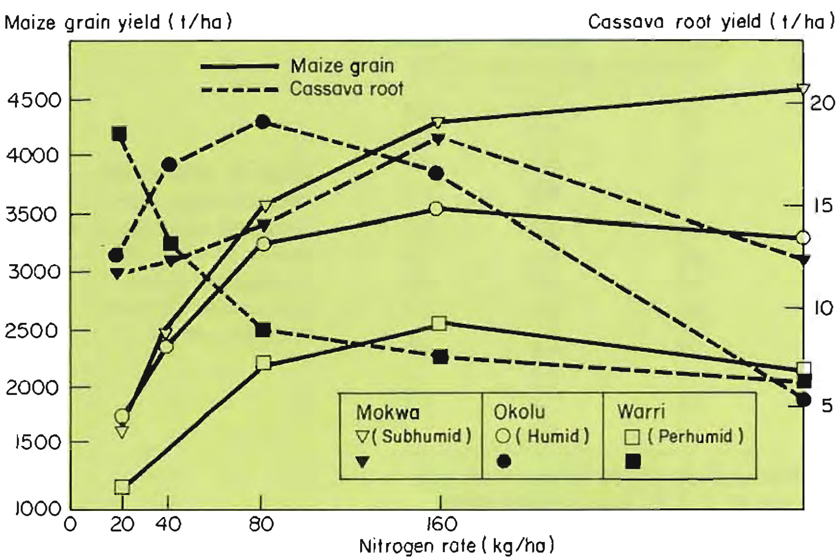


Figure 11. Effect of nitrogen fertilizer on maize grain and cassava root yields averaged over three varieties in each of three ecological areas in Nigeria; maize intercropped with cassava.

varieties. This is reflected in larger root size and higher harvest index, total biomass, and average root weight per plant obtained from the improved compared with the local varieties (Table 5). However, performance of the improved varieties in terms of root yield is below their potential for at least two reasons: sub-optimal plant population and production without chemical fertilizers.

The total cost of producing gari—a popular cassava food—was about 45% higher per ha and 20% lower per ton for the improved varieties because of increased harvesting and processing costs associated with higher yields but a lower cost per ton due to all other production costs being spread over the larger yields. Also, net revenue was higher by about 85% per ha and 75% per ton of gari for the improved than for the local varieties.

Collaborative research with national agricultural programs: One of the activities of IITA's cassava-cropping systems working group is collaborative research with national agricultural research systems and international research centers involved in cassava technology. Cooperative research has been initiated in the major agro-ecological zones of West and Central Africa. Scientists from several countries met twice at IITA during 1986 to discuss their research and make plans for future work related to cassava-based cropping systems. Then in 1987 at its annual meeting, the Research Collaborative Group (including participants from Cameroon, Ghana, Zaire and Nigeria) reported their results, some of which can be summarized as follows:

(1) Major constraints to cassava production in southwestern Zaire, coastal lowlands of Cameroon, central and western regions of Ghana, and southwestern Nigeria are low soil fertility, planting unimproved varieties, attacks by diseases and pests, and low end-product prices and high labor requirements for production and processing.

Table 4. Economic returns from intercropped cassava and maize at different ecological areas and under different nitrogen rates.

		Maize variety		
Location (Ecological areas)	N rate (kg/ha)	TZESR-W	TZSR-W	Hybrid
		Benefit/cost ratios (cost = 1.00)		
Mokwa (subhumid)	20	1.5	1.5	1.8
	40	1.7	2.0	2.0
	80	2.3	2.5	2.5
	160	1.6	2.3	2.3
Okolu (humid)	20	1.6	2.0	2.0
	40	2.3	2.3	2.5
	80	2.5	2.7	2.6
	160	2.1	2.1	2.1
Warri (humid)	20	1.8	1.9	1.9
	40	1.4	1.5	1.4
	80	1.2	1.4	1.4
	160	1.2	1.3	1.4

Note: Prices used (Naira/kg) were: 0.87 for N, 1.00 for open-polinated maize seed and 5.00 for hybrid, 0.15 for fresh cassava tubers after allowing 10% for post-harvest losses, 0.50 for maize, grain, and 5.00 per man day for fertilizer application.

(2) One hour on a cassava grating machine can save 21 hours of hard hand-labor for rural women who do most of the cassava processing in rural areas. Based on the amount of cassava processed by a rural household in one year in Oyo State, Nigeria, 441 work hours could be saved on the average for each family with available cassava processing equipment.

(3) The most efficient land-use efficiency in a cassava + mazie intercropping system is gained by planting cassava and maize either at the same time or at most 28 days after maize. Planting of cassava at later dates resulted in reduced productivity of the system regardless of site and soil type.

(4) Gross net returns are higher in a cassava-based mixture than in sole cassava. Market demand and higher prices, not necessarily high yields, determine land allocation to enterprises (such as yam and rice) which compete with cassava in the Abakaliki area of Nigeria.

(5) Planting cassava in Zaire in double rows with groundnuts at 40 cm × 20 cm spacing resulted in high yields and good monetary returns.

Table 5. Yield of improved and local varieties of cassava from 18 fields surveyed in the Ohosu area, Bendel State, Nigeria (1987).

	Varieties		
Yield parameter	Improved Mean	Local Mean	SE (±)
Fresh cassava root (t/ha)	19.6	11.2	3.59
No. of plants/ha (000)	7.0	7.8	1.49
Shoot fresh wt. (t/ha)	21.9	19.3	8.09
No. of roots/ha (000)	26.0	27.8	8.63
Av. root size (kg)	0.77	0.56	0.18
Harvest index	0.49	0.38	0.06
Total biomass (t/ha)	41.0	31.2	11.35
Av. root wt./plant (kg)	2.94	1.46	0.64

(6) Cassava variety TMS 30572 outyielded other improved varieties such as TMS 30211, TMS 30555, and U/41044 by about 30% in on-farm trials in southeastern Nigeria: 18.7 tons/ha compared with a range of 13 to 15.4 t/ha for the others when harvested at 12 months.

(7) Intercropping food crops (such as cassava) with young oil palm during the early years of oil palm establishment in Nigeria has no significant adverse effect on oil palm bunch yields and reduces establishment costs.

Health and nutritional status in cassava consuming households: A survey on the health and nutritional status of rural families who depend mainly on cassava in two villages in Oyo State in southwest Nigeria shows that the children under 12, especially those two and younger, suffer from inadequate protein, energy, iron, calcium, and other essential nutrients. These results indicate that sources of nutritional enrichment for children under 12 and for lactating mothers in cassava-dependent villages need to be made available. Severe malnutrition may irreversibly damage children mentally and physically so they do not attain full growth potentials.

As part of the IITA-UNICEF Program on Household Food Security and Nutrition, the study was conducted in 1986/87 by national scientists from the University College Hospital and the departments of Agricultural Economics and Human Nutrition of the University of Ibadan (Nigeria). It involved 209 persons: 100 from Iware village and 109 from Olorunda village; 28 households were involved with family sizes ranging from 4 to 15 and members ages from two weeks to over 60 years.

In general, infants of Iware (0–2 years) had severe protein energy malnutrition (PEM); Olorunda infants moderate PEM. This condition was mild for toddlers (3–5

"Cassava Peeling," a painting by Dorothy B. Hayes for the IITA/UNICEF Program on Household Food Security and Nutrition. According to a 1987 survey in Oyo State, Nigeria, women contribute 46% of the labor requirements for all stages of cassava production and utilization.

years) in Iware but severe for those in Olorunda. Age for height measurements were below normal in both villages with mild PEM.

Nutrient intakes of infants, mainly on breast milk, were especially low in energy, protein, iron, calcium, ascorbic acid, riboflavin, and Vitamin A; for toddlers the situation was only slightly better. Other low energy and protein intakes resulted in mild to severe PEM. An insanitary environment exposed children to parasitic infestation, and, if it resulted in diarrhea, absorption of nutrients in the intestine was reduced. When protein levels are already low, diarrhea can precipitate extreme malnutrition (kwashiorkor). Also, common childhood diseases such as measles, which are rampant in the villages, can drastically increase malnutrition.

Food consumption in these rural communities is generally below the FAO/WHO Recommended Dietary Allowances. These people, who lack purchasing power to buy from markets, depend primarily on what they grow to feed their families. Dietary intake depends on food availability which depends on a family's capacity to produce and procure food. But food being available does not ensure good nutritional status; that depends on the kind, quality, and quantity of foods and dietary practices. The latter involve food preferences, beliefs, and customs. Intra-familial food distribution favors adults, especially adult males. They are served first; children get only what is left.

Rice-based Cropping Systems in Inland Valleys

Sub-Saharan Africa has approximately 85 million hectares of inland valleys with almost three-fourths of them in West and Central Africa. These valleys, considered to be one of the most productive areas for growing rice and dry season root, tuber, grain legumes, and vegetable crops are flat-bottom and shallow varying in size and shape. With respect to hydrologic characteristics, they are either stream-flow (run-off and seepage, main sources of water) or river-flow (over-flow from river, main water source). Water conditions or balances and soil fertility are two major physical factors which determine productivity of rice-based cropping systems.

An opportunity for increasing the productivity of rice-based systems in inland valley areas in the short to medium-run lies in alleviating labor bottlenecks during the peak periods of the rainy season, intensifying the cropping activities during the labor slack period of the dry season, and identifying high yielding but short season rice and other crop varieties.

Rice—a major crop cultivated in inland valleys—is the only crop adapted to flooded conditions. After the harvest, most parts of inland valleys are under fallow during the dry season. A small portion is cultivated in the dry season for growing other crops which require less water, such as sweet potatoes, cassava, groundnuts, maize, and short season vegetables. In very wet areas, farmers grow a large proportion of these crops in big mounds and ridges to avoid excessive soil moisture which damages sensitive crops.

In most cases in the inland valleys, the same farmers cultivate the lowland and upland fields, with the former constituting less than one-third of the farm size. They follow two systems of cultivation, depending upon the use of land during the dry season. For example, in about 65% of inland valley fields in the Makeni, Sierra Leone area and about 40% of the fields in the Bida area, they practice an annual crop rotation of rice followed by cassava, or sweet potatoes, or vegetables; in the remaining fields, a rice-fallow system is practiced (Figure 12). Dry season crops are mixed cropped on many fields. They not only provide food and cash income during the hunger period when market prices are 50–75% higher than usual but become an important source of seed or planting material for the upland fields. Although their yield rates are modest, they are very attractive in terms of labor productivity: a return of N14 to N16 per man-day compared with a wage rate of N5. (N = Nigerian Naira.)

An annual cycle of mounding and flat tillage is practiced on about 80% of inland valley fields, with the rice planted on flat seedbeds and dry season crops on mounds. This tillage system recycles the organic matter and soil nutrients by incorporating the crop residues and weeds while making and spreading mounds. An important economic implication of growing dry season crops is that the land preparation labor input for rice (which occurs at the peak period) is reduced by 30–50%.

Farmers' choice of rice varieties is related to method of planting and planting dates and somewhat to field locations, but not to the method of land preparation. In general, there are four or five varieties used for direct seeding and 10 or more for transplanting. Direct seeding has been a traditional practice of farmers in the Bida area and about two-thirds of the inland valleys are presently seeding this way. Transplanting is the most common practice in the Makeni area because of heavy rains and fields become quickly flooded. The choice of a rice planting method is determined by the field moisture condition and how soon farmers have finished planting and weeding upland crops. Although direct seeding takes less labor than transplanting, the latter has the advantage of delayed sowing and less risk. A higher labor input for transplanting on fringes than in valley bottoms makes the latter field location the obvious choice.

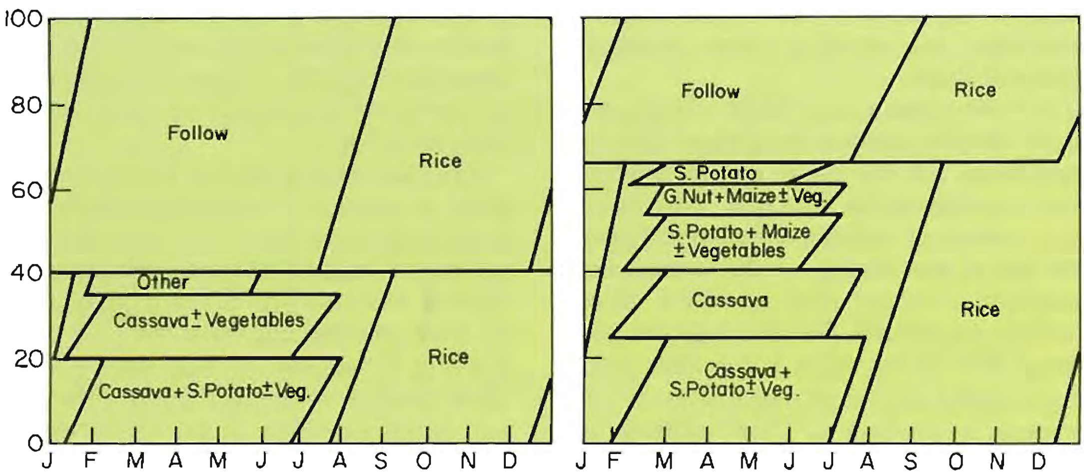
Rice and dry season crop production in inland valleys is constrained by physical, biological and socio-economic factors. One of the principal physical constraints is the lack of an organized structure and arrangement of farmers' rice fields. The plots are small, irregular in shape, and have either weak bunds or none at all. Lack of adoption of improved paddy systems involving levelling and bunding of rice fields in West Africa may be the reason for the slow progress and adoption of improved rice technology. The paddy field system in inland valleys of West Africa is still rudimentary. A properly maintained system can conserve water and increase sedimentation of clay, thereby improving soil fertility and crop production on a sustainable basis.

Low crop yields in inland valleys are also due to biological constraints such as weeds, insect pests and diseases, and to soil nutrient toxicities and deficiencies. Although high yielding rice varieties exist and are being grown by some farmers, yield potentials are not fully achieved because of the adverse effects of these factors.

Among the various socio-economic constraints impeding the productivity of rice-based systems are the shortage of farm labor, absence of efficient farm tools and farm machinery, lack of fertilizer and credit or cash capital to purchase farm inputs.

Aware of the constraints, IITA scientists are continuing research for the improvement of rice-based cropping systems. In a system approach, the improvement of inland valleys for increased and sustainable food crop production can be achieved through

Figure 12. Cropping patterns and crop calendars for inland valley fields in the Bida, Nigeria area (left) and the Makeni, Sierra Leone area (right).



Above, immediately after rice is harvested in December/January farmers in the Bida, Nigeria area make big mounds and/or ridges in inland valley fields and plant dry season crops. In April/May they move to upland fields to plant crops. In July/August they come back to inland valley fields to harvest dry season crops and plant rice; right, dry season crops of sweet potatoes, groundnuts, cassava, and maize grown on mounds in an inland valley in Sierra Leone.

improvement in soil and water management, crop varieties, and crop management. The former can be achieved with an improved paddy field system. During the 1986–87 cropping year, basic studies on water balance were initiated through detailed monitoring of ground and surface water of representative inland valleys in Bida where annual rainfall is about 1100 mm. Field research on simple paddy improvement was also established. The results: most of the bottom land can grow a crop of rice, whereas fields along the valley fringe have high drought probability and make rice cultivation risky; in paddies with continuous flooding for longer than 130 days, traditional, long-duration rice varieties can be grown; in those paddies with continuous flooding for 100–130 days, early-maturing improved varieties are suitable; and in those with less than 100 days of continuous flooding, rice cultivation becomes risky.

Nineteen farmer-managed trials showed the effect of field water duration on rice yields (Table 6). In fields where water remained more than half of the growth duration, rice yields were higher than in those fields with less than that. A yield difference of almost 100% can be obtained when fields are kept saturated or flooded for at least 50% or more of the growing period. Most paddies in the valley bottom maintained enough water to grow a rice crop, but those in the valley fringe did not retain sufficient water. Therefore, the rice crop suffered moisture stress, resulting in reduced yield.

Farmers' rice paddies are inefficient in retaining water and fertilizer nutrients. Preliminary on-farm trials showed water consumption considerably higher there (three to four times) than in improved paddies. Also, the response of rice varieties to fertilizer treatment was better in the improved paddies where yields were increased by 1.8–2.4 tons/ha (Table 7). These results suggest the need for research on low-cost improvement of the paddy system in the inland valleys of West Africa and the development of more appropriate technologies for the natural conditions of the farmers' rice paddies.

Table 6. Yield response of rice varieties to paddy water duration in small inland valleys; farmer-managed trials, Bida, Nigeria (1987).

Variety	Fertilizer level*	Paddy water duration** Less than 50%	More than 50%
		Yield (t/ha)	
Local	Farmer's	1.20	1.86
	Recommended	1.48	2.65
ITA 212	Farmer's	1.04	2.12
	Recommended	1.48	3.27
ITA 306	Farmer's	1.82	2.55
	Recommended	2.32	3.58
ITA 249	Farmer's	0.25	1.44
	Recommended	0.28	1.84
FARO 29	Farmer's	1.04	2.43
	Recommended	1.39	3.32
Fertilizer mean	Farmer's	1.07	2.08
	Recommended	1.45	2.93
Water duration mean		1.26	2.93

LSD (1%) for comparing means between water duration = 0.67 t
CV = 12.1%

**Farmer's level = 15-15-15 NPK (kg/ha). Recommended level = 90-60-30 NPK (kg/ha).*
***Fields under water saturation or over saturation (flooded) for a period of less or more than half of the growing period.*

Use of improved high yielding crop varieties suitable for inland valleys is by far the simplest technology that can be introduced to small-scale farmers. During the 1986–87 cropping season, on-farm trials with improved rice, sweet potato, and cowpea varieties were established in the inland valleys of Gara and Anfani, near Bida. Using grain yield and maturity as bases for farmers' assessment of the varieties, ITA 306 and ITA 212 were the most preferred. Their earliness and high yield attracted the attention of farmers (Table 8).

Sweet potatoes—one of the most common dry season crops grown by farmers in inland valleys following rice—are planted mostly on big mounds or ridges located in the lowest portion of the valley bottom where soil moisture remains throughout the dry season. Both the improved and local variety yielded about the same under the mounds but under the ridges TIS 2498 was superior. Overall, the improved variety outyielded the local sweet potato by about 1 ton/ha but it took longer to mature and harvesting was done about six months after planting. Earlier-maturing, drought-tolerant, and high-yielding varieties are needed in the drier areas and in wet areas varieties tolerant to waterlogging and tuber rotting. In each case, they should fit the traditional cropping system of local farmers.

Early-maturing cowpeas can benefit from residual soil moisture available immediately after rice is harvested. The results of variety trials conducted in farmers' fields in 1987 are shown in Table 9. Cowpeas are a potential short-maturing, dry-season crop in inland valleys but production depends mainly on the input delivery system and farmers' ability to purchase insecticides because

Variety	Fertilizer level*	Farmer's paddy; farmer-managed	Improved paddy Farmer-managed	Improved paddy Researcher-managed
Local	Farmer's	1.7	3.6	4.7
	Recommended	2.4	3.3	6.2
ITA 212	Farmer's	2.2	3.2	4.4
	Recommended	3.5	4.6	4.7
ITA 306	Farmer's	1.8	4.9	4.6
	Recommended	3.0	6.8	6.1
FARO 29	Farmer's	1.7	3.1	4.6
	Recommended	2.2	6.1	5.3
Mean	Farmer's	1.9	3.7	4.6
	Recommended	2.8	5.2	5.6

*Farmer's level = 15-15-15 NPK (kg/ha).
Recommended level = 90-60-60 NPK (kg/ha).*

Table 7. Rice yields (t/ha) from farmer's paddy and improved paddy; on-farm trial, Bida, Nigeria.

Table 8. Yields of five rice varieties in on-farm trials and percentage of farmers with better yields from the improved variety than from the local variety; data from 19 sites in Bida area, Nigeria (1987).

Rice variety	Yield (kg/ha)	Percentage of farmers on whose farm the improved variety outyielded the local
		At low fertilizer*
Local	1723	—
ITA 306	2396	90
ITA 212	1896	59
ITA 249	1168	21
FARO 29	2138	
Mean	1864	
SE (±)	465	
		At high fertilizer**
Local	2404	—
ITA 306	3314	74
ITA 212	2958	74
ITA 249	1511	26
FARO 29	2915	63
Mean	2620	
SE (±)	700	

**15-15-15 NPK (kg/ha).
**90-60-30 NPK (kg/ha).*

they are required to obtain good yields.

High crop yields in rice-based cropping systems depend not only on better crop varieties but also on improved crop management practices: fertilizer application, water and weed control, seedling quality, mulching, and insect pest control. Farmer-managed trials and monitoring of their management practices in Bida showed the relative contribution to yield improvement in rice by some important crop management practices (Figure 13). Weed control resulted in the largest yield increase (150%) with improved water control and paddy improvement next (100%).

The high priority farmers in inland valley areas give to upland crops makes it impossible to intensify rice production during the rainy season by growing two crops. Therefore, the improvement of a crop rotation system involving rice and dry season crops for the lowlands is more consistent with the farmers' resource base. An improved system requires short to mid-season rice varieties suitable for variable moisture conditions and extra-early varieties of cassava,

Table 9. Grain yield of dry season cowpea varieties grown under residual soil moisture in inland valleys after the rice crop in Bida, Nigeria (1987).

Cowpea variety	Maturity (days)	Yield* (kg/ha)
IT82D-889	62	970
IT84E-124	64	1207
IT84E-1-108	56	925
IT84E-60	62	1174
Local check	75	899
SE		± 76.1
CV (%)		14.5

**Two to three insecticide applications.*

sweet potatoes, cowpeas, maize, and soybeans for planting on residual soil moisture. Turn-around of rice fields to dry season crops is critical which requires the replacement of local photosensitive rice varieties by determinate rice types and efficient methods of cultivation and management of residual soil mositure.

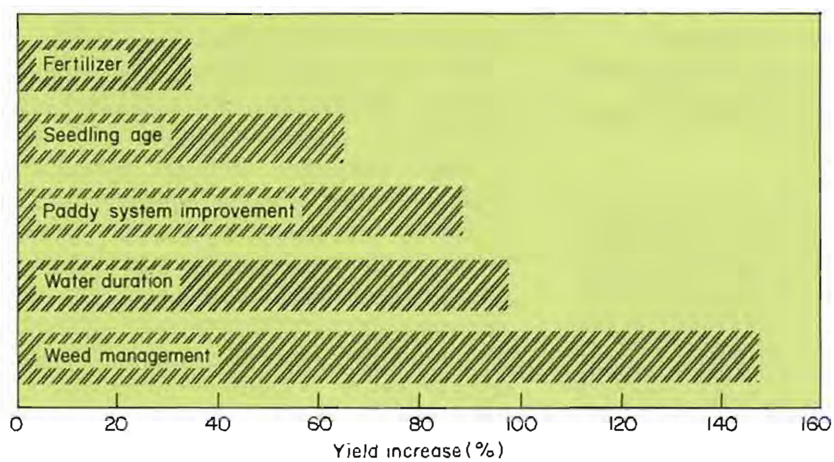


Figure 13. Relative contribution to yield improvement in rice by some agronomic factors in inland valleys.

Factors Affecting Field Establishment of Hedgerows in Alley Farming

To identify the causes of poor growth and chlorosis (yellowing) in two species of hedgerow trees used in alley farming on some farms in southern Nigeria, scientists monitored early growth and nodulation of *Leucaena leucocephala* and *Gliricidia sepium* in two Oxic Paleustalf soils in the greenhouse. They collected "poor" soil from an alley farm where the trees had chlorotic leaves and "fertile" soil from a farm where the trees had green leaves. They applied nitrogen (N) and phosphorus (P) fertilizers and inoculated with rhizobia as corrective measures in both soils.

As expected from the chemical properties of the soils, nodulation, dry matter production (Figure 14), N and P uptake of both *Leucaena* and *Gliricidia* were higher in the fertile than in the poor soil. The poor soil had 0.74% organic C and 0.053% total N and the fertile soil contained 24 and 89% more organic C and total N, respectively. The extractable P in both soils was equally low.

The relative symbiotic effectiveness (RSE) in nitrogen fixation, calculated as the ratio between nitrogen content of plants in the no-nitrogen treatment with or without *Rhizobium* inoculant and nitrogen content of plants fertilized with urea, was always lower in the poor than in the fertile soil. Values inferior to 50% were obtained for *Leucaena* in the poor soil, indicating the need to inoculate this legume with more effective rhizobia. For *Gliricidia*, RSE values were usually high, suggesting that this species fixed relatively more N in association with the indigenous rhizobia.

Inoculation with rhizobia increased the number of nodules only for *Leucaena* in the poor soil. Addition of P increased nodulation, plant growth, and N uptake. Increases for nodule numbers and dry weights were more pronounced in the poor soil than in

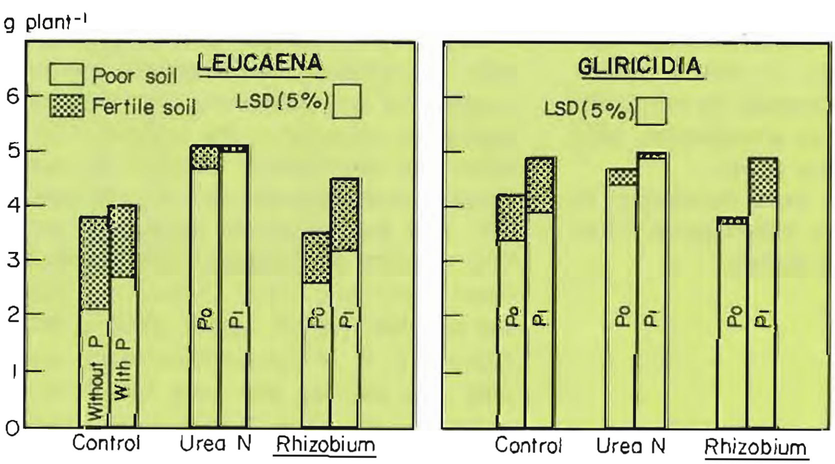


Figure 14. Effect of N and P fertilizers and inoculation with** rhizobia **on dry matter production of** Leucaena **and** Gliricidia **in two different soils, IITA greenhouse (1987).

the fertile. The highest shoot dry matter increases in both soil types were obtained when fertilizer N and P were applied simultaneously. Also, the highest N uptake by plants was obtained in these treatments and in the ones where rhizobia inoculants were used with fertilizer P.

Based on these results, the scientists concluded that low soil N and P contents were at least partly responsible for the nutritional disorders observed in the poor soil. Fertilizer N applied alone or with P in this soil increased shoot dry matter and N content of the trees to the same level as in the fertile soil that received no fertilizer. The positive response of plant dry matter production to N fertilizer in both soils, however, indicates that the symbiosis with indigenous rhizobia was not very effective, particularly for *Leucaena*. Inoculation with *Rhizobium*, although it improved shoot dry matter and N uptake in some cases, was not as effective as the use of fertilizer N. Therefore, more effective strains of *Rhizobium* need to be identified for these soils. Because the relative symbiotic effectiveness of *Gliricidia* was higher than that of *Leucaena*, the use of the former in alley farming should be encouraged to avoid the need for inoculation with rhizobia. Application of phosphorus is necessary to ensure proper nodulation, nitrogen fixation, and early growth of both species in Alfisols. Preliminary data also show that in acid soils *Leucaena* growth and nodulation are increased by the application of either lime or phosphorus, with lime producing a greater effect.

These experiments were conducted in collaboration with the International Livestock Center for Africa (ILCA).

Effect of Cover Crops on Soil Productivity in the Sudan Savanna

Results of trials in Burkina Faso in 1986/87 indicate that productivity of moderately eroded Alfisols of the Sudan savanna in West Africa can be improved by rotating a cereal crop with rapidly growing cover crops such as *Macroptilium artropurpureum* and *M. lathyroides* when combined with a minimum tillage system. Increases in maize yield were due primarily to improved soil physico-chemical properties near the surface under the cover crops.

Nine cover crops were sown in 1986: *Echinochloa colona*, *Digitaria ciliaris*, *Lablab purpureus*, *Cajanus cajan*, *Macroptilium artropurpureum*, *M. lathyroides*, *Vigna radiata*, *Psophocarpus palustris*, and *Alysicarpus vaginalis*. For comparison, maize (*Zea mays*), cowpea (*Vigna unguiculata*), and a bare fallow were also included. Residue from all treatments except from maize and cowpea plots was retained as *in situ* mulch on the minimum tilled soil. Maize variety SAFITA-2 was sown in all plots in 1987 and weeds controlled by handweeding.

Sand and silt content, soil nitrogen, available phosphorus, exchangeable calcium, mâgnesium and potassium, and total cation exchange capacity in the surface 0.05 m were not significantly affected by cover crops, but clay content, soil organic matter, pH, and exchangeable potassium were. Clay content and organic matter were related to ground cover at 47 days after planting in 1986. Where rapidly growing cover crops (e.g. *M. artropurpureum*) were sown, less clay and top soil were lost in runoff compared with slow growing cover crops or bare fallow.

Infiltration rates were the greatest in plots planted to *E. colona*, *M. artropurpureum*, *M. lathyroides*, *L. purpureus*, and *P. palustris* and lowest in bare fallow, pigeonpea (*C. cajan*) and maize plots (Table 10). By October 1987, infiltration rates had decreased significantly in all treatments except *M. lathyroides* and *L. purpureus*. The woody nature of *M. lathyroides* and *L. purpureus* crop residue resulted in a lower breakdown rate of mulch, thereby maintaining high infiltration rates in these plots.

Cover crops also affected soil temperature. Highest values of maximum soil temperature measured at 30 mm depth at 45 days after planting were in plots planted to pigeonpea, bare fallow, and maize and lowest in plots planted to *M. artropurpureum*, *P. palustris*, and *L. purpureus* (Figure 15). Soil temperature was low or high depending on how fast the cover crops covered the soil

	Infiltration rate (mmhr-1)	
	1987	
Cover crop	January	October
Zea mays	76.0	46.7
Vigna unguiculata	80.0	72.8
Bare fallow	15.2	15.0
Cajanus cajan	63.9	54.5
Digitaria ciliaris	99.9	55.1
Echinochloa colona	168.0	57.6
Alysicarpus vaginalis	91.9	74.5
Macroptilium artropurpureum	156.0	35.6
Macroptilium lathyroides	123.9	154.5
Lablab purpureus	167.7	117.7
Psophocarpus palustris	112.0	57.2
Vigna radiata	91.8	55.8
SE	15.4	15.1

Table 10. Effect of preceding cover crop on infiltration rate.

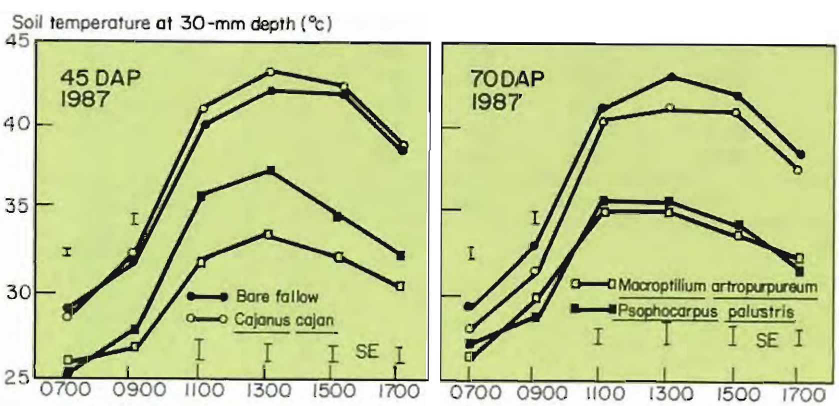


Figure 15. Effect of preceding cover crop on diurnal variation of soil temperature at a depth of 30 mm at 45 and 70 days after planting (DAP) during the growing season of 1987.

surface. Also, apparent pore sizes at 0.30 and 0.60 m depths were significantly affected by cover crops. The proportion of macropores was greatest and micropores lowest where *M. artropurpureum*, *M. lathyroides*, *L. purpureus*, *P. palustris*, and *E. colona* were sown.

Emergence of maize sown in 1987 was most rapid in plots previously sown to *E. colona*, *M. artropurpureum*, *M. lathyroides*, *L. purpureus*, and *P. palustris* in 1986 and slowest in those sown previously to maize, pigeonpea, or left as bare fallow because of improved soil physical and chemical properties, particularly organic matter and clay content in plots sown previously to cover crops. Consequently, these plots had more favorable soil temperature, moisture retention, and fertility. Dry matter and grain yields of maize were greatest in plots previously sown to *M. artropurpureum* and *M. lathyroides* and minimum in fallow plots (Table 11).

Table 11. Effect of preceding cover crop on maize emergence, relative leaf water content at 1300 h, and crop yield during 1987.

Cover crop	Emergence (%) 5 DAP*	Relative leaf water content (%) 72 DAP	Yield (t/ha) Dry matter	Yield (t/ha) Grain
Zea mays	54.9	65.0	1.1	0.2
Vigna unguiculata	77.4	70.0	1.6	0.2
Bare fallow	32.8	65.0	0.2	0
Cajanus cajan	53.4	69.0	0.6	0
Digitaria ciliaris	77.5	80.4	2.4	0.7
Echinochloa colona	91.6	89.4	3.3	1.1
Alysicarpus vaginalis	78.9	72.4	1.7	0.4
Macroptilium artropurpureum	91.7	89.6	4.3	2.2
Macroptilium lathyroides	86.3	90.4	5.0	2.4
Lablab purpureus	89.7	87.8	3.2	0.8
Psophocarpus palustris	85.8	90.2	3.9	1.5
Vigna radiata	75.0	70.9	2.0	0.5
SE	7.67	1.75	0.32	0.16

**DAP = Days After Planting*

Windrow Burning Effect on Soil Productivity after Deforestation

As one phase of a long-term project involving deforestation and landuse in the humid tropics, scientists recently measured the effects of windrow burning of dried vegetation from felled jungle on soil productivity. The overall objective of the long-term project, initiated in 1984 by the United Nations University and IITA in a forest southeast of Benin City, Nigeria, is to better understand the magnitude and trends in alterations of soil, hydrology, micro-climate, and biotic environments by deforestation, different landuse systems, and agricultural practices. (See *Research Highlights* 1984.)

After mechanically clearing 19 plots of 1 ha each, the felled jungle was collected in four equidistant windrows across the slope in each plot, the dried vegetation burned in 18 of the plots, and rice, maize, cassava, and plantain planted in them in 1985. The following year cassava was cultivated in these plots and the 19th plot burned in 1987.

Soil temperatures at 0.01, 0.05, 0.10, and 0.20 m depths were measured during windrow burning and the maximum temperatures reached were 215°C at 0.01 m depth, 150°C at 0.05 m, 105°C at 0.10 m, and 70°C at 0.20 m. Before the fire was started, the surface soil was nearly air-dried. Burning of biomass completely desiccated the top 0.13 m of the soil layer. It caused reduction in soil water content to a depth of 0.27 m. Below this depth, however, there was an increase in the soil water content after burning, probably caused by downward movement of water in response to thermal gradient.

Soil bulk density was lower by 2, 12, 4, and 3% at 0.05, 0.15, 0.25, and 0.35 m depths, respectively, in the windrow compared with non-windrow zones. Below 0.44 m depth, there was no appreciable difference between the two sites. Improved activity of soil fauna with time after burning might have lowered bulk density in windrows. Another likely factor affecting bulk density could be compaction associated with movement of large equipment on the land. A bulldozer with a front-mounted rake passed over the non-windrow areas

Crop	Variety	Cropping year	Yield (t/ha) Windrow	Yield (t/ha) Non-windrow	SE (±)
Rice	UPL-Ri-5	1985	3.9	2.0	0.43
	ISA 6	1985	2.6	2.0	0.34
	ITA 142	1985	1.5	1.4	0.17
Maize	TZESR	1985	1.2	1.0	0.40
Cowpea	White	1986	0.4	0.4	0.07
Cassava	IITA	1985–86	18.1	17.8	1.72
Cassava	IITA	1986–87	18.9	11.5	2.21
Plantain	Local	1987	9.3	0.1	0.36

Table 12. Effect of biomass burning in windrows on soil productivity. Windrows in forest-cleared plots were burned in March 1985. Cassava and plantain yields are based on fresh tubers and fingers, respectively.

The traditional practice of burning dried vegetation from felled jungle either* in situ *or in small heaps has advantages over windrow burning.

more often while collecting debris from the non-windrows and pushing the same in windrow zones. The bulk density differences affected the infiltration rates in the two zones. The steady-state infiltration rate was eight times faster in windrows than non-windrows.

Biomass burning increased organic carbon by 60% in the 0–0.10 m soil layer in windrow layers. Soil pH in the top soil (0–0.10 m layer) was significantly more in windrow compared with non-windrow zones: 22.8, 16.1, and 9.2% in the 0–0.10, 0.10–0.20, and 0.20–0.30 m layers, respectively. There was no effect of biomass burning on total nitrogen, but burning increased soil phosphorus content by 725, 400, and 400% in the 0–0.10, 0.10–0.20 and 0.20–0.30 m layers, respectively. Calcium increased by 682, 371, and 141%, magnesium by 98, 115, and 136% and potassium by 97, 225 and 306% in the 0–0.10, 0.10–0.20, and 0.20–0.30 m layers, respectively, in windrows compared with non-windrows. Chemical properties of soil were altered by the addition of a large quantity of ash in windrows following biomass burning.

Plantain height, growth, and yields were greater in the windrow than non-windrow areas. Also in the 1986–87 season, signigicantly more cassava tubers were produced (Table 12).

Burning of biomass in windrows after deforestation increased the productivity of soil in the burned area through the addition of ash. However, burning of biomass in windrows also introduced spatial fertility variation in the otherwise uniform field causing uneven crop growth. Therefore, biomass accrued from deforestation should not be burned in windrows but either *in situ* or in small heaps.

Annual Report Executive Summary
Grain Legume Improvement Program

Dr. S. R. Singh
Program Director

The major thrust within the cowpea research program has been to develop genotypes with high and stable yield potential and among the favorable characteristics of lines developed so far are these: resistance to some diseases and insects; early (60 days) and medium (75–80 days) maturity; grain and vegetable/fodder types; and different seed sizes, coat texture, and colors for various consumer preferences.

The current strategy for cowpea research involves change from breeding varieties for grain production in a monocrop situation with insecticide application to the development of varieties well adapted to the cereal farming systems of the savanna ecological zones in Africa and which meet the diverse needs of farmers for grain and fodder. The over-riding biological constraint is the damage caused by post-flowering insect pests. Crosses are being made with wild relatives of cowpeas from Africa to transfer insect-resistant genes, and collaborative links have been established with Purdue University in the United States and the University of Naples in Italy for basic research in host-plant resistance. Efforts are continuing to develop improved genotypes mainly for national programs in Africa. International trials and advance breeding nurseries were distributed upon request to 42 countries, including several in Asia and Latin America.

Insect resistance has been incorporated in several cowpea lines including TVx 3236 which has wide adaptability and high yields but resistance only to thrips. However, by using this variety as a parent, scientists developed IT84S-2246-4 last year which combines resistance to aphids, thrips, and the storage weevil. When tested in the savanna region, IT84S-2246-4 appeared to be suitable for the moist but not the dry savanna.

Research on host-plant resistance to post-flowering pests made additional progress because of improved methods for rearing several thousand *Maruca* larvae per day on an artificial diet and rearing pod sucking bugs in the laboratory by using dry cowpea seeds. Also wild cowpeas are being screened for resistance. One accession from *Vigna vexillata* appears to be highly resistant to those pests, plus the cowpea storage weevil.

Research on cowpeas for different regions and cropping systems:

Niger: An IITA scientist at ICRISAT's Sahelian Center (ISC) in Niamey is working on the development of varieties for the millet-based cropping systems in the Sahelian region. The research is conducted in close collaboration with ICRISAT and the

Institut National de Recherche Agronomique du Niger (INRAN). In addition to screening improved cowpea varieties, a program was initiated to improve local cultivars adapted to low input conditions.

Burkina Faso: The SAFGRAD team based at Burkina Faso concentrated on the development of cowpeas with tolerance to heat and drought and resistance to *Striga* and insects and disease for northern Guinea savanna, Sudan savanna, and Sahel.

Ghana: An IITA grain legume breeder based at the Crops Research Institute in Kumasi and working in collaboration with CIMMYT scientists, is screening and selecting cowpea lines for maize-based cropping systems. Several short duration lines have been identified and some promising lines have been released by the national program. A major effort is underway by the Ministry of Agriculture to multiply and distribute improved seeds to farmers.

Cameroon: A large number of cowpea lines were screened for sorghum-based cropping systems under a Bean/Cowpea CRISP Project. TVx 3236—a variety with moderate resistance to thrips and released in Cameroon in 1983—continues to be superior, and the demand for seeds reached 60 tons in 1987. This variety is also popular in neighboring Chad where large-scale seed multiplication programs are underway.

IITA/ICIPE collaborative program: An IITA cowpea breeder based at the Mbita Point Field Station of the International Centre of Insect Physiology and Ecology in Kenya worked on identifying and developing lines with pest tolerance and adapted to mid-altitude ecological zones in east and northeastern Africa. Extensive testing was done with and without insecticides and under intercropping (with maize) and monocropping. TVx 3343-01S from IITA, ICV-1 from ICIPE, and Machakos-66 from Kenya were identified as the most promising among the more than 400 lines tested for yield potential and stability. An ICIPE entomologist, based at IITA, has concentrated on the development of integrated pest management for cowpeas in humid and savanna zones. He conducted several on-farm trials in these ecological zones under both mixed and monocrop situations.

Southern Africa region: Distinctly different ecological zones and cropping systems in the nine Southern Africa Development Co-ordinating Conference (SADCC) countries require widely dispersed testing programs. Therefore, large quantities of cowpea germplasm, both advánced and segregating lines, were sent from IITA for evaluation in the region and extensive local materials were collected and evaluated by the Bean/Cowpea CRSP team. Two IITA lines, ER-7 and TVx 3236 (Rogonawa), and the local B005-C (Moragonawa) were released for farmer cultivation. Early and medium maturity cowpea varieties were tested in Tanzania where the land is not fully used in the short rainy season (300 mm) after the maize harvest. One early maturing line (IT83S-818) and a medium maturing line (IT82D-1007) produced about 1400 and 2500 kg/ha, respectively of fodder for livestock, plus 1500 kg/ha of dry grain.

Baseline data were collected on cowpea production and uses in 13 districts of Zimbabwe. Cowpeas were widely cultivated as a minor crop for household use by communal area farmers who usually grow the late-maturing, spreading-type in a mixture—mostly with maize. Green leaves are consumed as a vegetable (munyemba), dried and stored leaves (mufushwa), green peas (mukove), and dried grain boiled with maize (mutakura/inkobe) and cowpea paste (rupiza/bhizha).

Soybeans—a minor crop in Africa—makes an excellent grain legume grown in association with maize, either mixed or in rotation. They tolerate excessive moisture and drought stress better than maize. Twenty-nine African countries requested improved soybean seeds from IITA in 1987.

By screening a large collection of tropical germplasm, cultivars have been identified that nodulate freely using natural rhizobium present in tropical soils. They also have good seed longevity, plus other desirable traits, and several soybean lines, incorporating these traits have been tested by national programs. Among the improved soybeans developed at IITA and suitable 12° north and south of the equator are: TGX536-02D, TGX1025-8E, TGX923-2E, TGX984-2E, TGX849-313D, and TGX996-25E.

One of the constraints to soybean expansion in Africa has been the lack of utilization at village and household levels, but simple methods are being developed. This high-protein product could help alleviate severe malnutrition, and it can be easily incorporated into existing African diets without major changes in consumption patterns.

(In the following pages, a few 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 Grain Legume Improvement Program.)

Host-plant Resistance of Cowpeas to Post-flowering Insect Pests

Several insect pests have co-evolved with the cowpea plant—natural to the savanna region of West and Central Africa—and they constitute a formidable obstacle in the realization of its yield potential, unless protected with insecticides. Most cowpeas on the world market are grown in small holdings by peasant farmers whose meager cash resources impose upon them the need to adopt low input and economical production technologies. In this context, and in view of the persistently damaging role played by insect pests, varietal improvement centered around host-plant resistance appears to hold the greatest hope for cowpea production in the region.

Six major field pests of cowpeas can be found in most of the crop's production range in Africa and four of them—aphids, flower thrips, the pod borer (MPB) and pod sucking bugs (PSBs)—are usually more widely encountered. Considered together, these pests can cause up to 100% yield loss. The post-flowering pest species (thrips, pod borers, and pod bugs) of the cowpea pest complex cause the greatest yield losses, often ranging between 50 and 85%. The pod borers and pod sucking bugs are two of the most important and difficult insect pests encountered in the development of crop resistant varieties worldwide.

Table 13. Developmental parameters of the pod borer *Maruca testulalis* ***reared on artificial diets.***

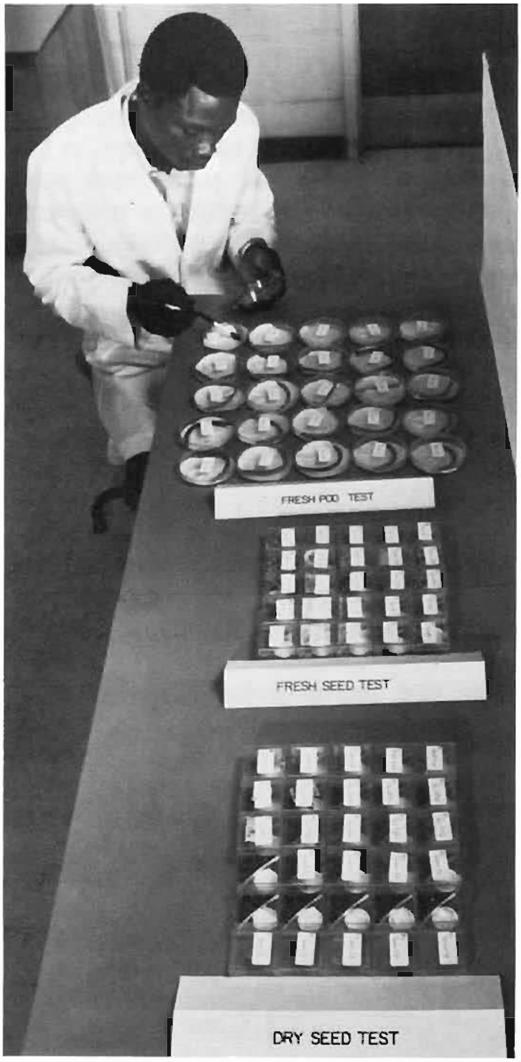
	Diet*		
Parameter	1	2	3
Days to pupation	12.5	13.4	11.8
Pupal weight (mg)	50.2	50.5	54.0
Days to emergence (pupa-adult)	7.1	7.0	6.8
Total development time (larva-adult) (days)	19.1	20.4	18.6
Percent pupation	79.0	84.0	94.0
Percent emergence	65.0	73.0	90.0
Growth Index	6.3	6.4	8.1

**Diet 1 = 25g of cowpea flour in 0.81 diet.*
Diet 2 = 38g of cowpea flour in 0.81 diet.
Diet 3 = 50g of cowpea flour in 0.81 diet.

Work on host-plant resistance to cowpea pests has been carried out at IITA for several years. Excellent sources of resistance have been identified for the pre-flowering pests (aphids, leafhoppers) and these have subsequently been incorporated into a wide range of elite cowpea varieties. In addition, moderate-to-low levels of resistance have been identified for the storage beetle (*Callosobruchus maculatus*) and flower thrips while low levels (generally in varieties with poor plant and seed characteristics) are available for the MPB and PSBs (Table 13).

Despite its level and ease of transfer, the real value of the resistance available against the pre-flowering pests cannot be fully utilized in the absence of useful levels of resistance to post-flowering pests, in particular the MPB which damages flowers and pods, and PSBs which damage pods. These two species are among the most damaging cowpea pests. Therefore, the two pests are being given increased attention in IITA's research work on cowpea resistance to insect pests.

Development of resistant varieties is a long process which, assuming that useful



Development of screening methodologies is crucial to the success of any host-plant resistance program. Here, in three tests run concurrently, a laboratory technician infests fresh cowpea pods with first instar nymphs of the pod-sucking bug and then follows the same process for each test. He checks every day for insect molting and mortality and determines insect survival on five different cowpea varieties.

levels of resistance are available in the existing germplasm, requires the combined effort of breeders, entomologists, physiologists, and biochemists to accomplish the following: (1) identification of resistance sources using well-defined and reliable screening procedures in the field and/or laboratory; (2) incorporation of this resistance through various hybridization techniques into desirable backgrounds; (3) recovery of the (transferred) resistance in breeding lines; (4) studies on the patterns of inheritance, and (5) investigations on the mechanisms of resistance. This process can take 5 to 10 years, and sometimes longer, depending on the target pest and crop species, *inter alia*.

Development of screening methodologies is crucial to the success of any host-plant resistance program. This process in the case of cowpea research work at IITA has been facilitated by detailed studies of the biology and behavior of the target pests. Also, the development of appropriate rearing procedures for insect pests has aided this process by making available large numbers of insects at the desired time and stages for field, laboratory and screenhouse evaluations. Scientists have developed insect rearing procedures for the MPB using an artificial diet containing cowpea flour and pod powder. Performance of this insect on three test diets is shown in Table 13. Diet 3 has been adopted as the rearing medium. The rearing facility has the capability of producing several thousand MPB larvae per week for use in resistance studies, the only limitation to increased production being space and manpower. PSBs also are being reared with ease and success using dry cowpea seeds.

Well established field screening procedures have been used in the past to identify resistance sources to the MPB and PSBs. These varietal sources include TVu 946, Kamboinse Local for the MPB, and TVu

1890 and TVu 1 for PSBs. However, the levels of resistance to both pests are low and even lower levels are recovered in crosses made to transfer the resistance to cowpea genotypes with other desirable traits. Where sufficient recovery of resistance, albeit low, has been obtained the seed characteristics have not met consumer acceptance. This has led scientists to intensify the search for better sources of resistance in both the cultivated and wild species, to obtain better and more useful resistance levels.

IITA field screening procedures have been modified to enhance the identification of moderate levels of resistance which were usually masked by the very high natural pest population pressures under which screening was conducted in the past. Such population levels are not widespread in the cowpea growing region. In addition, new laboratory bioassays have been developed to accelerate the process of resistance identification and subsequent recovery from segregating breeding lines for both pod sucking bugs and the pod borer. These techniques make use of the knowledge of the feeding behavior of both insects. In the case of the PSBs, fresh pods, fresh seed and dry seed were tested in exclusion cages. Based on the results (Figure 16), dry seeds will be used initially to screen large numbers of material for two types of resistance phenomena (antixenosis and antibiosis) to pod sucking bugs. At a later stage fresh pods will also need to be evaluated because in nature these constitute the first line of defense of the plant against this pest.

Using bioassays IITA scientists developed in 1984, fresh pod tests have shown that the resistant lines suffer much lower levels of seed damage compared with the susceptible cultivated lines (Table 14). Fresh pod segments have been used in choice arenas to demonstrate that cowpea

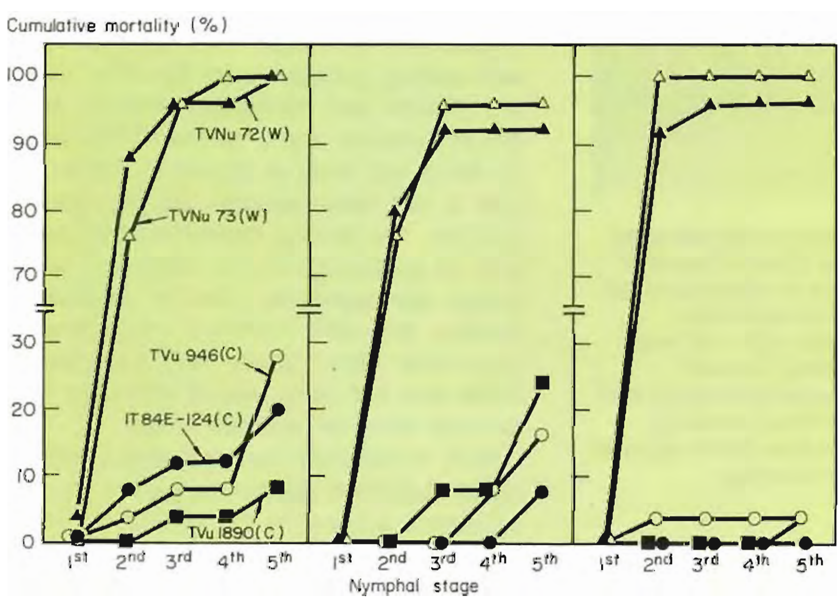
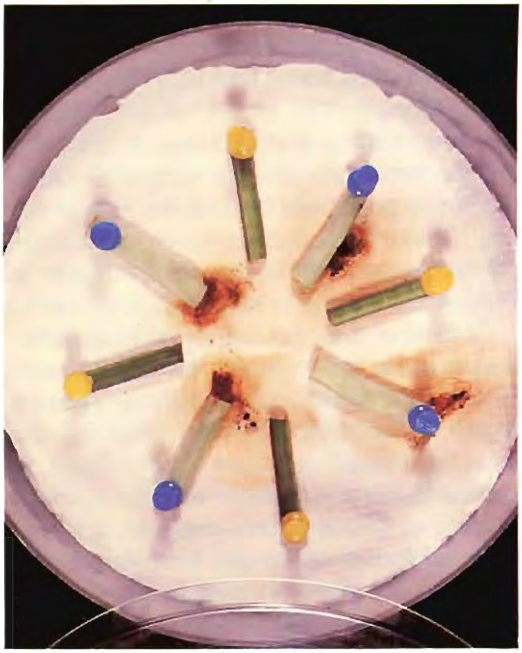


Figure 16. Cumulative nymphal mortality of pod sucking bugs** Clavigralla tomentosicollis **in laboratory tests using fresh excised pods (FPT), fresh fully formed seeds (FST), and dry seed (DST) of selected cultivated (C) and wild (W)** Vigna **species.



Dual choice arena used in the laboratory to screen for cowpea resistance to* Maruca *pod borer. The pod borers are released at the center of the arena and within three hours select the susceptible pod segments (marked with blue pins) and begin to feed on them. After eight hours they still have not fed on the resistant pods (marked with yellow pins). The test is terminated after 48 hours.

lines TVNu 72 and TVNu 73 (*Vigna vexillata* var *vexillata*) possess moderate levels of resistance to the borer (Table 15). These results have been corroborated by detailed studies on the development of this pest on these two lines which are wild cowpea relatives. The findings have stimulated systematic screening of the wild cowpea germplasm collection as well as the recently collected germplasm material. The two resistance sources identified so far are highly resistant to PSBs which suffer over 90% mortality during the young stages (nymphs) as shown in Figure 16. In the pod borer feeding is disrupted and larval weight reduced (Table 16).

Investigations are continuing to determine the factors conferring resistance to these two pests, but there is reason to believe that harmful secondary plant chemicals, and pubescence to a lesser degree, may be playing vital roles. These studies are being carried out in collaboration with a number of institutions, including the International Center of Insect Physiology and Ecology (ICIPE) in Kenya and Purdue University in the United States.

IITA has a cowpea germplasm collection of over 10,000 accessions. The lack of success in finding useful levels of resistance to MPB and PSBs notwithstanding, this resource represents tremendous genetic variability—an important asset in host-plant resistance work. The discovery of high levels of resistance in the wild cowpea relatives underscores the co-evolutionary adaptation of insect pests alongside cultivated cowpea varieties. This calls for an intensified search for greater and more diversified germplasm sources. The high levels of resistance present in the wild cowpea species have to be transferred to cultivated species so that the value of this resource can be fully exploited to the advantage of cowpea growers.

Table 14. Cowpea seed damage by adults of* Clavigralla tomentosicollis *during 24–48 hours of feeding exposure in laboratory tests.

Variety	Status	% Seed damage
IT84E-124	Cultivated	25.7
TVu 946	Cultivated	25.6
TVu 1890	Cultivated	16.0
TVNu 73S*	Wild	9.5
TVNu 72S*	Wild	9.1
TVNu 72N**	Wild	5.9
TVNu 73N**	Wild	5.8

**S = pods with hairs shaved off.*
***N = normal pods (unshaved).*

However, inter-specific hybridization is difficult in cowpeas and so far all previous attempts at hybridizing *Vigna unguiculata* with *Vigna vexillata* have been unsuccessful. Therefore, IITA has recently resorted to undertaking joint collaborative basic research using recent innovations in genetic engineering in an attempt to overcome this problem. Major collaborators in this effort are Purdue University and two universities in Italy: Universita di Napoli and Universita della Tuscia. The Government of Italy supports this research within the framework of the cowpea germplasm project with special funding.

The thrust of these studies will be the use of cell and protoplast, as well as callus culture techniques to generate the desired cowpea plant prototype. Recent work at IITA has centered on setting up suitable tissue culture techniques for use in callus induction and plant regeneration using Murashige and Skoog (MS) medium supplemented with different combinations of the auxins 2,4-dichlorophynoxyl acetic acid (2,4-D) and cytokinin (Kinetin). The results obtained so far are encouraging and attempts to generate shoots from calli are in progress. Other studies in protoplast culture are also under way. These and other useful biotechnological techniques are being explored both at Purdue University, in Italy, and elsewhere.

Collection and evaluation of new germplasm using the recently developed techniques and efforts to incorporate present levels of resistance in high yielding, disease, and insect resistant varieties (e.g. to aphids, thrips and storage weevil) continues as part of IITA's future research agenda. Also, additional resources have been allocated for the work on genetic engineering to fully exploit the potentially extensive arsenal of pest resistance presently locked up in the wild cowpea and other closely related species.

Table 15. Feeding preference by** Maruca testulalis **larvae in dual choice laboratory tests using cowpea pod segments (values are means of four replications).*

	Parameters			
Choice	Feeding ratio (FR)** (out of 4 segments)	Feeding severity (FS) (score)***	Feeding index (FR × FS)	Resistance ranking
IT84E-124				
(Susceptible check)	0.44	2.0	0.88	4
vs				
TVu 946				
(Resistant check)	0.31	1.0	0.31	3
IT84E-124	0.63	2.8	1.77	
vs				
TVNu 72	0.06	0.3	0.0	1
IT84E-124	0.63	2.8	1.76	
vs				
TVNu 73	0.06	0.3	0.02	1

**Tests were conducted using two 9–10 day old larvae left to feed for 48 hours.*
***Feeding ratio = number of segments attacked expressed as a fraction of total presented.*
****Feeding severity: Scale: 0 = no feeding; 1 = nibbling and production of scanty frass; 2 = moderate production of frass; 3 = abundant production of frass, extensive feeding.*

High levels of resistance to post-flowering pests found in some wild species of cowpeas (such as the one shown below) need to be transferred to cultivated species. In attempts to accomplish this, scientists at IITA and elsewhere are conducting basic research using recent innovations in genetic engineering.

Table 16. Pupal weight, percent pupation and adult emergence of the pod borer, *Maruca testulalis* ***reared on cultivated and wild cowpeas after 7–8 days (CATEGORY B) and 9–10 days (CATEGORY C) on artificial diet (values are means).****

	Pupal weight (mg)		% pupation		% adult emergence	
Variety	Cat. B	Cat. C	Cat. B	Cat. C	Cat. B	Cat. C
IT84E-124 (Cultivated)	52.7	49.2	92.9	90.0	78.4	77.1
TVNu 72 (Wild)	36.7	32.9	12.0	50.0	6.0	36.0
TVNu 73 (Wild)	51.7	39.1	6.0	63.0	4.0	50.8

**Pods were taped at point of detachment to prevent easy access.*
Data based on 70 insects for the cultivated and 50 for the wild cowpea.
Newly-hatched larvae (CAT. A) suffer 100% mortality on all test varieties. In nature these young larvae do not infest pods.

Cowpea Varieties for Different Agro-ecological Zones and Cropping Systems

Cowpeas—an important food legume produced in several countries around the world—are adapted to a wide array of soils and moisture regimes. Because this crop is versatile and fits in with different cropping systems, rotational niches, and marginal lands unsuitable for some of the major crops, it has expansion potential and offers opportunities for small-scale farmers to practice intensive cropping on their farms.

However, the most limiting constraint is damage by insects because the plant is vulnerable to pests from seedling to harvest stage and in storage. In spite of this and some other constraints, the cowpea production area has maintained a stable position, but any expansion will depend on alleviating the insect pest problems which are more severe in Africa than in Latin America and Asia.

The world's largest producer of this protein-rich crop (25% protein) is Nigeria (about 4 million ha) with Brazil second (1.7 million ha) and the Republic of Niger third (1.1 million ha). Thirteen other countries in Africa consider cowpeas an important crop. Cowpeas are grown in different agro-ecological zones of sub-Saharan Africa, but primarily in the drier regions of West Africa in mixture with millets and sorghum without any chemical protection. Insecticides are essential for pure or sole crop cowpeas.

Within the international agricultural research system, IITA has a global mandate to improve cowpeas and assist national programs in expanding cultivation. Scientists have developed a range of improved cowpea breeding lines with different maturities, plant and seed types, plus some disease and insect resistance. These have been made available to at least 45 national programs so they could select or develop varieties to suit their specific growing conditions.

IITA-bred varieties are being adopted in

Ecological zone	Varieties	Countries
Northern Guinea savanna	TVx 3236, KN-1 TVx 1999-01F	Burkina Faso, Benin, Mali, Nigeria, Guinea-Conakry, Ghana, Togo, Senegal.
Sudan savanna	KN-1, TVx 3236, TVx 1999-01F, KVx 30-305-3G, KVx 250-K27-18, KVx 268-K03-3	Burkina Faso, Senegal, Nigeria, Cameroon, Gambia, Benin.
Sahel savanna	SUVITA-2, TN 88-63, 58-57, KVx 30-305-3G, KVx 30-309-6G, KVx 30-470-3G TVx 3236	Burkina Faso, Niger, Mali, Senegal, Nigeria, Chad, Mauritania.

Table 17. Cowpea varieties adapted to different agro-ecological zones in various West African countries.

Scientists are now focusing on breeding cowpea varieties especially suited to mixed cropping with sorghum (shown here) and with millet in the moist and dry savanna zones in West and Central Africa.

several countries of Africa, Central and South America, and Asia. Popularity of the varieties is based on superior performance, maturity, and seed type. For example, VITA-1, VITA-3, and VITA-7, popular in Central and South America, are not in other regions. Similarly, those popular in West Africa may not be acceptable in East Africa and vice-versa. Why? Primarily because of agro-ecological requirements for different maturity groups and preference for seed type. For example, the preferred seed types in West Africa are large white or brown with a rough seed coat texture, but in Central and South America and East Africa cowpeas are used as a substitute for beans so consumers prefer red and brown seeds with a smooth coat.

Among the varieties listed in Table 17, TVx 3236 was the first to combine a moderate level of resistance to thrips and to receive wide acceptance in several ecological zones in Africa. It was then used as a parent for further incorporation of resistance to aphids and bruchids, resulting in a new cowpea line—IT84S-2246-4. It has a high yield potential and moderate resistance to diseases and to aphids, bruchids, and thrips.

Because of a wide range in maturity and plant types available in cowpea germplasm, scientists developed erect, early-maturing cowpea varieties and evaluated them in maize-based, cassava-based, yam-based, and rice-based cropping systems. In trials at IITA, from 400 to 800 kg/ha of cowpeas were obtained from maize intercrop and over 1 ton/ha from cassava and yam intercrops. Yields of the main crops were not affected. Where cowpeas were planted by farmers in Bida, Nigeria, after harvest of the rice crop, sufficient residual moisture remained in the hydromorphic lands to permit successful cropping of early to medium maturing cowpea varieties. Performance of five cowpea varieties in rice fallows at Bida are shown in the table on page 56.

IITA research on cowpeas in the years ahead will focus on plant resistance to insects and diseases and on breeding varieties especially suited to mixed cropping with sorghum and millet in the moist and dry savanna zones in West and Central Africa. Here the need is for new varieties with stability of yield rather than high yielding cowpeas that require insecticides and fertilizers which small farmers cannot afford. At present, farmers in these zones under mixed cropping are producing between 150 and 300 kg/ha of cowpeas. A variety that can yield from 400 to 500 kg/ha of dry seed with reasonable tonnage of fodder under current levels of management by farmers with little or no insecticides or fertilizers will make a significant improvement in cowpea production. IITA cowpea breeders will collaborate with ICRISAT farming systems scientists in these zones.

Varieties for millet-based cropping systems in the dry savanna: Pearl millet and cowpeas are grown extensively as intercrops in the dry savanna regions of West Africa and IITA scientists are developing new, high quality cowpea varieties for intercropping systems. IITA scientists based at the ICRISAT Sahelian Centre (ISC) in Niger have been screening contrasting cowpea plant types for intercropping with millet.

Spreading and indeterminate types were important factors influencing cowpea yield in both sole and intercrop systems. Therefore, research efforts are aimed at developing spreading plant types suitable for the millet-based systems and having resistance to the various stresses that limit production.

Traditionally, pearl millet is sown after the first substantial rainfall and cowpeas two to four weeks later. In this combination, the cowpea grain and fodder yield is low. Therefore, studies were conducted to determine the effect of manipulating agronomic components such as the date of sowing and spacing of the two crops. In one experiment, three morphologically different types of cowpeas were compared in association with pearl millet in two successive seasons at ISC: two early and one late-maturing cultivars. The former were planted at a density of 25,000 plants/ha—considerably higher than those used in the traditional systems (3,000 to 5,000 plants/ha). Yields of early cowpeas were improved by sowing them along with or shortly after the millet (Table 18). The late maturing cultivar significantly reduced millet yield when sown simultaneously and production of grain from cowpeas was negligible when planted three weeks after millet.

Sowing cowpea and millet in paired rows did not affect millet yields when compared with alternate rows. An acceptable yield of cowpea grain and fodder was also obtained. In another experiment, increasing the density of an early-maturing cowpea intercropped with millet did not significantly

Table 18. Grain yield (kg/ha) of cowpeas and millet at various times of planting morphologically different cowpea cultivars in relation to millet in Niger.*

Planting time	Erect early maturing cowpea	Millet	Medium maturity spreading cowpea	Millet	Late cowpea	Millet
Millet/Cowpea (same day)	250	1020	340	805	**	450
Cowpea, six days after millet	190	930	180	965	—	645
Cowpea 25 days after millet	95	1200	90	1025	—	1075
SE Cowpea	±54					
SE Millet	±63					

**Averaged over two years, 1985 and 1986.*
***No grain production on late cultivar.*

reduce the millet yield. The results indicate that cowpea performance may be improved and millet yields approaching sole crop levels may be obtained by manipulating row arrangements, planting dates, and densities of the two crops.

Farmers' use of improved cowpea varieties in Ghana: Because farmers in Ghana did not have improved cowpea varieties readily available to them until the early 1980s, they grew mostly indeterminate types at random spacing. But the introduction of improved varieties, on-farm verification/demonstration, and in-country training of 1,500 extension agents over the past five years have started to make a change in cowpea production in the forest, transitional, and savanna ecological zones.

Improved cowpea varieties are being developed for growing in cereal-based cropping systems. From the initial releases of improved seed, the Ghana Ministry of Agriculture estimates that about 33% of the total maize area of the forest zone was brought under a maize-cowpea rotation system by 1986. In the forest ecology, cowpeas are planted in sole stand in the minor rainy season beginning in September; in the savanna zone in the major rainy season beginning in June. Grain legume production has increased from about 13,700 tons in 1981 to 19,500 in 1986.

Four improved cowpea varieties had been released in Ghana by 1987: Boafo (TVx 1843-1C), Soronko (TVx 2427-1F), Asontem (IT82E-32), and Vallenga (IT82E-16). The latter two with 60 to 65-day maturity, red seed color and a yield potential of 2,000 kg/ha with three sprays but without fertilizer are most promising varieties (Tables 19 and 20). The newly developed brown-seeded cowpea variety TVx 4678-03E is superior to TVx 2427-1F and ready for release during 1988. It offers another seed color option to farmers. Based on reports from seed producing agencies in Ghana, the demand by farmers for seed of improved varieties is increasing (Figure 17). They sold 26 tons of cowpea seed in 1987 to approximately 3,000 farmers, and their target for 1988 is 75 tons for 9,000 farmers.

Ghana's cowpea development program began in the early 1980s at the Crops Research Institute at Kumasi in collaboration with the Grains and Legume Development Board, Ministry of Agriculture, IITA, and CIMMYT. The Project is supported by the Canadian International Development Agency (CIDA) and the Government of Ghana.

Cowpea varieties for sorghum/cowpea ecologies in Cameroon and Botswana: Under the Bean/Cowpea CRSP and USAID project, 800 cowpea lines were screened in Cameroon. In this country, thrips are a major pest of cowpeas and one line, TVx 3236, was found outstanding and released in 1983. This thrip-resistant line consistently produced a larger yield than the local varieties under a minimum insecticide application regime of two to three sprays; Figure 18 shows the increase in demand. It is also becoming popular in Chad where large TVx 3236 seed multiplication projects are underway.

Approximately 500 improved cowpea lines from IITA were tested over a three-year period (1983–85), along with about 700 local accessions under the Bean/Cowpea CRSP project, in Botswana. The emphasis was on identification of drought-resistant lines with high yield. Under this project, one line from IITA (ER-7) was released in 1985. After additional tests, TVx 3236 was released in 1987 as ROGONAWA. It has resistance to cowpea aphid-borne mosaic virus (CAMV), bacterial blight, and drought and consistently produces an average of 600 kg/ha. (Cowpea yields in Botswana range from 200 to 300 kg/ha.) A local line —B301—was found to be highly resistant

Variety and technology options	Average yield (kg/ha)	Yield increase (%)		
			Over local variety	
		Insecticide alone	With insecticide	Without insecticide
Vallenga with insecticide**	833	56	62	114
Vallenga without insecticide	535	—	—	37
Local with insecticide**	513	31	—	—
Local without insecticide	390	—	—	—
Mean	560			
LSD (5%)	405			
CV (%)	83			

**Results of 50 verification/demonstration trials (1986).*
***With three sprays.*

Table 19. Yield comparison of an improved cowpea variety Vallenga (IT82E-16) with a local variety under two levels of management in farmers' fields in Ghana.*

Year	Planting season	Variety: IT82E-32 (Asontem)	Variety: Local	Yield increase (%)
		(kg/ha)		
1984	1st	1404	1165	21
	2nd	886	622	42
1985	1st	1367	828	65
	2nd	1099	758	54
1986	1st	1556	641	143
	2nd	1735	1112	55
1987	1st	1609	1118	44
	2nd	1208	748	62

Table 20. On-station yield comparison of Asontem (IT82E-32) cowpea variety with local check across five locations in Ghana (1984–87). This variety was released in 1987.

to *Alectra vogelii*, a plant parasite. Tests for *Striga* resistance at the Weed Research Organization (WRO) in England showed it to be resistant to strains of *Striga* from Burkina Faso, Niger, and Nigeria. This is the first time a cowpea line has been identified as having resistance to three different Striga strains.

Screening for cowpea drought resistance in a dry area of Botswana.

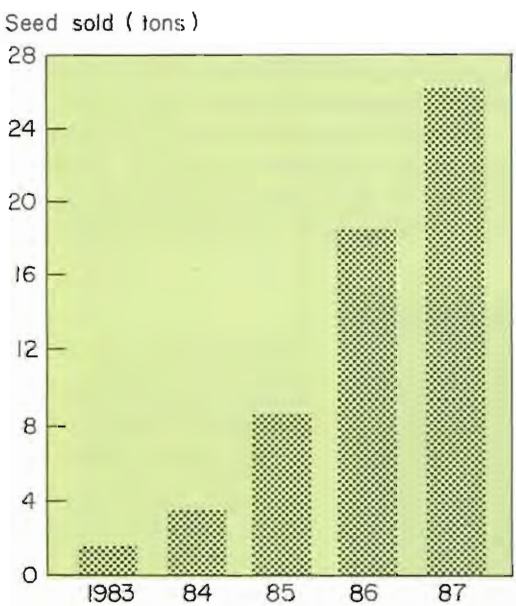


Figure 17. Yearly distribution of improved cowpea seeds by Ghana seed-producing agencies.

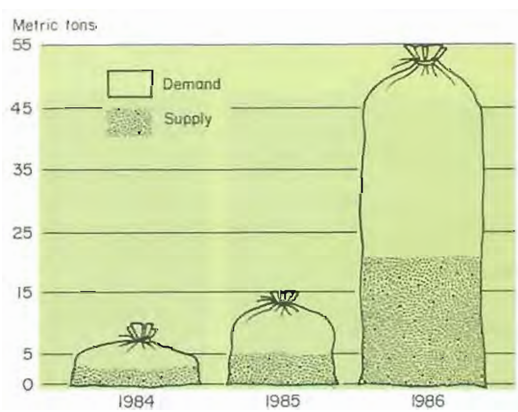


Figure 18. Seed demand by farmers in Cameroon for the improved cowpea variety TVx 3236 compared with the supply available.

Breeding for Multiple Virus Resistance in Cowpeas

Several viruses are known to occur in cowpeas and cause a substantial reduction in yield, particularly when the virus infection sets in early stages of plant growth. Over 25 viruses have been reported on cowpeas from different regions of the world. However, a large number of these are either of minor or localized importance. The two most important viruses in Africa are cowpea aphid-borne mosaic virus (CAbMV) and cowpea yellow mosaic virus (CYMV; syn. cowpea mosaic virus). Several others of lesser importance include southern bean mosaic virus (SBMV), cowpea mottle virus (CMeV), cucumber mosaic virus (CuMV), and cowpea golden mosaic virus (CGMV).

IITA initiated a systematic program in the early 1970s to: (1) identify and characterize different viruses; (2) screen germplasm lines for sources of resistance; and (3) develop improved cowpea varieties with multiple virus resistance. By concerted efforts of virologists and cowpea breeders, progress has been made in each of the three areas of research.

As a matter of routine, all lines from the breeding program are screened for resistance to CYMV, as well as two distinct strains of CAbMV. On an average, about 500 new breeding lines have been screened in this manner every year, beginning in 1978. Also, advanced breeding lines are evaluated for resistance to some of the other viruses known to occur in cowpeas in Nigeria: CMeV, SBMV, and CuMV. Elite materials, averaging 100 breeding accessions, are routinely evaluated for resistance/susceptibility to various newly-obtained isolates of the major viruses, as well as some of the less important ones. This is done in order to know their natural pathogenic variability and be prepared for possible occurrence of previously unidentified strains to which resistant materials would be susceptible.

Through systematic screening of a world germplasm collection maintained at IITA, a number of lines were identified which had either individual or combined resistance to

The two most important viruses infecting cowpeas in Africa: left, cowpea yellow mosaic virus (CYMV) and right, cowpea aphid-borne mosaic virus (CAbMV). All lines from IITA's breeding program are screened for resistance to both these and several other viruses.

Table 21. Reaction of cowpea parental lines to different viruses and strains.

Variety	Reaction to viruses*					
	CAbMV (common strain)	CAbMV (new strain)	CYMV	SBMV	CMeV	CuMV
VITA-1	R	S	R	R	S	MR
VITA-3	R	S	R	R	MR	MR
TVu 410	MR	R	R	R	S	R
Ife Brown**	S	S	S	S	S	S

**R = Highly Resistant; MR = Moderately Resistant; S = Susceptible.*
***This local improved variety has been used as a source of good agronomic and seed characters.*

several viruses. A more virulent strain of cowpea aphid-borne mosaic virus was observed in 1983 which infected some of the CAbMV resistant lines identified earlier. Therefore, all the known multiple virus resistant lines were screened against this new strain in order to select sources of resistance to both strains of CAbMV.

The most widely used parents in IITA's cowpea breeding program and their reaction to different viruses are shown in Table 21. None of the parental sources is resistant to all the viruses but through a combination of VITA-1, VITA-3, and TVu 410 it has been possible to combine multiple virus resistance.

To evolve an effective breeding strategy, systematic genetic studies were conducted to clarify the nature of inheritance of CYMV and CAbMV. F_1, F_2, and backcross data obtained from the crosses involving resistant and susceptible parents revealed that the resistance to CYMV in IT82E-16 is controlled by duplicate dominant genes and the resistance to CAbMV in the same breeding line by two recessive genes. Thus, the inheritance of resistance to these major viruses is rather simple and easily transferable through conventional breeding methods.

Through a combination of field and greenhouse inoculation of breeding materials with different viruses, a number of cowpea varieties have been developed which combine good agronomic characters with multiple virus resistance (Table 22). Virus resistant cowpea lines developed so far have a yield potential of between 1.2 and 2.0 t/ha under good management. Among these, IT82E-16 and IT82D-889 have been evaluated by several national programs for the past three years and found to be much superior to local varieties. IT82D-889 matures in 55–60 days and has done well as a short season catch crop in Thailand, Philippines, Sri Lanka, Tanzania, Kenya, Zambia, and Zimbabwe. This variety was recently released in Tanzania in the name of "Vuli-1", meaning short rains-1; IT82E-16 matures in 65–70 days and has also performed well in several countries. It was recently released in Ghana in the name of "Vallenga", meaning early. The new breeding lines are under extensive testing by several national programs.

Research is underway to incorporate multiple virus resistance to traditional varieties normally grown as mixed crops, as well as other improved breeding lines. The work will be extended to cover those viruses which are of regional importance such as cowpea severe mosaic virus (CSMV) and cowpea golden mosaic virus (CGMV). However, major emphasis will be on identification of new strains of important viruses which may make present resistant lines ineffective. Several types of CAbMV, CYMV, CMeV, and SBMV have already been identified. These strains are being characterized, and, as a standard practice, improved lines are being screened against these.

Efforts will be made to monitor occurrence of new strains/viruses in different parts of the world. IITA has already started distributing a set of multiple-virus-resistant breeding lines to various national programs as host differentials with known resistance and susceptibility to different viruses. Incidence of viruses on known resistant and susceptible varieties would indicate not only the type of viruses but also the possibility of new strains.

During the plant breeding and selection process, prevailing crop genotypes inevitably change, and, consequently, virus disease patterns change. The situation is made even more complicated by shifts in the incidence and importance of virus diseases brought about by changing agricultural practices.

National scientists are being trained and provided with sensitized ELISA (Enzyme Linked Immunosorbent Assay) plates for on-the-spot sample loading. They send the washed plates to IITA for identification of viruses. With active collaboration of personnel in national programs, IITA scientists believe it will be possible to identify new virus strains and breed resistant varieties before the new strains become widespread.

Table 22. Multiple virus resistant breeding lines of cowpeas.

	Reaction to different viruses*						
Variety	CYMV	CAbMV (new strain)	CAbMV (common strain)	CMeV	CuMV	SBMV	Maturity (days)
IT81D-1137	R	R	R	MR	MR	MR	75–80
IT82E-16	R	S	R	MR	R	R	65–70
IT82D-889	R	R	R	MR	S	R	55–60
IT83S-818	R	R	R	MR	R	R	60–65
IT83D-442	R	R	R	R	R	R	55–60
IT84D-449	R	S	R	S	R	R	75–80
IT85F-867-5	R	R	R	R	R	R	60–65
IT85F-2687	R	R	R	R	R	R	65–70

**R = Highly Resistant; MR = Moderately Resistant; S = Susceptible.*

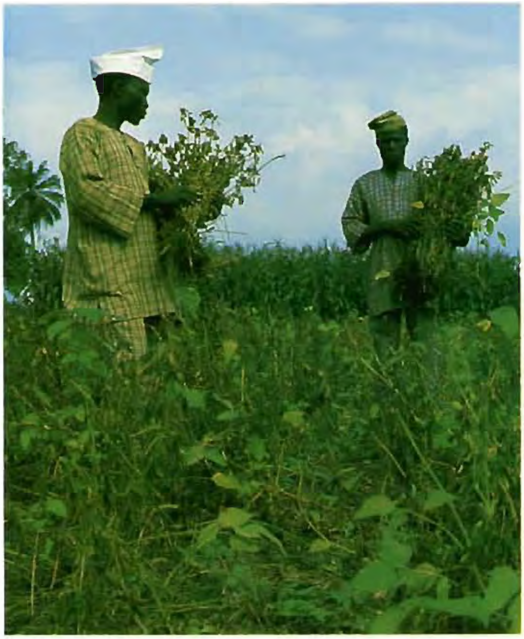
Dr. K.E. Dashiell, IITA plant breeder (third from left), shows improved soybean varieties which give good yields in most situations without the use of nitrogen fertilizer, inoculum, or insecticides.

Soybean Varieties for Tropical Africa and Introduction of Soybeans in Local Diets

Lack of suitable varieties is one of the reasons soybean production has been limited in tropical Africa, but this situation is changing. Recently improved varieties, specifically developed for this area of the world, have been distributed to national programs and a trend toward increased production of soybeans has become evident (in Nigeria, Zambia, and Zimbabwe, for example). Researchers in many national programs want to test the potential of the crop. In 1987, IITA received requests for improved seed from 73 organizations in 29 countries in Africa and from 23 organizations in 20 countries elsewhere.

Here are nine reasons for this growing interest in soybeans in tropical Africa: (1) technology introduced as both a production and utilization package; (2) approximately 40% high quality protein content—an important factor for millions of Africans who badly needed more protein in their diets; (3) few disease and insect problems in most areas; (4) a legume that fixes its own nitrogen; (5) an excellent rotation crop for cereals such as maize and sorghum because yields of these crops improve when

Plant breeders are developing new soybean varieties with resistance to shattering to make harvesting easier; also seed storability is being improved.



planted after soybeans; (6) resistant to the parasitic weed *Striga*; (7) grows well in most maize production areas; (8) almost no insect damage to stored grains; and (9) improved varieties for farmers which give good yields in most situations without the use of nitrogen fertilizer, inoculum, or insecticides.

When the soybean improvement project began in the early 1970s, IITA scientists started to evaluate the then available soybean varieties and found these weaknesses: poor germination, shattering, and bacterial pustule. They then identified lines with resistance to the latter two and began a search for lines that would germinate well. At first, the researchers believed that soybeans grown on land for the first time would not form nodules unless inoculated with *Bradyrizobium japonicum*—a practice too costly for family farmers in Africa. But experiences in Southeast Asia and observations on soybean farms in Nigeria and Tanzania contradicted this belief.

Therefore, from 1978 to 1983, IITA's soybean program directed its efforts toward the development of varieties that would nodulate with rhizobia indigenous to African soils (called promiscuous or free-nodulating varieties) and those with good seed storability under ambient conditions in the lowland humid tropics. This was a difficult task because the available germplasm lines with

Table 23. Performance of four soybean varieties tested at several locations in Nigeria (1987).

Soybean variety	Grain yield (kg/ha)	Nod. (1–5) *	Bact. pustule (1–5) **	Frog-eye leaf-spot (1–5) ***	Shattering (1–5) ****	Seed color	Seed storability
TGx 536-02D	1895	2.6	1.7	1.7	2.5	Green/yellow	Good
TGx 1025-8E	1912	2.9	1.3	1.3	2.1	Yellow	Fair
TGx 923-2E	1831	3.1	1.7	1.0	2.0	Yellow	Very good
TGx 984-2E	1821	2.6	1.5	1.5	2.0	Yellow	Good

**Nodulation score, 1 = no nodules; 3 = good nodulation; 5 = excellent nodulation.*
***Bacterial pustule scores: 1 = no disease symptoms; 5 = severe disease symptoms.*
****Frog-eye leaf-spot score: 1 = no disease symptoms; 5 = severe disease symptoms.*
*****Shattering score taken on guard rows 2 weeks after harvest: 1 = no shattering; 5 = 100% shattering.*

Production, harvesting, and processing of soybeans in the Guinea savanna of West Africa involve the farm family—men, women, and children. (Data from a recent survey on page 90 illustrate the extent of this involvement.)

these desirable characteristics were poor in almost all other respects. Also, the inheritance of both promiscuity and good seed storability is determined by many genes. Therefore, very large populations of the segregating generations had to be used because the probability of an individual plant having good seed storability, promiscuity, and other desirable traits was extremely low. For example, at least 250,000 breeding lines have been screened for desirable promiscuity and seed storability.

A 1987 field survey among 174 persons in three rural communities (Ikoyi, Igangan, Ijaiye) in Oyo State, Nigeria found that soybeans can be easily blended into existing diets without major changes in consumption patterns. As a protein supplement, soybeans have the potential of increasing the nutrient content of traditional dishes such as maize and porridge by about 300%. Fortification of foods with soybeans is a process quicker to implement than long-term changes in income for alleviating nutritional problems. It is also less expensive than biotechnological innovation attempts to genetically increase the protein content of available carbohydrates.

In Ikoyi and Ijaiye, soybeans have been produced and used at least for the past two years. The most common and widely adopted method is the use of soybeans as a substitute for egusi in soup and stew preparation. The use of soybeans for milk and in the preparation of akara and moin moin is also relatively well known by soybean producing households in both communities. The potential for soybean substitution in traditional foods is shown in Table 24.

The extent to which soybeans will substitute for other foods depends on the price of the "displaced" food, taste, availability of that food, method of preparation, whether or not soybeans are being marketed/cultivated, place in the diet of the substituted food, and consumer awareness of the nutritive value of soybeans. Compared with staples such as yam, cassava, maize, millet, and rice, soybeans can presently be termed a "minor food", but they have potential for adoption if both production and utilization skills are known.

Are soybean producers aware of the value of the product to children's health? Approximately three-fourths of them interviewed in Ikoyi and Ijaiye said they knew. (Although there are no soybean producers in the Igangan area, one-fourth of them in the survey sample indicated an awareness of the crop.) A primary reason some farmers gave for not growing soybeans was lack of a market.

As with most food crops in West Africa, production and processing of soybeans involve the farm family. For example, in 46% of all the households in the survey, adult males do tree felling and cutting assisted by male children. In the production operations, all the family members are involved, and in all the households, women complete most of the processing (Table 25).

The survey reported here will serve as one of the bases to monitor the impact of a three-year project funded by IDRC. In this project, IITA and the Institute for Agricultural Research and Training of the Obafemi Awolowo University focus on introducing improved soybean production and utilization technologies for use at the rural house-

Table 24. Percentage of household members who accepted the potential for soybean substitution in traditional foods, Oyo State, Nigeria (1987).*

	Ikoyi		Igangan		Ijaiye	
Food item	No. interviewed	%	No. interviewed	%	No. interviewed	%
Morning						
Pap, akara, moin moin	52	98	65	100	52	98
Amala	40	63	38	58	14	26
Boiled yam	17	27	14	22	8	15
Rice and beans	49	78	17	26	16	30
Bread	7	11	15	23	16	30
Afternoon						
Amala, lafun	48	76	33	51	52	98
Eba	19	30	18	28	28	53
Egusi soup	26	41	40	62	37	70

**Source: IITA/IDRC field survey*

Pap = *porridge made from fermented maize, sorghum, or millet.*
Akara = *deep fried doughnut, usually made from cowpeas.*
Moin moin = *steamed mixture of cowpea paste with ingredients and vegetable oil.*
Amala = *a thick porridge made from yam flour.*
Lafun = *a thick porridge made from fermented cassava flour.*
Eba = *a thick porridge made from gari, a fermented and roasted cassava paste.*
Egusi = *ground melon seed used in vegetable stews.*

Locally-produced soybeans (piled in pan lower right) are beginning to appear in some village markets for food uses. Next to the soybeans is a pan of dawa-dawa made from fermented soybeans and used for flavoring in soups and stews. A field survey shows that soybeans can be easily blended into several traditional African dishes as a high protein supplement without major changes in consumption patterns.

hold level. The survey was completed by an IITA socio-economist and three economists from the University of Ibadan with students serving as enumerators.

By 1984, IITA scientists had made considerable progress with incorporating those characteristics into many experimental lines which they began to test in several agroecological zones. This exposed the varieties to new pressures and allowed a quick identification of any weaknesses. And some weaknesses did show up. For example, in Zaria (Nigeria) most of the varieties shattered because of the hot and dry weather conditions at maturity and in Zonkwa (Nigeria) they were susceptible to Frog-eye leaf spot (*Cercospora sojina*). Also, other scientists in Nigeria, Cameroon, and Ghana expressed their concern about these two problems. The next step: a concentrated effort to develop improved screening techniques to find resistance. Among the results: selection of a new variety TGx 536-02D which was tested in farm trials in Nigeria. It averaged 1,800 kg/ha compared with the traditional variety Malayan which seldom exceeded 500 kg/ha. Seeds of the new variety were multiplied by the National Seed Service of Nigeria and an estimated 10,000 ha planted in that country in 1987. Also, a limited amount was grown in Ghana. Any problems with this variety? Although, in general, it performed well, a few farmers and scientists in national programs reported that it produced high frequencies of grain with green test in some environments, tended to lodge, had only a fair level of promiscuity, and resistance to shattering needed improvement.

Some other new soybean varieties, along with TGx536-02D, were tested in the 1987 All-Nigerian Nationally Coordinated Research Project in which these organizations were involved: Institute of Agricultural Research, Institute of Agricultural Research and Training, National Cereals Research Institute, University of Jos, and IITA. A summary of the results is presented in Table 23.

Even though the main target of IITA soybean research is and has been farmers of tropical Africa, reports indicate that some of the Institute's improved varieties have performed well in Latin America and Asia. Research is underway by IITA, in cooperation with national scientists in Africa, to develop varieties that are more promiscuous, have better seed storability, and greater resistance to shattering, bacterial pustule, and frog-eye leaf spot than those now presently available. Also, work has started on breeding for resistance to pod sucking bugs and foliar feeding insects and will begin soon on pyrenocheta leaf spot which has become a serious disease in parts of Zambia, Zaire, and Zimbabwe. As the soybean production area expands in several African countries, there is likely to be more disease and insect problems in the future. IITA and national scientists will continue to monitor the situation and initiate research if any new diseases or insects show signs of becoming a serious threat.

Table 25. Family involvement in soybean development and utilization in Ikoyi, Nigeria (1987).*

Soybean farm operation	Adult male	Adult female (in percentages)	Child male	Child female
Development				
Tree felling and cutting	50	25	16	9
Farm clearing/burning	59	30	11	0
Planting	71	22	7	0
Fertilizer application	50	25	25	0
Weeding	63	19	13	5
Harvesting	52	31	12	5
Threshing and bagging	54	34	8	4
Storage	63	18	12	7
Utilization				
Soaking	8	77	0	15
Grinding	9	91	0	0
Sieving	7	63	0	30
Boiling of milk	9	67	0	24
Akara-mix	7	63	0	30
Akara-fry	7	71	0	22
Moin-moin mix	9	91	0	0
Moin-moin cook	21	79	0	0
Soy-Ogi	15	85	0	0
Fermenting into iru	15	85	0	0
Soy-soup	9	91	0	0

**Source: IITA/IDRC field survey.*

Annual Report Executive Summary
Maize Research Program

Dr. Y. Efron
Program Director
(Until Jan. 12, 1988)

The strategic plan of IITA, completed in 1987, recognized the large potential for maize as human food, livestock feed, and industrial use and that the moist savanna zone had the greatest potential for increased production in West Africa. Therefore, the strategic plan called for development of a maize research station in the moist savanna. The plan and budget for its establishment were approved by the Technical Advisory Committee of the Consultative Group on International Agricultural Research (CGIAR). A search for a suitable location was initiated and it is expected that research activities will start during 1988.

Weather in 1987 adversely affected African maize production. In both the savanna and forest zones rains started late, forcing farmers to plant and replant. Late planting is usually associated with higher incidence and severity of diseases such as maize streak virus (MSV) and downy mildew—and 1987 was no exception. A very high incidence of maize streak virus (MSV) was observed in the savanna of Cameroon. It was also common in Nigeria and Ghana. The situation was aggrevated by heavy rains starting in June in the forest area, causing soil leaching problems, low solar radiation, and high humidity. These conditions also encouraged downy mildew development in the endemic area and the spread of the disease to new areas. This situation reinforced the program's major thrust of concentrating on stability through resistance breeding.

The efforts to diversify the availability of streak-resistant germplasm have continued. Conversion of 12 elite varieties to streak resistance was completed in 1987, including TZPB and TZB which are the most popular varieties in Nigeria. Six new varieties from the national programs of Cameroon, Ghana, Nigeria, and the Republic of Benin were added during the year to the conversion program. Further diversification of the streak-resistant germplasm is being achieved by using a single dominant yellow gene to convert (via backcross) selected white-grained, streak-resistant varieties to yellow-grained varieties. The conversion of several varieties was completed in 1987. Three of them are included in the early and intermediate maturing yellow grain international variety trials. They have been offered to national programs for testing in 1988. Also, the gradual build-up of the streak-resistant level within two populations—La Posta (pop 43) and TZUT-SR-W—was completed. These populations can now be considered streak resistant.

Because of the potential threat of the spread of downy mildew, the program has expanded its research activities to develop resistant varieties and inbred lines. Resources were allocated to improve the research facilities and capabilities at Owo, Nigeria in the downy mildew endemic area. At the same time, all the necessary precautions are being taken to prevent spread of the disease which is not being transmitted through well dried seeds.

Although few cases of anthracnose infection have been observed in maize in recent years, scientists want to be prepared in case of an outbreak. Therefore, research was started in 1987 to develop inoculation techniques and to study the reaction of different inbred lines to the disease. The inbreds 1201 and 1787 are very susceptible while 9450 and Ku-1414 are among the most resistant.

Stability and overcoming disease and other constraints are also major considerations in the hybrid maize project. Multilocation testing of inbred lines and experimental hybrids, including "hot spot" locations in Nigeria (Owo for downy mildew, Mokwa for *Striga*, Bagauda for drought, and Jos for *H. turicicum* and *P. sorghi*), has proven to be efficient and rewarding. The evidence: good performance of the hybrids in international trials in Africa as well as in other continents. During 1987 the hybrid 8321-18 continued to show exceptional stability in Nigeria and elsewhere. Development and testing of new three-way and double-crosses to economize and stabilize seed production also received special attention from scientists.

Initially, the program emphasized the development of hybrids adapted for the lowlands of Africa. The development of lines and hybrids for the mid-altitude lands was started later in cooperation with the national program in Cameroon. A number of promising hybrids were identified during 1987 both in that country and in Nigeria (Jos Plateau).

Resident research under the SAFGRAD/IITA project (with headquarters in Burkina Faso) terminated in March 1988. During the last year of the program, the scientists focused on agronomic and breeding research to combat drought—the major constraint in the project area. The use of tied ridges or shallow ditches between the rows was found to be a simple and effective technology to improve soil moisture. Also, simple and relatively cheap implements for use with animal traction were developed to facilitate the adoption of the tied-ridge techniques by farmers. This technique, which improves the moisture available for maize growth, was also used by scientists in the project to select improved crop lines for drought tolerance. The lines were evaluated under single and tied ridges which provided a low-cost and simple testing procedure for the response of maize genotypes to a range in available soil moisture.

Results of other agronomic research in the region showed:

- Maize yield increase of 400 to 1000 kg/ha with cowpeas as a preceding crop for maize rather than continuous maize.
- Significant residual nitrogen and phosphorus effects were obtained with maize, sorghum, and cotton three years after fertilizer application.
- Significant variety/fertility level interactions were found between varieties; local varieties did not show better adaptation to low N or P than improved varieties.

The SAFITA-2 maize variety consistently showed a good relative performance under low phosphorus conditions.

Avoiding severe drought damage by developing early and extra-early maturing maize varieties was also emphasized by the SAFGRAD project and additional progress recorded in 1987. But much research is still required to improve the agronomic characteristics and yield potential of extra-early maturing germplasm. As a result of the past few years of regional testing by the SAFGRAD regional program, four early maturing varieties were found to be the most stable and promising across years and locations: Capinopolis 8425 (yellow, dent); EV 8431 SR (yellow, flint); M.G. TZESR-W (white flint), and Gusau 81 pool 16, (white, dent); also these four intermediate to late maturing varieties: Kambainse (2) 83 TZUT-W, Across 83 TZUT-W, EV 8449-SR, and EV 8422-SR (all white). In addition, tests showed the variety Juane Dente de Bambley from Senegal to be stable and adaptable to less favorable environments.

The joint CIMMYT/IITA germplasm development project in cooperation with the University of Zimbabwe ended in 1987. The research effort of the IITA scientist was focused on fitting the leafhopper rearing technology for different climatic conditions, particularly the cold winter of Zimbabwe. Of the two main species in the area —*Cicadulina mbila* and *C. storyei*—the former was a better vector of maize streak virus (MSV). Sex ratio studies showed that many more females than males were produced and females were better transmitters of MSV. Also, because males are polygamous, a ratio of only 1 to 10 gave the best efficiency in the rearing culture. CIMMYT has taken full responsibility for the continuation of this work.

Four maize specialists—breeder, entomologist, economist, and agronomist (based in Lumumbashi, Zaire with the national maize program)—worked with national scientists in testing many varieties of different maturities in five locations: Kanrameshi, Kaniam, Gandaiika, M'Vuazi, and Kiyaka. The principal objective was to identify and incorporate resistance to MSV and downy mildew with locally adapted, high yielding varieties.

The National Cereals Research and Extension Project (NCRE) in Cameroon, in which the IITA maize program has been a partner for several years, reached a significant milestone in 1987. All the lowland maize breeding activities were turned over to a qualified Cameroonian breeder from the national program. During the past few years, several new streak-resistant varieties were identified and recommended for extension purposes and seed multiplication. Similarly, several populations with different maturity ranges were established for future breeding and crop improvement in the forest and savanna ecologies.

The establishment and improvement of maize populations were also major activities in the mid-altitude maize breeding program of Cameroon. Scientists concentrated on earliness, disease resistance, and acid tolerance. Useful results were obtained in combining ability studies of varieties from different sources, and the information will be valuable for future population improvement and hybrid development. Several promising experimental hybrids for the mid-altitude ecology were identified in 1987.

Research continues in efforts to obatin a better understanding of the production systems and development of low-intermediate input technologies. For example, tests show that although burying residue and burning it underground (as commonly done by farmers in the mid-altitudes of Cameroon) result in higher yields in the first two years, yields decline after that. Also, significant increases in maize yields were obtained without nitrogen application using crotalaria and other legumes as a fallow crop.

The 1987 cropping season in the Cameroon savanna was characterized by reduced and erratic rainfall. Maize plants were severely affected in many farmers' fields by MSV, *Striga*, termites, and borers. A survey at Sanguere, Cameroon in 13 farmers' fields showed a high correlation between planting date and the percentage of streak infection. The value and importance of streak-resistant varieties was well demonstrated and steps taken to rapidly increase seeds of these varieties for farmers' use. Results of research during 1987 also confirmed previous studies that the use of tied-ridges in combination with seed treatment (Furadan or Marshal) can increase maize yields significantly (up to 98%) and stabilize maize production in the high-risk environment of the Sudan-Sahalian zones of Northern Cameroon.

(In the following pages, a few 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.)

Hybrid Maize: Yield Potential and Stability in Lowlands and Mid-altitudes

Hybrid maize varieties have been developed to stand up against Africa's specific biotic stresses and to provide high and stable yields under farm conditions in different agro-ecological zones.

Lowlands: Since IITA's hybrid maize project started in 1979, more than 2500 hybrids have been developed and tested extensively in Nigeria and 10 hybrids have been commercialized. A total of 311 international hybrid trials have been requested by countries in sub-Saharan Africa, Asia, and Latin America, and approximately 65 research institutions in various parts of the world now use IITA inbred lines as germplasm sources. Some hybrids have stability across environments and different management and stress conditions. (See IITA Annual Report and Research Highlights 1985.)

Among the maize hybrids tested in the international hybrid trials since 1985, three hybrids—8321-18, 8321-21 and 8428-19—have produced large yields and shown wide adaptation and stability in 13 African countries: Republic of Benin, Burkina Faso, Ghana, Guinea Bissau, Nigeria, Togo (West Africa); Cameroon, Chad and Zaire (Central Africa); and Ethiopia, Swaziland, Tanzania,

This maize hybrid—8321-18—has produced large yields and shown wide adaptation and stability in 13 African countries.

and Reunion (East/Southern Africa).

Grain yields of three hybrids—one streak-resistant, open pollinated variety, Ikenne 83 TZSR-W-1 and two local checks—were estimated based on the mean yields of 62 trials (10 entries per trial). The selected three hybrids showed yield superiority to the improved streak-resistant, open-pollinated variety and local checks throughout testing regions in Africa (Table 26). They confer resistance or tolerance to maize streak virus, *Puccinia polysora*, *Helminthosporium maydis*, ear/stalk rots, *Striga hermonthica*, *Sitophilus weevil*, and *Eldana saccharina*. All these hybrids are crossed between tropical and temperate derived lines.

IITA-developed hybrid maize varieties are grown in over 100,000 hectares annually in Nigeria. Efforts have been made to produce seeds of the hybrids in Ethiopia, Cameroon, Ghana and Sudan.

Mid-altitudes: Approximately 9 million hectares of maize are grown in the mid-altitudes (800–1500m) of sub-Saharan Africa. Most of it can be found in east and southern Africa, but also some in the Jos Plateau of Nigeria and in Cameroon. The mid-altitude zone differs from that of the lowlands in climate as well as the presence of a different leaf blight (*Exserohilium turcicum*) and a different rust (*Puccinia sorghi*). Maize streak virus (MSV) is a production hazard across sub-Saharan Africa.

Some national maize research programs in this zone have a strong hybrid development section and hybrid varieties are widely grown in eastern and southern Africa. IITA started to develop in inbred lines for this zone in 1980, and approximately 500 lines reached the S3 stage by 1982. The sources of germplasm for the development were TZMSR-W—an IITA streak-resistant population—plus open-pollinated varieties and commercial hybrids collected from eastern and southern Africa.

Since 1985, 377 experimental hybrids have been developed and tested on the Nigerian Jos Plateau (1,300m). Based on three years of data (1985–87), five hybrids show a significant yield advantage (18 to 31%) over the streak-resistant, open-pollinated variety Across 83 TZMSR-W (Table 27). All hybrids were resistant to MSV and tolerant to highland blight, rust, and ear rot. The parental inbred lines can be used as sources of resistance or crossed to streak-susceptible local varieties to produce top-cross hybrids such as 8556-6 (COCA × TZMi 2). High-yielding, three-way crosses

Variety	West Africa 6 countries 44 trials	Central Africa 3 countries 10 trials	East/Southern Africa 4 countries 8 trials	Average yield
Hybrid				
8321-18	6.4	5.3	4.1	5.9
8321-21	5.9	5.1	4.8	5.6
8428-19	5.8	5.1	4.2	5.5
Open-pollinated				
TZSR-W-1	4.9	4.1	3.5	4.6
Local 1	4.7	3.6	3.7	4.0
Local 2	5.0	4.0	3.3	4.1
LSD (5%)	1.4	1.2	0.8	

Table 26. Grain yield (t/ha) of three maize hybrids, one streak-resistant open-pollinated variety and two local varieties (checks) in 62 trials across 13 countries in Africa (1985–87).

Right, performance of a maize hybrid (8534-3) which is streak and leaf blight resistant in contrast to a susceptible open-pollinated variety (left) at a mid-altitude zone at Jos, Nigeria.

and synthetics can be further developed from these materials.

Research on mid-altitude adapted hybrids has also been conducted in Cameroon under a program financed by USAID and the Government of Cameroon and executed by an IITA and Cameroon (Institute of Agronomic Research) team. Source germplasm included collections of the best available materials from Cameroon, countries in eastern and southern Africa, IITA, and CIMMYT. To provide a theoretical framework for inbred extraction and testing through formation of reciprocal source populations, scientists studied the combining ability pattern (performance in crosses) of several open pollinated populations. Parents represented: east Africa highlands (Kitale II and Ecuador 573); lowland tropics (four CIMMYT populations: Tuxpeno 43, 21, 49, and ETO 32); subtropics (CIMMYT population 34); and African mid-altitude (IITA population TZMSR). Trials were conducted at four sites ranging in altitude from 1000 to 1700 meters (Table 28). Principal conclusions from the two-year experiment were:

- Lowland by highland population crosses performed well in the mid-altitudes (1000–1500m), combining the better plant type of the lowland with the better yield and disease resistance of the highland population. Eto × Ecuador 573 and Kitale II × Tuxpeno could be used as reciprocal source populations.
- The highland by highland cross performed best at the highest site.

- Ecuador 573 conveyed a high level of resistance to highland rust (*Puccinia sorghi*), even in crosses with very sensitive materials.

Table 27. Grain yield (t/ha) of maize hybrids tested in mid-altitude locations in Nigeria.

Variety	1986 (5 loc.)	1987 (3 loc.)	Average yield
Hybrid			
8534-3	9.4	7.0	8.5
8535-23	7.6	9.2	8.2
8537-18	9.1	6.7	8.2
8536-23	9.0	6.7	8.1
Top cross			
8556-6	8.1	7.4	7.8
Open-pollinated			
Across 83 TZMSR-W	7.4	6.3	7.0
EV 8344-SR	6.4	2.8	5.1
LSD (5%)	1.6	1.4	

Table 28. Agronomic traits of selected varietal crosses of maize in four mid-altitude locations in Cameroon (1986).

Varietal cross	Days to silk	Ear. height (cm)	Root lodging (1–5)*	Highland rust** (1–5)*	Average yield (t/ha)
Kitale II × 43	80	158	1.7	2.3	11.1
EC 573 × 43	82	164	1.4	1.5	10.7
EC 573 × Kitale II	87	191	2.8	1.0	10.6
TZMSR × Kitale II	79	158	2.1	1.8	10.5
TZMSR × EC 573	81	162	1.6	1.3	10.0
Kitale II × 32	81	155	1.1	2.1	9.9
EC 573 × 32	81	147	1.6	1.1	9.4
43 × 32	78	122	1.2	3.4	8.1
TZMSR × 43	80	133	1.4	3.1	7.9
TZMSR × 32	78	133	1.5	2.4	7.6
LSD (5%)***	2	15	0.4	0.4	1.6

Rating scale 1–5; 1 = best.
**Rust rating from 1700m altitude site only.*
***Variety × location interaction used to test significance.*

Mass Rearing Leafhoppers for Maize Streak Resistance: Differences in Zones and Species

The best technique for mass-producing *Cicadulina* leafhoppers used for screening maize germplasm for resistance to maize streak virus (MSV) cannot be the same at the Harare Research Station in Zimbabwe and at IITA's headquarters in Ibadan, Nigeria because of the ecological differences in altitude and climate. The species *C. triangula* is the most efficient vector of MSV in Ibadan, but *C. mbila* is the best vector in Zimbabwe.

Oviposition studies conducted at the Harare Station showed that the average fecundity of *C. mbila* was 30 eggs per female compared with 70 for *C. triangula*. Therefore, more females of *C. mbila* need to be maintained in the culture for the same production rate. Mass-produced populations of *C. mbila* are characteristically predominated by females which were found to be better vectors of MSV than males. Also, males polygamously mate with as many as 12 females (Figures 19 and 20). Thus,

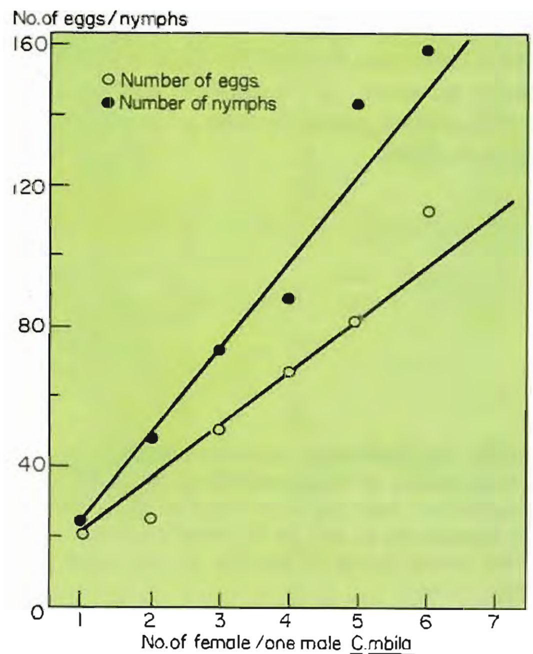


Figure 19. Influence on eggs laid and nymphs produced by increasing the number of female leafhoppers (C. mbila) per single male.

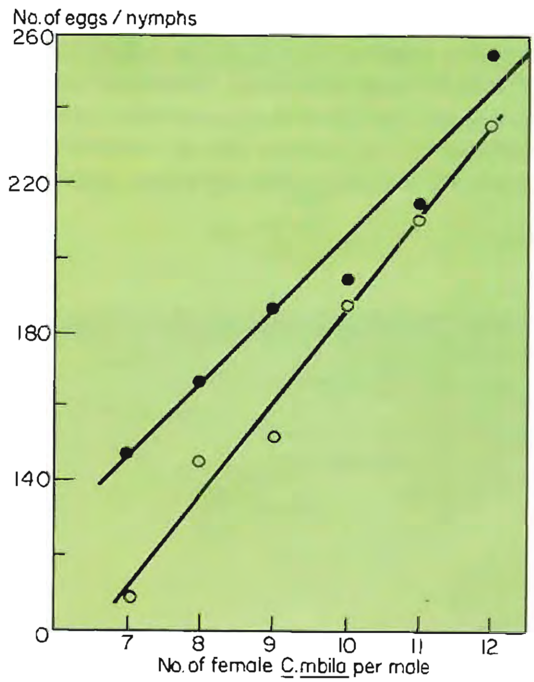


Figure 20. Influence on egg and numph production by increasing the number of female leafhoppers (C. mbila) with one male.

the mass-production strategy for *C. mbila* should be to maintain only enough males in the culture for breeding purposes.

Low temperatures and a dry atmosphere during the winter months of May to August in Harare created new problems: poor maize and millet seed germination, high levels of aphid contamination of the millet seedlings, a reduced fecundity and extended nymphal development period, and a lower efficiency of *C. mbila* to transmit the maize streak virus. The poor seed germination resulted in a reduced mass-rearing culture and a consequent reduction in leafhopper production, but plastic mulching and pre-germination of the seeds improved this situation.

In addition to competing with the leafhoppers for the millet seedlings, aphids contaminate the seedlings with honeydew which enourages fungal growth and the numphs trapped in it die. Large populations of aphids were effectively controlled using larvae and adults of the coccinellids beetle *Chilomenes sulphureus* and an unidentified wasp, as predators and parasites, respectively. Small populations of the beetle could easily be maintained on a wide range of aphid species for use against aphid contamination.

Leafhoppers normally lay eggs on the leaves or leafsheaths. A study of the behavior of *C. mbila* in nature and under greenhouse conditions has shown that this species lays eggs on roots of grasses. This finding, which has not been reported before, is apparently one of the mechanisms for the leafhoppers to survive during the cold winter months.

Temperatures within glasshouses in Harare varied during the daytime between 8°–24°C in the winter and 20°–36°C in the summer. Such wide temperature fluctuations caused several problems, including reduced fecundity of female *C. mbila*, weaker ability to transmit MSV, and increased mortality. Therefore, temperature-controlled mass rearing facilities in a mid-altitude zone are a basic requirement for rapid buildup of large numbers of *Cicadulina* leafhoppers within a short period for use when the rainy season starts.

C. mbila, ***the leafhopper species which is the best vector of maize streak virus (MSV) in Zimbabwe, lays eggs on roots of grasses. This apparently is one of the mechanisms for the leafhoppers to survive during cold winter months.***

Improvement of Streak Resistance in a Major Maize Population: La Posta

A gradual build up over several years of the streak resistance level within La Posta (Population 43), which is widely adapted to various maize growing regions in Africa, has been completed and the population can now be considered resistant to maize streak virus (MSV). Derived from a synthetic of 16 lines from the race Tuxpeno, it is of late maturity and relatively tall with white dent maize kernels. Although grown mainly in tropical lowlands, it also performs well in some parts of mid-altitude environments.

From 1974 to 1980, La Posta was improved from cycle 0 to cycle 4 by CIMMYT in Mexico using full-sib recurrent selection through the international progeny testing system. Because of its yield potential and high demand in many countries in Africa, it was moved to IITA in 1980 to improve resistance to MSV under a joint effort of CIMMYT and IITA. Streak resistance was built up in La Posta *per se* through modified full-sib recurrent selection. Taking precautions to avoid a decrease in yield potential, intensive selection for streak resistance was made at the intra-family improvement stage of the recurrent selection.

Artificial infestation of viruliferous leafhoppers, *Cicadulina* sp., to induce uniform streak pressure was used to select resistant plants. Simultaneously, a side car approach was used to incorporate streak-resistant genes from a resistance source (TZSR-W) to La Posta germplasm by backcrossing. Some highly resistant families of the backcross germplasm with good agronomic performance were introgressed to La Posta population in 1984 and 1986.

Rapid improvement of streak resistance has been accomplished in La Posta: Only 4.6% of selected families had plants showing some level of resistance in 1980; in 1984 (after two cycles of improvement) every family of 250 progenies had some resistant plants; in 1987 approximately 90% of 277 S_1 progenies showed a high level of resistance. (See Figure 21 for data on the frequency of contribution of streak resis-

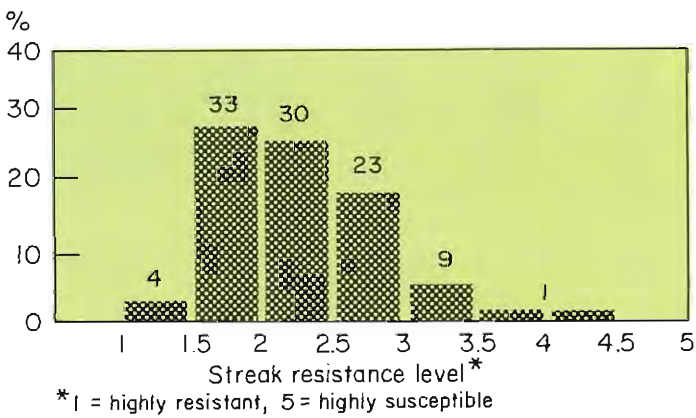


Figure 21. Frequency distribution of maize streak resistance level among 277 S_1 progenies of La Posta C7 under induced streak pressure.

tance under induced streak pressure.) Results of a trial during 1986–87 to evaluate the progress of La Posta between cycles 4 and 7 at several locations in Nigeria are shown in Tables 29 and 30.

After three cycles of improvement by modified full-sib recurrent selection under induced streak pressure, La Posta is now considered highly resistant to MSV. Nine streak-resistant experimental varieties (EV) were formed according to results of the International Progeny Testing Trial (IPTT) in 1984. Based on the results of IPTT in 1986, another six SR EV's are in the process of formation. They will be available soon for testing and multiplication.

Table 29. Maize grain yield, streak-resistance level, and other agronomic characteristics of different cycles of La Posta under induced streak pressure at Ibadan, 1986.

Cycle	Grain yield (t/ha)	SR level (1–5)*	% streak plants	Days to 50% silk	Plant ht. (cm)	% bad husk cover
C4	3.02	3.8	69.1	54.5	164	13.6
C5	2.68	3.3	60.0	54.3	167	22.9
C6	4.81	1.7	10.2	53.3	187	3.5
C7	4.60	1.2	0.0	53.5	190	8.8
Mean	3.78	2.5	34.8	53.9	177	12.2
CV%	19.1	—	—	1.7	9.0	—
LSD (5%)	0.74	—	—	0.9	4.4	—

Streak-resistance level: 1 = resistant, 5 = susceptible.

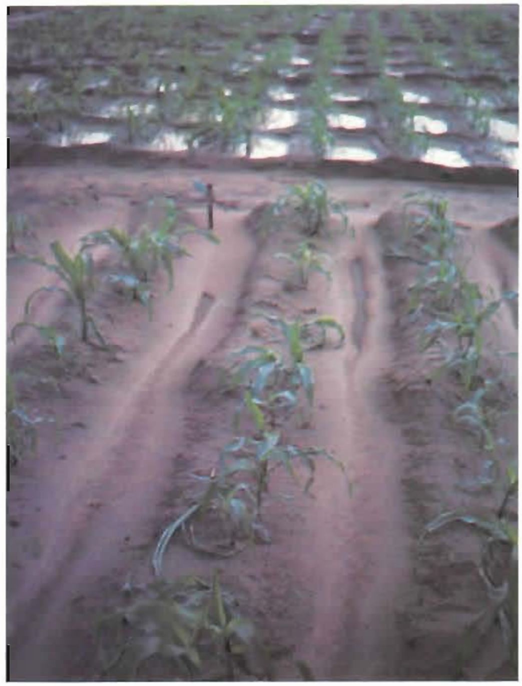
Table 30. Mean maize grain yield, yield index, and other agronomic characteristics of different cycles of La Posta in seven streak-free environments at four locations 1986–87.*

Cycle	Grain yield (t/ha)	Yield index**	Days to 50% silk	Plant ht. (cm)	% bad husk cover
C4	4.81	100.0	58.1	210	12.9
C5	4.59	95.4	57.3	207	11.4
C6	5.04	104.8	57.2	207	8.8
C7	5.37	111.6	57.0	209	8.0
Mean	4.95	—	57.4	208	10.3
CV%	17.1	—	2.7	7.0	—
LSD (5%)	0.44	—	0.8	7.4	—

**Ibadan, Ikenne, Samaru, and Funtua.*
***percentage of C4.*

Drought Tolerance for Early-maturing Maize in the Sudan Savanna

Because drought stress seriously affects maize yields in the semi-arid tropics of sub-Saharan Africa, finding ways to overcome this constraint has been one of the priorities of the regional IITA/SAFGRAD project based in Burkina Faso. One technique used by scientists in this project consists of testing maize genotypes (varieties or families) under greater or lesser moisture stress conditions using both simple and tied ridges.



Scientists used the technique of simple (front) and tied ridges (back) to test maize under different moisture stress conditions.

Tied ridges improve soil moisture availability by reducing or eliminating run-off. This technique is relatively simple, does not require expensive equipment, and could be easily adopted by scientists of national programs. However, it does require a careful field plot technique and trial supervision because opening of the tied ridges may be required to minimize waterlogging stress during frequent or heavy rainfall.

The maize germplasm chosen to evaluate the effectiveness of this technique of selection for drought tolerance was Pool 16 —an early white dent tropical pool developed by CIMMYT. Previous trials showed that Pool 16 performed well in the savanna belt of West Africa. Further experiments conducted under controlled irrigation in 1982 and 1983 in Burkina Faso found Pool 16 to be one of the best drought-tolerant materials among the 26 tested.

Performance of maize Pool 16 C_0 (left) and drought tolerant Pool DR C_2 (right) under moderate stress in Burkina Faso.

Full-sib family testing (219 families) of Pool 16 under both simple and tied ridges started in 1984. All families were also crossed to Pool 16-SR BC_4 to incorporate streak resistance. Family selection was based on average yield under both simple and tied ridges, percentage yield reduction under more stress (simple ridges), and other characteristics such as flower synchronization (interval between pollen shedding and silk emergence). Families with poor husk cover, ear rots, or other undesirable traits were discarded.

The 26 selected families were recombined to advance the population to cycle 1 (Pool 16 DR C_1; DR = drought resistance/tolerance). A balanced bulk of all 219 families was maintained as cycle zero (Pool 16 DR C_0); 194 full-sib families developed from Pool 16 DR C1 were tested in 1986 under simple and tied ridges at three locations in Burkina Faso. Based on these results, 31 drought-tolerant families were selected and recombined to advance the population to the next cycle (Pool 16 DR C_2).

The results of this selection program were evaluated in 1987 (Table 31). Four tests were conducted under simple and tied ridges in the Sudan savanna (high and medium moisture stress levels) and one test under flat planting in a ferrallitic soil in the northern Guinea savanna (slight moisture stress level). The mean yield performance of SAFITA-2—a check variety developed from Pool 16 in 1982—and cycles 0, 1, and 2 of Pool 16 DR moisture stress levels was 2.69, 2.88, 2.99, and 3.15 t/ha, respectively; the number of days to 50% silking was 51.7, 50.5, 50.6, and 50.3.

A trend in grain yield improvement was observed, with about 5% mean increase per cycle. The three Pool 16 DR cycles performed better than SAFITA-2 at all moisture stress levels. Pool 16 DR C_2 gave yields that were 28.9, 15.5, and 14.4% above those of SAFITA-2 under high, medium, and slight moisture stress levels, respectively.

Table 31. Maize grain yield (kg/ha) and days to 50% silking of three cycles of selections for drought resistance in Pool 16; data across four trials at two locations (1987).

Materials	Grain yield (kg/ha) under different moisture supply: Low	Medium	Adequate	Mean	Mean days to 50% silking
C_0	1654	2272	4699	2875	50.5
C_1	1893	2374	4692	2986	50.6
C_2	1846	2514	5093	3151[†]	50.3
SAFITA-2*	1432	2176	4462	2690	51.7

**Local recommended variety.*
†A linear trend fitted to a C_0, C_1, and C_2 cycle means was significant ($p < 0.05$).

Vulnerability of Maize to Anthracnose in Africa

Although anthracnose, caused by the fungus *Colletotrichum graminicola*, is one of the most destructive diseases of maize in some other parts of the world (including the U.S. cornbelt), only a few cases of infection have been observed recently in Nigeria. Nevertheless, IITA scientists want to be prepared in case it should become a serious problem on maize in Africa in the future. (Anthracnose has been reported from essentially all of the sorghum-growing regions of the world, including West Africa.)

In 1987, the scientists started developing inoculation techniques to study the reaction of different inbred maize lines to the disease. They inoculated by injection 4, 6, 8 and 10-week old potted plants of the inbred line 1787 at the same time in a screenhouse and found the plants to be vulnerable at all four growth stages. The first symptoms—dull leaves resulting from wilting—were observed one week after inoculation. This was followed by complete collapse of the stalk, soft rot, and fall-over along the region of inoculation within 10–14 days after inoculation. However, plants inoculated at the 10-week stage did not fall over.

In view of the extreme virulence of the pathogen on inbred line 1787, the scientists inoculated 28 elite lines developed at IITA from different tropical and temperate sources. For each inbred, 20 plants were inoculated at four weeks after planting. The inbreds displayed a wide range of symptoms on the leaves and stalk. In some lines such as 9030, stalk rot was not induced but there were distinct elliptical greyish tan leaf spots and in some other lines (1368 for example) the pathogen prevented the unfolding of the young leaves and incited severe blighting on the unfolded shoot. In other inbreds—1787, 4008, 1201, 5012, and 5057—the plants were killed by stalk rot within two weeks of inoculation. Other symptoms include leaf blanching, shoot dieback, and tillering. The lines 9450, 9496, 9236, and Ku1414 were consistently resistant to the stalk rot phase.

To investigate the leaf blight phase, four inbreds—1787, 2096, 9030, and Ku1414—were sequentially planted weekly to allow simultaneous foliar inoculation of one to six-week-old plants. All the lines except Ku1414 produced the leaf spot symptom on inoculation from two to six weeks after planting. This was the outstanding resistant line to both the stalk rot and leaf blight phases. About three weeks after the foliar inoculation, inbred line 1787 exhibited the stalk rot phase and the plants fell over at the soil level. The other three inbreds did not show any stalk rot infection.

IITA scientists are now screening open pollinated maize varieties for resistance to anthracnose and continuing their efforts to learn more about the mode of inheritance to resistance.

Annual Report Executive Summary
Rice Research Program

Following the strategic plan of IITA, the research program was restructured to focus on the inland valleys which offer a tremendous potential for increasing rice production in Africa. Over 300 crosses were made during the year, and, through a systematic search for donor varieties, new parent materials were introduced, including those for resistance to blast, tolerance to iron toxic soils, better plant type, and yield potential.

Dr. J. A. Lowe
Program Director

Also, scientists emphasized crossing for earliness to widen the range of growth duration in the breeding population. They evaluated segregating populations and pedigree materials and tested advanced lines in observational and replicated performance trials. Simultaneously with field evaluation, breeding materials were screened for major stresses, as well as for grain quality.

From early crosses made in 1983 and 1984, several advanced generation rice yellow mottle virus (RYMV) resistant lines were evaluated for yield potential in the field under virus-free conditions by comparing them with a susceptible but high yielding rice variety. A further test for RYMV tolerance was simultaneously conducted in the screenhouse using artificial inoculation. During 1988, scientists will attempt to quantify the yield advantage of tolerant varieties over susceptible ones under natural conditions in the field. A set of differentials for detecting RYMV strains from Sierra Leone, Niger, Kenya, and IITA has been identified and a collaborative research network formalized. The differentials included symptomless immune varieties to highly susceptible plants. Out of the 19 test lines developed between IITA and Niger's Plant Protection Service, four were found to be promising in terms of yield and tolerance.

Hydromorphic areas and inland valleys as rice growing environments generally suffer from widely fluctuating water regimes which often result in water deficits, flooding, or even submergence; add to those constraints complex disease and insect problems and often adverse soil conditions. For these wetland ecologies, scientists are working on the development of an array of varieties that can withstand the non-uniform and often unfavorable growing conditions. Such varieties should have these characteristics: tall seedlings with strong, early vegetative vigor; plants of intermediate stature and strong culm to resist lodging; moderately long, erect leaves; moderate tillering; insect and disease resistance; tolerance to adverse soils (notably iron toxicity); and good grain quality. Also, varieties differing in growth duration are needed to fit the cropping systems and farmers' agronomic situations.

During 1987, scientists evaluated 16 promising advanced rice lines in four different locations at IITA varying in water regimes: a range of conditions from one without standing water in an upper slope of an inland valley to one with 40–45 cm of standing water maintained in a paddy. Averaged across four locations, three new TOx lines were among those with the highest yield, plus good quality long and slender grains.

In the rainfed wetlands, particularly in the drought prone areas, blast is always a threat so IITA's breeding lines are rigidly screened for blast resistance in a special blast nursery and in all breeding trials in the field. Tests in 1987 showed four lines resistant to blast. In addition, they were high yielding in hydromorphic soils. A total of 4,642 lines were screened in the uniform blast nursery for leaf blast and most of the elite lines tested for neck blast in the field. Previously identified resistant varieties for both the uplands and lowlands continued to be resistant in several locations.

Lines being developed for iron toxic soils are screened in Liberia in collaboration with the Central Agricultural Research Institute (CARI) and WARDA and in Nigeria with the National Cereals Research Institute (NCRI). Several among the 155 advanced lines evaluated in 1987 were found promising.

Entomologists focused on screening germplasm and breeding lines for resistance to major insects with progress made on two: stalk-eyed fly *(Diopsis longicornis)* and pink stem borer *(Sesamia calamistis)*. New germplasm with good levels of resistance/tolerance was identified. Also, screening diverse genetic materials resulted in better sources of resistance to the storage pest Sitotroga cerealella. Research at IITA's high rainfall sub-station at Onne, Nigeria showed that much of the nutritionally-related disease problems on upland rice in this zone is due to silica deficiency in the soil and can be corrected by silica application, along with resistant varieties.

The national Coordinated Rice Evaluation Trials (CRET), managed and coordinated by NCRI, identifies superior varieties for release in Nigeria. Two years of CRET data from several upland locations in Nigeria showed average yields of over 3 t/ha for ITA 301, ITA 305, ITA 307 and ITA 315—all medium maturing selections. ITA 150 and ITA 257—upland varieties that mature in 100–105 days and suitable for the dry zone—averaged 2.7 t/ha. Two very promising lines for the lowland areas were ITA 312 and ITA 230. The latter averaged 6.2 t/ha over three years of testing in CRET. Both are medium-maturing selections with a growth duration of about 120–125 days.

Making improved germplasm available to scientists in national programs is an important function of a breeding program. The demand for seed of IITA's improved rice varieties and lines has increased from about 1.2 tons in 1984 to 7.7 tons in 1987. Of this amount, about 600 kg were used by IITA scientists for their experiments and 800 kg by other scientists in 24 countries outside Nigeria. The bulk of the seed (6.2 tons) was supplied to Nigeria. Also, IITA provided practical training to National Seed Service workers during 1987 to help them produce and process pure seeds of rice varieties for Nigerian farmers.

Studies on improvement and management of rice varieties continued to be the major emphasis in the National Cereals Research and Extension (NCRE) program of Cameroon. In Mbo Plain, where lower temperatures favor development of diseases, rice varieties ITA 212, ITA 222, and Cisadane continued to be the top performers with tolerance to the stresses in this location. IR 7167-33-2-3 was the best performer in Ndop Plain where the stresses are more severe because of a higher altitude. It was planted on an additional 3,000 hectares in 1987. Early planting in this cold-prone area produced higher yields since the flowering period avoided exposure to cold. This was particularly true for the medium duration varieties. New breeding lines developed at IITA, with genotypes adapted to this ecology, have shown promise in tolerating the stresses endemic to this region. Planting of ITA 222 and ITA 306 has been extended to pilot projects in northern Cameroon. These varieties have averaged over 7 tons/ha in the wet areas of this region.

National programs have requested that the International Rice Testing program for Africa (IRTP-Africa) initiate new sets of test materials for hydromorphic/inland valley ecosystems and also nurseries to evaluate tolerance to blast and rice yellow mottle virus (RYMV) diseases. Their requests for nursery sets have steadily increased over the past three years, along with improved returns of data for analysis and the sharing of information among collaborators.

An important reason for IITA's focus on the inland valleys was to complement WARDA's research which previously had not been concerned with this ecosystem. IITA has changed its strategy so as to assist WARDA to build a strong rice program for West Africa. IITA will phase down its rice improvement program as WARDA becomes operational, and it will collaborate with WARDA in farming systems research on the inland valley ecosystem. During the transition, IITA will continue the rice improvement program in order to support WARDA, while meeting the needs of a vast potential area of sub-Saharan Africa.

(In the following pages, a few 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 Rice Research Program.)

Overcoming Major Biological Constraints for Rice Production: Blast, Gall Midge, and RYMV

Because of the diversity of the rainfed wetlands as one of the target environments for IITA rice varieties, the screening and selecting process calls for a range of genotypes with these desirable agro-morphological traits: intermediate-to-tall stature, moderate-to-high tillering ability, moderately long and erect leaves, and good seedling and vegetative vigor. Tolerance to physical and biological stresses adds to stability of performance in the rainfed environments.

Blast: Caused by the fungus *Pyricularia oryzae*, blast reduces rice production in many areas. Large doses of nitrogen, high humidity, and long dew periods encourage blast development, particularly on susceptible varieties. In addition, crops suffering from moisture stress are more prone to blast attack. As part of their research to develop improved varieties for rainfed areas, scientists are selecting for genotypes with high yield potential and adequate resistance to blast.

During 1987, they conducted a trial in a hydromorphic area in one of the inland valleys at IITA. It was composed of two groups of 21 entries each, including two check varieties—IR 5 and ITA 308. Grouping was done on the basis of maturity—medium duration lines in one group, medium-late in the other. The trial was grown in three replications following the randomized complete block design using 12.0 m^2 plots; total fertilizer applied: 90-30-30 kg/ha (N, P_2O_5, K_2O). The entries were simultaneously screened in the blast nursery and Table 32 shows those that combine high yield potential and resistance to blast. Lines that yielded over 6 t/ha were TOx 3118-87-4-2 in Group 1 and TOx-3118-3-E3-1 and TOx 3142-1-1-1 in Group II. Although yields of the selected lines were not significantly higher than the check variety IR 5, all had better grain quality. Of the selected TOx lines, eight have long grains and two medium grain length.

Seeds of the selections are now being multiplied for further evaluation in IITA's outreach trials and for distribution to interested national programs for their own evaluation and use.

Gall Midge: One of the important insect pests of irrigated and rainfed lowland rice in some regions of Africa—the gall midge (*Orseolia oryzivora*)—has become well established in several countries, including Burkina Faso, Cameroon, Cote d'Ivoire, Gambia, Ghana, Guinea Bissau, Malawi, Mali, Niger, Nigeria, Togo, Senegal, Sudan, and Zambia. It is restricted only in Guinea and Sudan savanna zones. This species, morphologically distinct from the Asian species (*Orseolia oryzae*), is spreading to other rice growing areas.

The warm and humid environment in which rice is grown is conducive to proliferation of the pest. It attacks rice plants at the early tillering stage, stunts plant growth, and reduces grain yield. Under severe infestation, profuse tillering and stunting occur and few panicles are produced. A gall midge infested crop not only yields less but also is not uniform in flowering and maturity.

The female insect lays eggs singly on leaf blades or other parts of the leaf. The newly hatched larvae creep down the leaf sheath and feed on the meristematic tissue at the growing points of the tillers, forming tubular galls which resemble an onion leaf. The gall formation is attributed to a cellular response to a secretion "cecidogen" from the salivary glands of the feeding larvae.

Because the gall midge is an internal stem feeder, chemicals are not the best answer for control: development of resistant varieties is. IITA scientists, in collaboration with the national rice research programs of Burkina Faso and Nigeria, have been doing research to identify possible sources of resistance. "Hot spots" for field screening were identified in Karfiguela (Burkina Faso) and Edozhigi (Nigeria) and there a total of 734 rice varieties/lines from different parts of the world were screened. Reactions of test entries to gall midge varied between the two locations, indicating possible differences in virulence of this insect pest in Africa (Table 33). However, further

Table 32. Grain yield, agronomic traits, and grain characteristics of blast resistant rice lines for the rainfed wetlands selected from 1987 wet season trial, Ibadan, Nigeria.

Rice line entries	Yield (t/ha)	Plant height (cm)	Maturity (days)	Tillers per hill (no.)	Reaction to blast*	Grain characters** Length	Grain characters** Shape	Amylose (%)
Medium duration								
TOx 3118-87-4-2	6.56	113	119	15	R	Long	Slender	26
TOx 3133-75-1-2	5.58	102	134	15	R	Medium	Medium	25
TOx 3133-75-1-1	5.46	107	130	14	MR	Long	Medium	23
TOx 3108-66-5-1	5.42	103	130	14	R	Long	Medium	26
TOx 3133-59-1-3	5.38	105	119	10	R	Long	Medium	26
IR 5, Check	5.43	127	141	12	S	Short	Medium	30
ITA 308, Check	5.25	108	122	13	MS	Long	Slender	24
Mean	5.71							
LSD (5%)	1.40							
CV (%)	14.9							
Medium-late (duration)								
TOx 3118-3-E3-1	6.14	117	140	15	R	Long	Slender	26
TOx 3142-1-1-1	6.02	116	143	14	R	Long	Slender	27
TOx 3142-1-1-3	5.56	115	140	14	MR	Long	Medium	25
TOx 3052-46-E2-1	5.39	111	135	13	R	Long	Slender	26
TOx 3118-73-2-1	5.33	111	138	16	R	Medium	Medium	26
IR 5, Check	5.16	120	138	12	S	Short	Medium	30
ITA 308, Check	5.14	101	131	13	MS	Long	Slender	24
Mean	5.38							
LSD (5%)	1.38							
CV (%)	15.5							

Note: Data on reaction to blast were from the blast nursery; R = Resistant, MR = Moderately Resistant, S = Susceptible, MS = Moderately Susceptible.
**Descriptions follow the Standard Evaluation System for Rice, IRRI (1980).*

Newly planted rice field (left) has many silver shoots indicating the severity of infection caused by the gall midge (below) which is well established in several African countries. Its control can be best achieved through development of resistant rice varieties.

tests will be necessary to confirm this.

Screening diverse genetic materials and breeding lines to identify better sources of resistance to this insect continues.

Rice Yellow Mottle Virus: The need for rice lines tolerant to this destructive virus in tropical Africa is urgent and progress is being made to develop them. The virus can occur in epidemic proportions with devastating results, particularly when susceptible varieties are grown in wide areas and conditions for disease development become favorable. It is a threat to Africa's effort to increase rice yields in lowlands.

Rice yellow mottle virus (RYMV), which causes yellowing and stunting of rice plants leading to incomplete emergence of panicles with sterile grains, has been reported in several countries: Burkina Faso, Ghana, Ivory Coast, Kenya, Liberia, Mali, Niger, Nigeria, Rwanda, Sierra Leone, and Tanzania. The damage it can cause is well known in the Republic of Niger which experienced an epidemic in 1984 and 1985 and continues to wrestle with this production constraint.

Early screening trials showed that differences in resistance existed among rice

		Infestation (%)	
Designation	Source	Nigeria	Burkina Faso
BW 100	Sri Lanka	10.9	2.6
BW 78-7	Sri Lanka	6.6	3.9
Ptb 10	India	9.3	8.6
Dan Dauda B4	Nigeria	4.7	—
Jatau A1	Nigeria	6.7	—
Kalijira	Bangladesh	11.5	

Table 33. Promising rice cultivars selected for resistance to the gall midge (*Orseolia oryzivora*) in Nigeria and Burkina Faso.

varieties and a few were identified as tolerant to the virus. Because they did not have good plant type characteristics and lacked the yield potential to perform well in the wetlands where RYMV is likely to be a problem, IITA breeders, pathologists, and virologists intensified their research in 1983 with tolerant donor varieties and other improved germplasm. Breeding populations were subjected to vigorous screening and selection at IITA for desirable agronomic traits and tolerance to RYMV. Also collaborative work initiated in 1985 with the Plant Protection Service of the Republic of Niger allowed evaluation of breeding lines under natural field infection. Results of this evaluation will be available in 1988.

From the initial batch of crosses made in 1983 and 1984 and following the pedigree method of selection, a number of promising lines were identified. During the 1987 wet season, a trial with 19 lines developed for RYMV tolerance was conducted in the irrigated lowland areas of IITA under RYMV-free conditions. A separate test was conducted at the same time inside a greenhouse for tolerance to the disease.

Table 34 shows the entries that combine high yield and RYMV tolerance. Yield of the selected lines were significantly higher than FARO 34 but not significantly different from FARO 35 (ITA 212) which is a highly susceptible variety. Two of the selected lines yielded over 5 t/ha. The mean number of days from sowing to maturity ranged from 115 days for TOx 3058-28-1-1 to 126 days

Table 34. Grain yield and agronomic traits of selected rice yellow mottle virus tolerant lines at IITA (1987 wet season).

Rice line entries	Yield (t/ha)	Maturity (days)	Plant height (cm)	Tillers per hill (no.)	Reaction to RYMV*	Grain characters**		Amylose (%)
						Length	Shape	
TOx 3219-51-1	5.93	124	120	10	R	Long	Medium	29
TOx 3220-14-4-1	5.90	120	113	7	R	Long	Medium	29
TOx 3058-28-1-1	5.59	115	107	11	R	Long	Medium	30
TOx 3219-51-2-1	5.25	126	124	11	R	Long	Medium	30
TOx 3217-71-2-1	5.03	103	107	8	R	Medium	Medium	28
TOx 3211-42-2-1	4.87	126	113	13	R	Medium	Medium	29
TOx 3219-11-1-3	4.85	120	107	9	R	Long	Slender	27
TOx 3219-48-3-3	4.69	125	102	8	R	Medium	Medium	29
ITA 212 (FARO 35) Check	5.64	119	112	10	S	Long	Medium	27
FAROX 239-2-1-1-1 (FARO 34), Check	3.56	101	96	12	MS	Long	Slender	29
Mean	5.02							
LSD (5%)	1.06							
CV (%)	12.8							

*In greenhouse: R = Resistant, MS = Moderately Susceptible; S = Susceptible.
**Description follows the Standard Evaluation System for rice, IRRI (1980).

for TOx 3211-42-2-1 and plant height from 107 cm for TOx 3058-28-1 to 120 cm for TOx 3219-51-1-1. Varietal requirements of most farm areas are within these ranges.

Additional research may produce even better lines than this first group of entries tested. The search for new donor varieties for RYMV tolerance continued to diversify the sources of resistance.

Performance of Improved Rice Genotypes under Different Water Regimes

Africa has a tremendous potential for expanding rice production in the rainfed wetlands—a vast and underutilized area. But conditions there are very diverse due largely to differences in topography, soil variability, and lack of water control. For example, in an inland valley (a typical wetland), the rice crop planted in the fringes may experience drought while at the bottom of the landscape it may suffer from deep flooding or even submergence. Such variations also affect the incidence and severity of diseases, insect pests, and soil and weed problems. Because of these constraints, varieties bred for uniform and favorable irrigated lowland may not be suitable for the harsher and more variable rainfed wetland environment.

IITA's rice breeding program emphasizes not only yield potential but also tolerance to stresses, particularly those associated with uncontrolled and fluctuating water regimes. To simulate variable moisture regimes and to sample more rainfed environments, scientists conducted a trial at four sites during the 1987 wet season: two in a hydromorphic area of a small inland valley and two in an irrigated paddy. In the former, the trial was grown at the upper hydromorphic and the lower hydromorphic part of the valley and in the latter under shallow water or normal flooding (5–10 cm) and also under medium deep flooding (40–45 cm), the water being introduced after the crop had fully tillered. Included among the entries were eight TOx lines for rainfed lowland, six lowland and two upland varieties, plus two checks IR 5 and ITA 308 which are known to do well under rainfed conditions. The set of 18 varieties was grown in the four sites using a plot minimal size of 2.0 m × 6.2 meters with three replications; total fertilizer applied: 90-30-30 kg/ha (N_2, P_2O_5, K_2O).

The highest yielding entries were TOx 3118-47-1-1, TOx 3133-56-1-3, TOx 3118-56-1-1, TOx 3118-6-E2-3, ITA 306, and IR 5 (a check variety). The hydromorphic areas were newly opened and fertile and the crop matured without experiencing

One of four sites used to test the tolerance of rice varieties to variable moisture regimes. Shown here is a sloping hydromorphic area at IITA with dry upland conditions at the upper portion and wet swamp conditions below.

Table 35. Rice grain yield of selected entries from a trial conducted at IITA under four growing environments (1987).

	Grain yield (t/ha)*				
Entry	UH**	LH	SW	MD	Mean
TOx 3118-47-1-1	7.36	7.37	6.10	6.67	6.87
TOx 3133-56-1-3	6.71	7.70	7.10	5.62	6.78
TOx 3118-56-1-1	7.01	6.59	6.52	6.47	6.65
ITA 306	7.71	7.88	4.96	5.53	6.52
TOx 3118-6-E2-3	5.78	7.17	6.36	6.06	6.34
IR 5 (check)	7.84	7.33	7.57	5.78	7.13
ITA 308 (check)	6.39	6.65	5.26	5.52	5.96
Mean	6.27	6.16	5.27	5.06	
LSD (5%)	1.23	2.44	1.23	1.29	
CV (%)	11.8	23.9	14.0	14.4	

**Mean of three replications.*
***UH = Upper hydromorphic area; LH = Lower hydromorphic area; SW = Shallow water; MD = Medium deep water.*

drought stress. These factors account for the high yields. Yields from the upper and lower hydromorphic (UH and LH) were comparable. This was also the case with the yields under shallow (SW) and medium deep water (MD). Two entries—TOx 3118-47-1-1 and TOx 3118-56-1-1—yielded over 6 t/ha in all four environments (Table 35). The experiment in the paddies suffered flooding and submergence twice as the crop was approaching the heading stage—one of the possible reasons for the relatively lower yields in the paddies compared with those in hydromorphic soils.

Growing under flooded condition or wet hydromorphic soils did not affect growth duration of the test lines but those in hydromorphic soils showed a slight increase in tillering. Increased plant height was one notable effect of deep flooding in the irrigated paddies. Rice in shallow flooding averaged a height of 114 cm, those grown in medium deep water 134 cm which increased crop susceptibiity to lodging.

The TOx lines have a yield potential comparable to the blast susceptible IR 5, but they have a shorter stature and earlier maturity. Also, they have a much higher level of resistance to blast and possess a more desirable grain quality.

Progress in Rice Management Research for Iron-Toxic Soils

Finding practical solutions to iron toxicity has a high research priority, particularly for newly-developed inland valley swamps and hydromorphic areas where the problem is widespread. These areas hold the key to future increases in rice production in West Africa. One of IITA's strategies to overcome this problem is breeding rice varieties for resistance. The first product of this effort was the variety Suakoko 8 released in Liberia in 1978 through a cooperative program of IITA, USAID, and the Government of Liberia.

Certain management practices can also reduce iron toxicity. Periodic soil drainage allows oxidation of toxic ferrous iron to harmless insoluble forms. However, iron-toxic areas generally have drainage problems which are difficult and costly to correct. A low-cost management practice used by some farmers is to plant the rice on ridges which provides localized drainage for that part of the soil elevated above the water surface.

Recent research (1983–1986) measured the effectiveness of the new resistant varieties and of ridge planting, alone and in combination, in alleviating grain yield reduction due to iron toxicity damage. The trials were conducted on a farmer's field in a small inland valley in Imo State, Nigeria, using two IITA advanced breeding lines: high-yielding semi-dwarf ITA 212, susceptible to iron toxicity; and taller, lower-tillering ITA 247, resistant to iron toxicity and derived from Suakoko 8. Varietal responses to iron toxicity were measured in nine yield trials grown during the wet seasons of 1983, 1985, and 1986. Paddies differing in severity of toxicity were used to cover a range of levels from nontoxic to severely toxic.

Yield data plotted as affected by iron toxicity score are shown in Figure 22. The varietal difference in response to increasing toxicity was statistically significant. ITA 212 yielded 10% more than ITA 247 when toxicity was absent or very slight (score of 0–1). However, as the score increased, the varietal ranking reversed: ITA 247 gained a yield advantage over ITA 212 which increased steadily from approximately 10% under moderate toxicity (score of 4) to 250% under severe toxicity (score of 8).

The lower yield of ITA 247 compared with ITA 212 under nontoxic and slightly toxic conditions is probably due to a less desirable plant type of the former: leafy, susceptible to lodging, and late in maturity. Progress is being made in present breeding efforts to improve plant type and yield potential of resistant lines while maintaining iron toxicity resistance.

The flatter slope of the line for ITA 247 (Figure 22) indicates that in areas where the severity of iron toxicity is variable over the field or between years, this variety will give more dependable yield performance in the long term than would ITA 212. Stability yield is an especially important considera-

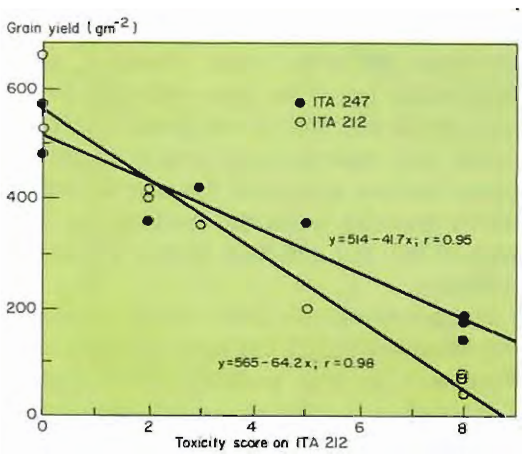


Figure 22. Rice grain yields of ITA 247 and ITA 212 as affected by increasing iron toxicity. (Data collected over three seasons: 1983, 1985, 1986.) A visual rating of symptoms of leaf bronzing and reduced growth on the susceptible variety ITA 212 served as the measure of toxicity (horizontal axis). Differences in the slopes of the two lines are statistically significant.

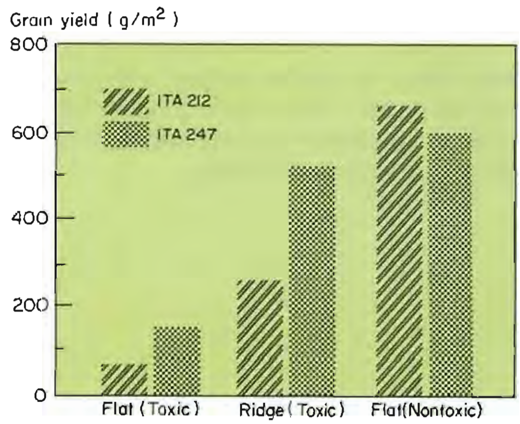


Figure 23. Yields of susceptible (ITA 212) and resistant (ITA 247) rice varieties, under conventional flat planting and under ridge planting on an iron-toxic soil in 1986. Bar on the right shows the average yield of ITA 212 and ITA 247 under nontoxic flat planting.

Flooding vs ridging: the latter was highly effective against iron toxicity. Ridging, plus a resistant variety, can substantially increase rice yields on iron-toxic soils.

tion for small farms in developing countries.

Soil ridging at least 12 cm above the water surface was also highly effective against iron toxicity, increasing mean yield of the varieties by 245% in 1986. In addition, it was found that ITA 247 responded significantly more than ITA 212 to ridging (Figure 23). This finding shows the importance of using a resistant variety to maximize the benefit from ridging. The combined use of ITA 247 and ridge planting increased yield in this severely toxic paddy by almost 600%, nearly reaching the level achieved in nontoxic paddies.

These results show that both a resistant variety and soil ridging can substantially increase rice yields on iron-toxic soils, especially when used in combination. The former requires little or no extra expenditures by farmers, the latter some hard work. Together they have great potential to reduce losses due to iron toxicity in many rice areas of West Africa.

Annual Report Executive Summary

Root, Tuber and Plantain Improvement Program

Dr. S. K. Hahn
Program Director

Highest priority in this program is given to cassava breeding and to research on the post-harvest technology and utilization of cassava. The program's resources are used primarily to breed improved cassava varieties for local adaptation to diverse ecologies and cropping systems. The crop is the chief source of dietary food energy for the majority of people living in the lowland humid tropics and much of the subhumid tropics of West and Central Africa, providing more than two and a half times as many calories as either maize or yams—the next two most important staple foods in the region. The tubers of many varieties keep well in the ground for a year or more, so cassava is the primary food reserve crop in Africa. Because cassava processing labor requirements may equal or exceed those for all other pre-harvest production activities, increasing research attention is being paid to this function.

The program also carries out research on two additional crops of high priority in the subhumid and humid tropics: plantains and yams. Both are staple foods for millions of Africans. IITA's global mandate for sweet potato improvement will be transferred during 1988 to the International Potato Center (CIP). Sweet potato germplasm developed by IITA is to be used by this center. Work on cocoyams was discontinued.

In addition to plant breeding, program scientists conduct research on the pathology, entomology, physiology, and nematology of cassava, yams, plantain, and sweet potatoes, and they cooperate in the special Africa-wide project for biological control of cassava mealybug and cassava green mite. They also cooperate with CIAT for the improvement of cassava, particularly through exchange of germplasm.

Cassava research: Earlier work resulting in the development of lines resistant to the two most destructive pathogens of cassava in Africa (cassava mosaic virus and cassava bacterial blight diseases) had a significant impact. The initial spread of the disease-resistant material was hindered only by the slow rate of multiplication of cassava planting material and by the restrictions on its movement imposed by national plant quarantine regulations. These barriers have been partially overcome, and clonal material is now transferred to over 30 countries *in vitro* as shoot tip cultures.

Following this success due to scientists in several countries, the emphasis in the present program is on the quality of cassava tubers and host-plant resistance to mealybugs and green mites. Tuber quality is assessed in terms of starch quality for incorporation in bread flours, cyanide content, consumer preferences, and skin and flesh color. White skinned and yellow fleshed tubers will be preferred if they can be processed into gari and other products without peeling and adding palm oil.

A recent finding gives a new impetus to cassava breeding strategies and to the study on evolution of *Manihot* genus. An improved cassava variety—TMS 4(2)1425—showed uniformity at F_1 (cassava normally segregates at F_1) when it was crossed as a female with several other *Manihot* species. This is a strong indication that apomixis is in operation. Since apomixis provides a method for cloning plants through seeds, international distribution and multiplication of improved genotypes will become simpler and easier for testing them under a wide range of environmental conditions without much phytosanitary risk and time required for phytosanitation.

A new method for rapid multiplication and ease of distribution of cassava planting material does away with the use of costly and bulky soil as a sprouting medium (four to six tons of soil per hectare). Short cuttings with two or three nodes are treated with a fungicide and put in a polyethylene bag. The residual moisture and light through the bag promote 95 to 100% sprouting in three to five days. The lightweight bag is easy and convenient to transport and store, so this new method should be of major help in the distribution of cassava planting material to farmers.

Nigeria has adopted six new IITA-improved cassava varieties for release to farmers after extensive testing over three years in the National Coordinated Research Project. The varieties produced large yields and showed good levels of resistance to cassava mosaic virus and cassava bacterial blight diseases. Two were resistant to cassava mealybug and green mite.

Because of a rising demand for bread as a staple food in parts of Africa, large wheat importations have decreased foreign exchange reserves. This called for the substitution of flours from tropical starchy crops. Previous studies at IITA demonstrated that flours of certain cassava varieties could successfully be used as a substitute and the most recent one shows that the substitution of water yam flour up to 40% can produce acceptable bread.

Yam research: Despite the complex reproductive biology of yams, crosses are made and up to 10,000 seedlings grown annually for clonal (F_1) selection. The selection criteria are chiefly disease expression, storability, utilization potential, consumer acceptability, and tuber shape. In collaboration with the Genetic Resources Unit, the program collects, maintains, and evaluates yam germplasm.

Yams are traditionally produced by reserving one quarter of the harvest for use as "seed" for the next crop. Scientists have made progress in improving the "minisett" and "microsett" systems to provide quality, low-cost, and abundant planting material. Several promising new water yam clones resulting from hybridization have been identified.

Sweet potato research: Clones resistant to weevils, the sweet potato virus complex, and root-knot nematodes have been produced. Over 50 non-sweet varieties (preferred by many people in West and Central Africa) have been selected from IITA's large germplasm collection and used in the breeding program. Improved IITA sweet potatoes have been sent to more than 50 countries and widely adopted in Cameroon, Sierra Leone, Nigeria, Rwanda, and other countries. Tissue culture methods are used to free elite planting material of pests and diseases, qualifying planting material for international distribution through quarantine barriers, rapid multiplication for scarce germplasm, and the conservation of genetic material. The Tissue Culture Unit has more than 1,500 clones of root and tuber crops and plantain being conserved in this way.

The problem of genetic instability for rapid multiplication and conservation has become an issue in the application of tissue culture technology. Therefore, five sweet potato varieties were selected to evaluate their stability after having been maintained in the tissue culture storage for the past six years. Compared with field maintained varieties, no morphological changes had occurred in the tissue culture material.

Plantain research: One of the program's major challenges is to help solve the problem of black Sigatoka disease in Africa, and IITA has accepted the responsibility to breed plantains and cooking/starchy bananas for resistance to this destructive disease. Some of this work will be done in collaboration with the Honduran Foundation for Agricultural Research (FHIA), which is a leader in such research in Central America, and with the International Network for the Improvement of Banana and Plantain (INIBAP). The latter, in collaboration with IITA, coordinates the West African Regional Cooperative for Research on Plantain (WARCORP). Members of this organization meet annually to review research results and strategies. It is a unique research organization, operating as a "research cooperative" between national agricultural research systems and an international institute.

Two scientists at IITA's substation in Onne, Nigeria are working on plantain breeding, germplasm collection, *in vitro* preservation, international transfer of material, "yield decline syndrome" (which occurs when the crop is not grown with continuous mulching in compound gardens), somaclonal variation, rapid multiplication, plantains in alley farming, and nematodes.

Post-harvest research: Special attention is being given to post-harvest handling of root and tuber crops with particular emphasis on cassava. A scientist with special skill and experience in the design and development of farm-level food processing machines has been added to the program, and he is working on the development of efficient but simple equipment that can be made in village workshops.

Assistance to national research programs: Improved elite materials were tested internationally in cooperation with national programs and selected crop lines evaluated in specific environments, including locations in Zaire with Programme National du Manioc (PRONAM), in Cameroon with Cameroon National Root Crop Improvement Program (CNRCIP), in Rwanda with Rwandan National Root Crop Improvement Program (RNRCIP), and in Nigeria with National Root Crops Research Institute (NRCRI).

The Programme National du Manioc was active in the improvement of cassava varieties and technology movement to the farm level and the strengthening of the national program with in-service and degree-related training. PRONAM continued the testing program of improved varieties in different environments and the multiplication and distribution to farmers in collaboration with other agencies.

The Cameroon National Root Crops Improvement Program continued to serve the smallholder farmer in the development of suitable low-input production systems using cassava, yam, sweet potato, and cocoyam crops. Not only was on-station testing conducted but farmers were enrolled in testing of local production systems, and they participated in crop multiplication to help meet the heavy demand for improved planting material. The Rwandan National Root Crops Improvement Program advanced its research on the special problems of highly varied topographical relief, altitude, and rainfall patterns. Farmer-oriented technology transfer for local production systems and farmer evaluation of promising improved material for introduction and adaptation were pursued. National program reinforcement was through networking, multilocational trials, in-service training, and regional workshops.

The East and Southern African Rootcrops Research Network (ESARRN) formally began operation in 1987 by establishing its headquarters at the Chitedze Agricultural Research Station in Malawi with an IITA breeder/coordinator heading the network. Priorities include introduction of resistant clones in tissue culture form, resistance to other major pests and diseases, manpower development through workshops, and in-country training and degree-related fellowships. ESARRN provided the necessary linkage to help break the feeling of isolation among the scientists in the region, encourage joint planning and sharing of information, and avoid duplication.

A total of 50 sweet potato clones, including IITA sources and local cultivars, were tested on over 200 farmers' fields for three years in the southern part of Mozambique. The three top clones (INIA 18, INIA 3, and INIA 10) were all from IITA sources. They gave an average yield of 32 t/ha—nearly twice that of local check varieties.

(In the following pages, a few 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 Root, Tuber, and Plantain Improvement Program.)

An Apomictic Type of Segregation in Interspecific Crosses of Cassava

Cassava (*Manihot esculenta*, Crantz)—known to be an allo-tetraploid plant with a basic chromosome number of nine—is normally a vegetatively propagated, cross pollinated, and monoecious plant. It is thus genetically very heterozygous and gives rise to segregation at F_1 generation when selfed and outcrossed with other varieties within species and with different species. Over 100 related *Manihot* species have been reported as allo-tetraploids with 2n (=4x)=36, and some of them have been crossed with cultivated cassava.

Several related wild species have been used in IITA's cassava breeding program to introduce their desirable genetic sources into cultivated cassava, particularly for resistance to diseases such as cassava mosaic virus (CMV) and bacterial blight (CBB) and to pests such as cassava green spider mite (CGM) and mealybug (CM) and for low cyanide content. Resistance to CMV and CBB and low cyanide characteristics have

The segregants (at F_1 generation) of the crosses of cassava cultivar TMS 4(2) 1425 (*Manihot esculenta*) with *M. chlorosticta* (M IV) on the left, *M. dichotoma* (left below) and *M. glaziovii* (right below) show uniform tuber shape and color similar to those of TMS 4(2) 1425, indicating apomixis. Since this mechanism provides a method for cloning plants through seeds, international distribution of improved genotypes will become simpler and easier for testing them under a wide range of environmental conditions without much phytosanitary risk and time required for phytosanitation and multiplication.

been successfully introgressed from *M. glaziovii* into high yielding, disease resistant, and good quality cassava varieties and populations.

In 1987, four IITA improved cassava varieties were crossed as female with related *Manihot* species such as *M. dichotoma* and *M. leptophylla*. An IITA improved variety, TMS 4(2)1425, was also crossed with *M. chlorosticta* and *M. glaziovii* in 1983. The characteristics of the parents used for the interspecific crosses are listed in Table 36.

The results of segregation of F_1 plants resulting from the interspecific crosses of cassava with the related *Manihot* species are shown in Table 37. When cassava varieties TMS 30572, TMS 63397, and TMS 91934 were used as females and crossed with *M. dichotoma* and *M. glaziovii*, the F_1 plants segregated into both cassava and respective *Manihot* species types. However, when cassava variety TMS 4(2) 1425 as female was crossed with *M. chlorosticta*, *M. dichotoma*, *M. glaziovii*, *M. leptophylla*, all the F_1 plants of all the interspecific crosses looked like TMS 4(2) 1425 and were very uniform, with the exception of one F_1 plant which was similar to *M. glaziovii*.

These observations are interpreted as an indication of apomixis, probably due to the development of gametophytes with unreduced chromosome numbers and of embryos without fertilization. This needs detailed cytological studies and further prog-

Table 36. Plant characteristics of the parents used for interspecific crosses between cassava (Manihot esculenta, Crantz) and related species.

Parent	Plant characteristics
Improved cassava varieties	
TMS 4(2)1425	White stem and tuber skin color; light green and pubescent young leaves; low branching height.
TMS 30572	Black stem and dark brown tuber skin color; dark brown and non-pubescent young leaves; medium branching height.
TMS 63397	Brown stem and tuber skin color; light green, glabrous young foliage at apex; medium branching height.
Related *Manihot* species	
M. glaziovii	Dark brown stem and root skin color; light green glabrous young foliage at apex; high branching height; plant heights 4 to 15 m; no tuberization.
M. dichotoma	Dark brown stem and root skin color; light green, glabrous young foliage at apex; cleft to base into strip-shaped lobes; plant heights 4 to 6 m; no tuberization.
M. chlorostieta	Climbing or creeping vines to 3 m; light green, glabrous young foliage at apex, cleft to the base into 5 lobes, oblong-lanceolate lobes; grayish brown stem color; brownish tuber skin; tuberization.
M. leptophylla	Subscandent, woody, vine-like shrubs, 3 to 4 m tall; brown stems; yellow green, pubescent young foliage at apex; no tuberization.

Table 37. Segregation among progeny of Interspecific crosses between cassava (*Manihot esculenta*, Crantz) and a number of related species.

Cross combinations	Segregation into cassava type and related species type with different stem colors							
	Cassava type				Related species type			
	White	Brown	Dark brown	Total	White	Brown	Dark brown	Total
1983 Crosses								
TMS 4(2)1425 × *M. chlorosticta* (M III)	—	—	—	230	—	—	—	0
TMS 4(2)1425 × *M. chlorosticta* (M IV)	—	—	—	296	—	—	—	0
TMS 4(2)1425 × *M. dichotoma*	—	—	—	177	—	—	—	0
TMS 4(2)1425 × *M. glaziovii*	—	—	—	428	—	—	—	0
1987 Crosses								
TMS 30572 × *M. dichotoma*	0	0	17	17	0	0	22	22
TMS 30572 × *M. glaziovii*	0	0	34	34	0	0	35	35
TMS 4(2)1425 × *M. glaziovii*	0	9	40	49	0	1	0	1
TMS 4(2)1425 × *M. leptophylla*	0	1	7	8	0	0	0	0
TMS 63397 × *M. dichotoma*	0	112	69	180	0	10	26	36
TMS 63397 × *M. glaziovii*	0	50	57	117	0	9	1	10
TMS 91934 × *M. dichotoma*	0	20	30	50	0	6	24	30
TMS 91934 × *M. glaziovii*	0	14	0	14	0	12	18	30
TMS 4(2)1425 open pollinated	214	61	65	340	0	0	0	0

eny testing to confirm the apomictic reproduction and to determine the mechanism associated with this phenomenon. The progenies from the crosses of TMS 4(2) 1425 x *M. glaziovii* and TMS 4(2) 1425 × *M. leptophylla* and from the open pollinated TMS 4(2) 1425 showed segregation into various stem colors. This means that the apomixis in this case is not obligatory but seems to be facultative. TMS 63397 also showed an apomictic trend to a certain degree when crossed with *M. dichotoma* and *M. glaziovii*.

TMS 4(2) 1425 is a selection made from the cross 58308 × Oyanrugba funfun. The clone 58308 which was used as the female parent is a derivative from the interspecific cross of cassava with *M. glaziovii*, and Oyanrugba funfun is a Nigerian local cultivar. It is therefore postulated that the origin of this apomixis seems to be associated with interspecific hybridization and polyploidal nature of cassava and its related *Manihot* species.

Apomixis increases the opportunity for developing superior gene combinations and provides a method for rapid incorporation of desirable characteristics. Incorporation of desirable genes from the apomictic TMS 4(2) 1425 with high yield, high dry matter, resistance to cassava mealybug and green spider mite, low cyanide, and poundability characteristics into other new improved clones and populations will become much easier. Particularly, incorporation of the recessive genes responsible for low cyanide from TMS 4(2) 1425 will be simpler and more effective.

Also, since apomixis provides a method for cloning plants through seeds, international distribution of improved genotypes will become simpler and easier for testing them under a wide range of environmental conditions without much phytosanitary risk and time required for phytosanitation and multiplication. Isolation is not necessary to produce the F_1 seeds and to maintain and increase parental clones. The apomictic mechanisms provide a challenge to scientists in cytogenetics, evaluation, plant breeding, cell culture, and molecular biology for transferring and using apomixis in the future to accelerate cassava varietal improvement.

New Alternative Technique for Sprouting Cassava without Soil for Rapid Multiplication

A previous report from IITA described a new method for rapid multiplication of cassava (*Research Highlights* 1983), but the latest research has resulted in a major improvement: ministem cuttings can be nursed in polyethylene bags without soil which makes this alternative method quicker, less expensive, and more convenient.

Under the method described in 1983, ministem cuttings (each with a node or two) are nursed for four to six weeks in polyethylene bags or nursery beds filled with garden soil before transplanting in the field. Large quantities of soil (over five tons on an oven dried basis) are needed to nurse cuttings for planting in one hectare, and the soil usually has to be excavated from another site and transported to the nursery. Approximately 50 man-days are needed to fill polyethylene bags with soil to nurse the cutting materials for one hectare, plus additional labor to plant one cutting per bag (10,000 plants/ha) and to care for the plants for four to six weeks before transplanting. Also, the planting materials are bulky and heavy to transport to the field, and the soil used could carry disease-causing organisms such as nematodes, fungi, and bacteria. Sterilizing the soil to overcome this problem is expensive and facilities to do this are not easily available.

With the latest technique, the ministem cuttings are dipped in a fungicide/water suspension. (The rate is 24 grams of Benlate or Demosan fungicide for each four liters of water.) Then the cuttings are put directly into perforated polyethylene bags and stored in a shaded area or under a roof. Various sizes of bags can be used—from small to large—as long as they are not completely filled. (About one-third of the top space needs to be empty to allow for aeration.)

Depending on the cassava variety, 95 to 100% of sprouting occurs in three to five days. In Togo, 100% sprouting was achieved with the variety "Nakoko" in two-and-one-half days, but some varieties may require a few more days to give a large percentage of sprouting. High humidity and temperatures inside the polyethylene bag promote a rapid and uniform sprouting. The sprouted ministem cuttings established well in the field at eight weeks after transplanting (Table 38).

The new technique has other advantages: the ministem cuttings can be stored for a few days, fairly large numbers carried by hand or transported over long distances with a limited space requirement, and they can be used for mechanical planting.

Table 38. Percentage of field establishment for cassava ministem cuttings pre-sprouted in perforated polyethylene bags.

Cassava variety	Condition of materials before transplanting	No. mini-stems planted	% establish-ment (8 WAT)*
TMS 4(2)1425	Sprouted with shoots & roots	950	89.3
TMS 4(2)1425	Sprouted with shoots only	1260	89.4
TMS 50395	Sprouted with shoots only	420	86.9

**WAT = Weeks After Transplanting.*

After being dipped in a fungicide/water suspension and put in a perforated polyethylene bag (above), 97% of the cassava ministem cuttings sprouted shoots within seven days. Right, IITA scientist Dr. J.A. Otoo holds cassava tubers from ministem cuttings five months after being planted in the field.

Nigeria Adopts Improved Cassava Varieties

Six new IITA-improved cassava varieties have been adopted by Nigeria after extensive field testing over three years in nine locations in a Nationally Coordinated Research Project (NCRP) funded by the Federal government. Three agro-ecological zones were covered in the tests: forest, savanna, and the transitional zone in between, along with high, moderate, and low rainfall areas and different soils.

National scientists inspect one of IITA's improved cassava varieties adopted by Nigeria.

The assignment for the team of IITA and Nigerian scientists who conducted the trials was to validate the claims of cassava breeders concerning varietal superiority before any varieties were recommended to farmers. Tuber yield, pest and disease resistance, food quality characteristics, and adaptation to ecological zones were assessed.

IITA-improved cassava varieties recommended by NCRP are TMS 50395, TMS 30572, TMS 4(2)1425, TMS 91934, TMS 30555, and TMS 63397. NCRP (Cassava) is a subtechnical committee of the National Crop Variety Release Committee which recommends varieties for official naming and release. The three-year mean yields of the varieties (1984–86) at Ibadan (moderate rainfall and medium soil fertility conditions) and Onne (high rainfall and poor sandy soil conditions) are presented in Table 39. TMS 50395 gave the highest fresh yield at Ibadan followed by TMS 91934; TMS 91934 and TMS 4(2)1425 produced the largest dry

Table 39. Cassava tuber dry matter yields (t/ha) of six IITA-improved varieties at Onne and Ibadan, Nigeria (1984–86).

	Ibadan				Onne				Two location mean
	1984	1985	1986	Mean	1984	1985	1986	Mean	
TMS 50395	8.4	4.2	11.2	7.9	6.0	4.1	6.6	5.9	6.9
TMS 91934	11.0	5.6	9.8	8.8	5.1	6.3	6.0	5.8	7.3
TMS 63397	10.2	4.8	8.3	7.8	5.9	6.8	4.4	5.7	6.8
TMS 30555	6.0	4.6	8.2	6.3	3.8	4.2	3.2	3.7	5.0
TMS 4(2)1425	6.6	6.0	7.9	6.8	7.6	5.4	7.4	6.8	6.8
TMS 30572*	7.3	5.7	6.7	6.6	4.3	5.6	5.4	5.1	5.9
LSD (5%)	2.3	2.5	3.5	1.5	1.2	1.6	1.3	0.9	0.8

**The variety most widely adopted by farmers in Nigeria.*

Table 40. Scores of six cassava varieties for resistance to diseases and pests at Onne and Ibadan, Nigeria (1986).

Variety	Resistance to CMV** 3 MAP***	CMV 6 MAP	CBB 3 MAP	CBB 6 MAP	CAD 6 MAP	GM
TMS 50395	2.7*	2.2	2.0	2.7	3.0	2.7
TMS 91934	3.0	3.0	2.0	2.7	2.7	2.2
TMS 63397	2.0	2.0	2.0	2.0	2.5	2.8
TMS 30555	2.2	2.0	2.0	2.5	2.7	3.5
TMS 4(2)1425	3.0	3.0	2.0	2.2	2.2	2.5
TMS 30572	2.0	2.0	2.0	2.5	2.7	3.2
LSD (5%)	0.4	0.3	N.S	N.S	N.S	1.1

Scoring based on a 1 to 5 scale: 1 = no damage, 5 = severe damage.
**CMV = Cassava Mosaic Virus; CBB = Cassava Bacterial Blight; CAD = Cassava Anthracnose Disease; GM = Green Mite.*
***MAP = Months After Planting.*

matter tuber yields at Ibadan and Onne, respectively.

In the savanna areas (Mokwa, Zaria, Jalingo), many of the improved varieties outyielded the local ones. For example, in Zaria, TMS 4(2)1425, TMS 50395, TMS 91934 and TMS 30572 recorded yield increases of 147, 70, 68, and 43%, respectively, over the local variety. In Mokwa, TMS 50395, TMS 4(2)1425, and TMS 30572 outyielded the local by 81, 73, and 54%, respectively.

At Umudike, in a high rainfall zone, TMS 50395, TMS 4(2)1425 and TMS 30572 yielded 100, 72, and 46% more than the local variety "Nwugo." At six and nine months after planting, TMS 50395 gave the highest yields in that area in 1986; when harvested at 12 months, tuber yield declined 31% compared with the yield at nine months after planting. It was therefore adopted as an early variety.

In addition to larger tuber yields, the six improved varieties showed some resistance to cassava mosaic virus, cassava bacterial blight, and cassava anthracnose disease (Table 40). TMS 4(2) 1425 and TMS 91934 showed a good level of resistance to the cassava green spider mite (Table 40). Cassava mealybug attack was not uniform. Four NCRP team members had the opportunity to observe TMS 4(2) 1425 and TMS 91934 in other trials at IITA to confirm the levels of resistance of the two varieties to the cassava mealybug and green spider mite. When the other varieties were attacked by the two pests during the dry season, they made some recovery after the rains started.

The quality of processed food (such as gari, lafun, and fufu') made from the improved varieties was rated "good" or "very good."

Flour from Root and Tuber Crops for Making Bread

With the increasing demand for bread in various African cities, large importations of wheat have contributed to the drain of foreign exchange reserves. Nigeria, for example, imported wheat costing more than $100 million in 1986 and in 1987 banned wheat imports completely. Substitution of wheat flour with flour from locally-produced starchy crops is being tried with limited success so far. Bakers are encountering technological problems in using substitute flours, a limited supply, and poor consumer acceptance of the bread. Therefore, IITA scientists have been conducting laboratory tests to determine the best varieties of selected root and tuber crops from which flour can be processed for making bread (*Research Highlights* 1984).

In the most recent tests, the researchers partially substituted water yam flour for wheat flour. A maximum substitution of 40% flour without the addition of any bread improver produced an acceptable product. Compared with cassava bread, yam bread is less crumbly even at a high flour substitution rate. Water yam (*Dioscorea alata*) flour produced better bread than white yam (*D. rotundata*). Bread loaves made of flour from water yam variety TDa 297 had better scores for taste, crumb texture and color, and crust texture and color than the other three varieties tested (Figure 24). This result showed that there is a difference in bread loaf quality depending on the yam specie and the variety within the specie.

Because of its inability to form a stable

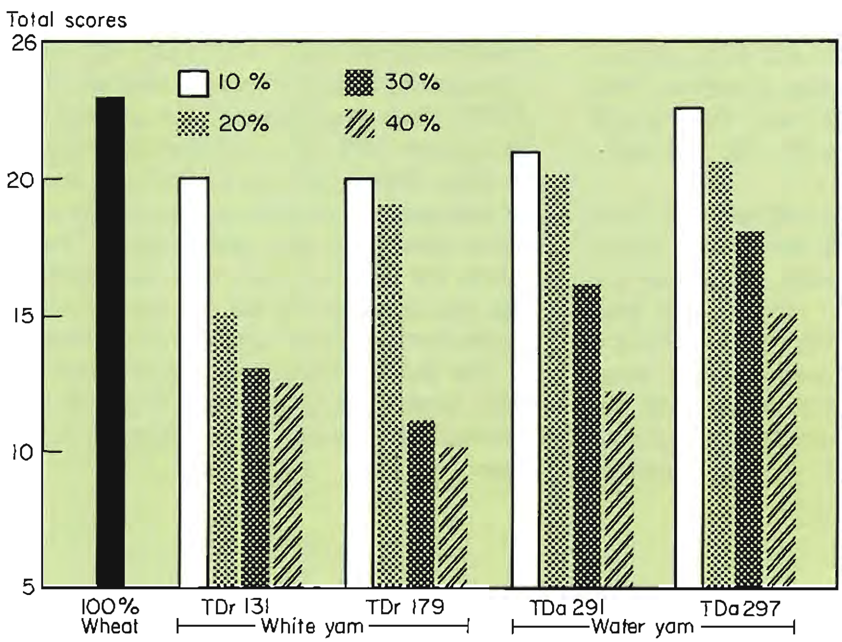


Figure 24. Total quality scores for bread made from wheat and various concentrations of yam flour produced from two white and two water yam varieties. The scores are based on taste, crumb texture and color, and crust texture and color with each characteristic rated from 1 to 5.

Appearance of bread loaves made from the flour of four yam varieties: (top photo) 10% substitution for wheat flour; (lower photo) 40% substitution.

dough, water yam cannot be processed into pounded yam—a preferred staple in West Africa. The production yield of water yam is about twice that of white yam but its utilization is limited. If water yam flour could be produced commercially in larger quantities for bakers and made into bread acceptable to consumers, farmers would be encouraged to increase water yam production.

Sweet Potato Field Cuttings Compared with *In Vitro* Plantlets

Because some questions have been raised about the genetic stability when the *in vitro* technique is used for both rapid multiplication and germplasm conservation, scientists are cultivating IITA root crops that have been maintained through this technique over the past six years. As a start, they selected five sweet potato varieties: TIB 11, TIS 2544, TIS 3017, TIS 8250, and TIS 70357.

The *in vitro* plantlets were transplanted first in the screenhouse and two months later planted in the field. At the same time, cuttings of the same varieties maintained in the field were also planted. The researcher used a randomized complete block design with three replications and had the plants harvested four months after planting. Morphological characters and yield data were recorded and compared on the two types of planting material.

No differences showed up in morphological characters (such as pubescence on the shoot apex, pigmentation on the petiole and stem, leaf shape, and color of the tuber skin and flesh) or in tuber dry matter content. However, there were significant differences between the two types of planting material in tuber yield and number of marketable tubers: *in vitro* planting materials had larger tuber yields and more marketable tubers (Table 41). The percentage of yield increase in the varieties ranged from 32–38% except for TIS 3017 which had only an 8% increase.

Researchers contribute the yield increase in *in vitro* material to the virus-free status of

In vitro *sweet potato plantlets produced larger and more marketable tubers than field cuttings: left, the harvest from one* in vitro *plant; right, the harvest from a field cutting. Out of five varieties, TIS (shown here) had the best performance.*

the planting material. The yield increase is expected to decline over successive planting seasons as the materials are exposed to natural infection pressure. The amount of decline depends on the disease pressure and the variety, but the yield increase can be sustained for several years if the planting materials are maintained under a low disease pressure condition.

Table 41. Yields of sweet potatoes using two types of planting materials: Field cuttings (FC) and virus-free cuttings (TC) using the* in vitro *technique.

Variety	No. tubers/plant marketable		Tuber weight/ plant (kg)		% weight increased
	FC	TC	FC	TC	
TIB 11	3.8	4.6	0.45	0.77	32
TIS 2544	2.6	3.5	0.27	0.59	32
TIS 3017	1.4	1.9	0.33	0.41	8
TIS 8250	4.5	5.2	0.72	1.10	38
TIS 70357	3.2	3.2	0.32	0.68	36

Annual Report Executive Summary
Genetic Resources Unit

On March 10, 1987, modern and expanded laboratory facilities were dedicated for IITA's germplasm "bank" which can store seeds and maintain their viability for more than a century, thereby conserving African foodcrop genetic resources for present and future plant breeding and related research. The Government of Italy provided the funds for this laboratory in the Genetic Resources Unit of the Institute.

The overall goals of this Unit include germplasm exploration, collection, preservation, characterization/evaluation, distribution, and documentation of rice, cowpeas, soybeans, Bambarra groundnuts, and yams. Also, scientists conduct research to increase the knowledge and usefulness of germplasm, and during 1987 they focused on cowpeas, Bambarra groundnuts, and other *Vigna* species.

Nearly 3,000 samples of germplasm of various crops were distributed on request to over 20 countries. IITA's crop improvement scientists and virologists were assisted in selecting numerous germplasm accessions from existing collections for their research. The Unit continued to characterize, document, and multiply/rejuvenate the germplasm. A total of 699 accessions of cowpeas, 1080 of rice, and 1350 of soybeans were characterized for up to 30, 41, and 4 characters, respectively. This characterized information was routinely updated by computer to provide fast retrieval of information. More than 10,000 accessions of germplasm, consisting of 4,839 accessions of cowpeas, 3,699 of rice, 1,350 of soybeans, 794 of Bambarra groundnuts, and 100 of miscellaneous legumes were grown for multiplication or rejuvenation during the year.

Research included genetic studies on purple cowpea cotyledons, interspecific hybridization between cowpea and wild *Vigna* species, and agronomical trials on Bambarra groundnuts. Also, in collaboration with scientists in Italy, research was conducted on cytogenetics in *Vigna* species and nutritional and anti-nutritional factors in *Vigna* which may relate to host-plant resistance.

IITA scientists turned to wild relatives of cowpeas for sources of resistance to pests and diseases. The process of collecting wild relatives of crop plants is often a long and arduous one which involves systematic study, survey, planning, and sustained exploration by teams of plant explorers. In 1987, scientists of the Unit collected the wild relatives of cowpeas in eight African countries. IITA continues its commitment as a genetic resources center which collaborates with national programs and the International Board for Plant Genetic Resources (IBPGR) in the exploration and collection of germplasm of IITA-mandated crops.

(In the following pages, a few 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 Genetic Resources Unit.)

Collecting wild rice in Zambia for IITA's extensive germplasm collection. Wild species of plants are being used because of their potential for breeding disease and insect resistant varieties of food crops.

Exploration for Wild Species of Plants and Research in Biotechnology for Germplasm Improvement

To increase the genetic diversity for plant breeding, IITA scientists, in collaboration with the International Board for Plant Genetic Resources and national programs, are concentrating on the exploration and collection of related wild species of cultivars that have not been adequately collected in earlier exploration activities in Africa. They launched plant exploration missions in 1987 in eight African countries and collected a total of 2,783 samples of many different crop species (Table 42).

The center of diversity of the wild species of the section *Catiang* of the genus *Vigna* to which cowpeas belong falls in the south and southeastern region of Africa. About 100 samples of the wild subspecies of *V. unguiculata* and wild species *V. nervosa*, all closely related to cowpeas, were found and collected in five countries of that region: Botswana, Malawi, Zambia, Zimbabwe, and Tanzania. Another 66 samples of the wild subspecies *dekindtiana* were also collected in Cameroon, Chad, and Niger. These new collections will offer both international and national scientists a much wider genetic diversity than they have had. Exploration trips during 1987 to the eight countries resulted in finding 1,478 samples of both wild and cultivated *vigna* species.

Africa is rich in rice genetic resources: two cultivated species, *O. glaberrima* (West African species) and *O. sativa* (Asian species), plus five indigenous wild rice species. The cultivation of *O. glaberrima* is confined to West Africa. *O. sativa* and *O. longistaminata* were by far the most commonly found species throughout the eight countries explored. Local maize germplasm was collected in Chad, Cameroon, Tanzania, and Zimbabwe, yams in Cameroon, and cassava in Tanzania and Cameroon. In addition, sorghum and millet germplasm samples were obtained for ICRISAT and Bambarra groundnut (*V. subterranea*), Fonio (*Digitaria oxillis*), and Sesame (*Sesame indicum*) for the Government of Niger. Also, the Genetic Resources Unit funded national programs in Ghana and Kenya for germplasm exploration during 1987.

Table 42. Germplasm collected in 1987 from eight African countries: 2,783 samples of different crop species.

Plant species	Tanzania	Zimbabwe	Zambia	Malawi	Botswana	Chad	Cameroon	Niger	Total
Legumes									
Vigna unguiculata cvs.	55	111	52	89	21	172	64	127	691
" subsp. *dekindtiana*	10	7	21	19	30	13	26	37	163
" subsp. *stenophylla*		1							1
" subsp. *tenuis*		1							1
Vigna nervosa		1							1
Other wild *Vigna* spp.	49	14	37	44	59	12	71	26	312
Vigna subterranea	6	48	52	59	9	70	32	33	309
Other pulses	128	74		5		78	35	2	322
Cereals									
Oryza sativa	84	13	4	26	3	22	4	42	198
O. glaberrima						17		17	34
O. longistaminata	12	2	1	14	11	7		16	63
Other wild *Oryza* spp.	8					1		7	16
Zea mays	50	44				72	5		171
Sorghum spp.		59				185			244
Pennisetum spp.		52				43			95
Digitaria oxilis								5	5
Root and tubers									
Dioscorea spp.							17		17
Manihot esculenta		7					2		9
Other crops									
Sesame indicum								49	49
Others	1	29				23	29		82
						Grand total			**2783**

To date, IITA scientists have completed more than 50 plant exploration missions in 24 countries in Africa and collected about 20,000 samples of germplasm (Figure 25). At present, the institute has approximately 30,000 accessions of germplasm, consisting of 15,000 accessions of cowpeas, 11,000 of rices, 2,000 of Bambarra groundnut, 1,400 of soybeans, and 1,000 of other miscellaneous species. All the germplasm material is preserved at IITA in a modern gene bank and seed laboratory facility which was dedicated on March 10 (1987). The Government of Italy provided a grant for this new facility in which germplasm can be kept viable for 100 years.

IITA receives germplasm from cooperators and volunteers throughout the world and provides seeds to scholars, scientists, and agricultural workers worldwide. It is a center of a worldwide effort to collect, evaluate, document, and preserve germplasm of cowpeas, rice, African food legumes, and yams to be used in plant breeding and other research.

Sources of high levels of resistance to cowpea coreid bug, *Clavigralla tomentosicollis* and cowpea pod borer, *Maruca testulalis* have been identified from the germplasm collection of *Vigna vexillata* (TVNu72 and TVNu73). Unfortunately, this species cannot be hybridized with cowpeas, but

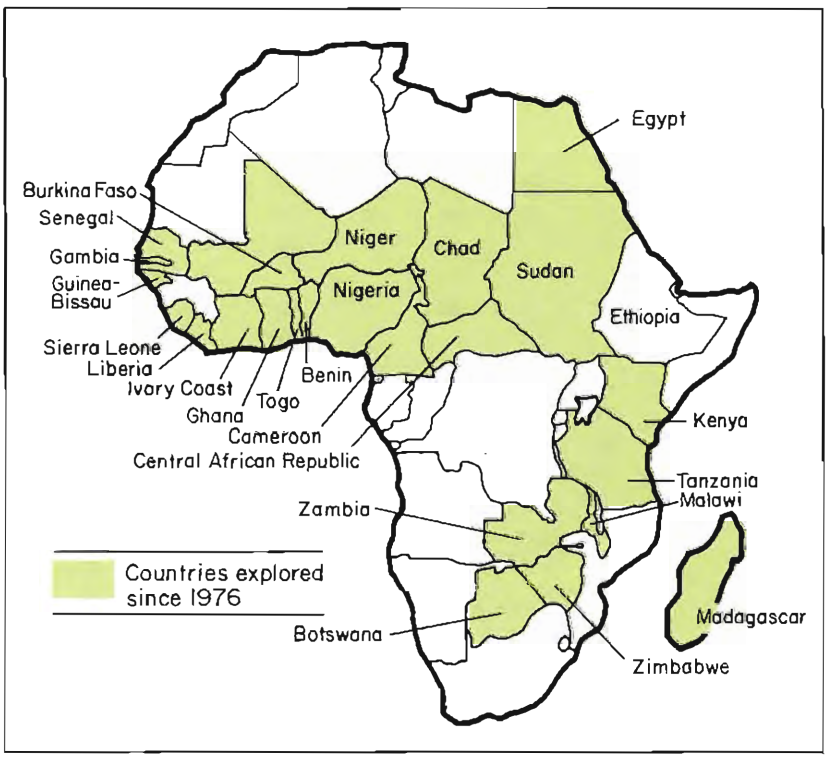
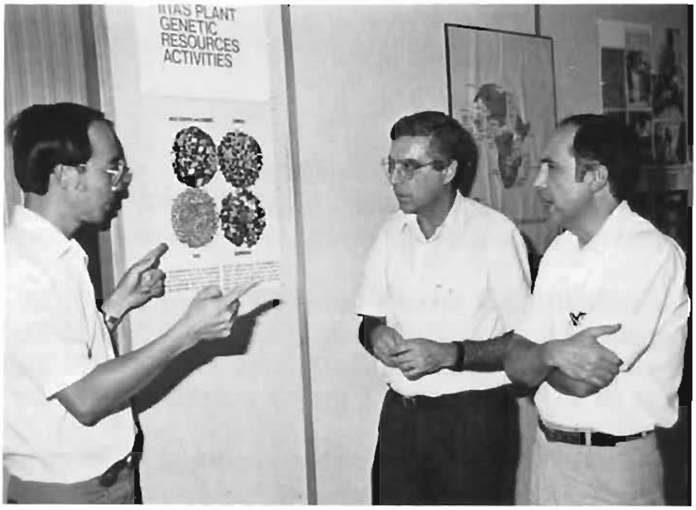
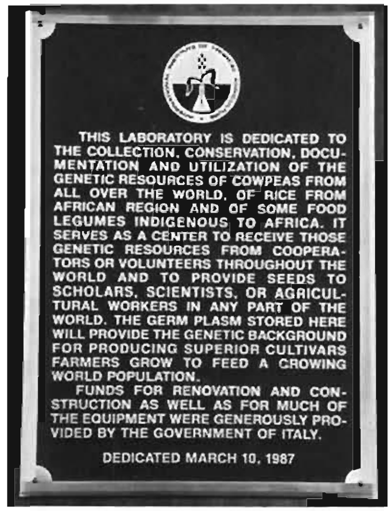


Figure 25. Over 50 plant exploration missions in 24 African countries have been carried out by IITA scientists since 1976. Eight countries were explored and 2,783 crop germplasm samples collected in 1987.





Dr. N.Q. Ng (left) describes some of the activities of IITA's Genetic Resources Unit, which are funded by the Italian government, to Luigi Monti (center), professor of agricultural genetics at the University of Naples, and Dr. P. Perrino, director of the Plant Germplasm Institute at Bari, Italy. Prof. Monti was one of the principal speakers at the dedication ceremony of the new facilities for IITA's germplasm laboratory on March 10, 1987.

joint collaborative research in biotechnology was established recently with the Universita' of Napoli and the Universitá della Tusci in Italy in an attempt to transfer the resistant gene from this species to cowpeas. In the initial stage of this research, scientists concentrated on setting up a suitable technique for callus induction and plant regeneration—the bottleneck for applying this innovation for cowpea breeding.

They have made some progress in obtaining calli from several explants of cowpeas by using Murushige and Skoog (MS) medium supplemented with a different combination of the auxin 2,4-dichlorophenoxyl acetic acid (Z, 4-D) and cytokinnin (Kinetin). Root formation from those calli was observed in a medium containing auxin napthalene acetic acid and cytokinin Benzyl adenine purine (BAP). Attempts to regenerate shoots from calli is underway.

The scientists have worked with protoplast culture in which fast dividing cells were obtained. The cells have the capability to fuse with *Nicotiana plumbaginifolia* protoplast, indicating that it may be possible to use the protoplast fusion technique to introduce alien genes into cowpea cultivars.

Annual Report Executive Summary
Virology Unit

Virologists' research activities included the collection, identification, and maintenance of new isolates (strains) of viruses relevant to IITA's plant breeding programs and a study of the importance of variability among such isolates to virus resistance.

This work is strengthened by a collaborative project between IITA/U.S. Department of Agriculture to produce monoclonal antibodies. In this project funded by USAID, the Institute purifies the viruses and their strains and sends them to the USDA laboratory for the production of the antibodies. These are used by IITA for the detection of viruses and their strains.

Cowpeas: Further valuable information was obtained on the importance and geographical distribution of such viruses as cowpea mottle virus (CMeV) and southern bean mosaic virus (SBMV). Cowpea yellow mosaic virus, cowpea mottle virus, and southern bean mosaic virus were identified from cowpea samples collected from IITA's substation at Cotonou in the Republic of Benin. This was the first indication of the presence of cowpea mottle virus in an African country other than Nigeria. Also, a new, previously unknown potyvirus was isolated from virus-diseased cowpeas in germplasm rejuvenation plots at IITA, both during the first season (May/August) and the second season (September/November) of 1987. The new virus is not or only remotely related serologically to cowpea aphid-borne mosaic virus (CAbMV). It was purified and an antiserum was produced.

In earlier screening of cowpea germplasm, the virologists found that resistance to cowpea yellow mosaic virus (CYMV) is not a rare trait; however whether resistance genes would prove to be stable and hold for the variety of types of this virus remained to be answered. Two cowpea germplasm accessions, one with a known, single-gene, dominant resistance and susceptible protoplasts (TVu 470), and the other with a known, single-gene, recessive resistance and resistant protoplasts (TVu 1944), were tested for resistance to five isolates of CYMV obtained over a period of years from widely different parts of the country. The reaction of earlier-mentioned two accessions to the five CYMV isolates was identical to that of the standard isolate. It appears, therefore, that CYMV is remarkably uniform. To get an impression of the variability of the prevalent types (strains) of CAbMV and SBMV various isolates of these viruses were compared on all 119 accessions initially selected for inclusion in the 1987 cowpea international testing nurseries. Although isolates differ in symptomatology and in their ability to infect certain genotypes, the majority of the accessions reacted much the same way to the various isolates of the three viruses used in the study.

Soybeans: A genetic diverse nursery with 200 accessions extracted from IITA's germplasm collection of this crop species was screened for resistance to the common isolate of SMV. Five accessions remained symptomless in these studies and when retested for resistance to a more severe but rarely found type of this virus, they also showed resistance to this isolate.

Cassava: Available levels of resistance to African cassava mosaic virus (ACMV) are not absolute. No genotypes are known that remain totally symptomless when inoculated with this virus. Even the highest level of such resistance available in some of IITA's improved clones and other advanced breeding materials show a certain, though low degree (incidence) of symptom expression, particularly during early growing stages. Later, however, they tend to outgrow such infection. In experiments with resistant varieties TMS 30572 and TMS 30001, the incidence of primary infection was zero, but 100% and 88% primary infection was observed in susceptible TMS 60506 and TMS 60447, respectively. The conclusion: cassava mosaic is strongly non-systemic in resistant varieties. As a result, the disease is self-eliminating in nature which explains persistently low infection incidences in IITA's improved CMD-resistant varieties.

Maize: During the annual virus disease survey across Nigeria, the virologists observed that the incidence of maize streak virus (MSV) was high in large sections of the Guinea savanna. However, anticipated reduction in yields were limited because most of the infection occurred at later growing stages. The incidence of maize mottle/chlorotic stunt virus (MMCSV) was found to be highest in Nigeria's northern maize growing areas, up into the northern Guinea and Sudan savanna. At higher altitudes, the incidence of MMCSV ranged from 25 to 50%.

A new virus disease was encountered in a common weed (*Rottboellia cochinchinensis*) in a large-scale maize production scheme near Mokwa in the southern Guinea savanna zone of central Nigeria. The virus proved readily sap-transmissible and, in serological studies, was identified as panicum mosaic virus (PMV). IITA's virologists found the isolate to be soil-borne. No vector has been reported so far for this virus.

Rice: In continuation of earlier comparative studies of the Kenyan strain (type strain) and the Nigerian strain of rice yellow mottle virus (RYMV), at IPO, Wageningen (The Netherlands), further studies were conducted with *O. sativa* and *O. glaberrima* accessions used as resistance donors for this virus in the breeding program at IITA. *O. sativa* varieties OS-6 and Moroberekan were tolerant to both strains whereas *O. glaberrima* accessions TOg 5674 and TOg 5681 did not show any symptoms with both the strains, and by using ELISA, no virus could be detected in them.

(Additional information on research activities referred to in this summary is available in the Annual Report of the Virology Unit.)

Improved Virus Detection Using Monoclonal Antibodies and Complementary DNA Techniques

Development or identification of virus-resistant cultivars is often the most effective means of limiting crop losses to virus diseases which threaten the food production potential of Africa. A sound knowledge of the pathogens, any variants or strains, and their distribution is a vital prerequisite for reliable resistance breeding. Virus indexing is also important for the collection, storage, and international exchange of plant material.

Diagnostic techniques are necessary to detect and identify the viruses occurring in the crop and in the breeding programs to monitor the effectiveness of resistance. The techniques chosen must be reliable, sensitive, rapid, and easy to use. The methods most commonly applied for virus indexing include: sap inoculation, vector transmission, grafting, serology, and electron microscopy. Biological techniques are not appropriate for surveying in other countries because of the time and facilities required. Serological diagnostic procedures are sensitive but often require less labor, space, and time, thus allowing field problems to be more thoroughly investigated since more samples can be processed. New serological tests with improved sensitivity such as Enzyme-Linked Immuno-Sorbent Assay (ELISA) and Immuno-Sorbent Electron Microscopy (ISEM) are used extensively. Results can be obtained within one or two days. Serological tests have been in regular use at IITA since 1978 for diagnosis and disease assessment, epidemiology, virus resistance evaluation, and virus indexing. Many national institutions have asked IITA to supply antisera for the identification of viruses in their countries. However, conventional polyclonal antiserum prepared in rabbits is produced only in limited quantity and varies in quality between batches.

Recent developments in biotechnology permit the production of monoclonal antibodies (MAbs) and cloned complementary DNA (cDNA) for the detection of viruses. The practical use of MAbs in ELISA and other sensitive tests such as dot-blot immunoassay (DBI) and Western blots allow improved sensitivity and specificity for the diagnosis of viral diseases. Monoclonal antibodies are derived by fusion of a mouse myeloma cell line with spleen cells (lymphocytes) from a mouse immunized with the antigen of interest. The resulting "hybridoma" cell lines retain the antibody-secreting property of the lymphocyte and the ability of the myeloma cell to grow continuously in culture. Individual hybridoma cell lines can be cloned; a clone will produce a continuous supply of identical antibody specific for a single antigenic determinant. By appropriate culture, essentially unlimited quantities of homogeneous MAb with defined specificity can be produced.

Hybridoma technology will allow the production of high quality serological reagents for the detection and differentiation of plant virus isolates; these reagents will also be available in essentially unlimited supply for standardization of detection procedures at locations in different countries, thus overcoming the ambiguities and limitations of serological methods to date. The ability to distinguish minor antigenic differences makes MAbs useful probes to examine virus relationships and virus epidemiology at a level not previously possible.

Most serological techniques rely on antisera (or MAbs) against the virus coat protein, the basic building block of the virus particle. The coat protein typically represents about one-tenth of the viral genome, and still less of the genome codes for the actual antigenicity of the coat protein. Complementary DNA (cDNA) methods allow examination of any part of the viral genome and therefore differences in other genes that may significantly affect the extent of crop losses to the virus but are not detected by current serological methods.

Purified viral genomic RNA can be used as a template to prepare cDNA using an enzyme called reverse transcriptase. The cDNA can be labelled directly or cloned into bacterial plasmids. Viral cDNA in a plasmid can be replicated in much the same way that hybridoma cells can be grown in culture; large quantities of a virus-specific reagent can be produced and distributed to those who need it. The cDNA can be labelled and used in a nucleic acid hybridization assay to detect the presence of viral infections of plants. At present, the most common labelling method for cDNA is with radioisotopes which have potential health hazards and limited shelf life; however, methods are being developed to use nonradioactive labels for detection in the hybridization assay.

Because cDNA techniques will allow comparison of all parts of the viral genome, it will be possible to differentiate virus isolates that have indistinguishable coat proteins. Virus detection by cDNA-hybridization is also often more sensitive than by serological methods. The use of cDNA technique by IITA virologists will improve their ability to detect and differentiate virus isolates.

IITA is benefitting from MAb and recombinant DNA technologies through cooperation with scientists at a United States Department of Agriculture Laboratory at Beltsville, Maryland. In this project funded by USAID, the Institute purifies the viruses and their strains and sends them to the USDA laboratory for the production of monoclonal antibodies and cDNA probes. These are used by IITA for the detection of viruses and their strains.

To date, the research has produced one MAb (7H8) reactive with certain isolates of sweet potato feathery mottle virus (FMV), the aphidborne component of the sweet potato virus disease complex, MAb 7H8 was compared with polyclonal antisera for detection of FMV in a number of tests including ELISA and DBI. Nonspecific reactions due to the presence of anti-host plant antibodies were commonly observed in tests with polyclonal sera; no nonspecific reactions were observed with the MAb in either ELISA or DBI. An ELISA using polyclonal antiserum and the MAb was superior to the use of either alone.

The Mab 7H8 does not detect all isolates of FMV, indicating the occurrence of other strains of the virus. Isolates that are not detected by 7H8 are being used to prepare further MAbs to improve the ability of IITA virologists to detect and differentiate FMV isolates.

International Cooperation Program

Collaboration and partnerships: Although much of IITA's research described in this publication is conducted in close collaboration with the scientists of National Agricultural Research Systems (NARS), the Institute has additional specific mechanisms to promote partnerships with them—training, resident scientist teams, and information services. The goal is to strengthen the capability of NARS to use and generate agricultural technology to satisfy their own national needs.

As a matter of policy and operating procedure, IITA scientists continued to consult with national scientists in many countries of Africa and invited leaders to special meetings to discuss alternative models of collaboration. During 1987, the Institute engaged in a number of different approaches, including research networking, international testing, regional coordination, and institution-building. It is exploring various models designed to meet NARS requirements at different stages of development, including the one shown in Table 43.

The large portfolio of special projects supported by several donors (Table 44) has enabled IITA to engage in a wide range of activities that extend technologies to specific agro-ecological zones and help build up the relatively small and underfinanced national systems in many parts of Africa. During 1987, this "outreach" program participated with national programs in 13 projects with a staff of 56 scientists.

National Cereals Research and Extension (NCRE) in Cameroon reinforced the work of the National Institute for Agronomic research (IRA) in commodity research programs to develop maize and rice germplasm adapted to different ecological zones of the country. The Testing and Liaison Units, made up of extension agronomists and agro-economists working closely with farmers, parastatals, and extension services of the Ministry of Agriculture, tested improved technologies through on-farm research throughout the country.

Semi-Arid Food Grains Research and Development (SAFGRAD), with headquarters in Burkina Faso, continued to develop and test improved maize and cowpea varieties and to improve cultural practices compatible with the farming systems used by farmers in the region. The Central and West African Maize and Cowpea Research Networks became operational and intensified multilocation testing of improved varieties in SAFGRAD-member countries.

Food Legumes Research, integrated with the activities of SAFGRAD, focused on the development of suitable cowpea varieties for the cereal farming systems of Sudan savanna and Sahel ecological zones of the region.

Applied Agricultural Research and Outreach in Zaire worked on the development and transfer of new technologies with emphasis on high yielding maize, cowpeas, soybeans, and cassava varieties suitable for sole and mixed cropping systems and adapted to various agro-ecological zones in the country.

National Root Crops Improvement in Cameroon helped to develop improved varieties and production systems suitable for small family farmers. Improved root crop varieties were multiplied and distributed throughout Cameroon.

Stage of Development	Commodity Improvement		Resource and Crop Management Research		Mechanisms for Collaboration	
Stage I	IITA	NARS	IITA	NARS	IITA	NARS
Early stage	Adaptive breeding of finished varieties for NARS.	Multilocational testing of IITA varieties.	Joint participation in the description of existing systems and constraints analysis.		Resident scientist team. Training technicians and M.Sc. candidates.	Counterparts to resident scientist team. Select technicians and graduates for training.
Stage II	IITA	NARS	IITA	NARS	IITA	NARS
Medium	Applied breeding of parental lines for NARS.	Line selection; national variety development and testing.	Share component technologies and methodologies for combining them into improved systems.	Test commodities and component technologies in national agro-ecological zones. Participate in networks.	Resident scientist team phases out. IITA research liaison scientist provides linkage. Start training Ph.Ds and trainers.	M.Sc. degree holders return from training and assume responsibility. Select Ph.D. candidates. Prepare for in-country technical training.
Stage III	IITA	NARS	IITA	NARS	IITA	NARS
Mature	Maintenance breeding. Pre-breeding research (biotechnology).	Major breeding program for national agro-ecological zones.	Long term, strategic basic research on crop and resource management problems, including methodologies.	Adaptive on-station and on-farm research. Testing new farming systems. Provide leadership in regional activities (networks, NARS-NARS exchanges).	IITA research liaison scientist continues linkage. NARS visiting scientist. IITA trains trainers and provides training materials.	Ph.Ds assume leadership. Conduct technical training for national and regional requirements.

Table 43. A model showing types of collaboration between IITA and National Agricultural Research Systems (NARS) based on different stages of development.

Farming Systems Research in Rwanda continued to select crop varieties and develop and test cropping systems adaptable to the semi-arid region of the Bugesera-Gisaka-Migongo (BGM) areas.

Grain Legumes Improvement in Ghana focused on the development of high yielding and multiple disease and insect pest resistant varieties of cowpeas and soybeans.

Eastern and Southern African Root Crops Research Network (ESARRN), inaugurated in 1987 with headquarters in Malawi, coordinated research activities in root crop improvement for national programs in Burundi, Ethiopia, Kenya, Malawi, Mo-

Table 44. Bilateral and multilateral collaborative projects (1987).

Project name	Location	Total staff	1987 Budget ($ × 1000)	Donor
National Cereals Research and Extension (NCRE)	Cameroon	14	2,760.2	USAID
Semi-Arid Food Grains Research and Development Project (SAFGRAD)	Burkina Faso	5	1,388.8	USAID
Zaire Applied Agricultural Research	Zaire	14	1,678.2	USAID
Cameroon National Root Crops Improvement	Cameroon	2	231.7	Gatsby Foundation
Food Legumes	Burkina Faso	1	217.7	IDRC
Rwanda BGM II Farming Systems	Rwanda	1	245.0	World Bank
Ghana Grain Legumes Improvement	Ghana	1	190.6	CIDA
East and Southern Africa Root Crops Research Network	Malawi	1	217.1 203.4	IDRC USAID
Africa-wide Biological Control of Cassava Pests	Nigeria	13	3,812.0	Consortium of donors*
Climatic, Biotic and Human Interaction in the Humid Tropics	Nigeria	1	179.0	UNU
On-farm Adaptive Research	Nigeria	1	139.4	IDRC
Soybean Utilization	Nigeria	1	81.7	IDRC
Bambarra and Kersting's Groundnut and Yam Bean Project	Nigeria	1	172.2	GTZ

**Denmark, West Germany, France, IFAD, Netherlands, Italy, and Switzerland.*

zambique, Sudan, Rwanda, Tanzania, Uganda, and Zambia.

Climatic Biotic and Human Interaction in the Humid Tropics continued studies on trends in the interactions between deforestation land-use systems and a range of crop and soil management practices of farmers in different ecological zones.

On-Farm Adaptive Research assisted in strengthening farming systems research capabilities in West African national and regional institutions and in focusing research findings and technologies on farmers' needs.

Soybean Utilization, a small pilot project started in 1987, worked on ways to improve household preparations of soybean based foods acceptable to rural families and on small-scale processing technology.

Bambarra and Kersting's Groundnuts and Yam Bean Research emphasized rejuvenation, preservation, biosystematic studies, and agronomic and nutritional evaluation of germplasm of the three crops.

Training: Since its first venture into training in 1971 and through 1987, IITA has trained 5,735 persons (Table 45), with most of them coming from countries throughout Africa. In the long run, this function may be the Institute's most enduring contribution to the solution of Africa's food problems and therefore warrants a high priority.

Technicians in group courses have accounted for the largest percentage of the training participants, but 10% were scientists receiving research training for postgraduate degrees. Group training is in French and English with simultaneous interpretation and with teaching material in both languages. The group courses, taught primarily at IITA headquarters in the past and heavily oriented to crop production practices, are becoming more research oriented. Also, the trend is toward more involvement of IITA with in-country training. In 1987, for example, the Institute, in cooperation with national and international scientists, offered 12 group courses in nine countries, plus 16 at its headquarters in Ibadan, Nigeria. Some of these in-country courses were conducted on a regional basis involving participants from three to 14 countries.

The number of Ph.D. and M.Sc. candidates from higher education institutions in Africa who do their thesis research under the direction of IITA scientists will be

Type of training	No. males	No. females	Total men and women	Women as % of total
At IITA headquarters				
Individuals	814	105	919	11.4
Group courses	3364	222	3586	6.6
Total*	4178	327	4505*	7.3

In addition, a total of 1,230 persons have attended courses outside of IITA headquarters during this period, making a grand total of 5,735. (Data not available on women in these courses held in several African countries.)

Table 45. Individuals and group training participants doing research and attending IITA courses from 1971 through 1987.

gradually increased in the years ahead. All reports indicate a great need for highly qualified African scientists with advanced degrees. Fortunately, the pool of prospective candidates is larger now than a few years ago. On November 1, 1987, IITA had 16 Research Scholars (13 men, 3 women) and 45 Research Fellows (37 men, 8 women) conducting research for M.Sc. and Ph.D. degrees, respectively. IITA is seeking effective means to increase the proportion of women participants at all training levels. In the past four years, only about 7% of African trainees at IITA were women. Given the important role women play in African agriculture, this record is not acceptable. An affirmative action program has been initiated to identify and encourage women to apply for training opportunities.

IITA's present training program is aimed not only at assisting Africans to do quality research on specific aspects of a particular crop but to identify problems constraining production, design and conduct research to confirm the problems and how they can be alleviated, test solutions under practical production conditions, and communicate the results.

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

Annual Report Executive Summary

Documentation, Information, and Library

Documentation, Information, and Library (DIL) is organized into seven units: Library and Documentation Center, Publications, Public Affairs, Graphics and Printing, Audio-visuals and Photography, Conference and Visitors' Center, and Interpretation and Translation. A summary of their activities follows.

Library services: Eleven training sessions on the use of the library database were arranged for scientists and trainees. A simple reference manual, *A Guide to the IITA Library Database*, was prepared and distributed to library users during the year. The Selective Dissemination of Information (SDI) service by which scientists receive regular printouts of lists of research publications that match their interest profiles was continued and extended to outreach staff. Fast online compilation and production of bibliographic lists were done regularly for library users. The Library was heavily used throughout the year both by IITA staff members and by persons *not* associated with the Institute. The latter reached an all-time high (Figure 26).

In collaboration with the Nigerian Association of Agricultural Librarians and Documentalists and the Academic and Research Libraries Section of the Nigerian Library Association, IITA organized a workshop during November 9–11, 1987; the theme: "Strategies for survival of Nigerian academic and research libraries during austere times."

Publications: The informative value of both the English and French editions of the *IITA Annual Report and Research Highlights* was further enhanced by the introduction of a *Focus* section with longer articles and broader perspectives. Four issues of *IITA Research Briefs* and *Echo de l'IITA* were published and mailed through the KLM distribution service. Three issues (two English editions and one French) of the *West African Farming Systems Research Network/Réseau d'Etude des Sys-*

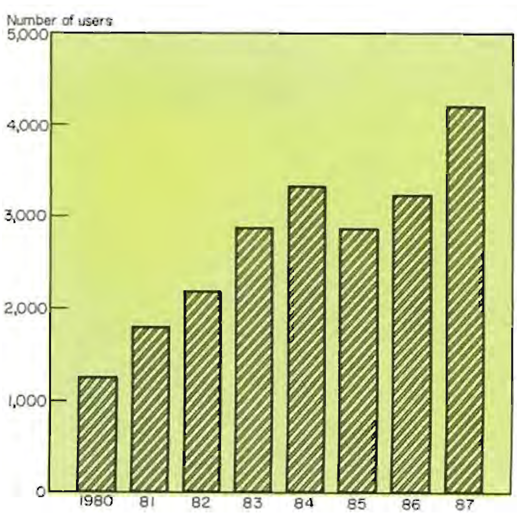


Figure 26. External users of the IITA Library from 1980 through 1987.

temes de Production en Afrique de l'Ouest Bulletin were produced, plus one issue of *Tropical Root Crop Network Newsletter*. Among the other 1987 publications were three books: *A Handbook of West African Weeds* by I.O. Akobundu and C.W. Agyakwa, *Soybeans for the Tropics: Research, Production and Utilization* edited by S.R. Singh, K.O. Rachie, and K.E. Dashiell, and *Weed Science in the Tropics: Principles and Practice* by I.O. Akobundu.

Monographs and pamphlets produced during 1987 include:

- *IITA: The Course Ahead*
- *IITA: Perspectives d'avenir*
- *An Exploratory Survey of the Ayepe On-Farm Research Pilot Area, Oyo State, Nigeria*
- *Cassava in Africa and the World Trends of Vital Statistics 1965–1984*
- *Improved Technology for Seed Yam Production*
- *Techniques Ameliorées de Production de Semenceaux d'Igname*
- *A Guide to the IITA Library Database*
- *A Farmer's Primer on Growing Cowpea on Riceland* (jointly with IRRI)
- *A Farmer's Primer on Growing Soybean on Riceland* (jointly with IRRI)

Table 46. European and American magazine articles on IITA (1986 and 1987).

Magazine	Country of Publication	Number of articles 1986	1987
Aerogram	U.K.	—	1
African Farming	U.K.	5	4
African Newsfile	U.K.	—	1
African Recovery	U.S.A.	—	1
Agribusiness Worldwide	U.S.A.	—	2
Agricultura de las Americas	U.S.A.	—	2
Agricultura Ricerca	Italy	—	2
America	U.S.A.	1	—
Ceres (FAO)	Italy	1	1
Development & Cooperation	West Germany	—	1
Development Forum	U.S.A.	—	2
Development International	U.S.A.	—	3
IDRC Reports	Canada	—	1
International Agricultural Development	U.K.	4	3
ILEIA	The Netherlands	—	2
International Pest Control	U.K.	—	1
Inter Tropiques	France	—	1
Phytoma	France	—	1
Span	U.K.	—	1
Standard Chartered Review	U.K.	1	—
The Courier/Le Courrier	Belgium	—	4
New Scientist		—	3
Topic	U.S.A.	1	1
Tuskegee Gram	U.S.A.	—	2
West Africa	U.K.	1	2
World Farmers' Times	Switzerland	—	1
Total		14	43

Media coverage: The work of IITA received considerable attention from both electronic and print media during 1987. The number of articles and news items in American and European magazines increased from 14 in 1986 to 43 in 1987 (Table 46). The coverage of IITA in Nigerian magazines also increased from 7 articles in 1986 to 16 in 1987 (Table 47). While the coverage in Nigerian newspapers was extensive (102 items), it was less than in 1986 (Table 48). (These figures are conservative because not all published articles in the media about the work of IITA are known to the Institute.)

Other activities: The Audio Visual/ Photography Unit conducted training courses on scientific photography for IITA scientists and senior technicians and initiated work on a number of video documentaries. The Interpretation and Translation Unit translated in French approximately 3,800 pages from English originals and provided translation services for two major conferences and 16 training courses.

Many farmers' groups, diplomats, government officials, journalists and others visited IITA during the year, including about 200 secondary school groups. The Conference Center provided logistical support for 12 major conferences and workshops.

Table 47. Nigerian magazine articles on IITA (1986 and 1987).

	Number of articles	
Magazine	1986	1987
African Concord	—	4
African Guardian	1	—
Agric News	—	2
Expansion Today	—	3
Newswatch	2	3
The Catalyst	1	—
The Spear	—	1
ThisWeek	—	3
Tropical Farming & Food Processing	1	—
UBA Monthly Business	2	—
Total	7	16

Table 48. Nigerian newspaper articles on IITA (1986 and 1987).

	Number of articles	
Newspaper	1986	1987
Business Concord	20	4
Business Times	3	1
Community Concord (Ondo)	5	3
Community Concord (Oyo)	—	1
Daily Sketch	13	11
Daily Times	12	6
The Guardian	20	10
National Concord	7	10
New Nigerian	29	14
Nigerian Tide	2	—
Nigerian Tribune	27	24
The Punch	3	1
The Reporter	—	1
The Standard	—	2
The Statesman	2	—
Sunday Glory	5	—
Sunday Guardian	5	4
Sunday Mail	—	1
Sunday New Nigerian	—	2
Sunday Sketch	9	2
Sunday Standard	—	1
Sunday Times	2	1
Sunday Tribune	—	1
Sunday Vanguard	1	1
The Vanguard	1	1
Total	166	102

List of Principal Staff

Administration

L.D. Stifel, Ph.D., director general
B.N. Okigbo, Ph.D., deputy director general
K.S. Fischer, Ph.D., deputy director general (research)
J.H. Davies, B.Sc., deputy director general (management)
M.A. Akintomide, B.S., AICTA, director for administration*
D.N. McDonald, C.A., acting director of budget and finance*
R.A. Smith, M.B.A., director, budget and finance
S.E. Adalumo, M.Sc., E.E., computer/electronics and operation officer
B.A. Adeola, FCIS, Accountant
K.A. Aderogba, J.P., FCIS, principal administrative officer
J.A. Akintewe, M.R.C.P. (U.K.), medical officer
J.O. Badaki, B.A., M.B.A., human resources manager
N.N. Eguzozie, B.Sc., computer programmer
C.A. Enahoro, manager, Ikeja Guest House
D.L. Fennell, administrative assistant to the director general
L.A. Hughes, SRN, SCM, senior nursing sister*
R. Martins, M.Sc., systems analyst*
L.J. McDonald, B.A., LL.B., computer manager
G.R. McIntosh, C.M.A., financial management system manager accounting procedures FIS
A.R. Middleton, B.Sc., manager, International House
O.O. Ogundipe, M.D., senior medical officer
F.O. Ogunyemi, FCAA, accountant
R.I. Olorode, security superintendent
M.E. Olusa, administrative assistant to the director for administration
T.D. Oluyemi, M.Sc., computer programmer
D.J. Sewell, manager, aircraft operations
J.C. Seymour-Griffin, FCA, ATII, internal auditor
R.O. Shoyinka, B.S., personnel manager
W.M. Steele, Ph.D., special assistant to the director general
S.J. Udoh, AMNIM, chief accountant
D. Wheeler, C.P.A., FIS project manager
A. Yusuf, B.S., controller of stores

Resource and Crop Management Program

D.S.C. Spencer, Ph.D., program director
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C. Garman, M.Sc., agricultural engineer*
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N.D. Hahn, Ph.D., socio-economist
A.E. Ikpi, Ph.D., visiting economist
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T.L. Lawson, Ph.D., agroclimatologist
P. Lippold, Ph.D., USAID liaison scientist*
K. Mulongoy, Ph.D., soil microbiologist
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J. Smith, Ph.D., agricultural economist
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Grain Legume Improvement Program

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J. Ehlers, Ph.D., cowpea breeder, Kenya
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B.B. Singh, cowpea breeder
K.E. Weingartner, Ph.D., food technologist

Maize Research Program

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Rice Research Program

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Root, Tuber and Plantain Improvement Program

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Africa-wide Biological Control Program

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A.K. Bhatnagar, assistant director
E.O.A. Akintokun, research vehicle service officer
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A.C. Butler, buildings and site service officer
O.O.A. Fawole, automotive service officer
P.G. Gualinetti, construction site engineering service officer
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Resource and Crop Management Program

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Grain Legume Improvement Program

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Maize Research Program

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Rice Research Program

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Root, Tuber and Plantain Improvement Program

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R. Ndibaza (Tanzania), University of Ibadan, Nigeria
P.N. Ociti (Uganda), University of Ibadan, Nigeria
M. Simwambana (Zambia), University of West Indies*

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Farm Management

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Africa-wide Biological Control Program

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Research Scholars

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S.J. Mugalu (Uganda), Wye College, University of London
G. Odour (Kenya), Imperial College, London
A.J. Sumani (Zambia), University College Cardiff, U.K.

Consultants

Dr. V.A. Adeyeye: Survey on technology adoption among the Alarola women farmers and their household members, Ijaiye-Orile, Nigeria.
Prof. J. Strauss: Econometric modelling in cassava consumption study.
Mrs. Alison Weingartner: Publications for Resource and Crop Management Program.
Mrs. J. Claassen: Annotated bibliography on food crops utilization and nutrition.
Dr. Lowell Bradner: Editing assignment.
Dr. F. Byrnes: Future course of action for IITA's Training Program.
Dr. G. Godo: Report on climate soils, crop and cropping systems around research facilities in the forest zone of Cote D'Ivoire.
Mrs. K.E. Parker: Extensive socio-economic studies on cowpeas in Nigeria.
Dr. S. Dittoh: Soybean utilization survey.
Dr. A. Ikpi: Food crops utilization and nutrition and soybean utilization survey.
Dr. Lily Ohiorhenuan: Soybean utilization survey.
Mrs. Farida Hasnoputro: Coordinator for a training program on cassava and soybean utilization in Oyo State, Nigeria.
Mrs. O.A. Fabuluje: Socio-economic interviews in the township of Ijaiye, Nigeria.
Ms. Maura Mack: Food crops utilization and nutrition.
Mrs. Janet Kwatia: Cassava processing utilization.
Mrs. C. Boavida: Training in Biological Control Program.
Mr. N. Lutaladio: Literature search on cassava in Africa.
Mr. A.B.O. Ogedegbe: Study of soil-fauna for the IITA-UNU project at Okomu, Bendel State, Nigeria.
Dr. D. Sindiren: Budget and finance.
Prof. W.B. Ward: Annual report and research highlights.

Publications

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