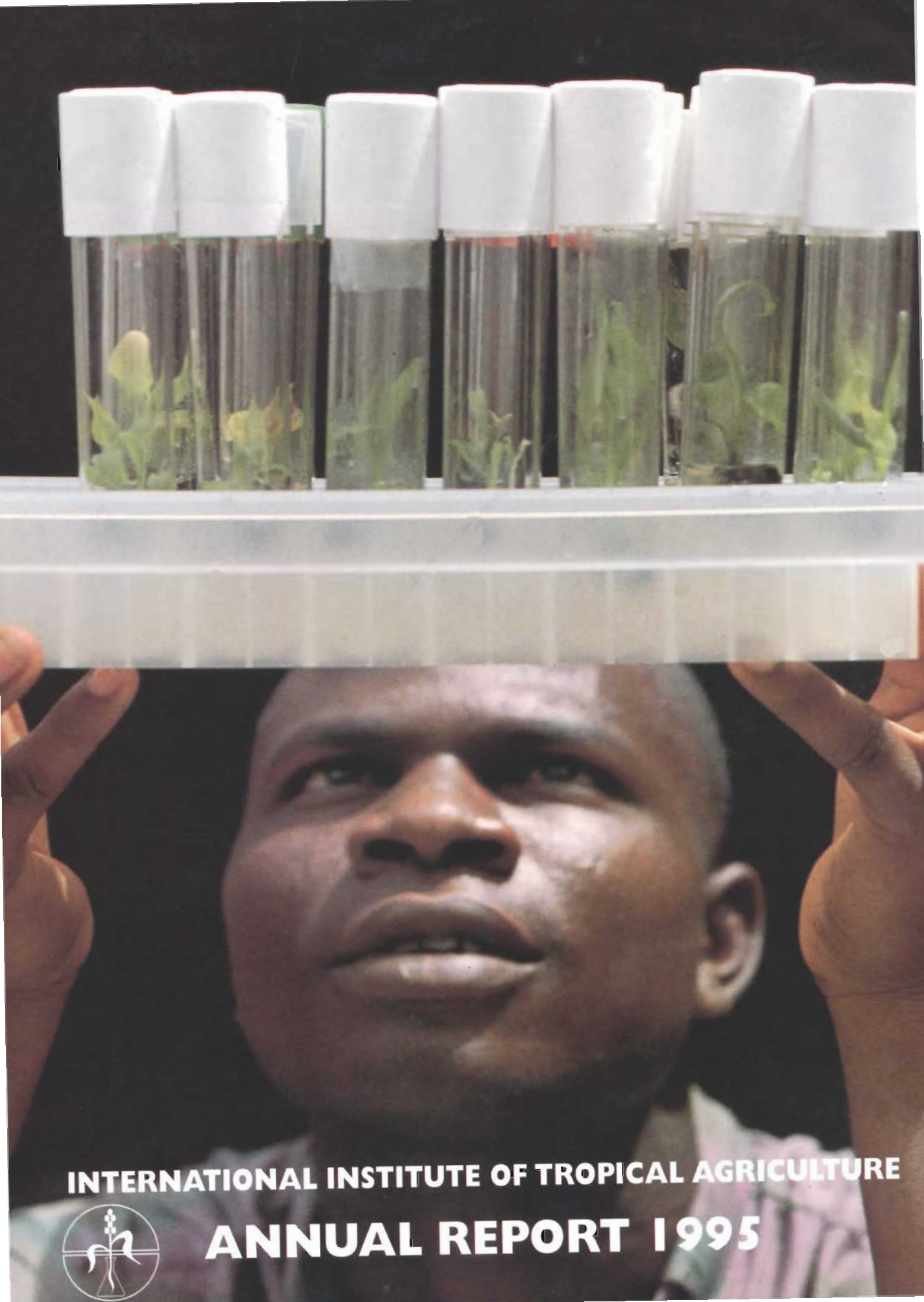

INTERNATIONAL INSTITUTE OF TROPICAL AGRICULTURE

ANNUAL REPORT 1995

The International Institute of Tropical Agriculture (IITA) was founded in 1967 as an international agricultural research institute with a mandate for specific food crops, and with ecological and regional responsibilities to develop sustainable production systems in Africa. It became the first African link in the worldwide network of agricultural research centers known as the Consultative Group on International Agricultural Research (CGIAR), formed in 1971.

IITA is governed by an international board of trustees and is staffed by approximately 150 scientists and other professionals from about 40 countries and 1,500 support staff. Most of the staff are located at the Ibadan campus, while others are at stations and work sites in other parts of Nigeria and in the countries of Benin, Cameroon, Côte d'Ivoire, Ghana, Malawi, Mozambique, Tanzania, Uganda, and Zambia. Funding for IITA comes from the CGIAR and bilaterally from national and private donor agencies.

IITA conducts research, training, and germplasm and information exchange activities in partnership with regional and national programs in many parts of sub-Saharan Africa. The research agenda addresses crop improvement, plant health, and resource and crop management within a farming systems framework. Research focuses on smallholder cropping systems in the humid and subhumid tropics of Africa and on the following major food crops: cassava, maize, plantain and banana, yam, cowpea, and soybean.

The goal of IITA's research and training mission is to improve the nutritional status and well-being of low-income people of the humid and subhumid tropics of sub-Saharan Africa.

Global links. Cosponsored by the World Bank, the Food and Agriculture Organization of the United Nations (FAO), the United Nations Development Programme (UNDP), and the United Nations Environment Programme (UNEP), the CGIAR is an informal association of over 40 governments, international organizations, and private foundations. The CGIAR provides the main financial support for IITA and 15 other international centers around the world, whose collective goal is to improve the quantity and quality of food production in developing countries.

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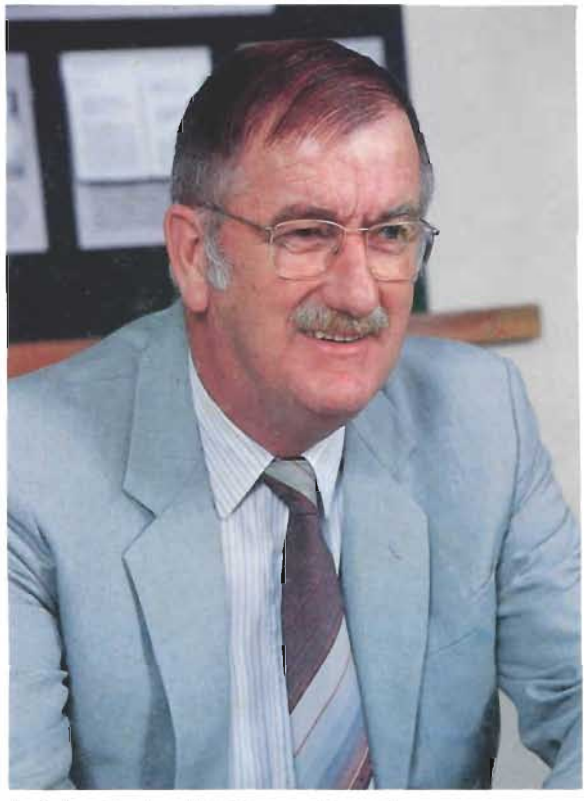


Dr Lukas Brader, IITA Director General

The year 1995 was marked by a number of important events. I would like to reflect on the development of the System-wide program for integrated pest management as well as the ecoregional program for the humid and subhumid tropics of sub-Saharan Africa and, in particular, highlight the findings of the Institute's Fourth External Program and Management Review.

System-wide and ecoregional programs

In 1995, IITA activities were affected significantly by the development of System-wide and ecoregional programs. These well-defined programs are designed to be conducted in an integrated and collaborative manner with all relevant partners. IITA had the leadership of two such initiatives: the System-wide Program for Integrated Pest Management and the Ecoregional Program for the Humid and Subhumid Tropics of sub-Saharan Africa.

The Integrated Pest Management Program is part of the response of the Consultative Group on International Agricultural Research (CGIAR) to concerns expressed at the United Nations Conference on Environment and Development convened in Rio de Janeiro in 1992. Some of those concerns crystallized in the Agenda 21 program, whose objectives include finding sustainable solutions to the problems posed to the environment and human health by pesticide abuse. A summary of this System-wide initiative is presented on pages 35–39 of this Report.

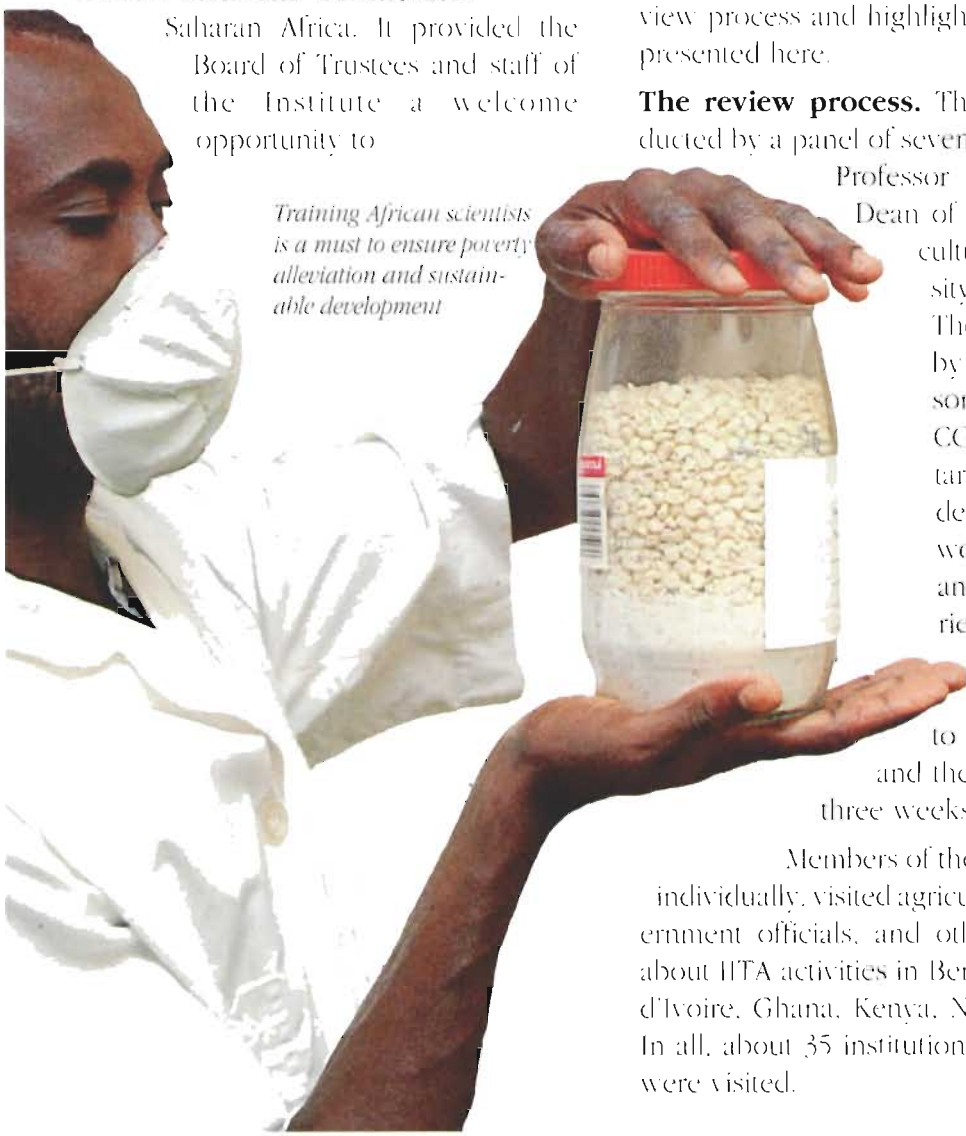
The Ecoregional Program for the Humid and Subhumid Tropics of sub-Saharan Africa is a highly collaborative mechanism involving relevant CGIAR centers, national agricultural research and extension systems of the region, and international organizations such as the Food and Agriculture Organization of the United Nations (FAO) and France's Centre de coopération internationale en recherche agronomique pour le développement (CIRAD).

The Program seeks to assist smallholder and medium-scale farmers to improve their well-being and alleviate poverty through the use of sustainable production technologies and postharvest systems that increase productivity and food security, while minimizing natural resource degradation. The Program will be implemented through three agroecosystem consortia: the Humid Forest Consortium, the Moist Savanna Consortium, and the Inland Valley Consortium. The article on pages 20–23

describes the process of forming the extensive partnerships for its implementation. IITA regards this Program as a critical element in the massive effort required to move African agriculture forward.

External Program and Management Review

The major event of 1995 was the Fourth External Program and Management Review of the Institute. The review was both comprehensive and in-depth, covering the research and training activities of the Institute, its governance and management, as well as the perceptions of its collaborators and beneficiaries in sub-Saharan Africa. It provided the Board of Trustees and staff of the Institute a welcome opportunity to



Training African scientists is a must to ensure poverty alleviation and sustainable development

- assess the changes that had been instituted since the last review and the assumption of office of a new Director General in 1990,
- obtain a necessary and methodical feedback from many of our stakeholders on our research and training activities, and
- reexamine our program and management strategies in the light of the difficult and complex challenges that sub-Saharan Africa continues to face with respect to food security and the sustainability of natural resources.

The review turned out to be a most rewarding exercise and provides a sound basis for IITA's future evolution. A summary of the review process and highlights of its findings are presented here.

The review process. The review was conducted by a panel of seven persons chaired by Professor Eduardo Venezian, Dean of the Faculty of Agriculture, Catholic University of Chile, Santiago. The Panel was assisted by two resource persons, one each from the CGIAR and TAC Secretariats, and an independent consultant (who worked on governance and finance). It was carried out in two phases: a preliminary phase from 26 November to 1 December 1994; and the main phase during three weeks in April 1995.

Members of the Panel, in groups or individually, visited agricultural scientists, government officials, and others knowledgeable about IITA activities in Benin, Cameroon, Côte d'Ivoire, Ghana, Kenya, Nigeria, and Uganda. In all, about 35 institutions in seven countries were visited.

As part of the review process, questionnaires were distributed to a wide cross-section of individuals in various institutions in sub-Saharan Africa who had professional or official links with IITA's research and related activities. The TAC secretariat received the responses, and analyzed and presented the results to the review panel. Those receiving the questionnaires were asked to

- evaluate IITA's programs and collaborative mechanisms;
- indicate their views on IITA's mission, goals, long-term research strategies, and priorities;
- indicate the degree of their satisfaction or dissatisfaction with regard to their interaction with IITA during its last medium-term planning exercise;
- comment on IITA's strengths and weaknesses, and on IITA's major contributions to their respective countries.

Other sources of information for the Panel included responses to a letter sent to other CGIAR centers, international organizations, and advanced institutions collaborating with IITA; a survey of IITA international and national staff asking for their views on program and management issues; and responses to a letter sent to all CGIAR members. Finally, the Panel had access to a large array of documents and data provided by IITA and by the secretariats of TAC and the CGIAR.

Findings of the Review Panel. The Panel completed its task and submitted its report to the Chairperson of TAC and the Executive Secretary of the CGIAR on 29 April 1995. Highlights are presented in the following paragraphs.

The main center of excellence

The panel remarked that IITA had undoubtedly become the main center of excellence for agricultural research in tropical Africa. This broadly acknowledged fact stems not only from the magnitude of research undertaken over the years since the Institute was founded, but also from the quality of its scientific staff and research output, the institutional continuity, and the effective management of its operations. The breadth and strength of complementary research support from sister IARCs and other advanced institutions tapped by IITA's collaborative linkages have also contributed to its regional impact. The Panel regards the consolidation and recognition of IITA as a powerful research institution in itself a major achievement, having significant implications for countries in tropical Africa.

Control of the larger grain borer, a pest of stored maize, is high on IITA's research agenda

The last five years

The Panel noted that, in response to CGIAR System-wide trends and in order to implement the recommendations of the last External Program and Management Review, as well as for internal institutional reasons related to the appointment of a new Director General in 1990, the Institute had made some remarkable changes in program and management over the past five years. It remarked:

"The Review Panel has found the center noticeably stronger both scientifically and managerially than it was at the time of the 1990 External Review. These changes constitute in themselves important accomplishments because they position the Center better to face future challenges. In sum, the Institute has been substantially revamped and renovated over the past five years...and this leaves it reasonably well poised to proceed with its research without further major organizational disturbances.

We believe IITA is now well positioned to catalyze further agricultural research in sub-Saharan Africa in its mandated responsibility."

The changes are:

- Broadening of the geographic scope of IITA's research beyond the lowland humid and subhumid tropics of West and Central Africa to include the mid-altitude, and lowland humid and subhumid tropical areas of East and Southern Africa.
- Further decentralization of research to facilitate the implementation of the ecoregional approach, and to focus more sharply on crop improvement, plant health management, and resource and crop management research in the zones where the mandated crops are grown. This decentralization also promotes closer collaboration with the francophone countries of the region served by IITA.
- Completing the transfer of rice research to WARDA, while maintaining effective participation in some aspects of germplasm management of the crop. Arrangements were also clarified for stronger collaboration with sister IARCs that share mandates on some crops with IITA.
- Restructuring of the Institute's management, organization, and procedures, which notably improved the internal work environment.
- Reorganization of the research programs into Divisions and Programs within Divisions, with some conceptual redefinitions, which are still evolving, especially in crop and resource management research. New directors were appointed for all three research Divisions.
- Changes in program planning and management system, which is progressively being shifted towards a project-based (bottom-up) approach, eventually forming a soft-matrix structure. This will facilitate greater participation in program development by scientists in an interdisciplinary fashion, thus enhancing the orientation to systems and ecoregional research sought in IITA's Strategic Plan.

Sustained delivery of research results

The Panel highlighted a number of outstanding research results obtained over the last five years, and declared:

"The Panel commends the Institute for its sustained delivery of research results and collaborative activities with the NARS, achieved while the Center was adjusting to new directions and organizational modes and at the same time strengthening management and scientific staff. The Panel wishes to stress that some of the research findings have been of practical value to farmers, and are reported to be having an impact on the welfare of rural families and consumers alike.

In sum, IITA has shown over the past five years strong vitality, innovation, and improved staff commitment and enthusiasm, notwithstanding the financial stringency and consequent belt-tightening measures that it had to implement. The Panel considers that these achievements merit recognition and support within the CGIAR System."

Endorsement

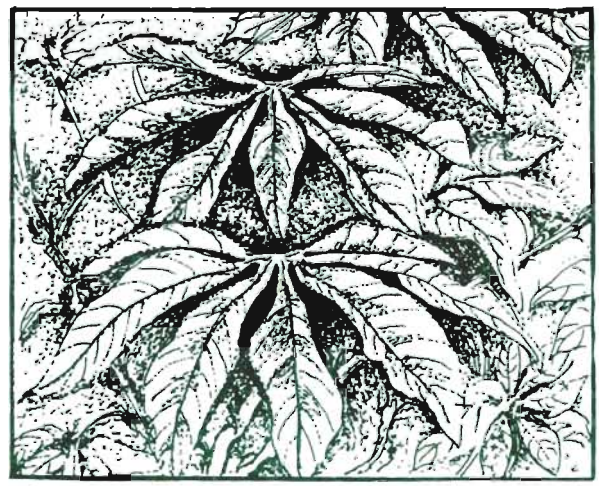
The CGIAR endorsed the recommendations of the Panel and TAC's commentary on the Panel's findings at the International Centers' Week 1995: *"The review report was positive and opti-*

Research output

The Panel called attention to some research results and activities which it considered important achievements:

- Continued production of improved germplasm of cassava, cowpea, maize, yam, and plantain and banana, which are passed on to national agricultural research systems (NARS) for further development and distribution to farmers.
- Techniques to induce flowering in cassava landraces and in yam, which broaden the scope of the breeding program.
- The development of methods to regenerate cowpea from cellular tissue, as a key step in eventually achieving genetic transformation.
- Identification and, in cooperation with NARS, release of new exotic phytoseiid predators of the cassava green mite, which opens very positive perspectives for biological control of this serious cassava pest.
- Improvement of a screening method for maize downy mildew resistance has allowed rapid development of resistant germplasm, which is now used by NARS in the development of varieties to combat outbreaks of this disease.
- Development of integrated pest management of *Striga*, partly through breeding of maize and cowpea cultivars with tolerance to this parasitic weed, and the identification of trap-crops able to stimulate *Striga* germination in the absence of the host.
- Development of high-yielding plantain cultivars with resistance to black sigatoka. (For this striking achievement, IITA received the 1994 King Baudouin Award.)
- Studies were completed on characterization of production systems in inland valleys, on production constraints for cereal farmers, on the introduction of legumes for fallow management, and on determinants of sustainability in certain rehabilitated lands.
- Technological improvement of alley cropping has progressed with the inclusion of new leguminous and woody species.
- The last stage of an Africa-wide collaborative study on cassava (COSCA) was completed. It shows, for example, that 60 percent of the area in Nigeria is planted with IITA-derived varieties.
- The development of prototype tools and equipment for cassava processing, which are coming into use in some countries.
- Postharvest utilization techniques have also been developed for soybean, and plantain and banana. These create new consumption and nutritional options, while expanding market opportunities for these crops.
- Training of researchers for NARS continued at a strong pace, with approximately 2,400 persons having participated in courses and research activities conducted by IITA over the last five years.

mistic about IITA. The center has been substantially strengthened over the past five years, which the Panel attributed to IITA's Board and Management, especially its Director General. IITA is well regarded by the research community in Africa, especially with respect to its research on germplasm and plant health management, and leadership in emerging ecoregional initiatives. IITA has broadened the geographic scope of its activities to include eastern and southern Africa, decentralized research responsibilities, completed the transfer of rice research responsibilities to WARDA, and reorganized its management structure. The internal work environment has improved notably."



Almost 200 million people in sub-Saharan Africa (40% of the population) rely on cassava

The World Food Prize 1995

The 1995 World Food Prize was awarded to Dr Hans R. Herren for his work at IITA on the biological control of the cassava mealybug.

Dr Herren, an entomologist and the Director of the Plant Health Management Division of IITA, helped to conceive the program in 1977 from its inception to its spectacularly successful completion. He left the Institute in 1994 to take up the position of Director General of the International Center for Insect Physiology and Ecology (ICIPE) in Nairobi, Kenya.

The World Food Prize is considered the foremost international agricultural award recognizing outstanding individual achievement in improving the quality, quantity, or availability of food in the world. The World Food Prize laureate receives $200,000 and a sculpture created by Saul Bass, the world-renowned designer. The award committee is chaired by Norman E. Borlaug who won the 1970 Nobel Peace Prize for his efforts to eradicate hunger and build international prosperity.

IITA's expertise in biological control is now being employed to address various other pest problems in Africa: the cassava green mite in the entire cassava belt of Africa, the mango mealybug in West Africa, the water hyacinth that disrupts water transport and destroys peasant fishing industries in East and West Africa, the larger grain borer that pulverizes stored maize, and the ancient plague represented by locusts. Biological control is a crucial element in the new System-wide Program for Integrated Pest Management.

Summing up

There is no doubt that 1995 was an exciting and rewarding year for IITA. Although adequate financial support for agricultural research remains a concern, we are optimistic that the Institute will be able to meet the expectations of the agricultural development community in sub-Saharan Africa. We look forward, in particular, to effective implementation of the newly formed cooperative arrangements, which should help achieve our goals.

Farmers participate in research conducted by IITA scientists

During 1995, the process of reorienting IITA's research agenda to project mode was fully realized. From a total of 23 projects which were identified initially, 16 projects were formed.

The following presentation summarizes the scope of each project and reports the achievements during the year.

Conservation and Genetic Enhancement of Plant Biodiversity

The goal of this project is to improve conservation and utilization of plant biodiversity to contribute in a sustainable manner to food security in sub-Saharan Africa. Ongoing activities include evaluation and documentation of germplasm collections with descriptors (both conventional and molecular) and the application of improved methods for pathogen detection and diagnosis to facilitate the safe movement of germplasm.

IITA geneticists are investigating the genetic nature of the phenotypic variation observed in IITA mandate crops, leading to an increased knowledge of the gene action controlling the most important economic traits. Using this baseline information, IITA breeders continue to synthesize source breeding populations and parental lines, for further improvement and international distribution.

Highlights

- Comprehensive utilization of all germplasm accessions of the wild *Vigna* species, *V. vexillata*, for wide crossing with cultivated cowpea. This was based mainly on improved seed recovery from seed-recalcitrant accessions, and the development and routine use of a robust embryo rescue protocol.
- Most local landraces of cassava in West Africa (some 200 accessions) were introgressed into improved breeding populations.
- A large quantity of germplasm from Centro Internacional de Agricultura Tropical (CIAT) was introgressed and backcrossed to confer resistance to African cassava mosaic disease (ACMD). The latter two activities are major contributions to broadening the genetic base of cassava in Africa. They also provide valuable resource materials for preventive breeding against the chance introduction of ACMD into Latin America.
- Much progress was made in genetic research on *Musa*. Complete characterization of the most important *Musa* taxonomic groups with quantitative and qualitative descriptors was accomplished. This enabled the assessment of phenotypic variation in IITA's *Musa* gene bank and provided insight into the evolution and domestication of plantain and banana.
- Evaluation trials of about 3,000 genotypes (mainly secondary triploids) were carried out at Onne. The results will allow the identification of heterotic groups, the determination of combining abilities, and the assessment of the interaction between genotype and cropping system in *Musa* breeding.

Agro-ecosystem Development Strategies

This project aims to focus the efforts of scientists from national agricultural research systems (NARS) and international systems on well-defined and targeted agro-ecosystem development strategies for alleviating poverty and arresting resource degradation.

Highlights

- A survey of farmers' nutrient management practices and land-use mapping by remote sensing of the forest margins in the benchmark areas were completed.
- A village household census in the research villages was also accomplished.
- The social profitability of alternative resource management technologies (e.g., short fallow systems, burning practices) was assessed. Information on cropping systems for most of West and Central Africa is now available in databases.

Short Fallow Stabilization

Rapidly growing populations in West and Central Africa as well as urbanization have resulted in land-use intensification and increasingly short fallow periods. As a result, land degradation is widespread. IITA's research aims to arrest such resource degradation through the development of short fallow systems.

One short fallow system that has shown considerable promise is based on the use of *Mucuna*, a fast-growing leafy leguminous plant. Bacteria in the roots of *Mucuna* utilize atmospheric nitrogen in the soil to form organic nitrogen compounds which assist plant growth, at no cost to soil nitrogen stocks. Subsequent dieback of *Mucuna* contributes organic matter to the soil and improves fertility of degraded soils. *Mucuna* has yet another virtue: because of its abundant and rapid growth, it can suppress and kill weeds (such as the notorious Speargrass, *Imperata cylindrica*) that are otherwise extremely difficult to control.

Highlights

Planted *Mucuna* fallows have been adopted by thousands of farmers in the southern areas of Benin Republic. This has become a case of success breeding success, with local and international nongovernmental organizations (NGOs), such as Sasakawa 2000, showing interest in the system

and helping to promote its adoption by farmers elsewhere. Another factor that should accelerate the adoption and spread of the system is the finding that *Mucuna* seeds can be prepared in a form suitable for human consumption. Hitherto, the thought that the seeds had no economic value was a significant hindrance to the more rapid adoption and spread of planted *Mucuna* fallows.

Other plant species, including trees that have multiple uses, have been screened in Benin, the savannas of Nigeria, and the forest zone of Cameroon for use in short fallow systems. The two best species in the Nigerian savanna were *Mucuna pruriens* and *Lablab purpureus*; these have been established on farmers' fields. In the forest zone of Cameroon, two tree legumes (*Cassia spectabilis* and *Calliandra calothysus*) have been found promising. Their benefits under various residue management systems are being tested in farmers' fields.

Farming System Diversification

This project aims to increase the productivity and cash income of smallholders in West and Central Africa through the diversification of farming systems. Working with national agricultural research and extension systems (NARES) and farmers, project scientists develop new and complementary income-generating enterprises.

Major opportunities for diversification of food production systems for food security and income generation have been identified, and some factors responsible for farmers' pursuing these opportunities have been studied. Enterprises include fruit tree plantations, non-timber forest products, fisheries, livestock, and dry-season crop production in inland valleys. A major opportunity in the inland valleys appears to be off-season maize when prices are higher in both humid and savanna zones.

Improving Plantain- and Banana-based Systems

The development of sustainable plantain and banana production in different ecological zones of sub-Saharan Africa is the goal of this project. This goal is being pursued through integrated pest and disease management, and breeding of high-yielding cultivars with desirable fruit quality and resistance to many pests and diseases. The project, carried out in collaboration with NARES, also seeks to develop sustainable resource and crop management practices.

Highlights

- Participatory rural appraisals, diagnostic surveys, and on-station trials, undertaken in lowland West Africa (Ghana, Nigeria) on plantain systems and in highland East Africa (Uganda) on banana systems, gave a better understanding of the importance and the interactions between biotic and abiotic constraints (sigatoka diseases, root nematodes, banana weevil, banana streak virus, soil fertility, and farmers' crop management practices).
- Clean planting material was demonstrated to be a key component in nematode and weevil control.
- In multi-locational and advanced evaluation trials carried out in Cameroon, Côte d'Ivoire, Ghana, Nigeria, and Uganda, black sigatoka resistant hybrids with stable and high yields, and with acceptable fruit quality for local markets were identified.
- On-farm testing done in collaboration with the extension services of an oil company in southeastern Nigeria showed that PITA-2 (TMPx 548-9), one of the best improved black sigatoka resistant tetraploid hybrids, always outyielded the False Horn landrace Agbagba, even under low inputs or poor environments.
- Methods for the assessment of variability in root systems of *Musa* were developed. Also, two morphological traits (stomata length and epicuticular wax) were demonstrated to be potential mechanisms of resistance to black sigatoka disease. Seven *Musa* hybrids, previously developed for high yield and black sigatoka resistance, were selected for their field tolerance to banana streak virus.
- A workshop for *Musa* researchers in West and Central Africa was organized in 1995. Participants included researchers from the International Network for the Improvement of Bananas and Plantain (INIBAP), France, Centre Régional Bananiers et Plantains (CRBP, Cameroon), NARS scientists from Côte d'Ivoire, Ghana, Guinee, Nigeria, Togo, and Zaire, and Nigerian extension agents associated with agricultural development projects (ADPs), and NGOs as well as IITA scientists based in Benin, Cameroan, Ghana, Nigeria, and Uganda.
- Screening of landraces for female fertility, conducted at IITA's East and Southern Africa Regional Center (ESARC) in Uganda, indicated that genetic improvement of East African highland bananas is feasible through crossbreeding. Of the 50 landraces screened so far, 27 were seed-fertile, with an average recovery of 20 seeds per bunch. The number of potential female parents may increase further as another 50 landraces are yet to be screened.
- Also at ESARC, the first production cycle of the multi-locational evaluation trial of IITA plantain and banana

hybrids was completed and fully analyzed. Three hybrids (TMPx 548-4, 1658-4, and 5511-2) outyielded the reference plantain and highland banana cultivar, and showed black sigatoka resistance, acceptable duration, and good ratooning. Yield stability will be examined in subsequent ratoon crops.

Cassava Productivity in the Lowlands and Mid-altitude Agroecological Zones

This project develops, evaluates, and promotes improved and adapted cassava germplasm for the lowland and mid-altitude agroecological zones of sub-Saharan Africa. It also develops agronomic and other practices to ensure sustainable cassava production and utilization. Interaction with national programs is fostered through long established links in West and Central Africa, two root crop research networks covering East and Southern Africa, and commencing in 1995, the increased level of cassava research at ESARC, Uganda.

Highlights

The project continues to make excellent progress in genetic improvement, and in delivering germplasm to collaborators for evaluation and selection to suit local requirements.

- A total of 584,802 seeds, covering 3,397 families of broad-based improved populations of cassava, were distributed to 21 countries in 1995. IITA received seeds collected from local landraces constituting 122 families from four countries, in pursuit of efforts to utilize favorable traits in African landraces.
- In addition to multiple pest and disease resistance, the traits emphasized include early vigor (high foliage yield for leaf vegetable), root characteristics (high carotene content, early bulking, ease of peeling, root shape, food quality), and adaptation to short season production in inland valleys.
- Long-term experiments on various agronomic and physiological aspects of production systems in the lowland savanna and forest-savanna transition zones yielded results that will be used to formulate improved production packages during 1996. The packages will cover cassava-based cropping systems for inland valleys, intercropping systems for uplands, and improved husbandry practices for enhanced yields.
- IITA's mid-altitude activities for cassava improvement increased considerably in 1995. In addition to the use of ESARC's Sendusu Research Farm at Namulonge, the Uganda national program provided a site for use at their Serere Research Station, near Soroti in mid-northeast Uganda. This site was chosen because it is a "hot spot" for pests and diseases of special interest, such as cassava green mite and cassava mosaic disease.
- The quantity of virus-indexed clones that are held in tissue culture at IITA was increased considerably in 1995 to a total of 235 improved lines and 11 selected local cultivars. In addition to virus-indexed stock, 273 African landraces are maintained in vitro.

Improvement of Yam-based Systems

Efforts to improve the productivity of yam-based farming systems recorded progress in three key areas: increasing the knowledge base of yam production systems; generation of healthy planting materials in large amounts (an essential requirement for regional testing of improved germplasm); and nurturing links with yam researchers in national programs.

Highlights

- Surveys were carried out in Nigeria, Benin, Togo, and Ghana to study the following aspects of yam-based systems:
  1. existing biological and socioeconomic constraints, farmers' perceptions of such constraints, and their management strategies;
  2. distribution of yam varieties, and the criteria used by farmers for selecting varieties; and
  3. extent and severity of yam pests and diseases.

  Additional surveys will be conducted in Uganda, Tanzania, and Malawi in 1996, focusing on socioeconomic and biological constraints to, and opportunities for, expanded yam production.
- Different ways of propagating yams were evaluated in the field in Ghana and Nigeria, and a survey of the feasibility of their adoption by farmers was conducted.
- Progress was also made in yam pathology, including screening of the germplasm, and studies of the foliar symptoms and epidemiology of yam diseases.
- A total of 4600 plantlets and 3500 mini-tubers from the 20 most important yam genotypes were sent to collaborators in 14 countries. Additionally, 4900 plantlets from certified genotypes were established for production of mini-tubers for international distribution.
- Building upon earlier progress in genetic improvement, the first set of regional yam varietal trials is planned in at least four countries in West Africa during 1996 in which improved and local landraces will be evaluated. In 1995 both IITA and NARS partners were engaged in tissue culture and field propagation of the materials required for the 1996 regional trials.

Improvement of Maize-grain Legume Systems in the Moist Savanna

Maize-grain legume systems in the moist savanna of West and Central Africa have the potential to provide a major portion of the calories and protein needed for human consumption and for livestock, as well as raw materials for agro-based industries. To realize this potential is the objective of IITA's research project to improve the productivity of maize-grain legume systems in the moist savanna. The strategy entails placing equal emphasis on improving crop varieties and the management of the cropping system.

In 1995, there was a radical change from defensive breeding for resistance to pests and diseases to breeding for attributes that can have a positive impact on the productivity of the cropping system. The attributes include high nitrogen fixation, efficient use of phosphorus and nitrogen, and optimizing leaf area relative to grain yields and plant residue production. Agronomic studies are focusing on developing cultural practices that maximize the benefits of grain legumes to maize in a crop rotation system.

Highlights

An efficient method to quantify nitrogen fixation was developed. The procedure will be integrated into the soybean breeding program in 1996. Computer simulation models were employed to study resource use and nitrogen fixation potentials of early, medium, and late maturing soybean lines.

During 1995, parent materials were selected to form a population of maize tolerant to nitrogen stress, building upon earlier studies of nitrogen-use efficiency. Initial crosses will be evaluated under low and high nitrogen in 1996. The first evaluation of the nutrient contributions of different soybean varieties and residue management techniques to a subsequent maize crop began in 1995 and will continue in 1996.

Cowpea-Cereal Systems Improvement in the Dry Savannas

In 1995, cowpea breeding in the dry savannas continued to emphasize the genetic improvement of indigenous varieties for adaptation to low input, intercropping systems, concentrating on improvement of resistance to prevailing biotic and abiotic constraints to productivity.

Highlights

Breeding lines were evaluated for both grain and fodder yields, and were screened in the laboratory as well as in the field for desirable traits, including drought tolerance and adaptation to poor soils. To support this main activity, studies were conducted on the genetics of drought tolerance, photosensitivity and plant type, breeding methods for intercropping, and physiological studies of crop competition (root distribution and effects of shade) under intercropping conditions.

The identification of cowpea accessions with drought tolerance and the transfer of the trait into advanced breeding lines has led to progress in the development of germplasm adapted to drier environments, where postflowering insect pests are appreciably less of a problem. Preliminary evaluations conducted in 1995 indicated that these, very dry, so-called marginal environments do have productive potential when varieties adapted to the dominant stresses of heat and drought are available. At test sites in Niger Republic (Sahelian zone, less than 300 mm of annual rainfall) grain yields of 500–1000 kg per hectare were obtained in a preliminary evaluation of breeding lines, when no insecticides were applied. The trials will be continued in 1996 in collaboration with the national program.

In the Sudan savanna, several cowpea varieties planted near the end of the rainy season, after the harvest of the main millet and cowpea crops, yielded 400–900 kg per hectare of grain and 500–1100 kg of air-dry fodder at 60–70 days after sowing. The potential of cropping short duration cowpea on residual moisture following the rainy season will be further studied in 1996.

Biological Control of Pests in the Farming System

The goal of the project is to enhance the livelihood of farmers and maintain sustainability through the preservation of biodiversity. The project's contribution consists in research and implementation of biological control of pests and weeds in the farming system, particularly those that cut across mandate crops. The second pillar of the project is the support to biosystematics, which is the starting point of all research in biological control.

Self-sustaining solutions to some pest and weed problems which affect farmers, sometimes indirectly, are developed for and with NARES or village organizations, while individual farmers or fields are not usually targeted. NARES are given the capability to combat particularly invasive species quickly, and in a sustainable manner.

Highlights

- Field trials in Niger on 50 hectare plots, using the fungus *Metarhizium flavoviride* against Sahelian grasshoppers, demonstrated successful control.

- In Mauritania, hopper bands of desert locusts were successfully infected with this fungus, but mortality was difficult to quantify.
- Farmer participatory trials in Mali and Niger, an economic consultancy, and further progress in mass production, formulation, and packaging of the fungus set the stage for its use by NARES.
- Implementation of classical biological control of the spiraling whitefly and mango mealybug continued in coastal West Africa, in collaboration with the Technology Transfer and Training Unit.
- The necessary backing in biosystematics was improved through the construction of an insect museum, and regional contacts are being consolidated through the BioNet framework.

Integrated Management of Legume Pests and Diseases

The goal of this project is to reduce risks of crop loss in farmers' fields in Africa through the development of integrated pest management (IPM) technologies that increase cowpea and soybean productivity in a sustainable manner. New IPM components, developed in collaboration with NARES, are to be integrated with existing ones, tested, and disseminated under the auspices of the PEDUNE project (Protection ecologiquement durable du niebe). Thus, small-scale farmers and the extension services are offered options for improved IPM technologies, which have been tested in different ecological zones.

Highlights

- Resistant progenies from wild cowpea × cultivated cowpea crosses were made by pyramiding genes for resistance to *Maruca testulalis*, and new resistance genes were identified in wild relatives.
- Two Bt endotoxins were identified for use in cowpea transformation.
- New sources of cowpea resistance to anthracnose, aschochyta blight, and bacterial blight were identified.
- Neem seed preparations were shown to cause more than 80 percent egg mortality in pod borers and some pod-sucking bugs.
- Pupae of the thrips parasitoid, *Ceranisus menes*, from the strain collected in 1994 from Malaysia were imported and tested in Cotonou. Although frequent stinging by the parasitoid was observed, no parasitoid developed, indicating poor host adaptation. However, a second exploration to India and Borneo yielded 3 other parasitoid strains, which are presently reared under quarantine at the University of Wageningen.
- During the same trip, two promising parasitoids of *M. testulalis* were found in Malaysia.

Integrated Management of Maize Pests and Diseases

The project aims to reduce pre- and postharvest losses of maize caused by pests and pathogens in sub-Saharan Africa. It seeks to facilitate regional implementation of projects and to strengthen the capability of NARES to carry out research and to disseminate the results. Thus, NARES are enabled to test, adopt, and promote resistant germplasm from IITA, and also to use improved infestation/infection methods to screen their material. Furthermore, the project develops new options for IPM in the field and in the rural storage systems, and integrates these with existing ones.

Highlights

- Good control of the larger grain borer (LGB) by its exotic natural enemy, *Teretriosoma nigrescens*, was documented for southern Benin.
- Field data matched predictions of a simulation model, which is based on life-table data.
- Electroantennogram studies revealed that LGB and *T. nigrescens* react equally well to LGB pheromone.
- Protection against LGB attack was attributable mainly to good husk cover.
- Levels of resistance in maize varieties to the downy mildew disease, especially those grown in Nigeria, were increased. The level of resistance of Pop 9043 DMRSR, a high-yielding variety with less than 65 percent level of resistance to downy mildew, was increased to about 80 percent in one cycle of selection under artificial infestation. Other varieties resistant to downy mildew, including the hybrid 8644-27 (marketed by Premier Seeds, Nigeria, as Oba Super 2), are being extensively deployed by NARS in Nigeria to curb the disease in those areas where it is endemic.
- On the basis of spore fall counts and the observed reduction in the spread of downy mildew, it is concluded that the eradication campaign in Nigeria against this pathogen is beginning to have some impact.
- Seed transmission of downy mildew was demonstrated.
- Mycotoxin infection on stored maize in Africa and its impact on public health was discussed at a meeting in Cotonou.
- Two exotic and one African species of *Cotesia* were released in Benin against *Sesamia calamistis* and *Coniesta ignefusalis*, while the parasitoid *Telenomus isis*, an important control agent of *S. calamistis* and *Busseola fusca* in southern Benin, will be sent to East Africa for testing.

• The late season storms in 1994 clearly demonstrated that borer resistant populations of maize lodged much less than the unimproved controls. In 1995, new borer synthetic populations were constituted from proven resistant inbreds and were advanced together with other borer populations through a cycle of improvement under artificial infestation. Moreover, new germplasm sources with resistance to both species of spotted stem borers were introduced from East Africa for testing against *Sesamia calamistis*. Initial results suggest some level of cross resistance to the three borer species.

Integrated Control of Cassava Pests and Diseases

This project seeks to increase cassava productivity in Africa through the further development, testing, and implementation of sustainable plant protection, in collaboration with NARES. It is increasing the knowledge base, implementing biological control of the cassava green mite, developing IPM systems, and increasing the capability of NARES.

Highlights

• The exotic phytoseiid *Typhlodromalus aripo*, predator of the cassava green mite, spread over 150,000 km^2 of West Africa, i.e., a 100% increase over 1994, and now covers significant areas of Ghana, Togo, Benin, Nigeria, and Cameroon. It is also established in Kenya and Uganda. Preliminary impact studies show significant pest reductions.

• Based on diagnostic surveys in Ghana, Benin, Nigeria, and Cameroon, the ESCaPP (Ecologically Sustainable Cassava Plant Protection) project established regional cassava plant protection research priorities and conducted training.

• From five countries, 320 strains of the causal agent of cassava bacterial blight (CBB) were characterized, and a new detection method was developed.

• Epidemiology and yield losses due to CBB were determined in different ecological zones and some resistance mechanisms against CBB, African cassava mosaic virus, and anthracnose were identified.

• Cassava storage fungi and new cassava pathogens were identified from different regions. Antagonists for the biological control of rot fungi were selected, and methods for their mass production developed.

Integrated Management of *Striga* and other Parasitic Plants

The project, being implemented in collaboration with NARES, aims to reduce infestation of *Striga* spp. and the associated crop yield loss, and to improve soil conditions. It evaluates and disseminates sustainable technologies against parasitic plants, with emphasis on rotation with selected non-host legume cultivars.

Highlights

• Selected legume cultivars in rotation with maize were shown to reduce the seed inoculum by causing "suicidal germination" of *Striga* seeds while improving soil fertility.

• A simple laboratory procedure for selection of legume cultivars that cause suicidal germination of *Striga* spp. seeds was validated in the field. Based on this, routine evaluation of cowpea and soybean breeding lines for this trait was initiated. Similarly, the International Livestock Research Institute (ILRI) adopted the procedure to identify non-host pasture legumes for rotation.

• Natural soil suppressiveness to *Striga* spp. was identified and improved by inundation with fungi and bacteria, previously isolated and selected at IITA.

• Improvement of levels of resistance of cowpea to *Striga gesneriodes* and *Alectra vogelii* continued. In on-farm testing, farmers recognized the value of this trait and requested further seed supplies.

• The importance of ensuring that crop seeds are free of *Striga* spp. seeds, to prevent contamination of farmers' fields, was recognized.

• Progress in developing high yielding maize cultivars, with *Striga* spp. resistance continued. Sources of resistance were identified in some African landraces and in their wild species *Zea diploperennis*. They were successfully introgressed into the improved cultivars.

• To augment maize resistance, an efficient herbicide seed treatment was evaluated.

Improving Postharvest Systems

The postharvest project aims to increase the income-generating capability and improve the nutritional status of farmers, processors, and consumers, in both rural and urban communities of Africa.

A series of demonstrations and workshops were held in West Africa to promote postharvest technologies developed at IITA. This process of information dissemination culminated in an international conference on "Postharvest technology and commodity marketing" held in Accra, Ghana during 27–29 November 1995. A postharvest engineering project was established in Ghana to promote the commercialization of research results.

Designs of different pieces of equipment (thresher, polisher, mechanical press, and the grating/chipping

machine assembly) that were released in 1994 were demonstrated to be technically efficient. Users provided feedback which was incorporated to improve their performance. The grating and chipping machines developed are being adopted with little or no modification. They have been found to increase grating and chipping efficiencies, and they provide options to expand the utilization of cassava and other root crops. Local supply of the main component parts are now being addressed by designing patterns and molds for the grating and chipping plates to allow fabrication by small-scale manufacturers.

A mechanical slicing machine for cassava and other root crops was developed and tested. It will be modified to optimize the operating efficiency. An auger-type grain polisher was modified and introduced. It is useful for palm oil digesting and palm kernel cracking. Adaptation to incorporate a cleaning mechanism is in progress.

Surveys to characterize postharvest systems and identify opportunities for postharvest research and implementation were carried out on soybean utilization, cassava substitution, marketing of newly bred plantain hybrids, and agro-processing equipment. Studies confirmed that soybean products were being sold extensively and that cassava substitution formulations had been adopted widely by processors in Nigeria.

Studies also showed that the registration of Pita 9, a plantain hybrid developed at IITA, was facilitated by experiments that highlighted its processing quality traits.

The economic feasibility of the various postharvest technologies developed at IITA was studied. The study examined whether the designed output level at which the equipment can be utilized justifies an investment decision. Results show that most of the technologies have strong potential for generating profits, whether they are used exclusively by the owner, for custom-hiring, or for both hiring and own use.

Training continued to be an integral part of technology development. To support development partners (NARS, NGOs, and other rural development agencies), training on the operation, maintenance, and management of equipment is being conducted.

Recombinant DNA, Molecular Diagnostics, and Cellular Biotechnology for Crop Improvement

This project aims to advance genetic improvement beyond the norms associated with the application of conventional breeding and diagnostic techniques. It seeks to make available new molecular and cellular tools and products to collaborating scientists for germplasm enhancement and dissemination of the IITA mandate crops.

Highlights

- Development of a protocol that is now used routinely for the rescue of 4-day old embryos from the wide cross of cowpea with *Vigna vexillata*, with a plant recovery rate of at least 70 percent.
- Shoot regeneration via organogenesis was obtained from cowpea explants; multiple shoots were formed and these subsequently developed into plants. This achievement, in a crop previously regarded as recalcitrant, has opened up possibilities for genetic engineering of cowpea. See article on pages 14–19.
- As part of collaborative projects with the John Innes Center, UK, and the World Bank, several diagnostic tests for detecting banana streak virus were developed. These tests will enhance the distribution, in collaboration with the International Network for the Improvement of Banana and Plantain (INIBAP), of IITA's improved *Musa* germplasm.
- In a collaborative project, the Natural Resources Institute (NRI), UK, developed a PCR test for yam virus II (YVII) and successfully transferred it to IITA. This test is at least a thousand fold more sensitive than ELISA. Moreover, it is simple, rapid, and inexpensive. This diagnostic tool will give IITA more confidence in dissemination of improved germplasm of white yam (*Dioscorea rotundata*) to national programs.
- Based on RAPD molecular markers, the phylogenetic relationships among Guinea yam and their wild relatives were elucidated. This will assist the breeding program both to exploit the wild yam genome for useful traits and to develop marker-assisted selection.
- Through collaborative links with the Scottish Crop Research Institute (SCRI), UK, a diagnostic test based wholly on monoclonal antibodies was developed for East African and African Cassava Mosaic Virus. The test was developed by a Nigerian national program virologist working with IITA. It is relatively simple to use and is adoptable by national programs with limited virology facilities. Cassava mosaic disease surveys in Kenya and Uganda, coordinated with the national programs, confirmed the usefulness of the test.

IITA BIOTECHNOLOGY RESEARCH

BRINGS BENEFITS TO AFRICAN FARMERS

Shoot regeneration of cowpea from cotyledon (in vitro, ×20)

A technological bridge

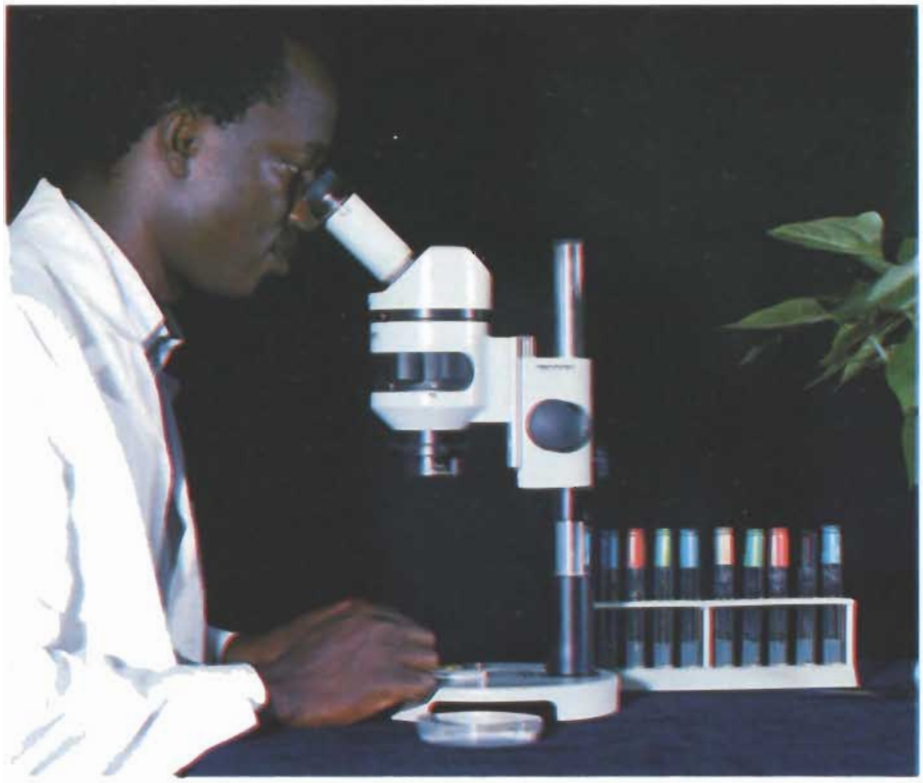
The most sophisticated technology, the technology of the richest, is sometimes the appropriate tool to solve the problems of the poorest. This is the case with biotechnology in relation to some major production problems of certain crops that are important in the farming systems of sub-Saharan Africa.

IITA established a Biotechnology Unit in 1990. Through activities in biotechnology as well as in some other research areas, IITA maintains strong links with advanced laboratories in other continents, thus forming an effective technological bridge between the highly industrialized countries and sub-Saharan Africa. Major institutions collaborating in our biotechnology research have included Purdue University (USA), University of Minnesota (USA), Auburn University (USA), University of Naples (Italy), Portici University (Italy), Germplasm Institute, Bari (Italy), Vancouver Research Station of Agriculture Canada, Natural Resources Institute (UK), John Innes Center (UK), Wye College, University of London (UK), University of Reading (UK), and the Universities of Ghent and Leuven (Belgium). Work has focused on 3 crops: cowpea, plantain, and yam.

Biotechnology, through recombinant DNA, enables researchers to explore new means to control insect pests, diseases, and weeds. It can improve a plant's ability to withstand environmental stresses, such as drought and unfavorable soil conditions. In addition, it enhances crop storability and quality; for example, it can increase the level of proteins that contain essential amino acids. Biotechnology can also expand scientific knowledge of plant resistance and the interactions of plants, pests, and biological control agents with the rest of the ecosystem.

IITA uses biotechnology to complement traditional methods of crop improvement—methods that the Institute has successfully applied over the years to develop highly productive varieties of several crops, including cassava, cowpea, and soybean.

Safety is a primary concern in applying biotechnology



IITA's research contributes to making sub-Saharan Africa self reliant in food production

In promoting the application of biotechnology in sub-Saharan Africa, IITA is attentive to the concerns expressed throughout the world about possible ecological and health risks. IITA recognizes that for any new technology, it is important to weigh the potential benefits against the risks and possible costs of its widespread adoption. Hence we have built a specially designed laboratory (a containment facility) that conforms to international safety standards for biotechnology research.

Implementation of our active support of proper regulations and guidelines for carrying out biotechnology research started in Nigeria. During 1993–1994, our scientists worked closely with officials of Nigeria's Federal Ministry of Agriculture and Natural Resources, as well as other Nigerian scientists, to develop safety guidelines for biotechnology research and for testing and using products resulting from such research. The need for national biosafety guidelines is a major element of Nigeria's National Policy on Environment. This is reflected in the Environment Impact Assessment Decree No. 86 of 1992.

The objectives of the guidelines are to ensure public and environmental safety in biotechnology research and development, and in industrial production processes. Special emphasis is on the need to prevent accidental releases of genetically modified organisms, and on the prescription of appropriate conditions for testing and use of products of biotechnology research. The guidelines cover the following specific topics:

- Genetically engineered microorganisms.
- Genetic transformation of plants and animals.
- Recombinant DNA (rDNA) technology in the development of vaccines and pharmaceutical products.
- Large-scale production and the deliberate release of microorganisms, plants, animals, and other products derived from rDNA technology.
- Appropriate measures to avoid adverse effects on human health and the environment, which might arise from the deliberate or accidental release of genetically modified organisms (GMOs).

- Scientifically based process of risk assessment of specific GMOs before release is authorized.
- Importation and use of GMOs and other biotechnology products.

Due to the rapid evolution of this science, these guidelines cannot be regarded as rigid laws. Biotechnogy scientists will periodically review them to reflect new knowledge.

A workshop on Implementation of Biosafety Guidelines in Nigeria, the first such workshop, was held 16–20 January 1995. It was organized with and supported by the Biotechnology Advisory Commission of the Stockholm Environment Institute. A solid basis has thus been laid for the safe conduct of biotechnology research in Nigeria. Similar developments are under way in some other countries of sub-Saharan Africa.

Cowpea biotechnology

The significance of cowpea in African agriculture has several dimensions. It is the primary source of good quality protein for many poor people, particularly in the drier areas of West Africa. It also features prominently in the recipes of several food products relished by both the rich and the poor. It is estimated that cowpea is an integral part of the diet of about 120 million people. Cowpea is thought to be a crop of African origin. Whereas it has been most widely domesticated in West Africa, its center of diversity is in southern Africa. The region of greatest production is West Africa, which accounts for about 70 percent of total world production. It is important in the farming systems of the region as a crop normally interplanted with cereals, providing some benefits in soil fertility as a nitrogen-fixing legume.

Using traditional breeding methods, IITA scientists have bred many relatively high-yielding cowpea varieties that are resistant to diseases and a few insect pests. Some of the varieties mature in only about 60 days compared with more than 100 days for traditional varieties, while others have such desirable characteristics as drought tolerance. For example, some drought-tolerant varieties have been distributed extensively in war-torn, drought-prone Mozambique. These varieties have been adopted by farmers, and they continue to grow well in certain ecological niches. Varieties that can be intercropped in the cereal (sorghum and millet) farming systems of the Sudan Savanna and the southern Sahel are also being bred.

Yet, insect pests remain an intractable impediment to cowpea production. Each phase of development of the cowpea plant attracts one or more pernicious species of insect pests. Some chew the leaves, some cause the flowers to abort, others suck the seed-bearing pods, while some drill through the pods to destroy the seeds. There is no respite for cowpea even after harvest. Other insects (bruchids) attack the seeds in storage; they bore holes into them rendering them unmarketable, and may even turn them into unusable powdery mass.

Research using traditional plant breeding and entomological approaches has yielded only limited success, because cultivated cowpea varieties simply have no genes for resistance to certain insect pests that could be used for cross-breeding. IITA scientists should know. IITA's collection of cowpea varieties is the largest in the world—about 15,000 accessions are held in the Institute's Genetic Resources Unit. Thus, to keep cowpea free of insect pests requires the application of insecticides virtually from the day of planting to the day of sale in the market, an unsound option from economic, health, and ecological standpoints.

Biotechnology offers hope for an economically and ecologically appropriate solution to the multifaceted insect problem. Two approaches are possible. The first involves transferring the required genes from wild relatives of plants related to the cowpea plant through cross-breeding. This type of breeding involving different plant species is called wide crossing. Another approach is to introduce insect resistance genes from unrelated plant species directly into cowpea through manipulation at the cellular and molecular level. This is pure genetic engineering. IITA scientists are adopting both approaches.

A number of wild relatives of cowpea are resistant to insect pests. Among them are *Vigna vexillata* and *Vigna oblongifolia*. It is from these that IITA scientists are trying to transfer genes into the cowpea (*Vigna unguiculata*). This has not been easy. Crossing cowpea with *Vigna vexillata* is extremely difficult. The resulting embryos that should eventually develop into plants do not survive beyond 4–5

days. They abort spontaneously. If this hurdle is not overcome, no gene can be transferred from the wild cowpea relatives.

In 1995, IITA scientists solved the problem of the aborting embryos. This involved taking out the immature embryos, "harvesting" them, as soon as possible after fertilization, and placing them in a specially formulated culture medium able to support their development. The challenge was to come up with a formulation of the culture medium that would consistently support the in vitro development of the embryos.

The scientists determined the mineral composition of the embryos, and used the result as the starting point for the culture medium. They eventually identified the appropriate proportions of other chemicals (carbohydrate sources, plant growth hormones, etc.) to add to the basic chemical mixture that mimicked the mineral composition of the embryos. The immature embryos germinate in the new culture medium, and are thereafter nurtured into full plants. Through this process of wide crossing, cowpea plants resistant to insect pests are produced.

Another strategy consists in genetic engineering to insert foreign genes into the cowpea plant using the soil bacterium *Agrobacterium tumefaciens* as a vector. Genes can also be inserted by direct means, using a biolistic gun or electroporation. The intent is to create transgenic (carrying foreign genes) cowpea.

Genes from wild varieties are transferred to domestic varieties to increase their resistance

To create a transgenic plant, scientists must

- isolate the gene to be transferred
- find appropriate mechanisms to transfer the gene into plant cells
- insert genetic markers to identify those cells that have been transformed
- regenerate the transgenic cell or tissue into a complete plant
- develop the means to ensure the proper expression of the new gene in the plant.

IITA scientists and their collaborators are working on all aspects of creating transgenic cowpea. Plants being explored for useful genes that could be inserted into cowpea include edible legumes, such as African yam bean, Bambara groundnut, and lablab; these legumes are endemic in West and Central Africa.

For cowpea and other legumes, the most limiting phase of the process is developing a reliable method of plant regeneration from transformed tissue. IITA scientists have made a major breakthrough. They have solved the plant regeneration problem. They formulated a new culture medium where in vitro regeneration of cowpea can be reliably achieved. Of 19 elite cowpea varieties tested, the procedure succeeded in 5.

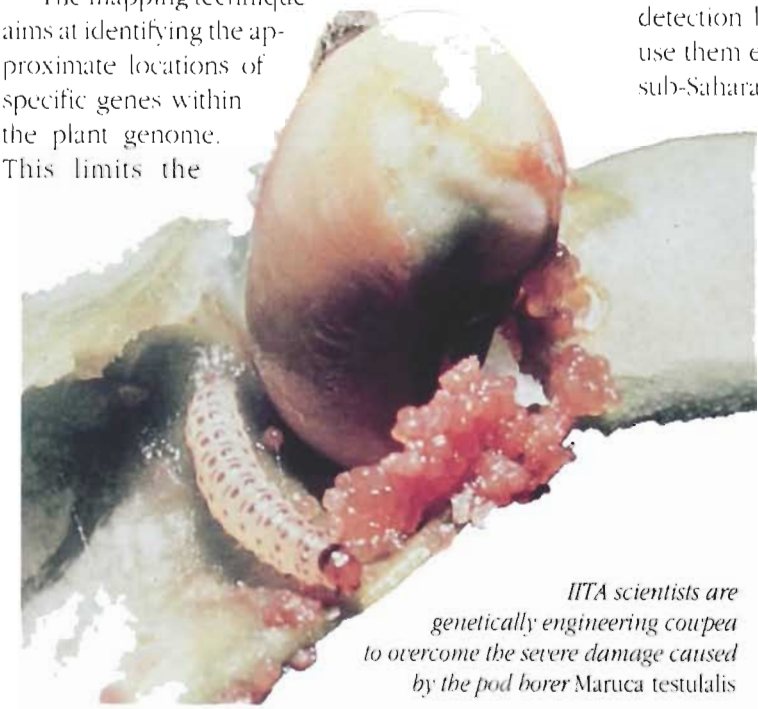
The next challenge is to develop a method of regeneration that works for all varieties. A problem that arises when plants are cultured from undifferentiated tissue is that the plants may sometimes be strikingly different from one another and from the parent plant. This phenomenon is known as somaclonal variation. With the cowpea varieties so far tested, the new culture medium does not result in any somaclonal variation, ensuring that the parent plant and any transformed tissue will be regenerated unchanged.

The procedure has been repeated and confirmed to be successful at two advanced laboratories: the John Innes Center in the United Kingdom, and the Portici University in Naples, Italy. International collaboration has been facilitated by the use of electronic mail. Scientists are in touch almost every day. They can perform the same experiments in parallel, exchanging ideas and discussing problems as they proceed. This results in rapid progress towards the development of a highly productive, insect and disease resistant cowpea for the benefit of African farmers and consumers.

Other applications

Mapping genes. To obtain a better understanding of the genetic make-up of the crop plants in IITA's research mandate, scientists in the Biotechnology Research Unit and their collaborators in other laboratories are constructing genetic maps using a sophisticated procedure called Restriction Fragment Length Polymorphism (RFLP).

The mapping technique aims at identifying the approximate locations of specific genes within the plant genome. This limits the amount of plant DNA that must be searched to isolate a given gene. RFLP maps are being made for cowpea and its wild relatives, yam, and cassava. Significant progress has already been made in the molecular mapping of yam and cowpea.



IITA scientists are genetically engineering cowpea to overcome the severe damage caused by the pod borer Maruca testulalis

Molecular diagnostics. IITA and its collaborators use biotechnology to identify and characterize organisms that cause economically important crop diseases. The technique is based on Polymerase Chain Reaction (PCR) and monoclonal antibodies. PCR technology enables scientists to rapidly generate large amounts of genetic material from a trace amount, which otherwise would be too small to detect and analyze. The technology is routinely used to screen plantain and banana for the banana mosaic virus (BMV), a constraint to the rapid dissemination of the new plantain varieties bred by IITA. PCR is also used for the detection of the yam mosaic virus.

The use of monoclonal antibodies enables reliable information to be collected quickly on the identity, on the distribution of strains, and on their importance. IITA and Agriculture Canada have prepared monoclonal antibodies for viruses that are economically important for IITA mandate crops, and therefore to the populations of sub-Saharan Africa. Over the years, IITA has supplied virus detection kits, as well as the supplies required to use them effectively, to scientists in 19 countries of sub-Saharan Africa. Thus, virus detection research is now carried out by many African scientists in their own countries. IITA thereby helps to build a valuable database on a subject of considerable importance to Africa's food security.

Training

IITA aims to enhance the capability of African institutions to conduct biotechnology research to assess and use biotechnology techniques and products. Hence, training is a major activity of the Unit. Since 1990, the unit has trained about 50 African scientists and six students are currently conducting research for their PhD degrees. The training activities have included three annual workshops conducted during 1991–1993 on the use of monoclonal antibodies for the detection of crop viruses. A total of 35 scientists from 19 countries participated in those training workshops.

ECOREGIONAL PROGRAM:
A Mechanism for Sustainability and Partnership in Agriculture

A CGIAR initiative

A concerted effort started in 1994 by IITA, the convening center for an ecoregional initiative by the CGIAR, has resulted in a highly collaborative, comprehensive, and innovative program of research and development for two major ecological zones of sub-Saharan Africa: the moist savanna and the humid forest zones. The program was developed through a process of consultation. It involved the national agricultural research and extension systems (NARES) of 13 African countries, international agricultural research centers (IARCs) working in Africa, international development organizations, and some overseas advanced research institutions.

The goal of the Program is at the heart of IITA's mission. It seeks to assist smallholder and medium-scale farmers to improve their well-being and alleviate poverty through the use of production technologies and postharvest systems that increase productivity and food security. By minimizing natural resource degradation, such production technologies can be sustained over long periods.

A holistic approach

The program integrates commodity improvement and component research with research in natural resources management, research on policy and institutional issues, and increased participation by potential beneficiaries and other interested parties. It seeks to improve information management, and to develop innovative mechanisms for the spread and diffusion of technologies. It is being implemented through three consortia:

- Moist Savanna Consortium
- Humid Forest Consortium
- Inland Valley Consortium.

Each consortium addresses the specific agricultural research and development needs of its agroecological zone. The relevant objectives, expected outputs, and the activities to be undertaken have been agreed upon through extensive consultations.

The Inland Valley Consortium, hosted by the West Africa Rice Development Association (WARDA), has been operational since 1994. It was designed and launched before the Technical Advisory Committee (TAC) of the CGIAR called for a comprehensive ecoregional program. Its development will now take place under the umbrella of the larger ecoregional program.

Consultation and participation

A particularly noteworthy feature of the new program is the extent of consultation and participation that led to its development. Therefore, a wide range of partners is envisaged in its implementation. To help conceptualize the program, IITA put in place a comprehensive mechanism for consulting potential partners, including an ecoregional advisory task force. IITA also appointed a senior and highly experienced research manager to work fulltime on the project as the ecoregional program coordinator.

Moist Savanna Zone

The moist savanna zone (MSZ), characterized by a length of growing period (LGP) of between 150 and 270 days, has a high capacity to produce food. It occupies about 29% of the total cropland of sub-Saharan Africa.

Major crops

Maize, Sorghum, Millet, Cowpea, Cotton, Cassava, Soybean, and Yam.

The Ecoregional Program Advisory Task Force, comprising representatives of NARES, IARCs, and international and regional development organizations, met four times between June 1994 and April 1996. The Task Force discussed and decided on the research and development needs and priorities, the implementation strategies, and the most appropriate partner institutions.

As a contribution towards the formulation of the program, the Food and Agriculture Organization of the United Nations (FAO) and IITA organized a conference on the moist savanna zone. The conference was attended by representatives of 19 sub-Saharan African countries. Another conference on agroforestry was arranged jointly by IITA, the International Centre for Research on Agroforestry (ICRAF), and the Centre de coopération internationale en recherche agronomique pour le développement (CIRAD).

During 1995, the program coordinator visited 15 countries, briefing leaders of various research and development organizations and creating awareness of the CGIAR ecoregional approach among potential partners within African national agricultural research and extension systems, as well as non-governmental organizations (NGOs). On the recommendation of the Ecoregional Advisory Task Force, consultants were hired to prepare detailed program documents for both the Moist Savanna and Humid Forest consortia. The two documents were reviewed widely, and revised to form the basis for the action plans of the consortia.

Formal launching

Further consultations were undertaken early in 1996 with CIRAD and FAO. The program coordinator made a second round of visits to potential partner countries, confirming interest, and initiating country surveys.

From 16 to 19 April 1996, an expanded advisory task force meeting, attended by senior research directors from all partner countries, was held at IITA in Ibadan, Nigeria. The Moist Savanna Consortium and the Humid Forest Consortium were officially launched on 19 April 1996 when the countries participating in each consortium signed a Memorandum of Understanding which describes their commitments and obligations and those of IITA as the Program Convenor.

Participants at the meeting considered and approved the draft consortia documents, an action plan for 1996 and 1997, and a budget proposal for 1997. IITA was requested to prepare and to circulate the agreed program on behalf of its partners, and to secure the necessary funds for program activities in 1997 and beyond.

Inland Valleys

Inland Valleys are defined as the upper reaches of river systems, inland in respect of the main rivers and the main tributaries. An inland valley system comprises valley bottoms and minor floodplains which may be submerged for part of the year. Their hydromorphic fringes, and contiguous upland slopes and crests, extend over an area that contributes runoff and seepage to the valley bottom.

Major crops

Rice, Sugarcane, and Vegetable crops.

This Ecoregional Program for the Humid and Subhumid Tropics of Sub-Saharan Africa (EPHTA) was conceived, mindful of the fact that the growth rate of agricultural production is not keeping pace with rapidly rising demand resulting from high population growth rates and rural-urban migration. Furthermore, it is projected that the demand for agricultural production would triple by 2025, relative to the 1990 level, even if annual population growth rates stabilized at 2.5 percent. The bleak prospect is further worsened by an increasing degradation of the natural environment.

Objectives and short-term priorities

The Program formalizes and strengthens close collaboration among national agricultural research and extension systems, international and regional agricultural research and development organizations, and relevant stakeholders. The specific research and development activities are designed to achieve three sets of objectives:

- develop and transfer more productive and sustainable agricultural systems for the moist savanna zone;
- develop and protect the humid forest ecological zone and improve the livelihoods of people living in this zone; and
- develop inland valley agroecosystems in an environmentally sound manner.

Short-term priorities have been established and are already being implemented. Before the end of 1996, field activities of the two new consortia will be well under way. In Cameroon, the benchmark area for the forest margins is now fully functional. Surveys, stakeholder fora, and baseline reports in preparation for benchmark area development will be completed in northern Nigeria in 1996, and initiated in southern Nigeria and Benin Republic. Resource management surveys as well as soil and vegetation appraisals will be completed for a minimum of four benchmark areas by 1997.

Another short-term priority of the ecoregional program is information management and exchange. Country reports and state-of-the-art papers will be published and distributed. A newsletter will be started covering all consortia, and support will be provided to the journal *Agricultural Systems in Africa*, as a cost-effective means of disseminating findings within the ecoregion.

Initial achievements

The partnerships already formed, the intensified awareness of the challenges facing agricultural development and environmental protection in sub-Saharan Africa, and the consensus reached on the strategies for facing up to these challenges can be justifiably chronicled as initial accomplishments of this new program.

Humid Forest Zone

The Humid Forest Zone of sub-Saharan Africa includes areas with over 271 days of crop growing period with a daily mean temperature of above 20°C and annual rainfall of 1400–4000 mm at altitudes below 800 m.

Major crops

Cassava, Banana, Plantain, Maize, Yam, Oil palm, Coffee, Cocoa, and Cowpea.

Intensified resource use challenges agricultural research. Farmers' real and felt needs and what they acknowledge as their high priorities also challenge the scientists. Yet, research can take advantage of local know-how and farmers' experiences over generations.

The Humid Forest Program has a multidisciplinary team of biological, physical, and social scientists. Research first focuses on understanding rural people and their farms, their interaction with their environment and their ecological setting, in order to identify the most appropriate interventions. This article illustrates what makes farmers' experiences the beginning of wisdom in agricultural research.

The traditional cropping system of the humid forest zone of southern Cameroon has changed in recent decades in response to a number of socioeconomic factors. The change has led to a different weed situation that places a greater labor burden on women relative to men. IITA scientists, through surveys conducted among women farmers in the area, have documented the nature of the problem and obtained information to guide future research in weed management.

Increased population density coupled with improved access to markets in some parts of the forest zone has resulted in much greater demand for land and a consequent inability to maintain the traditional long fallow periods of 15 to 20 years. Moreover, there is a shortage of labor for forest clearing because young men migrate to towns and cities. Therefore, land is cropped for much longer periods and fallows are often less than 5 years. A consequence of shorter fallows in the traditional slash-and-burn agriculture has been, in general, a greater weed problem, a shift in the species of weeds, and the relative importance of individual weed species.

Women are usually responsible for food crop production. They plant, weed, and harvest the fields of mixed food crops. Thus, weeds are primarily a women's problem. Men clear the forest and take care of cash crop production. Shorter fallows have meant a lighter workload for men, because it is easier to clear the bush fallows (dominated by the exotic perennial, *Chromolaena odorata*) than to cut down trees in a secondary forest.

In contrast, women end up spending more time weeding. After slashing and burning these fallows, women have to hoe out the rootstocks of *Chromolaena odorata*, an activity that can nearly double the time spent on land preparation. Furthermore, shortened fallows result in a significantly greater weed pressure at first weeding, and often an additional weeding is required in the cassava stand after groundnut and maize have been harvested.

The nature of the weed problem

Plants are perceived as weeds when they affect the crop negatively or make the farmer's field work more tedious. Through interviews with women farmers in southern Cameroon, IITA scientists have gained a deeper understanding of the problems weeds cause. In the mixed cropping phase of the traditional farming system involving the cultivation of groundnuts, these problems may be grouped into the following seven categories:

The most common weeds in southern Cameroon

A total of 77 women farmers who were hand weeding in six villages in southern Cameroon were asked what the three most common weeds in their locality were.

Chromolaena odorata was ranked highest. Depending on the village, between a third and all (100 percent) of the women questioned ranked it among the top three. It was least common at both ends of the fallow spectrum, i.e., in areas of long fallows and areas of very short fallows.

The common weed species, in order of the frequency of their mention, are

- *Chromolaena odorata*
- *Ageratum conyzoides*
- *Sida corymbosa*
- *Sida rhombifolia*
- *Stachytarpheta cayennensis*
- *Triumfetta cordifolia*
- *Trema orientalis*
- *Dioscorea bulbifera*
- *Mucuna pruriens* var *pruriens*
- *Euphorbia heterophylla*

- Weed species that grow faster than the crop or wrap themselves around the crop, causing shading and consequent poor crop growth. Moreover, climbing species are difficult to separate from the crop at weeding. Weeds responsible for this type of problem include *Chromolaena odorata* and *Euphorbia heterophylla*, which grow aggressively. Others like *Dioscorea bulbifera* and *Mucuna pruriens* var *pruriens* are climbers and wrap themselves tightly around crops.
- Some weeds produce thick mats of seedlings in large patches or numerous shoots that resprout from low-lying stem parts and roots. Women find clearing such dense weed growths time-consuming and tedious. In this category are *Stachytarpheta cayennensis*, *E. heterophylla*, *Ageratum conyzoides*, and to a lesser extent, *C. odorata*.
- Some weeds are hard to pull out because they have strong tap roots and they develop woody stems rapidly. Examples are *Sida corymbosa*, *Sida rhombifolia*, and *S. cayennensis*.
- Some weeds dry out the soil, thereby allegedly reducing crop yields. They include *Sida corymbosa*, *S. rhombifolia*, and *S. cayennensis*.
- Some weeds easily break off close to the ground, and they produce new shoots, requiring another round of weeding. Therefore, to avoid breakage, great care must be taken in removing such weeds (making it a tedious and time-consuming operation). Two of the common weeds, *E. heterophylla* and *A. conyzoides*, are of this nature.
- Some weeds have spikes that may injure women and children as they attempt to remove them, while others have bristly hair that can strongly irritate the skin. Examples are *Smilax kraussiana* and *M. pruriens* var *pruriens*. Among weeds that may hurt the hands of farmers are those that are difficult to uproot because of their woody stems and strong tap roots, such as *S. corymbosa* and *S. rhombifolia*.
- Farmers have observed that some weeds are associated with pests and diseases of crops. These include *A. conyzoides*, *S. cayennensis*, *S. corymbosa*, and *S. rhombifolia*.

In Africa, women are often responsible for food production

Ambivalent weeds

Under certain circumstances, plants that are not generally perceived as weeds may interfere with a crop of current main interest. Women farmers have devised ways of dealing with such ambivalent weeds. For example, in certain parts of Cameroon, cocoyam tubers in the soil can sprout rapidly once the field is established and compete vigorously with planted groundnut. The women cut back the leaves of the cocoyam to retard its growth and permit undisturbed development of the groundnut crop. Once the groundnut has been harvested, the cocoyam is allowed to establish again among the cassava crop, whose growth it does not affect appreciably.

Water leaf (*Talinum triangulare*) is both a weed of cultivated crops as well as a leaf vegetable. The farmers' strategy is not to remove it completely, but to reduce its population so low that it does not compete effectively with cultivated crops. This ensures that the water leaf is available for consumption and that the crops are not adversely affected.

Some plants that are clearly troublesome weeds during the cropping cycle may play useful roles in the agro-ecosystem. *Chromolaena odorata* is one such. It was introduced into West Africa in the first half of this century. Its rapid vegetative development and its massive production of airborne seeds have allowed it to spread to large areas of the region. Once established, it develops into a dense thicket in almost pure stands. The plant has become an important component of the natural succession in the slash-and-burn cropping systems with short fallows.

Reports indicate that as a fallow species, *C. odorata* can return substantial amounts of nutrient-rich litter to the soil, thereby improving the soil's chemical and physical properties. Furthermore, it suppresses the growth of the extremely noxious grass weed, *Imperata cylindrica*. Old farmers in the Nkometou III area of southern Cameroon recall that before *C. odorata* moved into the area, *I. cylindrica* was the main short fallow species. They welcomed *C. odorata* as God-sent when it got to their area in the late 1960s, because of its suppression of the immensely problematic *I. cylindrica*.

However, *C. odorata* has been a mixed blessing. As an important weed problem in arable cropping, it has led to a greater workload for women and children who are responsible for weeding. The challenge for researchers is to develop management strategies that reduce its negative effects during the cropping cycle and enhance its soil rejuvenating properties during the fallow phase (an attribute important for the sustainability of crop production).

Other lessons

The information gathered by tapping into the knowledge-base and experiences of the women farmers has given an insight into some of the changes taking place in the weed communities of southern Cameroon and the impact of such changes. There is a clear shift in dominance of weed species as fallow periods become shorter. Species that dramatically increase the tedium of weeding (such as *A. conyzoides*, *S. corymbosa*, *S. rhombifolia*, *E. heterophylla*, and *M. pruriens* var *pruriens*) are replacing species that are easy to hand-weed (like *Triumfetta cordifolia* and *Trema orientalis*).

Some of the findings surprised researchers. For example, they did not know that *Ageratum conyzoides* was as common and as much of a weed problem as farmers reported it to be. Moreover, they did not expect *S. cayennensis* and *E. heterophylla* to be so widely spread in some villages. The fact that three weed species (*S. corymbosa*, *S. rhombifolia*, and *S. cayennensis*) dry out the soil was unknown, but scientists could link it to soil compaction.

The challenge for researchers is now to develop integrated weed management options that can make a real difference in the lives of women farmers.

Maize production soars

A phenomenal increase in maize production has occurred in West and Central Africa in recent years. It is the result of the introduction of high-yielding, drought-tolerant, early, and extra-early maturing varieties coupled with the combined activities of a collaborative network of scientists in the region. The introduced varieties have a yield potential of 5 tonnes per hectare, and are ready for harvest as green maize (eaten boiled or roasted) in 60 days, or as dry grains in only 75 to 80 days. Ordinarily, the maize crop matures in about 120 days.

The average annual growth rate of maize production in the region for the period 1983–1992 was 4.1 percent. The comparable figure for Eastern and Southern Africa for the same period was 0.9 percent, or less than a fourth of the growth rate in West and Central Africa. Some countries recorded extremely high annual growth rates: Burkina Faso (17.1 percent), Ghana (8.3 percent), Guinea (7.6 percent), and Mali (7.5 percent).

The land area devoted to maize production has also increased significantly (an average of 2.7 percent per year for the region). Much higher expansion rates were reported for several countries: Guinea (9.4 percent), Burkina Faso (7.4 percent), Mali (6.6 percent), and Zaire (5.5 percent). Nigeria, the most populous country in the region, scored substantial gains as well. The annual rate of growth in area cultivated to maize was 3.5 percent, and the annual gain in production was 5.3 percent.

In each country, the rate of growth of production exceeded the rate of growth of land area devoted to cultivation. This indicates that the increases in production were due to gains in yield per unit area, and not merely to expansion of area.

Evidence abounds

Evidence of the gains in maize production in the region literally stares an investigator in the face. Green maize boiled on-the-cob, or roasted, has become a common sight along roadsides in villages and towns and along highways in the Sudan savanna. Green maize is available as early as April where farmers take advantage of the residual soil moisture along the river banks. This early production helps alleviate hunger when the previous harvests have been largely depleted, and when the new plantings of other crops and traditional varieties are not ready for harvesting.

As a result of increased production, dried maize is available in local markets for much longer periods than in the past. This is true not only of markets in large Sahelian towns such as Bamako and Ouagadougou, but also in many villages and small towns throughout the region. Moreover, new uses have been found for the increased production. Maize is being substituted for sorghum and millet in some local dishes, and industries are using it for brewing and for oil extraction. Everybody seems to have benefited—the farmers who grow the crop, the major distributors, the so-called middlemen and women, the petty vendors selling green maize on the roadside or selling dried maize by the cup, as well as industrialists.

Regional collaboration

IITA scientists started work on new maize varieties under the auspices of the Semi-Arid Food Grain Research and Development Project (SAFGRAD). The SAFGRAD Project, covering maize, sorghum, millet, and cowpea, was sponsored by the Scientific, Technical, and Research Commission of the Organization of African Unity (OAU/STRC) and the US Agency for International Development (USAID). IITA was responsible for the maize and cowpea components of the Project.

The development of extra-early varieties of maize (varieties maturing fully in 80 days) became a research objective in 1984 and followed earlier success in breeding early (90-day) varieties. Achievement of the new objective called for activities that only an international research organization stood any chance of successfully carrying out. Maize varieties with potentially appropriate characteristics were assembled from around Africa, Colombia, India as well as from the extensive collection at Centro Internacional de Mejoramiento de Maizy y Trigo (CIMMYT) and evaluated in field experiments.

Maize has become increasingly popular with farmers in sub-Saharan Africa. This farmer may once have produced only sorghum and millet. Now, like many others, he has adopted maize.

In the savannas where sunshine is in abundance, maize ears are debusked and spread out to dry in the open. This is a first step in reducing postharvest losses and in making them ready for shelling.

Women traders come to the roadside to sell maize to middlemen and market "queens," who will move their produce on to many major markets.

Roasted green maize on-the-cob is a very popular roadside snack. It is a source of income for women petty traders. Maize is an important source of carbohydrate, protein, vitamins (the B group), and minerals. Thus it provides children with much needed nutrients. The early varieties ensure that this food is available when other food crops are immature in the field. Green maize provides cheap food to poor families. Other maize food products include flat breads, couscous, and gruels.

IITA maize scientists are devoting attention to grain quality so that farmers can be provided with varieties that cater to consumer preferences. The food value of new varieties is also monitored. Small improvements can have large benefits for family health.

Two yellow-grained indigenous varieties (landraces) from Burkina Faso and one white Colombian variety were selected following careful experimental assessment of 80 varieties. The three varieties had the virtue of being extra-early (for example, the Colombian variety flowered 42 days after planting, 7 days earlier than the local check variety). But both had relatively low yield potential —2 tonnes per hectare. The three extra-early varieties were crossed to selected promising, improved white and yellow varieties to develop new varieties combining extra-early maturity with other desirable agronomic characteristics.

By 1987, one yellow and three white varieties that mature in 75–80 days and with a yield potential of 3 tonnes per hectare had been developed. By this time, the West and Central Africa Maize Network (WECAMAN) had become the maize component of the second phase of the SAFGRAD Project. The network comprised maize scientists in the various national agricultural programs of the region and in the international agricultural research and development centers. The four extra-early varieties were offered to national programs of the region for evaluation and further development.

Disease resistance

National program scientists were enthusiastic about the new varieties' extra-earliness in the humid ecological zones of the region, although the varieties had been developed for the Sudan Savanna. Yet, to grow them in the humid zones would require them to be protected against several diseases.

Historically, diseases were not a problem in the Sudan Savanna. However, scientists surmised that climate change, including erratic rainfall at the beginning of the season, would cause changes in farming practices. Such changes could induce an increased buildup of maize disease organisms, and usher in hitherto nonexistent diseases.

For these reasons, scientists began, in 1988, to breed resistance to diseases into the extra-early varieties, including the maize streak virus disease, a disease unique to the African continent.

IITA had already bred resistant varieties and developed techniques for incorporating the resistance into other varieties (an accomplishment for which it won the King Baudouin Award for International Agricultural Research in 1986).

Promising streak resistant, extra-early varieties were tested by scientists, members of WECAMAN. They also conducted agronomic trials to determine the optimal farming practices for the new varieties. The recommendations they came up with raised the yield potential of the varieties to 5 tonnes per hectare.

Inherent advantages

The new extra-early varieties were released by WECAMAN, the maize network. They have been adopted widely by farmers in the Sudan Savanna and in the Sudan-Sahelian transition ecological zone. Their extra-earliness ensures that they fit into the shortening growing season, enabling them to escape drought, and generally reducing the risk to farmers caused by climate change. Their multiple disease resistance enlarges their zones of ecological adaptation, leading to a considerable expansion of maize area in West and Central Africa.

Adoption and spread of the varieties have been facilitated by the participation of many national agricultural programs. Internal trade within countries has aided the movement of the new varieties across ecological zones. The increased trade among neighboring countries in West and Central Africa (much of which is informal) has also helped the spread of the varieties.

The quiet revolution represented by the expansion of highly productive, disease resistant maize varieties across the savanna belt of West Africa is a testimony to the efficacy of scientific creativity and well-conceived research collaboration.

Maize is an excellent source of carbohydrates

"Sweet are the uses of adversity," a statement by William Shakespeare, aptly describes the experience of Malawi and some countries of east and southern Africa hit by devastating droughts in 1991-92 and 1992-93. Malawi, a small land-locked country of about 10 million people, which also had below average rainfall in 1993-94, was one of the most severely affected. A project designed to relieve the immediate adversities of the drought has paved the way to a future of much greater food security for the country.

For 30 years, official agricultural policy had emphasized maize, the staple food of the majority of Malawians, and a crop to which 70 percent of arable land was devoted, and also encouraged the cultivation of tobacco and other cash crops like cotton. Resources, human and material, for research and extension were concentrated on maize and tobacco. But when the droughts hit, maize production was reduced by 50 percent, causing famine and severe economic hardship for farm families. Cassava and sweetpotato were the only food crops that survived the droughts and provided food for their growers.

A drought-recovery project

During the growing season of 1991-92, Malawi's national root crops program initiated a small-scale project for the rapid multiplication and distribution of cassava stems and sweetpotato vines for planting by farmers in drought-prone areas.

In the 1992-93 and 1993-94 cropping seasons, the small project received a boost from USAID-Malawi and USAID's Office of Foreign Disaster Assistance (OFDA) in Washington, both of which wished to help Malawi to recover from the effects of the drought. They provided funds for an expanded project entitled "Accelerated Multiplication and Distribution of Cassava and Sweetpotato Planting Material as a Drought Recovery Measure in Malawi."

The expanded multiplication project was implemented in 1992-93 by the East and Southern Africa Root Crops Research Network (ESARRN) and in 1993-94 by the Southern Africa Root Crops Research Network (SARRNET). The networks are staffed and managed by IITA and a sister organization, the International Potato Center (CIP), with headquarters in Lima, Peru. Within the system of international agricultural research centers supported by the Consultative Group on International Agricultural Research (CGIAR), IITA has responsibility for cassava research and development in Africa while CIP is in charge of sweetpotato.

In 1993, ESARRN split into two networks: the East Africa Root Crops Research Network (EARRNET) and the Southern Africa Root Crops Research Network (SARRNET). IITA-SARRNET, as the successor of ESARRN in Malawi, had the overall technical responsibility for the project, but worked in close collaboration with the Malawi National Root Crops Improvement Program and a number of NGOs.

The goal of the expanded project was to increase food security and incomes of rural households in the drought-prone areas, through accelerated multiplication, distribution, and farmer adoption of improved cassava and sweetpotato varieties that had already been tested in Malawi. Specific objectives included the following:

- assist cooperators (primarily extension agents and nongovernmental organizations (NGOs) to establish permanent multiplication sites in each of the major root crop production areas;
- provide training, technical support, and advice to cooperators managing multiplication sites;
- multiply improved cassava and sweetpotato varieties at 20 primary and 50 secondary multiplication sites throughout the country;
- provide financial and technical support to cooperators in the distribution of planting materials to an estimated 300,000 smallholder farmers; and
- produce cassava and sweetpotato planting materials sufficient to plant about 2,200 hectares of cassava and 4,500 of sweetpotato during two subsequent cropping seasons. (More sweetpotato planting material can be produced in a given period because of its much shorter growth cycle and its more profuse production of stems used for planting).

Policy review

The experience of the drought years, coupled with the initial success of the drought-recovery project, compelled a review of official policy to avert similar hardships in the event of future droughts. The future promises more droughts, according to a team of African scientists working under the auspices of the African Center of Meteorological Applications for Development. They remarked that for all subregions of Africa, the outlook was more of the same problems of increased weather variability and extremes already being experienced, only that the problems would get worse.

The team stated: "Increased incidence of famine is likely to be the most tragic consequence of climate change in Africa. This will not be as an inevitable outcome of climate change, but because of the prevailing conditions of poverty." Thus for Malawi, as for other countries of sub-Saharan Africa, an agricultural strategy to deal with future droughts is an absolute imperative.

In November 1994, following a strategic planning conference, Malawi's Ministry of Agriculture and Livestock Development adopted a strategy of food crop diversification, giving much higher priority to two drought-tolerant crops: cassava and sweetpotato. These two crops are particularly important from the standpoint of food security because, in addition to their drought tolerance, their requirements for external inputs are low. They also grow reasonably well in poor soils, and they can adapt to a wide range of ecological conditions.

Before the droughts, both crops scarcely received more than a footnote in the Research Master Plan of Malawi's Department of Agricultural Research. In the words of a 1995 report, "a maize mentality prevailed obscuring the contribution of

Cassava can grow in poor soils, thus ensuring that food is available to resource-poor households

cassava and sweetpotato to food security." Today, a root crops commodity program has been developed. Cassava and sweetpotato are being promoted through a series of campaigns involving the mass media, as well as meetings and conferences. The "maize mentality" has been discarded, and the new official policy is explicit and unequivocal:

"Root and tuber crops are important, especially as a source of food and cash. Even in areas where maize is the staple food, root and tubers are an important food supplement. They are particularly important as food security crops in times of drought and survive relatively well in marginal areas.

Production of maize in areas that are not suited to its production, largely as a result of low rainfall, will be discontinued to give room for more drought resistant crops such as cassava and sweetpotato."

In the new Agricultural Research Master Plan produced in 1995 by the Ministry of Agriculture and Livestock Development, six out of the country's eight Agricultural Development Divisions gave cassava the highest priority, while the other two Divisions gave it priority number 3 on a scale of 1 to 4.

Farmers' preferences. Government policy is one thing; farmers' preferences can be quite different. In this instance, the perceptions of government officials and those of farmers were in perfect harmony. In a 1993 survey of farmers in Malawi, 96 percent of those surveyed indicated their willingness to expand their production of cassava by more than a hectare, and sweetpotato by over three quarters of a hectare each. There was only one potential bottleneck: the lack of planting materials of both crops. That was the primary objective of the drought-recovery project.

Objectives surpassed

Between September and October 1995, a team of independent consultants assessed the performance of the project. The review involved interviews and surveys of all categories of participants in the project, as well as some non-participating farmers. They report that the project had been a huge success; it had achieved all its specific objectives and even surpassed some of them.

Durable partnership. At the institutional level, the team applauded the fact that the project had influenced a major change of agricultural policy by the Government of Malawi, a change favoring diversification of crops and with an emphasis on the cultivation of cassava and sweetpotato. Furthermore, the project was commended for forging a synergistic partnership among an estimated 200,000 individual farmers, 12 NGOs, and many church groups, village groups, researchers, extension agents, and administrators. The linkages thus formed were highly effective for the transfer of the technology of multiplying planting materials, and improved distribution and adoption.

They noted that the partnership would outlive this particular project and would address other agricultural issues in future. The performance of the NGOs at the grass-roots level was reported to be outstanding. Field workers belonging to different NGOs collaborated among themselves and also cooperated closely with Government extension agents. The NGOs had developed the first "fact sheets" on cassava in the local language. In other words, the project has helped to create a framework of collaboration that will contribute towards sustainable agricultural development in the country.

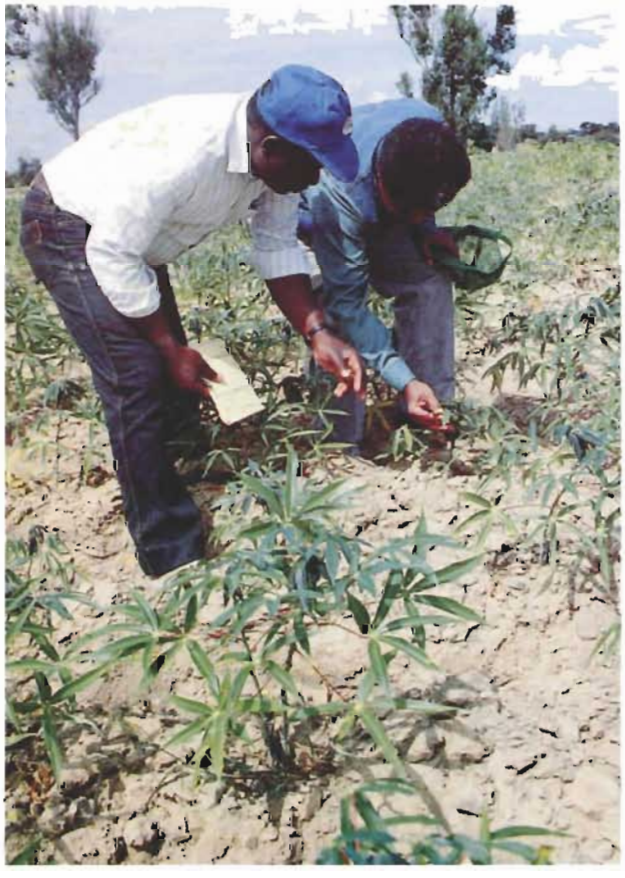
The area (95,000 hectares) devoted to cassava production in the 1994/95 season was 31 percent higher than that in the previous season. That of sweetpotato, at 61,000 hectares, was 63 percent higher. There were corresponding increases in production: 31 percent for cassava and as much as 92 percent for sweetpotato. These substantial increases were unmatched by any other crop commodity during the same period. Indeed, crop estimates throughout the country indicated that cassava, sweetpotato, and soybeans were the only food crops that had gained in area planted and total production during the project years.

Hunger months reduced. Malawi, like many countries of sub-Saharan Africa, experiences periods of hunger every year, particularly severe during January to March. The hunger months vary from household to household, depending on the size of food stocks and the number of persons in the household, as well as the amount of cash available for purchasing food in the markets.

The project evaluation team found that villages where new cassava varieties were not grown at all experienced an average of 5.5 hunger months, whereas the average was only 2.0 in villages where more than 200 farmers grew the crop. The reduction in hunger months as a result of growing sweetpotato was similar to that of cassava. The practice of utilizing the leaves of both crops as vegetable was widespread during the hunger months.

Benefits to women. Economic case studies comparing cassava and sweetpotato with maize, cotton, and tobacco at low, medium, and high levels of crop management over the three-year period of the project showed that the net profits were 4–5 times greater for cassava and sweetpotato.

Cassava grows well in marginal areas



Women were the primary beneficiaries of the project. They were mostly responsible for making all the decisions regarding planting materials, planting area, harvesting time, and quantity for sale. They played a key role in the multiplication and distribution through their group and club institutions.

Sustainability

The strong collaborative partnership established among all the key players in agricultural development bodes well for the long-term sustainability of cassava and sweetpotato cultivation in Malawi. An effective multiplication and distribution system is firmly in place. Farmer adoption was nearly 100 percent where planting materials were available. Some farmers were reported to have made 160 km round trips by bicycle to obtain planting materials for their nurseries; such strong interest should help ensure a lasting impact.

Another important factor that points firmly to sustainability of the project is the extraordinarily strong sense of ownership of the project and commitment to it evidenced by the stakeholders at all levels. There was a high degree of cooperation among all parties involved in all project activities. These activities were accorded a very high priority. It is certain that the activities of the project will continue with minimal support and encouragement. The highly participatory approach adopted in project implementation must have contributed to the great sense of ownership by the diverse groups of stakeholders.

Because of the history of official neglect, extension and NGO field workers had very limited knowledge of the farming practices associated with cassava and sweetpotato cultivation. The training conducted by the project was therefore very important. It will be necessary to do more of such training and also to strengthen the research capability of the national root crops commodity team.

Agenda 21, a long-term program of activities aimed at protecting the global environment in ways that harmonize with development goals, was one of the most important outcomes of the United Nations Conference on Environment and Development (UNCED) held in Rio de Janeiro in June 1992. In furtherance of the objectives of Agenda 21, the CGIAR has sought to coordinate, strengthen, and maximize the impact of the activities of its Centers in the field of environmentally safe pest management through the development of a System-wide Program for Integrated Pest Management (SP-IPM).

As a follow-up to UNCED, the CGIAR set up a Task Force to address the recommendations of Agenda 21. At the 1993 International Centers' Week, the Task Force proposed three areas for inter-Center collaboration; one of these was an initiative on Integrated Pest Management (IPM). A planning meeting was convened by IITA during 4–6 May 1994 at the Agricultural University of Norway, As. Administrative and financial support was provided by the Norwegian Agricultural Development Agency (NORAGRIC) and the Norwegian Ministry of Foreign Affairs. The meeting brought together a wide range of individuals and representatives of organizations with a major stake in the application of IPM in the context of agricultural development.

Definition of IPM

Integrated Pest Management (IPM) is a broad, holistic approach to minimize the impact of pests (insects, mites, fungi, bacteria, viruses, weeds, etc.), ensure sustainable production, preserve the environment, safeguard human health, and promote the well-being of people. IPM seeks to preserve and enhance natural pest control factors in the ecosystem, and incorporates compatible measures such as genetic improvement of the crop plant, modification of crop production practices, and careful management of associated natural habitats. Pesticides may be used but only as a last resort, and should be applied judiciously to minimize environmental damage and to ensure compatibility with other components. Inherent in this definition is the need for an understanding of underlying ecological processes. The impact of IPM is measured not only in terms of gains in crop yields, but also from considerations of its environmental and social effects.

Program rationale

IARCs should optimize their comparative advantage in Integrated Pest Management (IPM) research by pooling their resources and imaginatively combining the wide range of disciplines and expertise available within Centers. They should forge effective partnerships, on the one hand, with specialist research organizations and, on the other, with national agricultural research systems (NARS) and NGOs concerned with implementation of IPM. The key to successful generation and adoption of IPM strategies should be sought in a flexible, interactive approach, which brings researchers from a wide range of disciplines into close collaboration with end-users, transcending conventional barriers to research and implementation.

This group proposed that CGIAR Centers should officially adopt IPM as their preferred approach to crop protection. It outlined ways in which pertinent activities within the CG System could be improved and given more prominence, with a view to increasing their impact on agricultural development as a whole. The proposal was approved by CGIAR Center Directors at their mid-year meeting in 1994.

The proposal was developed further in February 1995 at a meeting of Center representatives at the International Service for National Agricultural Research (ISNAR) in the Hague. At that meeting, the initiative was redefined in terms of a System-wide Program on IPM of the CGIAR (SP-IPM) with a steering group called the Inter-Center Working Group on IPM. Subsequently, discussions were held with the IPM Facility which focuses on participatory implementation, and with the IPM Forum which plays the role of a facilitator with increasing emphasis on providing IPM-related information. It was agreed that the policies and operations of these entities would be coordinated through cross-representation on each of their respective steering groups.

The Technical Advisory Committee (TAC) of the CGIAR approved the System-wide Program in mid-1995. The development agencies of the governments of Norway and Switzerland provided financial support, and the consultative process culminated in the formal launching of the Program in January 1996. IITA is the Convening Center, and houses its Coordinator and Secretariat.

Research Themes, Task Forces, and Discussion Groups

The activities of the System-wide Program on IPM are organized into research themes. A Task Force or Discussion Group is responsible for the further development and implementation of each research theme. A CGIAR Center acts as the convenor for each Task Force or Discussion Group, with the responsibility of bringing together interested parties both within and outside the CGIAR.

The role of the Task Force is first to define more clearly the issues to be addressed and to formulate a strategy for addressing them. It is then to identify existing activities and resources already available, and finally to put together an effective group of partners to tackle the outstanding problems. Discussion Groups were formed in cases where issues needed to be better defined. Some of these are expected to remain as fora for discussion which will support both project implementation and the advocacy role of the System-wide Program, while others may develop into full-scale research themes in their own right.

Criteria for projects

Criteria for selecting project areas to be tackled have been defined and a process for project development agreed upon, from formulation, through peer review, to eventual submission to donors. Adherence to selection criteria is seen as a way of providing a unifying theme and identity to the activities of the System-wide Program, as well as assuring their maximum possible impact.

Insecticide overuse is the major cause of insect pest outbreaks

Projects must respond to farmers' needs, must fill identifiable gaps in existing knowledge, and must have wide potential impact. Beyond the issue of demonstrable need, the System-wide Program should undertake projects where the CGIAR Centers have special comparative advantage in providing solutions. For example, the Centers are able to assemble multidisciplinary research teams to carry out thorough analysis of underlying processes. They can form partnerships to implement projects involving researchers and implementers from several organizations and from different geographical regions.

Pest management projects must fill identifiable gaps in existing knowledge

Research Themes of the System-wide Program

Existing Task Forces and their lead centers

- Cereal stem borers (CIMMYT)
- Insect pests of grain legumes (ICRISAT)
- White flies and associated virus diseases (CIAT)
- Parasitic weeds (IITA)
- Weed management in upland rice (WARDA)
- Tsetse and trypanosomiasis management (ILRI)
- Methodologies for farmer participatory research (CIAT)
- Functional agro-biodiversity (ICIPE).

New Task Forces to be established

- IPM of soil-borne pathogens (ICARDA)
- Evaluation of methodologies for IPM implementation and impact assessment (CIP)
- IPM of weeds (interim lead center: WARDA)
- IPM of multi-host diseases (IRRI).

Discussion Groups recently formed

- Biotechnology in IPM (CIP)
- Entomopathology (IITA)
- Crop loss assessment (IRRI)
- Agroforestry pests (ICRAF).

The commitment to resolve complex and previously intractable problems is reflected in the priority given to projects such as that addressing whiteflies and Gemini viruses that cause severe losses to a wide range of crops around the world.

The need to form more effective partnerships between researchers and implementers to ensure greater impact of IPM research at the farm level was a key issue in establishing the System-wide Program. Farmer participation in both research and implementation is seen as crucial for such interaction. The desire to identify successful models for this process is explicit in the establishment of two of the Task Forces.

Ecoregional initiatives were also identified as a compatible model for encouraging effective partnership and for ensuring that CGIAR activities are responsive to regional needs. It was, therefore, proposed that the System-wide Program should make deliberate efforts to interact constructively with relevant ecoregional initiatives. It was thought, for example, that locating IPM pilot projects at ecoregional benchmark sites might have both strategic and scientific benefits.

The Task Force on implementation methodologies also addresses the crucial issue of impact assessment. Sustainable pest management may have benefits well beyond the immediate objective of higher crop yields. But indicators for assessing benefits in terms of human and environmental health are not well established. Development of

appropriate methods for fully evaluating costs and benefits will help highlight the true contribution of IPM to sustainable agriculture.

Sixteen research themes have so far been identified; Task Forces or Discussion Groups have been constituted for all of them (see box). Some Task Forces are clearly targeted towards developing a research project which will tackle a major pest problem, such as those caused by cereal stem borers or parasitic weeds. Other Task Forces, such as those on Functional Agro-biodiversity, and Farmer Participatory Research, address issues that cut across many research themes and are intended to provide methodologies or unifying approaches that underpin their activities.

Information and advocacy

In addition to the research themes, the Program will play a major role in the management of IPM information and in promoting public awareness of IPM and related issues. It will encourage the exchange of relevant information among CGIAR Centers and their research partners.

To avoid needless duplication of efforts and to facilitate the development of partnerships, it is necessary to know who is doing what and where. A priority of the Program is to establish a database of current IPM projects at the CGIAR Centers and to integrate it with an existing database of some 2,000 IPM projects recently completed or ongoing in developing countries by other organizations.

The Program will also work with others, especially the International IPM Working Group, to promote wider public awareness of IPM activities within the Centers and of issues relevant to IPM in general. To reach a wide target audience, the Program will take advantage of the current worldwide revolution in electronic information and also make use of conventional media.

The successful implementation of IPM is particularly sensitive to its economic and social context, and especially to the regulatory framework of agriculture. An important objective of the Program is, therefore, to provide a collective voice and a sharp focus on issues of special concern to IPM.

One issue of overriding concern is insecticide abuse with its devastating effect on human well-being and on environmental quality. With this in mind, the Inter-Center Working Group on IPM recently prepared a statement on insecticide abuse. The statement identifies the misuse of insecticides as the major cause of pest outbreaks in developing countries, and encourages donors to link development assistance to a commitment by recipient countries to reduce insecticide dependency (see box).

Concern was expressed that important policy decisions are being made based on estimates of yield losses derived from outdated, unreliable data and methodologies. It was agreed to establish a Task Force to develop an adequate and authoritative response to this need, based on data currently available in the CG Centers.

Statement on Insecticides by the CGIAR Inter-Center Working Group on IPM

Insecticide overuse is the major cause of insect pest outbreaks in intensified agriculture in developing countries. Examples of insecticide-induced, production-threatening pests include whiteflies, planthoppers, armyworms, thrips, leafminers, and mites. In addition, field use of insecticides is a major occupational, public health, and environmental hazard.

Insecticide overuse continues to be associated with

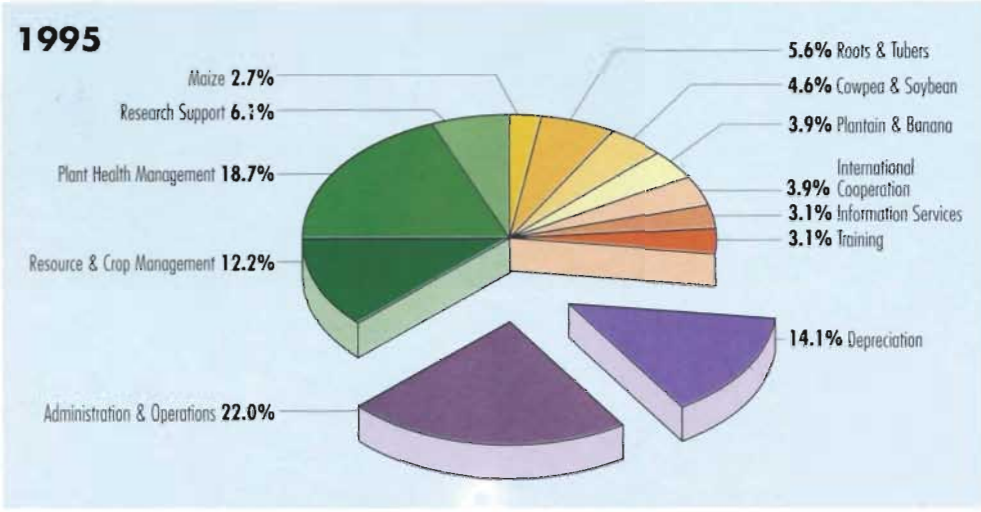
- outdated government policies promoting the use of insecticides, which do not reflect the current state of scientific knowledge;
- aggressive marketing and promotion by the pesticide industry, especially as markets shrink in developed countries; and
- continued use of development assistance, grants, and loans to subsidize insecticide sales.

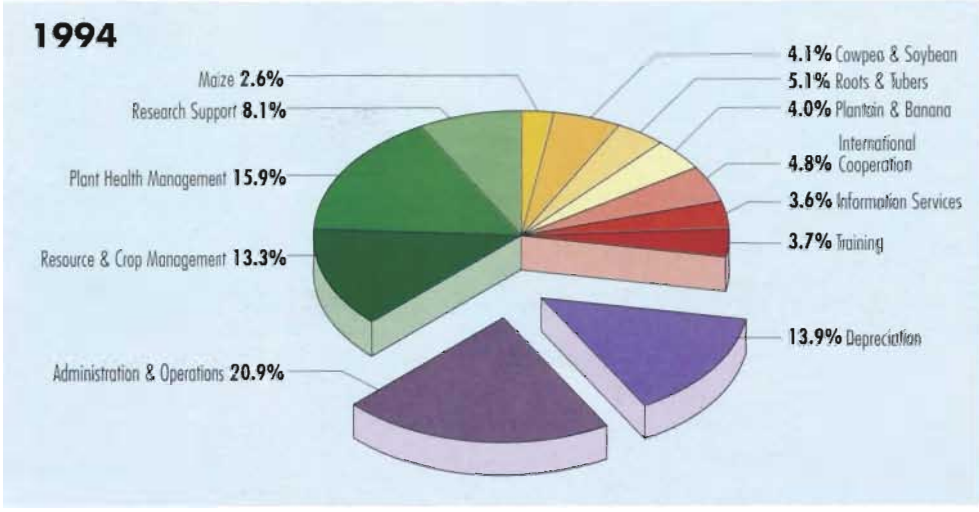
The System-wide Program on IPM urges IARC scientists and managers to inform policymakers, scientists, and the general public about the impact and causes of insecticide overuse. It also urges multilateral and bilateral aid agencies to link their development assistance to commitments by recipient countries to reduce insecticide dependency.

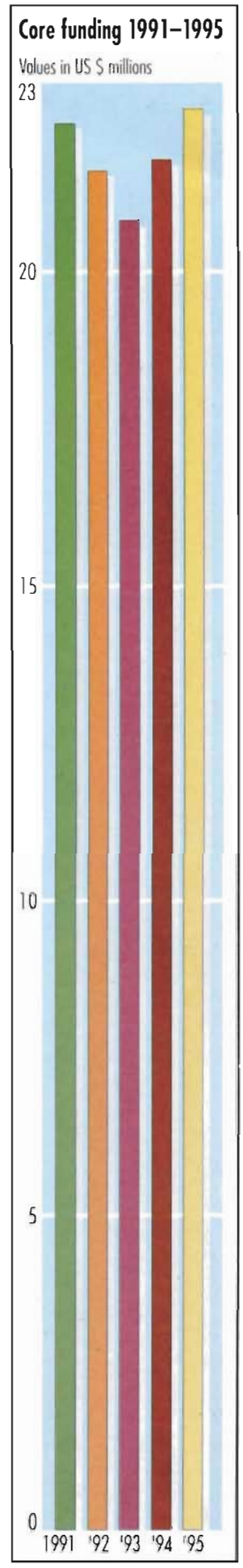
Food first, a major step towards improving the quality of life for all

FOR THE RECORD

Major resource allocations







NOTE:
The core budget is used to fund those research-related activities essential in meeting the CGIAR objectives for developing countries.

IITA
Statement of Financial Position
31 December 1995
Expressed in US$ thousands

ASSETS	1995	1994
Current assets		
Cash and cash equivalents	20,740	24,516
Accounts receivable		
Donors	2,933	2,352
Others	1,135	1,390
Inventories	1,328	1,135
Prepaid expenses	243	941
Other assets	131	140
Total current assets	26,510	30,474
Fixed assets		
Property, plant and equipment	70,693	65,111
Less: accumulated depreciation	38,330	35,181
Total fixed assets—net	32,363	29,930
Total assets	58,873	60,404
LIABILITIES AND FUND BALANCES		
Current liabilities		
Accounts payable and other liabilities	4,325	4,123
Accrued salaries and benefits	4,840	5,019
Payments in advance—donors	7,690	8,937
Total current liabilities	16,855	18,079
Net assets		
Capital invested in fixed assets	32,363	29,930
Capital fund	2,448	4,796
Operating fund	7,207	7,599
Total net assets	42,018	42,325
Total liabilities and net assets	58,873	60,404

IITA
Statement of Activity
31 December 1995
Expressed in US$ thousands

REVENUE	1995	1994
Grants	31,837	31,569
Investment income	987	652
Total revenue	32,824	32,221
EXPENSES		
Research programs	20,896	19,620
Conferences and training	2,465	2,303
Information services	776	778
General administration	2,185	2,116
General operations	3,353	2,429
Depreciation	3,541	3,017
Total expenses	33,216	30,263
Excess of revenue over expenses	(392)	1,958

IITA

Statement of Cash Flows

31 December 1995

Expressed in US$ thousands

	1995	1994
Cash flows from operating activities		
Excess of revenue over expenses	(392)	1,958
Adjustments to reconcile net cash		
Provided by operating activities:		
Depreciation	3,541	3,017
Gain on disposal of assets	85	115
Decrease (increase) in assets:		
Accounts receivable—donors	(581)	3,076
Accounts receivable—others	255	(338)
Inventories	(193)	(10)
Prepaid expenses	698	(8)
Other assets	9	125
Increase (Decrease) in liabilities:		
Accounts payable and other liabilities	202	(406)
Accrued salaries and benefits	(179)	1,044
Payments in advance—donors	(1,247)	4,074
Total adjustments	2,590	10,689
Net cash provided by operating activities	2,198	12,647
Cash flow used in investment activities:		
Acquisition of fixed assets	(5,974)	(2,866)
Net (decrease)/increase in cash and cash equivalents	(3,776)	9,781
Cash and cash equivalents: End of year	20,740	24,516
Beginning of year	24,516	14,735
(Decrease)/increase in the year	(3,776)	9,781

IITA

Donors 1995

Expressed in US$ thousands

DONORS	Core Funding	Complementary Project Funding
Austria	150	427
Belgium	1,317	673
BMZ (Germany)	1,534	541
Canada	966	88
Commission of the European Communities	237	203
Denmark	1,120	52
Ford Foundation	-	32
France	333	281
Gatsby Charitable Foundation	-	86
International Council for Research in Agroforestry	-	48
International Development Research Centre	-	607
International Fund for Agricultural Development	-	129
International Institute of Biological Control	-	553
Italy	300	-
Japan	3,590	-
Korea, Republic of	50	-
Netherlands	1,261	23
Nigeria	6	3
Norway	664	-
Overseas Development Administration (UK)	-	15
Rockefeller Foundation	-	391
Sasakawa Foundation	-	96
Sweden	273	-
Switzerland	540	374
United Kingdom	634	-
United Nations Development Programme	-	1,441
United States Agency for International Development	4,017	2,734
University of Hohenheim	-	218
World Bank	5,655	63
Other Miscellaneous Contributions	-	107
Closed Projects	-	5
TOTAL	22,647	9,190

IITA Research Projects

Project Title	Overall Goal	Collaborators
Conservation and Genetic Enhancement of Plant Biodiversity	Improve conservation and utilization of plant biodiversity to contribute in a sustainable manner to food security in sub-Saharan Africa	IARCs, networks, African NARS, regional organizations, AROs
Agroecosystem Development Strategies	Increase effectiveness of NARS and international system scientists in the humid and subhumid zones of West and Central Africa	NARS, ICRAF, CIFOR, CIAT, CIRAD, Michigan State University, and NGOs
Short Fallow Stabilization	Arrest resource degradation due to land-use intensification in West and Central Africa	NARS, ICRAF, ILRI, TSBF, IFDC, and AROs
Farming Systems Diversification	Increase smallholder production and cash income in West and Central Africa through farming systems diversification	NARS, ILRI, WARDA, ICRAF, CIFOR, CIRAD, AROs, and NGOs
Improving Plantain and Banana-based Systems	Develop sustainable *Musa* production in different ecologies of sub-Saharan Africa	African NARS particularly those of Nigeria, Ghana, Cameroon, Uganda; IAPSC, INIBAP, IPGRI, CRBP Cameroon, FHIA Honduras, KU Leuven, NRI, IIBC, universities in Africa, Europe, North America
Cassava Productivity in the Lowland and Midaltitude Agroecologies of Sub-Saharan Africa	Increase and sustain cassava production and utilization in SSA	MSC, HSC, IARCs, networks, NARS, regional organizations, AROs
Improvement of Yam-based Systems	Assist farmers to achieve a sustainable increase in the productivity of yam-based systems through adoption of improved technologies	MSC, networks, NARS, AROs
Improvement of Maize-Grain Legume Systems in the Moist Savanna of West and Central Africa	Encourage farmers to adopt technologies which increase productivity of maize-grain legume systems in the Guinea savanna	Various consortia, IARCs, networks, NARS, AROs
Cowpea-Cereals Systems Improvement in the Dry Savannas	Increase and sustain cowpea production in the dry savannas	Various consortia, IARCs, networks, NARS, AROs
Biological Control of Pests in Three Agroecosystems	Enhance the livelihood of farmers and maintain sustainability through the management of biodiversity	NARS, NGOs, the Inter-African Phytosanitary Council; international institutions, in particular IIBC, ORSTOM, NRI, GTZ, universities in Africa, Europe, North America
Integrated Management of Pests and Diseases of Legumes	Reduce risks of crop loss in farmers' fields in Africa	NARS, particularly of West and Southern Africa, IARCs, universities in Africa, Europe, and North America, and specialized institutions such as IIBC
Integrated Pest Management of Pests and Diseases of Maize	Reduce pre- and postharvest losses of maize to pests and pathogens in sub-Saharan Africa	NARS of most of West and Central Africa; and some from East and Southern Africa, Inter-African, Phytosanitary Council; IARCs, e.g., CIMMYT, ICRISAT, WARDA, ICIPE, NRI; universities of Africa, Europe, and North America
Integrated Management of Pests and Diseases of Cassava	Increase cassava productivity in sub-Saharan Africa	NARES of about 25 African countries and universities in Africa, Europe, and America, including internationally active institutes (ORSTOM, NRI, GTZ), CIAT, EMBRAPA
Integrated Control of *Striga* and other Parasitic Plants	Reduce infestations of *Striga* and other parasitic plants, as well as the associated crop yield loss, and improve soil conditions	Various consortia, IARCs, NARS, regional organizations, and AROs
Improving Postharvest Systems	Increase the income-generating capability and improve the nutritional status of farmers, processors, and consumers in both rural and urban communities of Africa	NARS, CIAT, AROs, NGOs, and local cooperatives and industries
Recombinant DNA, Molecular Diagnostics, and Cellular Biotechnology for Crop Improvement	Advance the efficacy of genetic improvement and germplasm dissemination beyond the norms associated with the application of conventional breeding and diagnostic techniques	IARCs, networks, NARS, AROs
Improving the Impact of IITA's Research Results	Strengthen the effectiveness of NARS in the generation and utilization of appropriate research results	NARS and regional AROs in sub-Saharan Africa, other Centers, donor agencies, journalists, and the media

IITA improved germplasm releases

Country	Crop	Breeding line/variety
Angola	Cowpea	TVx 3236
	Maize	TZMBR-W
Belize	Cowpea	VITA-3
Benin Republic	Cowpea	VITA-4, VITA-5, IT81D-1137, IT82E-16, IT82E-32
	Cassava	TMS 30572, TMS 30572A, TMS 4(2)1425
	Maize	TZB-SR, 43-SR, DMR-ESR-W, 30-SR, 9 021-18 (Oba super 1), 8644-27 (Oba super 2)
Bolivia	Cowpea	IT82D-442, IT82D-889
Botswana	Cowpea	ER-7, TVx 3236
Brazil	Cowpea	4R-0267-01F, VITA-6, VITA-3, VITA-7, TVx 1836-013J
Burkina Faso	Cowpea	TVx 3236, VITA-7 (KN-1)
	Maize	EV 8422-SR, EV 8430-SR, EV 8431-SR
Burma	Cowpea	VITA-4 (Yezin-1)
Burundi	Cassava	TMS 40160/3, TMS 40160/1
Cameroon	Cowpea	IT81D-985, IT81D-994, TVx 3236
	Maize	TZB-SR, TZPB-SR, TZB derivation, DMR-ESR-Y, Kasai-SR, Suwan 1-SR, 8321-18, 8556-6
	Cassava	TMS 8034, TMS 8017, TMS 8061, TMS 82516
Cape Verde	Cassava	TMS 91934*, TMS 30555*
Central African Republic	Cowpea	VITA-1, VITA-4, VITA-5, TVx 1948-01F, Vita-7
	Maize	TZSR-W-1, TZSR-Y-1, TZB-SR
Chad	Cowpea	IT81D-994
Colombia	Cowpea	IT835-841
Congo	Maize	8644-27
Cuba	Cowpea	INIFAT-94*, IT84D-666 (Cubanita-666)*, IITA-Precoz (IT86D-386)*, IT86D-782 (Tropico-782)*, IT86D-792 (Yarey 792)*, IT84D-449 (Titan)*, IT86D-314 (Mulatina-314)*, IT885-574-3 (OR-574-3)*,
El Salvador	Cowpea	TVx 1836-013J, VITA-3, VITA-5
Equador	Cowpea	VITA-3
Ethiopia	Maize	Gusau 81 TZB, Gusau TZB-SR, 8322-13,
	Cowpea	TVx 1977-01D
Egypt	Cowpea	TVu 21, IT82D-716, IT82D-709
Fiji	Cowpea	VITA-1, VITA-3
Gabon	Cassava	CIAM 76-6, CIAM 76-7, CIAM 76-13, CIAM 76-33, TMS 42025, TMS 30555, TMS 30337, TMS 40160, TMS 4(2)1425
	Maize	TZPB, TZ sweet
Gambia	Cassava	TMS 60142
	Cowpea	IT84S-2049 (Soso royal)
Ghana	Cowpea	IT82E-16, IT83S-728-13, IT83S-818, TVx 1843-IC, TVx 2724-01F, IT84S-2049 (Soso Royal)
	Maize	49-SR, Pool 16-SR, 43-SR, QPM Pop63-SR
	Cassava	TMS 30572, TMS 50395, TMS 4(2)1425
	Soybean	TGx 297-192C, TGx 306-036C, TGx 88-849C, TGx 536-02D, TGx 297-10F, TGx 813-6D
Guinea	Cowpea	IT85F-867-5 (Pkoku Togboi), IT85F-2805, IT835-990, IT83D-340-5, IT81D-897, IT82E-16, IT875-1463
	Cassava	TMS 30572
	Maize	TZSR-Y-1, EV28-SR, DMR-ESR-Y
Guinea Bissau	Cassava	TMS 4(2)1425, TMS 60142
Guatemala	Cowpea	VITA-3
Guyana	Cowpea	ER-7, TVx 2907-02D, TVx 66-2H, VITA-3
Haiti	Cowpea	VITA-5
India	Cowpea	VITA-4, TVx 1502
	Maize	TZi lines as parents
Jamaica	Cowpea	VITA-3, ER-7
Korea, Rep. of	Cowpea	VITA-5
Korea, Rep. of	Cowpea	VITA-5
Liberia	Cowpea	IT82D-889, TVx 3236, VITA-5, VITA-4, VITA-7
	Cassava	CARICASS 1, CARICASS 2, CARICASS 3
Mauritius	Maize	TZSR-Y-1, TZSR-W-1
	Cowpea	TVx 3236
Mali	Maize	Suwan-1SR
Mozambique	Cowpea	IT82E-18
	Cassava	TMS 30001, TMS 30395, TMS 42025
	Maize	Matuba (DMR-ESR-SEMOC-1)
Nepal	Cowpea	IT82D-889, IT82D-752
Nicaragua	Cowpea	VITA-3
Niger	Cassava	TMS 4(2)1425
	Maize	TZESR-W
Nigeria	Cowpea	IT84S-2246, TVx 3236, IT82E-60, IT81D-994, IT86D-719, IT86D-721, IT90K-76, IT89KD-374, IT88D-867-11
	Cassava	TMS 50395, TMS 30572, TMS 30001, TMS 4(2)1425, TMS 30555, TMS 91934, TMS 82/00058, TMS 81/00110, TMS 81/00661, TMS 90257, TMS 84537, TMS 820249*, TMS 820422*, TMS 30555 P3-2*
	Soybean	TGx 849-313D, TGx 1019-2EN, TGx 1019-2EB, TGx 1448-2E, TGx 536-02D, TGx 306-036C, TGx 1485-ID, TGx 1440-IE
	Maize [open-pollinated]	TZPB, 096EP6, TZMSR-W, TZSR-Y, TZSR-W, TZEYR-W, TZESR-Y, DMR-LSR-W, DMR-LSR-Y, DMR-ESR-W, DMR-ESR-Y, TZB-SR, TZPB-SR, EV 49-SR, POOL 16-SR, Suwan 1-SR, EV43-SR
	Maize [hybrid]	8321-18, 8321-21, 8322-3, 8322-13, 8329-15, 8341-5, 8425-8, 8428-19, 8434-11, 8505-2, 8505-3, 8505-4, 8505-5, 8505-13, 8644-27, 8644-31, 8644-32, 8516-12, 8535-23, 8556-6, 9021-18 STR, 9022-13 STR
	Cooking banana	Cardaba
Pakistan	Cowpea	VITA-4
	Maize	TZi 18, TZi 25 as parents
Panama	Cowpea	VITA-3
Paraguay	Cowpea	IT86D-1010, IT87D-2075, IT87D-697-2, IT87D-378-4
Peru	Cowpea	VITA-7
Philippines	Cowpea	IT82D-889
Rwanda	Cassava	TMS 30572, Gakiza (UYT bulk 1977), Karanga (PYT bulk 1977)
	Maize	TZMSR-W
Sao Tome & P	Maize	TZSR-Y-1, TZSR-W-1
Senegal	Cowpea	TVx 3236
Seychelles	Cassava	SEY 14, SEY28, SEY32, SEY41, SEY52
Sierra Leone	Cowpea	TVx 1999-01E, IT86D-1010, IT86D-721, IT86D-719, IT82E-32, TVx 3236, Vita-3
	Maize	TZSR-Y-1, EV 28-SR, DMR-ESR-W
	Cassava	ROCASS 1, ROCASS 2, ROCASS 3, NUCASS 1, NUCASS 2, NUCASS 3, 80/40
Somalia	Cowpea	TVx 1502
	Maize	DMR-ESR-W
Sudan	Cowpea	IT84S-2163 (Dahal El GOZ)*
	Maize	DMR-ESR-W, DMR-LSR-W, Gusau TZB
Sri Lanka	Cowpea	IT82D-789, IT82D-889, TVx 309-01G, TVx 930-01B
Swaziland	Cowpea	IT82E-18, IT82E-32, IT82E-71, IT82D-889, IT82D-889 (Julmtilane)*
Tanzania	Cowpea	TK-1, TK-5, IT82D-889
	Maize	DMR-ESR-W
Thailand	Maize	TZi 18, TZi 25 as parents

(continued on page 46)

Graduate research completed at IITA during 1995

Degree sought	Country of origin	University (U)	Sponsor	Name	M/F	Research topic
Crop Improvement						
PhD	Tanzania	U Ibadan, Nigeria	IITA-UNDP	Makame, M.H.	M	Genetic variation, stability of performance of cassava clones and their responses to intercropping with sweet potato in Zanzibar, Tanzania
MSc	Nigeria	U Ibadan, Nigeria	Self	Abdullahi, I.	M	Investigations on the seed transmissibility of cucumber mosaic virus (CMV)
PhD	Cameroon	U Ibadan, Nigeria	IITA	Ebot, M.	M	Studies on the resistance to frogeye leaf spot (*Cercospora sojina*) and mode of inheritance in soybeans
PhD	Cameroon	U Ibadan, Nigeria	Self	Fokunang, C.N.	M	Evaluation of cassava genotypes for resistance to anthracnose and other major diseases
PhD	Cameroon	U Ibadan, Nigeria	Self	Nukenine, E.N.	M	The interaction of *Mononychellus tanajoa* Bondar with other arthropods as influenced by cassava resistance and the bases of resistance
MSc	Nigeria	U Ibadan, Nigeria	Self	Bello, T.	M	Development of a serological assay to detect *Colletotrichum lindemuthianum* in cowpea
MSc	Nigeria	U Benin, Nigeria	Self	Oziegbe, S.	M	Plant regeneration in cowpea (*Vigna* spp.) using meristem culture
MSc	Nigeria	U Ibadan, Nigeria	Self	Longe, O.B.	F	Anther culture in cowpea: *Vigna unguiculata* (L.) Walp
PhD	Cameroon	U Ibadan, Nigeria	IITA	Bakoh, M.Y.	F	Inheritance of promiscuous nodulation and resistance to bacterial pustule disease in soybean [*Glycine max* (L./Merrill)]
MSc	Nigeria	Federal U Technology Owerri, Imo State, Nigeria	Self	Agindotan, B.	M	Identification and differentiation of rice yellow mottle *sobemovirus* by polyclonal and monoclonal antibodies
MSc	Nigeria	U Benin, Nigeria	Self	Aigbedion, J.	M	Plant regeneration in yam (*Dioscorea* spp.) using meristem culture
MSc	Nigeria	U Ibadan, Nigeria	Self	Oki, T.	F	Seasonal and age variations in cyanogen content and linamarase activity of cassava leaves
PhD	Belgium	Katholieke Universiteit Leuven, Belgium	Self	Craenen, K.	F	Morphological and cytological studies of non-host and host plant/pathogen interactions of the black sigatoka pathogen *Mycosphaerella fijiensis* (Morelet) on *Musa* spp.
MSc	Nigeria	U Ibadan, Nigeria	Self	Kalu-Okoro, N.	F	Induction of somatic embryogenesis and plant regeneration in cowpea *Vigna unguiculata* (L). Walp
PhD	Germany	U Hanover, Germany	GTZ	Heuberger, H.	F	N efficiency in maize
Plant Health Management						
MSc	Nigeria	U Science & Technology Port Harcourt, Nigeria	Self	Nwauzoma, A.B.	M	Evaluation of different crop management practices on symptom development of black sigatoka (*Mycosphaerella fijiensis* Morelet) on plantain
PhD	Côte d'Ivoire	Simon Fraser U, Canada	IITA	Konan, K.	M	Seasonal abundance of *Sesamia calamistis* (Lep.: Noctuidae) and bionomic studies of its egg parasitoid *Telenomus busseolae* (Hym.: Scelionidae)
PhD	Guinée	U Montreal, Montreal Quebec, Canada	GTZ	Traore, L.	M	Une nouvelle association hote/parasitoide pour le controle biologique du charancon noir du bananier et du plantain *Cosmopolites sordidus* Germar (Coleoptera: Curulionidae)
PhD	Côte d'Ivoire	Imperial College of Science, Natural History Museum, UK	IITA	Anga, J.	M	Phylogenetic systematics of the world Ariogyrini (Hymenoptera: Encyrtidae), parasitoids of mealybugs (Homotera: Psuedococcidae) of economic importance
PhD	Kenya	U of Amsterdam	IITA	Odour, G.	M	Abiotic factors and the epizootiology of *Neozygites cf. floridana*, a fungus pathogenic to the cassava green mite
MSc	Nigeria	U Ibadan, Nigeria	Self	Sangoyomi, T.E.	F	Studies to evaluate the importance of *Rhizoctonia solani* as a pathogen of yam (*Dioscorea* spp.) in Nigeria
MSc	Cameroon	U Ibadan, Nigeria	Self	Koona, P.	M	Characterization of damage and feeding behaviour of selected pod sucking bugs on *Vigna* species with variable resistance and growth habits
PhD	Nigeria	U Ibadan, Nigeria	IITA/Self	Umoren, U.E.	M	Nutritional evaluation of wild and cultivated cowpea (*Vigna unguiculata* (L.) Walp.) varieties and the biochemical basis of their resistance to some insect pests
PhD	Nigeria	U Ibadan, Nigeria	IITA/FF	Akintobi, D.C.	F	The role of physical and biochemical factors of cowpea [*Vigna unguiculata* (L.) Walp.] seed on its resistance bruchid *Callosobruchus maculatus* (F.)
PhD	Cameroon	ABU, Zaria, Nigeria	IITA	Mungo, C.M.	F	Biology and epidemiology of *Sphaceloma* spp.: causal organism of cowpea scab
PhD	Nigeria	U Ibadan, Nigeria	Self	Bolaji, O.	F	Susceptibility of some maize varieties to *Sitophilus zeamais* motsch *Sitophilus oryzae* (L.), and *Mussidia nigriveniella* rag
PhD	Nigeria	U Ibadan, Nigeria	IITA/FF	Udoh, J.	F	A study of aflatoxin levels in maize collected from five major agroecological zones of Nigeria
MSc	Ghana	U Cape Coast, Ghana	IITA/FF	Forjoe, G.	F	Response using leaf and seed neem extracts on hemipteran pests of cowpea

Degree sought	Country of origin	University (U)	Sponsor	Name	M/F	Research topic
Resources and Crop Management						
MSc	Nigeria	Rivers State U Science and Technology, Port Harcourt, Nigeria	DLO/ISF	Hamadina, K.M.	M	Effect of selected cover crops and *Dactyladenia barteri* mulch on an Ultisol in the humid tropics
MSc	Cameroon	Rivers State U Science and Technology, Port Harcourt, Nigeria	DLO/ISF	Kanmegne, J.	M	Evaluation of species suitable for improved short fallows, their potential role in soil organic matter and nutrient dynamics in the humid tropics
PhD	Zaire	Rivers State U Science and Technology, Port Harcourt, Nigeria	IITA	Kadiata, B.D.	M	Biological nitrogen fixation in some woody legumes with potential use in alley cropping
MSc	Nigeria	U Ibadan, Nigeria	Self	Adeola, R.O.	M	Effect of dry season grazing on N dynamics & earthworm activities in two cropping systems
MSc	Nigeria	U Ibadan, Nigeria	Self	Olimah, J.A.	M	Decomposition of various fallow vegetation and dynamics of soil fauna in a degraded Alfisol during fallow regeneration
PhD	Nigeria	U Ibadan, Nigeria	Self	Akinnifesi, F.K.	M	Root activities of hedgerow and crop and their effect on nitrogen use in leucaena alley cropping system
MSc	Cameroon	U Ibadan, Nigeria	Self	Mbandi, E.	F	Recovery and persistence of introduced and indigenous rhizobia nodulating herbaceous legumes *Mucuna pruriens* and *Lablab purpureus* in a derived savanna of Nigeria
PhD	Nigeria	U Ibadan, Nigeria	IITA	Idinoba, M.E.	F	Water balance studies for selected crops in humid and subhumid zones of Nigeria
PhD	Ghana	U Science & Technology, Kumasi, Ghana	Govt/IITA	Kaleem, F.	F	Nitrogen fixation in soybeans under solecrop and maize intercrop and residual effect on a following maize crop
PhD	Nigeria	U Ibadan, Nigeria	Self	Ochai, S.	M	An analysis of the economic behaviour of small-scale farm households in Kogi State, Nigeria
PhD	Sudan	Cornell U, USA	RF	Abdelgadir, H.A.	M	Biological nitrogen fixation as an alternative N biofertilizer to synthetic N fertilizers
MSc	Belgium	Katholieke Universiteit Leuven, Belgium	KUL/SOM	Casaer, J.	M	Microbiological characteristics of the soil organic matter under a 16 year old arboretum, established on an Alfisol and Ultisol
MSc	Belgium	Katholieke Universiteit Leuven, Belgium	KUL/SOM	Oorts, K.	M	Physicochemical characteristics of the soil organic matter under a 16 year old arboretum, established on an Alfisol and Ultisol
PhD	Nigeria	U Ibadan, Nigeria	IITA-WAU	Oluwasemire, O.	M	Microclimate improvement and soil protection aspects of intercropping with leguminous cover crops

(IITA Improved Germplasm Releases *continued from page 44***)**

Country	Crop	Breeding line/variety
Togo	Cowpea	VITA-5, TVx 3236
	Maize	49-SR, 8322-13-STR, TZESR-W
	Cassava	TMS 4(2)1425, TMS 30572
Uganda	Cowpea	TVx 3236, IT82E-60
	Cassava	TMS 30572 (as Migyera)
		TMS 60142 (as Nase 1)
		TMS 30337 (as Nase 2)
	Soybean	selection from IITA breeding lines (Nam 2)
	Maize	Acr 83 TZMSR-W, 8535-23, 8556-6
Venezuela	Cowpea	VITA-3
Vietnam	Maize	TZi 25 as parent
Yemen	Cowpea	TVx 3236, IT82D-789, VITA-5
Yemen, South	Cowpea	VITA-5, VITA-7
Zaire	Cowpea	IT82E-18, Vita-6, Vita-7
	Maize	83TZMSR-W, Ik 83 TZSR-Y-1, DMR-ESR-W
	Soybean	TGx 814-76D, TGx 849-294D
	Cassava	Kinuani, F100, TMS40230/3
Zambia	Cowpea	TVx 456-01F, TVx 309-1G
	Cassava	LUC 133

Publications by IITA staff

Contributions by IITA staff to scientific literature that became available during 1995, including journal articles, book chapters, papers in monographs or conference proceedings, published abstracts, and research notes or disease reports. Also included are (1) publications based on work done by IITA staff prior to their joining IITA, especially where the work reported is of interest to IITA; (2) publications by staff who have left IITA, which are based on work done while they were at the Institute.

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ABU Ahmadu Bello University (Nigeria)
CGIAR Consultative Group on International Agricultural Research
CIAT *Centro Internacional de Agricultura Tropical*
CIFOR Center for International Forestry Research
CIMMYT *Centro Internacional de Mejoramiento de Maiz y Trigo*
CIP *Centro Internacional de la Papa*
CIRAD *Centre de coopération internationale en recherche agronomique pour le développement* (France)
COSCA Collaborative Study of Cassava in Africa
CP *Colegio de Postgraduados* (Mexico)
CRBP *Centre régionale bananiers et plantains*
EARRNET East African Root Crops Research Network
EPHTA Ecological Project for the Humid and Subhumia Tropics of Tropical Africa
ESARC East and Southern Africa Regional Center
ESARRN East and Southern Africa Root Crops Research Network
ESCaPP Ecologically Sustainable Cassava Plant Protection (IITA)
FAO Food and Agriculture Organization of the United Nations
FF Ford Foundation
FHIA *Fundacion Hondurena de Investigacion Agricola* (Honduras)
GTZ *Gesellschaft für Technische Zusammenarbeit* (Germany)
HFC Humid Forest Consortium
IARC international agricultural research center
ICARDA International Center for Agricultural Research in the Dry Areas
ICIPE International Center of Insect Physiology and Ecology
ICRAF International Centre for Research in Agroforestry
ICRISAT International Crops Research Institute for the Semi-Arid Tropics
IDEFOR *Institut des fôrets* (Côte d'Ivoire)
IFDC International Fertilizer Development Center
IIBC International Institute of Biological Control (UK)
ILRI International Livestock Research Institute
INIBAP International Network for the Improvement of Bananas and Plantain (France)
IPM integrated pest management
IPGRI International Plant Genetic Resources Institute *zootechnique* (Burundi)
IRRI International Rice Research Institute
ISF Institute of Soil Fertility (Netherlands)
ISNAR International Service for National Agricultural Research
IVC Inland Valleys Consortium
JIC John Innes Centre (UK)
KUL *Katholieke Universiteit, Leuven* (Belgium)
MSC Moist Savanna Consortium
NARES national agricultural research and extension systems
NARO National Agricultural Research Organisation (Uganda)
NARS national agricultural research systems
NGO non-governmental organization
NIFOR Nigerian Institute of Oil Palm Research
NRI Natural Resources Institute (UK)
NSS National Seed Service (Nigeria)
OAU Organization for African Unity
OAU/STRC Organization of African Unity/ Scientific, Technical and Research Commission
ODA Overseas Development Administration (UK)
OFDA Office of Foreign Disaster Assistance
ORSTOM *Institut français de recherche scientifique pour le développement et coopération*
PASCON Pan-African *Striga* Control Network
SAFGRAD Semi-Arid Food Grains Research and Development (Project)
SARRNET Southern Africa Root Crops Research Network
SSA sub-Saharan Africa
TAC Technical Advisory Committee of the CGIAR
TARC Tropical Agricultural Research Center (Japan)
TSBF Tropical Soil Biology and Fertility Program
U University
UI University of Ibadan
UNCED United Nations Conference on Environment and Development
UNDP United Nations Development Programme
USAID United States Agency for International Development
USDA/ARS United States Department of Agriculture/Agricultural Research Service
VSO Volunteer Service Organization (UK)
WARDA West Africa Rice Development Association
WAU Wageningen Agricultural University
WECAMAN West and Central Africa Maize Network
WI Winrock International

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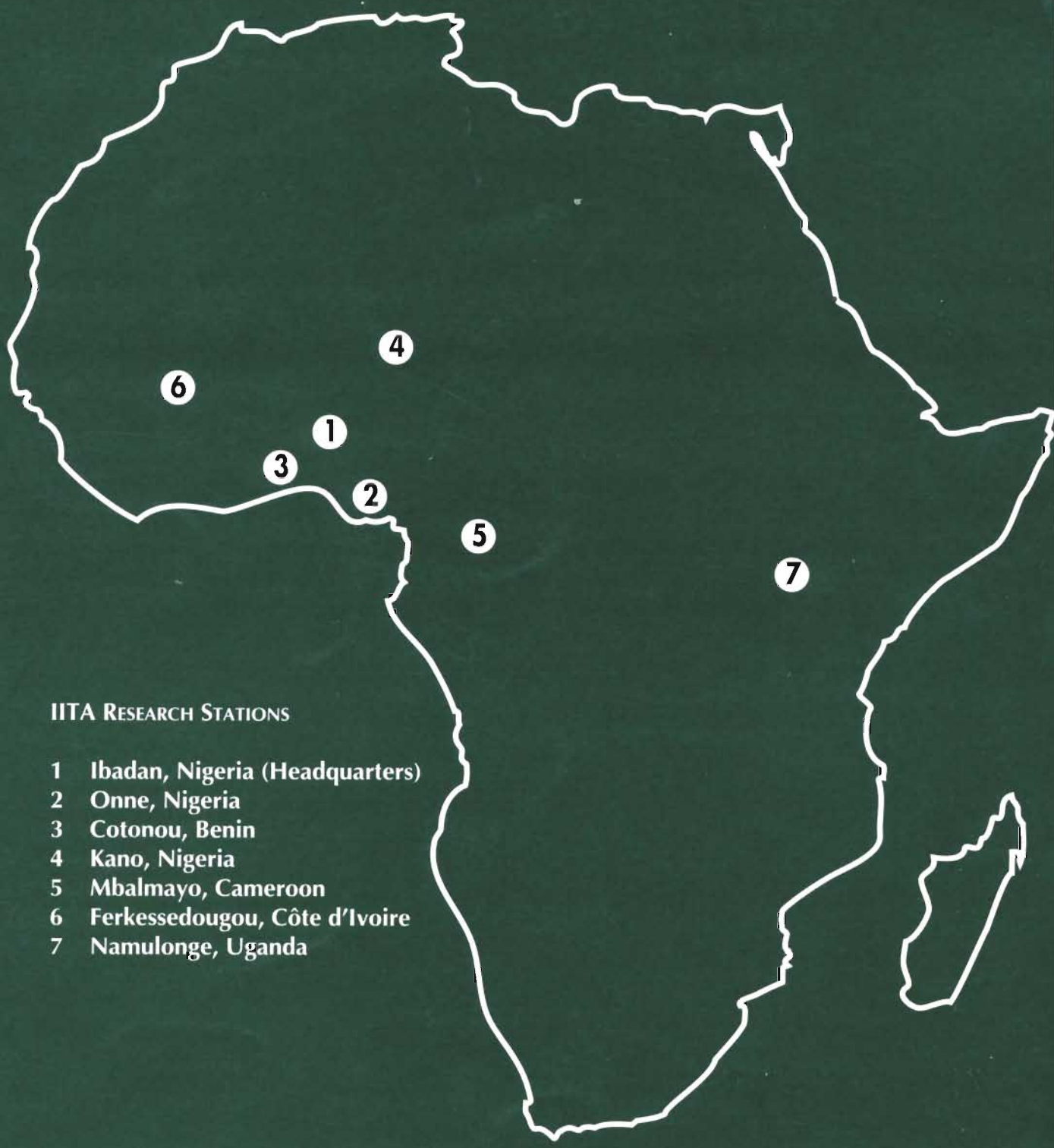

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