INTERNATIONAL INSTITUTE OF TROPICAL AGRICULTURE

ANNUAL REPORT 1989/90

IITA Annual Report 1989/90

INTERNATIONAL INSTITUTE OF TROPICAL AGRICULTURE

Contents

Director General's Report

Director General's 1989/90 Report

In my fifth and final report as Director General, I am pleased to announce that the IITA Board of Trustees recently elected a strong new leadership team for the Institute. Dr. Nicholas Mumba, Permanent Secretary, the Ministry of Agriculture of Zambia, was elected the new Board Chairperson to succeed Mr. Luis Crouch. Dr. Lukas Brader, a distinguished science manager and currently Director of the FAO Plant Production and Protection Division, was elected the new Director General, effective December 1990.

In this last report I will attempt to assess the current state of the Institute and its capacity to deal with the interrelated problems of malnutrition, poverty and sustainable agriculture in Africa.

Twenty-three years ago, long before sustainability became a burning issue, the founders of IITA had a vision of a new institute in tropical Africa explicitly dedicated to this specific issue. They charged IITA to develop sustainable agricultural systems that could replace the region's traditional bush-fallow, or slash-and-burn, cultivation; while increasing the productivity of the key food crops in these systems. IITA's mandate reflects both the essential difference and the critical link between the goals of feeding hungry people today and developing sustainable systems that will serve future generations.

Our founders recognized that the major advances in agricultural technology for the temperate zones were not well suited to the resource-poor farmers of tropical Africa. To serve these people, IITA scientists had to recognize the diversity of their farming conditions and to understand the crop production systems that they had developed over centuries or even millenia.

IITA has received increasing recognition for the quality of its scientific achievement during the past five years. Scientific research is a long-term process, and I have been fortunate to be Director General during a period when research started well before my tenure is producing benefits for African farmers. One of the hallmarks of successful international agricultural research is the King Baudouin Award presented every two years by the Consultative Group on International Agricultural Research (CGIAR). Within this year IITA will have received two of the last three King Baudouin Awards — the 1986 Award for the development of maize varieties resistant to the streak virus and the 1990 Award, with Centro Internacional de Agricultura Tropical (CIAT), for the dramatically successful research on the biological control of the cassava mealybug.

When I joined IITA five years ago, it seemed clear that the Institute could not continue this record of creativity unless it sharpened program focus, set priorities and developed a strategic framework for its research on sustainable agriculture. An extensive, participatory Strategic Planning Study was conducted during 1986-1987 that confirmed IITA's commitment to sustainable agriculture, while recommending major program changes toward that goal: (1) sharpened program focus, (2) integration of research into a systems approach, and (3) enhanced collaboration with partners in national agricultural research systems.

Sharpened Program Focus

The four strategic elements of IITA's new program focus are:

- The lowland humid and subhumid tropics of Africa
- The smallholder or family farmer
- Farming systems
- Major agroecological zones

First, we narrowed our geographic concentration to the lowland humid and subhumid tropics of West and Central Africa, a vast area including more than 20 countries and over 40 percent of the population of sub-Saharan Africa. With the termination of IITA field projects in Asia, Latin America and the Caribbean — while our collaboration with regional and national research agencies on relevant research in those regions continues — our work is now clearly targeted on a region of acute need. This decision reduced diffusion of research effort without compromising IITA's status as an international center.

IITA's second element of program focus was on the smallholder or family farmer. This policy represented a departure from the earlier assumption that the products of IITA research were scale neutral. While some of the technology generated at

A Nigerian farmer harvests improved cassava tubers.

IITA is of equal value to large and small farms, we recognized that research must be designed specifically to enhance the productivity of the farming systems used by African smallholders. Later I give examples of how this decision is affecting our research objectives.

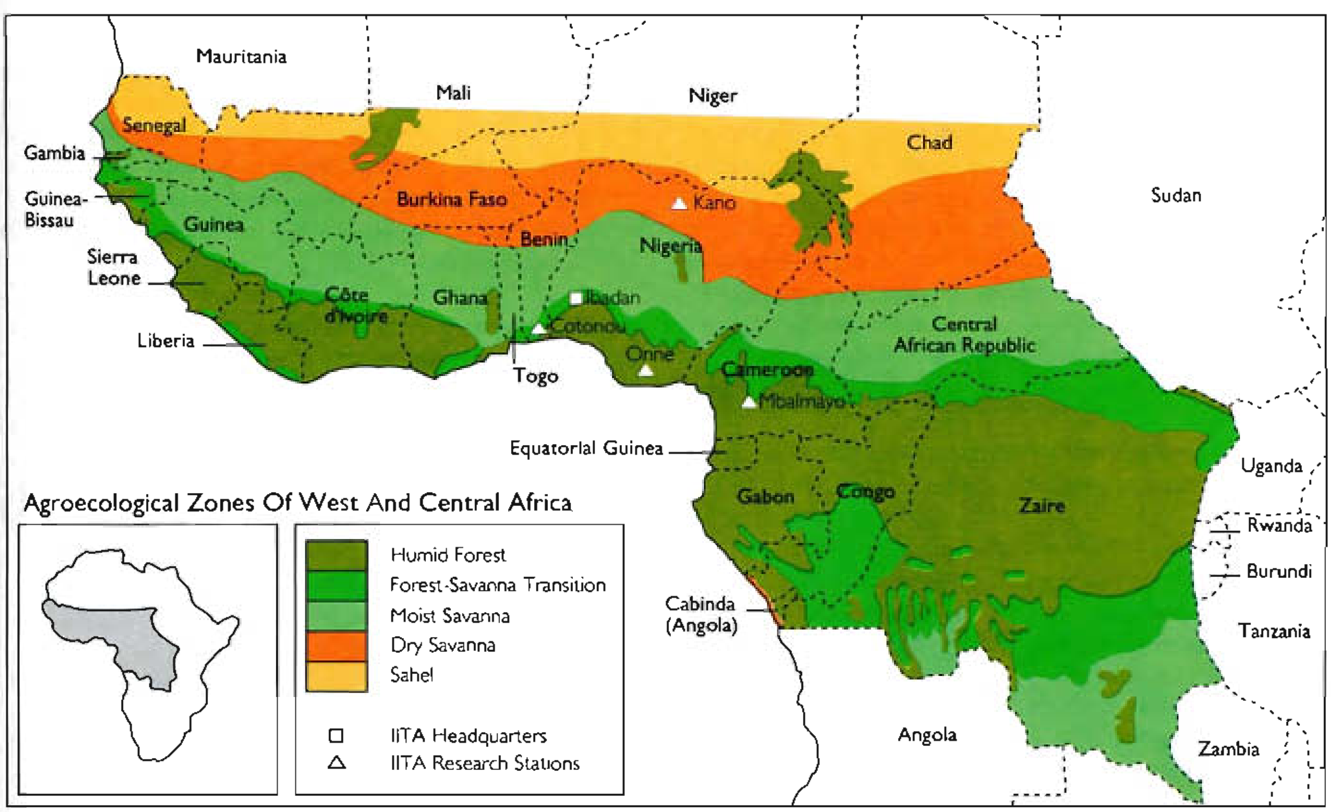
Most African farmers are small-scale farmers, using manual methods to grow complex mixtures of crops in traditional farming systems. Men and women, they are efficient in the use of available resources and responsive to incentives. These farmers are poor not because their holdings are small but because their farming systems frequently have low and declining productivity. With the right kind of support, they will adopt appropriate new technologies, produce the surpluses needed to feed Africa's growing population, and provide the foundation for broad-based economic growth.

The third element of focus involved a fundamental strategic decision to integrate IITA's research on the basis of farming systems. Farming systems research is not new at IITA, but the IITA Strategic Plan defines a fresh approach. The philosophy behind this stems from the need to address the difficult issue of the design of appropriate technology.

Farmers generally adopt technological change in a stepwise manner—one component at a time. Change in any component of the cropping system has, however, much wider implications than its immediate target. For instance, introduction of a pest-resistant, high-yielding variety may accelerate soil fertility decline and increase inter-crop competition; or changes in planting dates may affect the availability of labor for other tasks such as weeding. The farmer is, of course, concerned with managing his whole cropping system and judges the value of new technology by its contributions to the productivity of the system as a whole.

The IITA scientist must therefore address the issue of technology development at the system level. This can only be done by truly interdisciplinary research — the inculcation of a systematic, interactive approach to research issues right through from planning to implementation. For many researchers, trained in the classical reductionist disciplines of science, this involves a new way of approaching their work. A commentator once likened IITA's organization to a series of independent columns that had evolved over 15 years without connecting links. We are now working to forge those links. The organizational changes to achieve this are described later in this report.

The fourth and last element of focus was on the major agroecological zones of the region, outlined on the map below. In the preparation of the Strategic Plan, it was clear that the major researchable issues varied significantly by agroecological zone — problems of specific pests and diseases and of adaptation to the cropping systems of the region. International research was required because the environments cut across many countries, some of which are too small and poor to mount effective research on their range of priority problems.



Agroecological Zones Of West And Central Africa

Accordingly, the decision was made to decentralize research to small stations in the key zones of West and Central Africa. In addition to IITA's headquarters station at Ibadan, in the transition zone between the forest and savanna, a research station was established in 1990 in the dry savanna of Nigeria for work on cowpeas in sorghum- and millet-based farming systems. Another station is nearing completion in the humid forest zone of Cameroon, primarily for research on cassava and resource management involving agroforestry and fallow management systems. A third station is planned for the moist savanna for maize-based systems. In research on rice-based farming systems, we also recognize the distinct inland valley ecosystem which occurs in all ecological zones.

Decentralization of IITA's research was a logical stage in the evolution of the Institute. In the first stage of IITA's history, it was apparent that commodity research could make the greatest contribution to sustainability by developing germplasm resistant to major diseases for use by national systems. With access to genetically diverse germplasm and sophisticated research support, the commodity scientists could do this work most effectively at IITA headquarters.

Moreover, they were notably successful in breeding resistance to major pathogens — cassava bacterial blight and African mosaic disease, diseases of maize such as lowland rust and blight and the streak virus, rice blast, and numerous cowpea pests and diseases. These successes were adopted over a large range of ecosystems in Africa. They provide stability of yield to these commodities, enabling present research to focus more on adaptation to diverse cropping systems in the major environments.

Integration of Research into a Systems Approach

The second theme of the strategic planning process was integration. IITA's organizational structure for research was revised to form three main thrusts, all of them integrated through their focus on the major agroecological zones of West and Central Africa. These thrusts are:

- Resource management research — the study of the natural resource base in order to refine existing resource management technologies and devise new ones for the small-scale farmer.
- Commodity improvement research — breeding of improved crop varieties to stabilize and increase smallholder productivity.
- Crop management research — synthesis of products of resource management research and plant breeding into sustainable, productive cropping systems for the smallholder.

Discussion is under way concerning the establishment of a fourth thrust, pest management research, that would draw upon IITA's resources in pest management, including the Biological Control Program, to form a new integrated pest management program.

The long-standing challenge at IITA to inculcate a farming systems orientation throughout the Institute has been noted. After considering various organizational alternatives to promote multidisciplinary collaboration, we adopted the simple innovation of inter-program, systems-based working groups, each responsible for farming systems research in one of the three major agroecological zones of the region: the humid forest, the moist savanna, and the inland valleys. Each multidisciplinary group has a full-time economist and agronomist, as well as part-time member scientists from the commodity improvement programs. This was a crucial new mechanism because, as shown in Diagram 1, it integrated the work of IITA's commodity improvement and resource management scientists at the farming systems level.

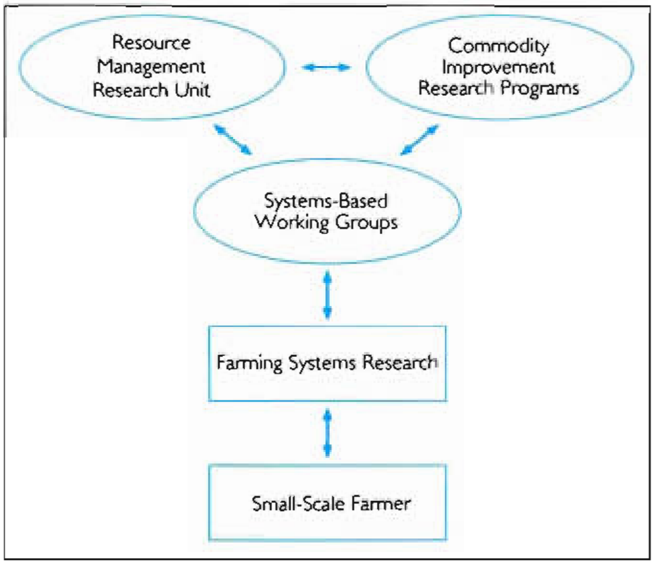


Diagram 1. Integration of IITA Research Programs

The working groups are providing a validation function involving on-farm testing of technologies generated by experiment station research, an adaptive research function involving the adjustment of existing technology to a particular set of environmental conditions, and a feedback function to scientists developing resource management technologies or breeding improved varieties. Through this process, IITA scientists are brought together in a common effort to understand major farming systems and to produce new varieties and technologies for their improvement.

A start has been made in institutionalizing the environment in which scientists will change their behavior and accept new and unconventional objectives in their work. If successful, this reorientation will amount to a shift in the research paradigm at IITA. When discussed by the CGIAR in May, the donors agreed that the adoption of this research strategy must be recognized as risky because its productivity is still uncertain, but they urged IITA to persevere in this new direction because of the disappointing impact which the conventional commodity-improvement research paradigm has had in Africa.

In planning this integration, IITA had to determine the appropriate balance between research on resource management and on breeding, recognizing that they both produce component technologies integrated through the farming systems working groups. There is no conceptually correct or optimal balance between them. Research on resource management cannot be conducted in isolation from the crops to be grown with these resources, and vice versa.

Moreover, there are significant differences between research on resource management and research on commodity improvement: differences in research complexity, time horizon, extension potential, and relative importance among different agroecological zones. Research breakthroughs that have the most immediate impact generally result from improved commodity varieties, but commodity research alone will not solve the sustainability problem. Recognizing the need for balance in the research program, a decision was made in the strategic planning process to double the relative level of staffing for resource management research over five years, as shown in Table 1. To provide a critical mass of scientists for commodity improvement research — while assuring that new technologies are appropriate for farming systems — a concurrent decision was made to reduce the scope of commodity improvement research from nine to six commodities. Research on sweet potatoes, rice and cocoyams is being phased out.

Table 1. Distribution of Core Scientists Among IITA Research Programs

Type of Research	Actual 1989	Actual 1990	Plan 1993
Resource Management	16%	24%	32%
Commodity Improvement	55%	48%	47%
Crop Management	29%	28%	21%
	100%	100%	100%

Enhanced Collaboration with National Agricultural Research Systems

The third theme of the Strategic Plan was cooperation with national agricultural research systems. In 1987, the IITA Board of Trustees upgraded the status of the International Cooperation Program by establishing the new position of Deputy Director General for International Cooperation. This was followed by extensive consultations with the leaders of African national systems to develop a strategic plan for international cooperation, with the objective of building partnerships with national systems to assist them to strengthen their capability to use and generate technology to satisfy their own needs.

Because IITA technology is of little use in countries which lack the capacity for effective collaboration, we have been encouraged by donors and by African governments to accept the responsibility to assist in building such capacity, to the extent that we have a comparative advantage and that such activity does not weaken our vitality as a research institute. Over a transition period of five to ten years, we are operating more downstream toward adaptive research than would be customary for an international center. We distinguish the requirements of national systems at different stages of their institutional development according to a conceptual framework that emphasizes the dynamic relationship required for IITA to meet their strategic needs.

IITA's Strategic Plan provided for new and revitalized mechanisms for promoting partnerships with national systems. I refer here to four of these mechanisms: networking, research liaison scientists, resident scientist teams and training.

First, collaborative research networks connect IITA with national and regional agricultural institutions in Africa and beyond, to address specific issues of common interest. Networks provide smaller countries, many of which are unable to mount comprehensive research and development programs, with forums for participation in agricultural progress. IITA acts as a catalyst in promoting and managing appropriate networks for the tropical and subtropical regions of Africa. Because it is a major source of scientific research in the region, IITA often assumes the coordinating role during a network's early stages.

IITA is presently coordinating four collaborative research networks: the Eastern and Southern Africa Root Crops Research Network (ESARRN), the Cowpea and Maize Research Networks of the Semi-Arid Food Grains Research and Development (SAFGRAD) Project, and the Alley Farming Network for Tropical Africa (AFNETA). In addition, IITA has actively encouraged the rationalization of research networks in the region, particularly across the francophone and anglophone zones.

The second mechanism is research liaison scientists. We place high priority on deepening our understanding of the highly diverse national systems of West and Central Africa. Research liaison scientists have been appointed, each to serve a group of countries by studying their requirements and linking them to IITA and other sources of technology and assistance. In the conduct of their research, IITA scientists continue their direct association with national scientists. The liaison scientists are responsible for coordinating such activities in each country and managing special cooperative projects within them. The goal is to ensure that IITA partnerships with national systems are responsive to their own strategic needs and genuine concerns.

The third mechanism is in-country resident scientist teams. Over the last decade, IITA has invested over 300 scientist-years working within national programs of the region, thus giving us unique experience with these institutions and a comparative advantage in such collaborative activities. The objectives of resident scientists are to conduct adaptive research, thus feeding back information to IITA and other international centers, and to strengthen the capability of national programs to sustain such research without external assistance. This emphasis on building capacity for adaptive research complements ISNAR's role in improving the management of research systems. Recent studies confirm that national research leaders have very strong demand for this form of assistance.

The fourth mechanism is training. Since 1971, IITA has trained almost 6,000 Africans. Although most of them have been technicians in group courses, more than 400 have been students conducting research for postgraduate degrees. We work with IITA alumni who are rapidly moving into key positions of responsibility in African national systems. In the long run, training may be IITA's most enduring contribution to the solution of Africa's food problems, and it is being accorded higher priority than in the past. IITA has made significant changes by devoting more of its "core" or permanent resources to training, by increasingly decentralizing group training to national institutes, by shifting emphasis from group training to supporting graduate research, especially of Africans at the M.Sc. and the Ph.D. levels, and by increasing the proportion of women participants in training at all levels.

Model for Sustainable Development

With a mandate for research on sustainable agricultural systems for the lowland tropics of Africa, we feel a responsibility to attempt to conceptualize the role of research in realizing this objective. A simple model identifying the technology requirements at different stages of development has been a useful heuristic device for stimulating scientific discussion at IITA about how research can contribute to the efforts of smallholders to move from subsistence agriculture onto a path leading toward more productive and sustainable agriculture. In the following pages I describe this preliminary model as it applies in the humid forest agroecology of south-eastern Nigeria, the most densely populated region in sub-Saharan Africa.

The indigenous farming systems which have evolved in the forest zone have remained productive because of cropping strategies which maintain and restore the soil's productivity and reduce pest and weed problems — complex cropping patterns and sequences, mixtures of tree crops and annuals, home gardens and, most importantly, by the regrowth of natural vegetation during fallow periods of 5 to 20 years. Growing population densities and increased intensity of land use have caused fallows to be shortened to as few as 2 or 3 years, resulting in sharply declining soil productivity and increased pressure from weeds and pests. The regression line in Diagram 2 shows the inverse relationship between population density and the years of fallow in south-eastern Nigeria.

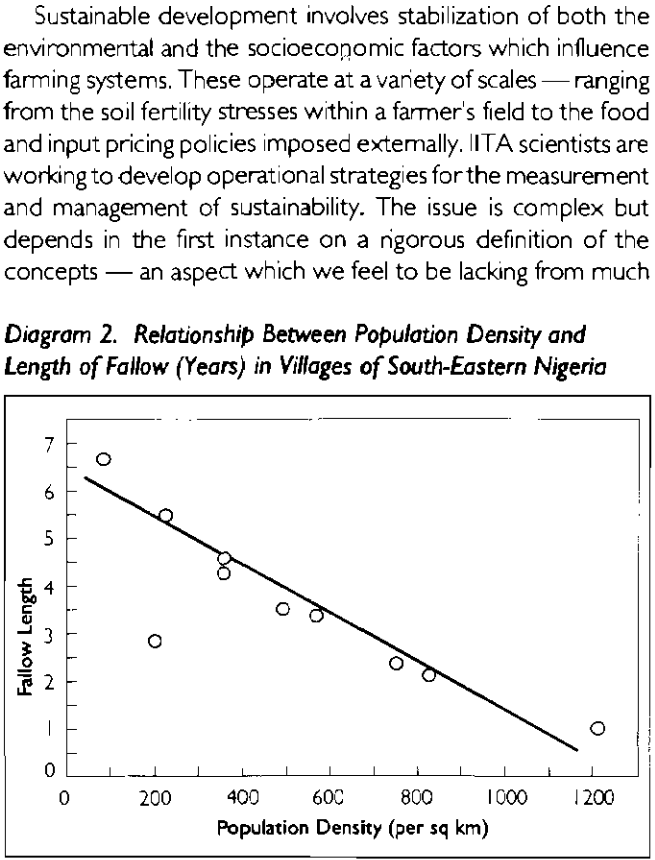
Behind the statistics is the reality that traditional farming systems are being destabilized, forcing farmers to cultivate marginal lands or to destroy the forest reserves in a vicious circle of human and environmental impoverishment. The secondary forest, previously sustained by long fallows, is being transformed into bush that is less able to regenerate soil and provide traditional secondary benefits. Farmers in densely populated villages must for the first time purchase fuelwood, others are intensifying their intercropping, adult males without land are becoming increasingly common, and communal land ownership is giving way to a commercialized system of individual rights to land tenure. A Nigerian geographer has concluded that "the shortage of food is leading to a restructuring of the social organization on a new economic basis that is replacing traditional kinship relationships." South-eastern Nigeria may be a microcosm of the conditions that will prevail in more extensive rural areas of Africa in the future.

Turning to the conceptual model of sustainable agricultural development, Diagram 3 portrays three phases of development of the farming system, from traditional to intermediate to market-oriented. Like many models, this is a highly stylized simplification that raises as many questions as it answers. This is particularly true of the vertical axis showing that the output of the system provides benefits in the form of increased short-run production, and/or greater sustainability.

IITA's goal is to develop agricultural systems that are both productive and sustainable. By representing these benefits as alternatives in the diagram, we acknowledge that there may inevitably be trade-offs between short-run productivity on the one hand and the conservation demands of sustainability on the other. In the high-population-density region of south-eastern Nigeria, we can assume that the productive benefits can be measured in terms of increased yield per area of desirable crops. The measure of sustainability is more complex, but the simplest approach is to equate it with stability of yield. Increased predictability of output from year to year represents a lowering of risk for the farmer. It also creates a situation in which resource conservation, although not guaranteed, at least becomes possible.

Sustainable development involves stabilization of both the environmental and the socioeconomic factors which influence farming systems. These operate at a variety of scales — ranging from the soil fertility stresses within a farmer's field to the food and input pricing policies imposed externally. IITA scientists are working to develop operational strategies for the measurement and management of sustainability. The issue is complex but depends in the first instance on a rigorous definition of the concepts — an aspect which we feel to be lacking from much

Diagram 2. Relationship Between Population Density and Length of Fallow (Years) in Villages of South-Eastern Nigeria



of the burgeoning literature on the topic.

The horizontal axis of Diagram 3 shows examples of technologies that become relevant as the farmer moves from a traditional to a market-oriented system. Given the urgent need for marketable surpluses to feed urban populations, IITA's objective must be to advance farmers toward sustainable food production systems that are increasingly commercialized and can make optimal use of higher levels of purchased inputs.

Many national and international researchers in Africa have been working to produce Phase III technology characterized by high-input, sole-crop packages that produce high yields on experiment stations. But the dramatic success of this "green-revolution" strategy in Asia has not been duplicated in the forest zone of Africa because most farmers are in Phase I, the inputs are not available and, most importantly, the packages do not fit in farmers' complex, bush-fallow cropping systems.

The bush-fallow rotation system characteristic of the forest zone has traditionally been a sustainable system compatible with the land-abundant situation. There is mounting concern in Africa, however, that sustainability is threatened by rising population densities. Ironically, part of the stress comes from use of improved crop varieties that increase nutrient removal without compensating soil amendments.

IITA has been very successful in developing technologies that permit more intensive cultivation by stabilizing output through reduced risks. Such stability arises from crop varieties resistant to pests and tolerant of adverse environmental factors; biological approaches that avoid the need for chemicals and work with nature to solve farmers' problems; and technologies that protect output from postharvest loss.

Assuming that the farmers could afford it, the simple addition of fertilizer to the system might be thought sufficient to sustain production, thus permitting the smallholder to jump over Phase II and enter Phase III. While that would be a short-term possibility to increase production, numerous examples from the humid tropics have shown that it is not a long-term solution. Diagram 4 illustrates this point with experimental data gathered over seven years of annual cropping without fallow at Ibadan, in the forest-savanna transition zone. The addition of fertilizer raises maize yields initially, but that is not sustainable. The soil is rapidly degraded as organic matter is mineralized and nutrients are leached to depths beyond the reach of crops. The soil becomes increasingly acid, it loses structure, becomes compacted, and in the worst case is itself eroded.

Thus it is apparent that there can be no easy progress from Phase I to Phase III, even were the farmer able to purchase and use external inputs. The key to the transition from what is essentially subsistence farming to market-oriented farming, using purchased inputs, lies in an understanding of the traditional system of shifting cultivation, and the restorative role of the natural fallow which sustained low levels of production in these fragile environments for centuries.

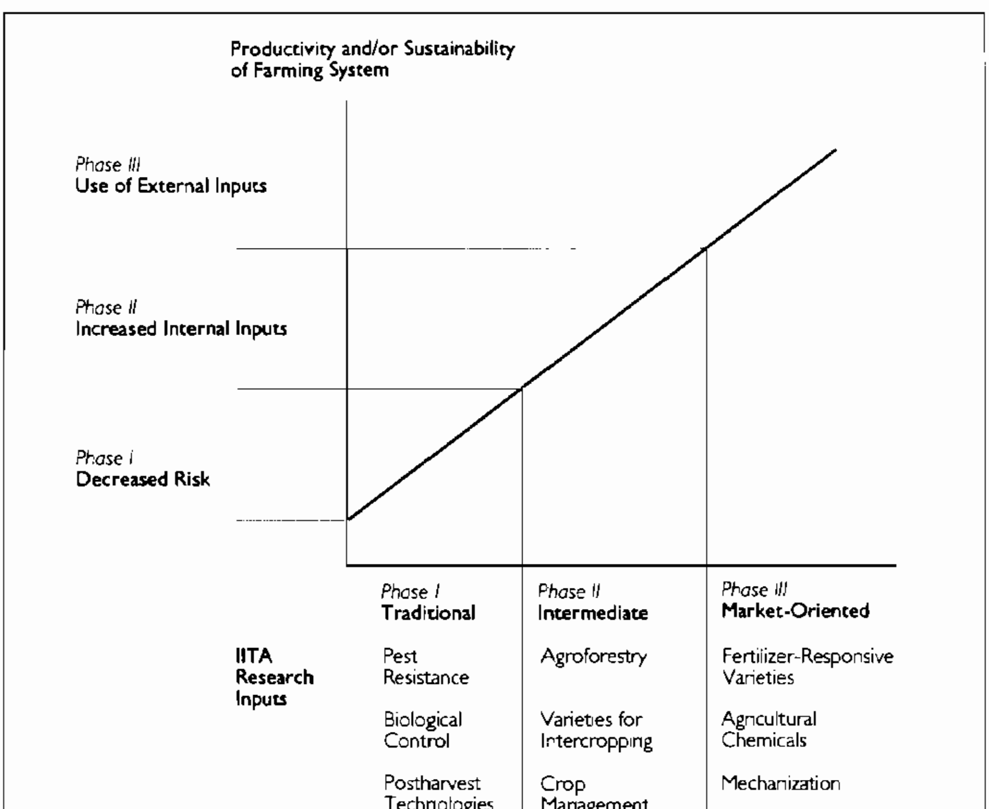


Diagram 3. IITA Research Inputs at Different Phases of Smallholder Development

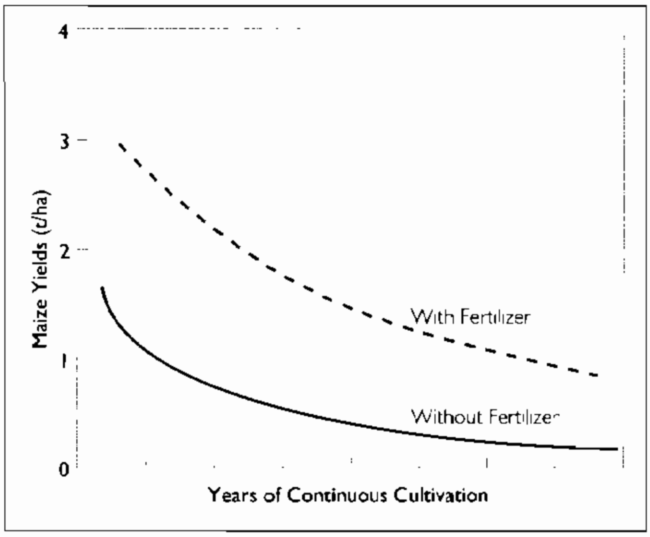


Diagram 4. Relationship Between Length of Continuous Cultivation and Maize Yields at IITA, Ibadan

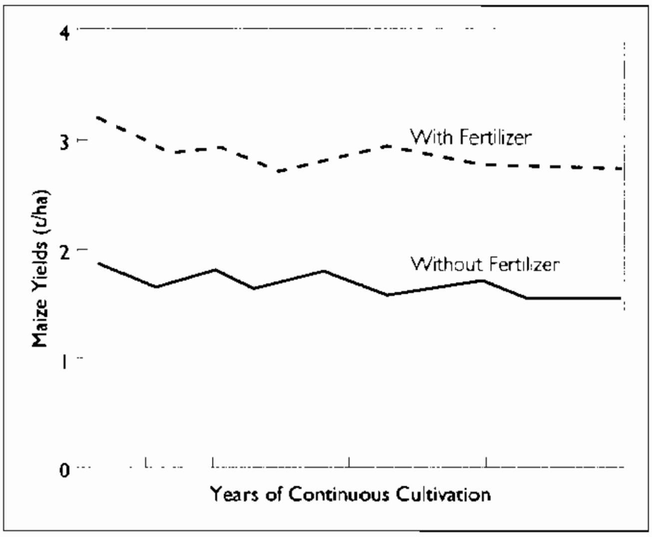


Diagram 5. Sustainability of Maize Production in Alley Farming Systems at IITA, Ibadan

The biological processes by which the vegetative fallow sustains production of food crops are now better understood. They include:

- Vegetative cover to minimize soil surface erosion
- Recycling of nutrients from lower soil layers to the crop rooting zone
- Increased input of nitrogen by fixation by leguminous trees or herbaceous species in the fallow or cropping system
- Organic matter accumulation at the soil surface and the consequent improvement of biological activity, water infiltration, and moisture and nutrient retention

IITA research in Phase II seeks technologies which integrate these interna biological processes into improved intercropping systems that enhance stability and increase productivity.

Diagram 5 shows experimental results of maize production in alley farming systems at IITA. Alley farming has all of the elements just described; it minimizes the trade-off between production and sustainability inherent in traditional bush fallow, because it merges the fallow and cropping cycles in time but separates them in space. Although alley farming has not yet been adapted to the acid soils of the humid forest zone, it serves here as a model to demonstrate how it might be possible to increase cropping intensity and sustainability.

The lower curve of Diagram 5 shows that resource-poor farmers can sustain intermediate levels of production in an improved management system such as alley farming using internal inputs. But these systems face biological limits that can be overcome only with modern external inputs. This is shown by the upper curve of the diagram. The addition of fertilizer to the alley cropping system increased production without the destabilizing effects seen in the monocrops of Diagram 4.

Alley cropping is only one solution to the problems of the resource-poor farmer, and may indeed only be applicable to a limited range of environments. Nonetheless the principles it embraces, as outlined in the previous paragraphs, are of general utility. IITA is developing a suite of alternative multi-species systems involving trees and/or herbaceous legumes.

In Phase III of the model, we recognize that external inputs are essential if farmers are to increase their output to the level shown in the upper curve. Farmers able to benefit from such technologies will be those who are increasingly able to commercialize their operations by selling surplus output and purchasing inputs. They will benefit from research, some of which is already "on the shelf," on the development of crop varieties that are more responsive to fertilizer and good management, and to simple and appropriate mechanization.

Technology, of course, is only one of the inputs into agricultural development, and the partial nature of this model must be emphasized. It is meant to show how technology inputs and the properties of the system change as the farmer moves from the closed, internally controlled traditional system to an open and more externally directed, market-oriented system. The stages should not be considered mutually exclusive nor the trajectory linear. Stage III is most subject to destabilization because of its dependence on market forces, thus requiring continuing iteration in land use management to optimize the efficiency of external inputs.

Research for Sustainable Agriculture in the Forest Zone

IITA has been successful in breeding resistance to major pathogens of food crops of the humid forest zone. Improvements for Phase I that can be integrated relatively easily into existing farming systems are illustrated by IITA's research on cassava and plantains as I describe in the following paragraphs. IITA scientists realized major research breakthroughs on these

Looking at the Bottom Line
Assessing IITA's Impact

Economists have clearly demonstrated that public investment in agricultural research in Asia and Latin America has produced great benefits, evidence that is important in sustaining the financial support required for successful research. With the exception of IITA's success in biological control of the cassava mealybug, however, there is limited quantitative evidence that research is producing similar dividends in Africa.

We are frequently asked, "What is the impact of IITA's research?"– a question that is inevitably followed by "How do you know?" Understandably, people want to know whether IITA's improved agricultural technology is increasing food production and improving the well-being particularly of the poor.

The answers to these questions are complicated by the fact that IITA contributes intermediate products whose benefits depend on the actions of others for their impact. We conceive of IITA as a link in a chain (see diagram below) stretching from basic research laboratories in the developed world, through the CGIAR centers to national research institutes, then extension agencies, and finally to our ultimate target, the African farmer.

No matter how well conceived, IITA technologies generally require adaptation by national scientists to specific agro-ecological environments. Impact can be restricted by weak linkages among national researchers, extension agencies and farmers which are beyond our control.

IITA's program of activities also results in two indirect benefits whose impact is even more difficult to measure.

1. We help to strengthen national agricultural research agencies through our programs of training, networking and resident scientist teams. We need to devise methodologies for measuring the impact from such activities on national institutional development, which is critical to raising food production.
2. We contribute to the advancement of basic scientific principles and methods. Some examples are the first classical biological control program on a continental scale, the refinement of breeding techniques which permit utilization of genetic diversity, and the conceptual approach to resource management research for sustainable agriculture in the humid tropics.

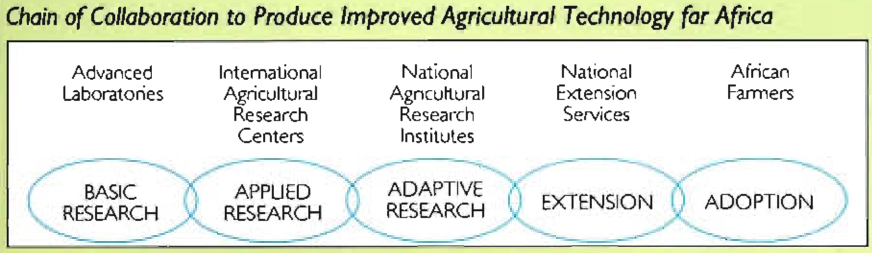
The bottom line is, of course, impact in farmers' fields. Lack of reliable statistics on agricultural production in most African countries, however, prevents us from conducting cost/benefit studies which can quantify the dimensions of the impact from research – such as have, in Asia and Latin America, shown impressive returns.

In the absence of statistics, we have had to content ourselves with anecdotal reports from IITA scientists, testimony from collaborators in national programs and scattered surveys. However positive such reports have been, we need firmer evidence to satisfy donor concerns and to guide us in planning our research agenda. Accordingly, we are devoting resources to new studies that will provide data on the impact of improved technologies in farmers' fields.

Take the case of cassava, the poor man's crop of tuberous roots which farmers can leave in the ground until needed. IITA has been conducting research on cassava for two decades without reliable data on crop production or distribution. According to the director of the Federal Office of Statistics in Nigeria, statistics on cassava are the worst of any major crop – there exist "as many versions of production series as there are organizations interested in agriculture in this country". In 1987 IITA launched the Collaborative Study on Cassava in Africa (COSCA; see description on page 37 of this volume) in order to collect basic data on cassava in Nigeria and five other countries. More narrowly defined studies are under way about other IITA commodities.

Knowledge of the field performance of improved technologies will become increasingly important as IITA shifts emphasis from commodity research, with its potential for green-revolution type of breakthroughs, to research on the more complex and long-term issues of sustainable agricultural systems.

Chain of Collaboration to Produce Improved Agricultural Technology for Africa



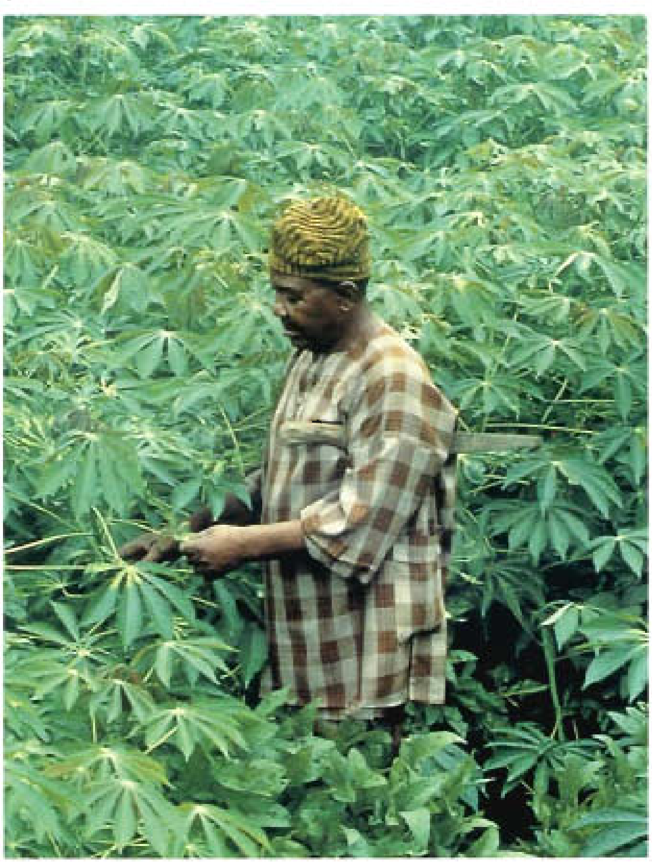
two staple crops during 1989-1990.

Cassava. Cassava-based cropping systems are the dominant farming systems in the forest zone. IITA will expand its cassava breeding in 1991 to its new humid forest station in Cameroon in order to adapt cassava to the acid soils, to improve labor productivity of these systems, and to meet diverse local needs.

IITA is able to decentralize the cassava improvement program because the major pest constraints — viruses, bacteria and mealybug — have been overcome by past work at the Ibadan and Cotonou facilities. Despite the notoriously poor statistics on cassava, improved stable varieties are known to be spreading throughout Nigeria — improved cassava planting material was available in about 90 percent of the Nigerian villages surveyed in 1990 by IITA's Collaborative Study of Cassava in Africa (COSCA).

Breeding objectives for cassava in some countries must take account of the importance of cassava leaves in human diets. And everywhere there is economically significant variation in the length of time in which tubers are left in the ground before harvest. The range extends from less than 12 to more than 18 months, with important implications for breeders because quality declines as the fiber content of tubers increases with age.

Improved cassava with bushy branches helps to reduce weed growth.



Among the breeding concerns which relate to production, it is necessary to take account of variations in plant architecture appropriate for cassava in different cropping systems. IITA's priority is to develop varieties for smallholders who are intercropping cassava in mixed systems. They prefer cassava with an erect growth habit and few branches because it minimizes competition for light with interplanted crops such as maize.

Commercial farmers growing cassava for the market, on the other hand, prefer profusely branching, bushy cassava because it smothers weeds when grown as a sole crop, just as it would smother any crop in an interplanted mixture. This attribute, valued because it decreases labor requirements, is expressed most obviously in IITA varieties which hold their leaves well because they are resistant to diseases which cause premature leaf fall.

These diverse production requirements call for diverse breeding strategies. In addition, diverse utilization requirements call for cooperation between IITA's cassava breeders and postharvest technologists. For example, there is variation within the African cassava belt in the cyanide content of cassava tubers. In many regions the so-called sweet cassava is preferred because it is low in cyanide, and can be easily processed for consumption; in other regions the preference is for products that are prepared by fermentation and heating which drive cyanide out of the grated or ground tubers of bitter cassava.

Biological control research is appropriate for Phase I farmers and there can be no better example than the biological control of cassava mealybug in Africa referred to earlier. The story is well known — the collaboration with CIAT, the International Institute for Biological Control (IIBC) and with many other organizations; the exploration in Central and South America; the discovery of the tiny *Epidinocarsis lopezi* wasp and its introduction into Africa after quarantine by IIBC in England; and release of the wasp over the African cassava belt where it has decreased mealybug populations below the level of economic damage. Without inputs of any kind from the African farmer, the application of high-quality biological control science has resulted in savings of food crops valued in billions of U.S. dollars. (See story "IITA/CIAT Research in Biological Control..." in Research Highlights section.)

African cassava growers will benefit from important research breakthroughs by IITA scientists this year — the establishment of a predaceous mite, *Neoseiulus idaeus*, that is a natural enemy of the destructive cassava green spider mite; and the discovery of apomixis and polyploidy among products of crosses between cassava and its wild relatives that expands the breeding potential of Africa's most important crop.

Plantains. As a result of the Strategic Planning Study, IITA has expanded research on plantains, an important component of farming systems in the humid forest zone. According to FAO statistics, bananas and plantains are the second most economically important crop category in Africa, surpassed only by cassava. Plantains are an ideal crop for small-scale farmers in the humid forest zone because they fit easily into their farming systems and produce high yields throughout the year.

IITA has worked on the major constraints to plantain production for many years, with emphasis on the agronomy of the so-called "yield decline syndrome", the low multiplication rate, and on nematodes which are serious pests of the crop. The decision to expand this effort was based upon the urgent need to deal with threatened devastation by black Sigatoka disease.

Black Sigatoka disease is the overriding constraint in plantain production worldwide. Its fungal spores, dispersed by wind and water, are beyond the control of plant quarantine measures. It causes plantain leaves to wither, resulting in losses so high that the crop may become uneconomical to grow. The disease, accidentally introduced into Central Africa recently, spread rapidly to the north, reaching Nigeria in 1986. It can be controlled by fungicides, but at a high cost beyond the means of African farmers.

IITA's strategy for research on black Sigatoka has two major thrusts. First, East African cooking bananas have been screened for reaction to the disease, and some have been found which are resistant. Those likely to be acceptable to consumers are being multiplied and distributed in Nigeria. Although West Africans are unfamiliar with cooking bananas and much prefer plantains, these resistant clones are potential alternatives if plantains decline in West Africa, and they are being tested in the region in collaboration with the International Network for the Improvement of Bananas and Plantains (INIBAP).

Second, IITA established the first plantain breeding program in Africa with the chief objective of breeding plantains resistant to black Sigatoka. Recalling the disastrous impact of the rosette disease on groundnut production in northern Nigeria, officials from the Federal Ministry of Agriculture supported IITA's plans to launch an urgent research campaign to control black Sigatoka at our station at Onne, eastern Nigeria. It took IITA 10 years to develop resistance to streak virus in maize, which is a much simpler crop for breeding purposes. There was tremendous pressure on IITA agricultural scientists to save plantains for the millions of smallholders who depend on them for their subsistence and livelihood.

I am very pleased to be able to report that IITA had an important breakthrough in this work in 1989, much earlier than could have been expected. IITA's plantain breeder has succeeded in making artificial crosses between Sigatoka-susceptible plantains and resistant diploid bananas, and he has obtained viable seed. From about 100 seedlings raised from the hybrid seeds, three plants appear to be resistant to black Sigatoka and have the characteristics of plantains. If Sigatoka-resistant plantains can be extended widely to smallholders in the humid forest zone, this will be another example of the impact possible from biological approaches that remove risks and sustain production.

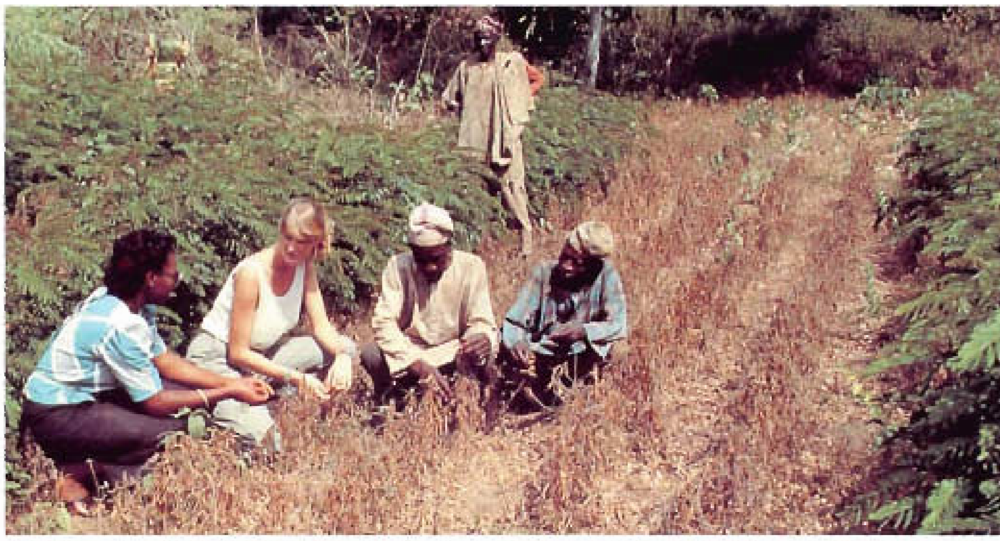
The research described above on cassava and plantains is increasing the short-run productivity of smallholder systems in the forest zone, but it does not enhance their sustainability. At the present time, under conditions of shortening fallow in the humid forest zone, there is no viable proven technology for the farmer that will sustain fertility under annual cropping. Cultivation can not be intensified from the addition of fertilizer alone because its application rapidly leads to greater acidification and toxicity of the soil — it would not be economically feasible to apply the amount of lime and other soil additives necessary to sustain fertility of these soils.

Resource-Management Research. New technologies are required (1) that draw upon farmers' knowledge and are consistent with farmers' systems, (2) that build upon knowledge of the resource base and the biological processes that enable vegetative fallow to sustain food production, and (3) that involve new intercropping systems that enhance stability and productivity.

IITA is increasing research on the determinants of sustainability and degradation of the resource base. Much of the conventional wisdom about what is happening to bush-fallow systems rests on limited scientific evidence. Since the pioneering studies by Nye and Greenland in the late 1950s, for example, little research has been conducted in this region to quantify the factors responsible for the rapid decline in soil productivity following land clearing. Using a stable bush-fallow system as the standard, field experiments are needed to produce empirical data on the relation of fertility decline to farmers' strategies, such as fallow management, crop mixtures, fertilizer use and weeding.

The utility of empirical data resulting from field research is limited, however, by the high variability of the micro-environments in the region and the many years that are required to test the sustainability of technologies. Shortcuts are necessary in approaching the extrapolation and testing of research results. IITA is tackling this by a two-pronged attack. The first strategy is to develop a detailed database of the environmental and socioeconomic characteristics of our mandate area. This information can be summarized in the form of maps — for instance, of climatic zones, distribution of soil constraints, population densities or market access indicators. More importantly, the data will be organized in a geographic information system which can be accessed by researchers of any discipline to determine the biophysical and socioeconomic potentials and constraints of their own technological interventions.

The second thrust is to investigate the underlying determinants of sustainability in the farming systems under study at IITA. This involves interdisciplinary research on all natural resources — climate, the storage and transportation of water, soil fertility, pests, weeds and diseases, the physiology of plant growth —



IITA staff study firsthand with farmers the problems of olley farming with soybeans between rows of leguminous shrubs.

and of the interactions between them. It also embraces studying the interaction between these biophysical determinants and socioeconomic regulators of the system such as the patterns of labor availability and capacity for utilization of inputs. The output of this research will be ecological-economic models which, when linked with the geographic information system databases, should give us sensitive insights into the "portability" of our technological innovations.

Agroforestry will be an essential component of improved systems to achieve sustainable food production in this zone. The traditional bush-fallow system is itself a form of agroforestry which under population pressure must be modified to make it sustainable. The basic elements of agroforestry must be studied in order to develop a range of improved land-use options.

Among the possible agroforestry interventions, research on alley farming is the most advanced at IITA. While on-station research in the transition zone at Ibadan has produced prototype technologies for widespread on-farm testing, there are still unanswered problems associated with the acid soils of the forest zone that require on-station research. For example, germplasm collection and evaluation are necessary to identify trees or shrubs with the required attributes of "alley species" and which thrive on acid soils. We are often asked whether, after so many years of research, farmers are using alley farming and, if not, why they are not. In trying to find answers, IITA and the International Livestock Center for Africa (ILCA) have planted over 100 alley farming plots in individual farmers' fields. Studies are underway on the economic value of the hedgerow species, or "carrier cash crops" to make hedgerow establishment more attractive, and on hedgerow management techniques for weed control. Scientists are now examining results through the filters of the farmers' objectives, economic profitability and adoption potential. In all cases we are exploring how to minimize the conflict between farmers' short-term needs for production and the longer-term benefits of sustainability.

Agroforestry is sometimes said to combine the art of traditional farming with the knowledge of modern science. But some consider the science base to be limited, with an unhealthy imbalance between vast development projects and low levels of research. Over the last decade IITA scientists have attempted to correct this deficiency, and we now have several years of experience of process-level studies on alley-cropping systems at the Ibadan station. These investigations have deepened our understanding of the mechanisms whereby hedgerow trees influence the fertility of soil, including the responses of the most commonly used trees to management practices and competitive interactions with associated crops.

IITA's new station in Cameroon is intended to be a center of excellence for agroforestry research in the humid forest zone. Research will be an interactive process there, involving characterization of the environment, studies of the processes of tree-crop interaction, and design of new systems. Progress may require modifications in the land tenure system, so that farmers have secure ownership and an incentive to invest in trees. Such systems might be quite novel and complex, or refinements of present systems. We might envision a system for the twenty-first century with three components: the compound garden around the household; an improved fallow with a multi-canopy of commercially useful trees and intercropping of such high-value, labor-intensive food crops as vegetables; and a third field of cash-crop perennials, possibly oil palm or rubber. Such research requires creative thinking to define new scenarios for sustainable development.

IITA is relying increasingly on resource and crop management research concepts such as agroforestry that will facilitate the farmer's transition from traditional farming systems to the intensified higher-input, partially commercialized systems required for Africa to feed itself again. The research models and issues vary significantly by agroecological zone. My discussion has concerned the humid forest zone, the most difficult environment within IITA's mandate for developing productive and sustainable systems to support expanding populations. The environment within our area of primary focus with the greatest potential for producing marketable surpluses in the short run is the moist savanna of West and Central Africa. IITA is also intensifying its research for this zone, where remarkable changes in cropping systems are occurring and where scientific breakthroughs will have their greatest immediate impact.

Conclusions

Control of the quality of research and management of the international research centers belonging to the CGIAR is implemented by a quinquennial process of external program and management reviews. The review panels consist of experienced and tough-minded scientists and science managers, who in the course of their lengthy and in-depth reviews become thoroughly familiar with the work of the particular center.

IITA's quinquennial review was conducted early in 1990 by panels led by two distinguished science managers: Dr. Jim McWilliam chaired the External Program Review and Sir Ralph Riley chaired the External Management Review. They reviewed and evaluated progress over the past five years.

The years 1986-1987 saw enormous change at IITA. The strategic planning exercise led to new priorities and strategies for an integrated program of research and international cooperation. Management changes included major staff retrenchment caused by the 1985 financial crisis, a restructured personnel system, and a new financial information and controls system.

The year 1988 was a year of consolidation. The top management team was rebuilt, and the new program strategies in IITA's first Medium-Term Plan became operational.

The year 1989 was an exciting year in which we strengthened the scientific team and launched the new initiatives in the Medium-Term Plan. In my last semi-annual letter to staff in 1989, I expressed the view that "much remains to be done, but IITA is in excellent condition to move forward boldly on its challenging mission to make it the world's premiere scientific institution for the agriculture of the humid tropics of Africa."

The external review panels were penetrating and comprehensive in their assessment of IITA. They made numerous important and useful recommendations on most of which the Board of Trustees has already taken action.

What was most encouraging was the panels' strong general endorsement of the Institute. They congratulated IITA for its "vision of the future and explicit strategies to achieve its objectives in the complex setting of current and future African environments." They concluded that successful management changes provide a "powerful base for research" — the stage has been set for "new levels of productivity and impact."

Agricultural research to produce improved technology will grow in importance in Africa during the last decade of the twentieth century and beyond. Population pressure on resources will remain severe in Africa where there is still little evidence of a demographic transition from high to lower levels of fertility. The malnutrition and poverty that must be projected into the next century will inevitably exacerbate environmental degradation and enhance the urgency of developing sustainable agricultural systems.

Fortunately, many African political leaders now recognize that accelerating food production is both an immense task and an essential prerequisite for national economic development. Macroeconomic policy reforms and strengthening of infrastructure are occurring in numerous countries. Improved agricultural technology will increasingly be identified as the constraint in getting agriculture moving in Africa. This constitutes a stark challenge and an opportunity for IITA and all the CGIAR centers active in Africa.

Laurence D. Stifel
Director General

Research Highlights

IITA/CIAT Research in Biological Control Wins the 1990 King Baudouin Award

IITA and Centro Internacional de Agricultura Tropical (CIAT) were selected to receive the 1990 King Baudouin Award for International Agricultural Research, for their research on the biological control of the cassava mealybug in tropical Africa. Dating from the 1970s, the joint research effort backed a biological pest-control program at IITA which has effectively eliminated the threat of massive crop losses from the mealybug for Africa's cassava farmers.

Sponsored by the Belgian Government, the King Baudouin International Agricultural Research Award is made biennially by the Consultative Group on International Agricultural Research (CGIAR) for outstanding research achievements. In 1986, IITA received the same award for its achievement in developing improved maize varieties resistant to maize streak virus.

The cassava mealybug research and control program has covered all the interactions of the pest in the different agroecological zones of Africa which it inhabits: crop, pest, natural enemies, hyperparasitoids, alternative hosts, economic factors and other aspects. The program was designed to address development needs for human and material resources in institutionalizing the biological control approach in tropical Africa. This holistic approach has made it a large project—the largest classical biological control effort in the world.

From its inception the program has entailed extensive collaboration among 25 universities, research institutes, international and intergovernmental agencies in Africa, Europe, North and South America. The funding of the project has involved many donor agencies that formed a sponsoring group with a consultative review procedure. The size and scale of the campaign led to the relocation of the IITA Biological Control Program to new facilities in Cotonou, Republic of Benin, the only program research center of its kind in the CGIAR system.

Classical approach

The classical approach of biological control, whereby the natural enemy of an introduced pest is likewise introduced in order to control the pest population in the new environment, proved to be well suited to meet the problem in sub-Saharan Africa. Communications and extension services in the region are weak and farmers are generally poor. A solution involving no investment, maintenance or other action by farmers was called for. Since the introduced enemy populations reproduce and disperse themselves, no distribution system beyond the research project was necessary.

The goal of biological control, in this case, was to create a stable equilibrium between the mealybug and its natural enemies, through introductions of those enemies selected for their effectiveness and specificity. The basic strategy was to search for the predators and parasitoids of the cassava mealybug in the native habitats of the pest in South America. The aim was to establish a complex of enemy species that would provide lasting and economic control of the mealybug across the diverse environments of the cassava belt.

Predators or parasitoids were sent to the International Institute of Biological Control (IIBC) in London for rigorous screening to ascertain their specificity for the mealybug and to assess any possible problem that could arise if they were introduced into Africa. After such certification, and with the approval of the Nigerian Plant Quarantine Service and the Inter-Africa Phytosanitary Council, the enemy species were sent from England to IITA in Ibadan, Nigeria.

At IITA, scientists developed systems for mass reproduction of the enemy species. They devised new techniques and facilities to rear natural enemies in large numbers. Extensive laboratory and field experiments were conducted to determine the suitability as predator and parasitoid of each introduced species. Successful predators and parasitoids were released from the ground, or aerially utilizing an aircraft specially designed and equipped for the purpose. Finally, releases were followed by monitoring surveys to determine whether or not released natural enemies had established successfully and to document the effectiveness of their control of the cassava mealybug.

The world has become a global village. No matter how strict plant quarantine regulations are, and no matter how efficient the enforcement agencies, unwanted introductions of pests cannot be completely stopped. This biological control research project offers one potentially important mechanism for combating future accidental introductions into sub-Saharan Africa.

The Mealybug Problem

The cassava mealybug was accidentally introduced into Central Africa at an indeterminate time and described as *Phenacoccus manihoti* (Homoptera: Pseudococcidae). In 1973 it was reported to be causing serious damage to cassava in Zaire by two IITA scientists and in the Congo by the Institut de Recherche Agronomique Tropicale et de Cultures Vivrières. By 1976, there were widespread mealybug outbreaks in the Bàs-Zaire, Bandundu and Shaba regions of Zaire. The pest spread across the cassava-growing areas of Africa at about 300 kilometers per year.

Currently it occurs in 32 countries in Africa's cassava belt, as identified on the above map. While it was found to have come from a restricted area in South America, the mealybug proved to be very versatile when it invaded Africa by spreading to cassava in all agroecological zones.

In 1977, IITA held a workshop on the cassava mealybug in Zaire which brought together agronomists and breeders working on cassava, mealybug specialists and biological control scientists from Africa, Europe, North America and Latin America. They concluded that both biological control of and resistance breeding against the cassava mealybug were feasible, and urged IITA to begin a research program. IITA initiated a program in 1980 to breed cassava varieties resistant to the pest. This effort has recorded some successes and it is still continuing.

A modest project in biological control commenced at IITA in 1979. Today, after a decade of support from donor agencies of developed countries (Austria, Belgium, Canada, Denmark, Germany, Italy. Netherlands, Norway, Sweden, Switzerland and the European Economic Community), African Development Bank, Food and Agriculture Organization of the United Nations (FAO) and International Fund for Agricultural Development (IFAD), that initial effort has grown into what is probably the world's largest biological control program, ano it has begun to target other major pests as the original aim has been fulfilled.

During this period, CIAT was already acquiring expertise in the biological control of the cassava mealybug. In 1975, mealybugs were found attacking cassava on the CIAT farm at Palmira, Colombia. They were identified as *P. gossypii*. Studies of the biology, ecology and natural enemies of the species began in 1976. Aware of CIAT's mealybug research, IITA requested CIAT to search for *P. manihoti*, the pest species in Africa. The request subsequently expanded into collaboration between IITA and CIAT in the search for the natural enemies of *P. manihoti* in South America.

The IITA/CIAT search for enemies of *P. manihoti* followed on the efforts of IIBC wh ch had initiated exploration for *P. manihoti* and its enemies in 1977 in the Caribbean, Venezuela, the Guyanas, and northeastern Brazil. After various explorations in several countries of tropical America, *P. manihoti* was finally discovered in South America late in 1980 by a CIAT entomologist. On a mission to Paraguay, he found mealybugs attacking cassava in Cacupe Research Center. In 1981, an IIBC scientist visited CIAT where a joint exploration to Paraguay for natural enemies of *P. manihoti* was planned. The joint mission collected a number of species, including the parasitoid wasp *Epidinocarsis* (=*Apoanagyrus*) *lopezi* (Hymenoptera), that has subsequently proved exceptionally effective in Africa. Further explorations from Mexico to Colombia, Brazil and Paraguay by an IITA team brought back other species of natural enemies, which were sent to IIBC for quarantine and later shipped to IITA.

So far 10 species have been brought to Africa; most have been released at least in some localities. Three parasitoids (*Epidinocarsis lopezi*, *E. diversicornis* and *Allotropa* sp.) and four predators (*Hyperaspis jucunda*, *H. notata*, *Diomus* sp. and *Sympherobius maculipennis*) have been recovered after the releases. Some could be established only in restricted areas with particular climate or plant-growth characteristics. *E. lopezi*, *H. notata* and *Diomus* sp. are widely established. These natural enemies are considered to constitute the effective complex which keeps in check populations of *P. manihoti* in its original South American habitats.

Scientific accomplishments

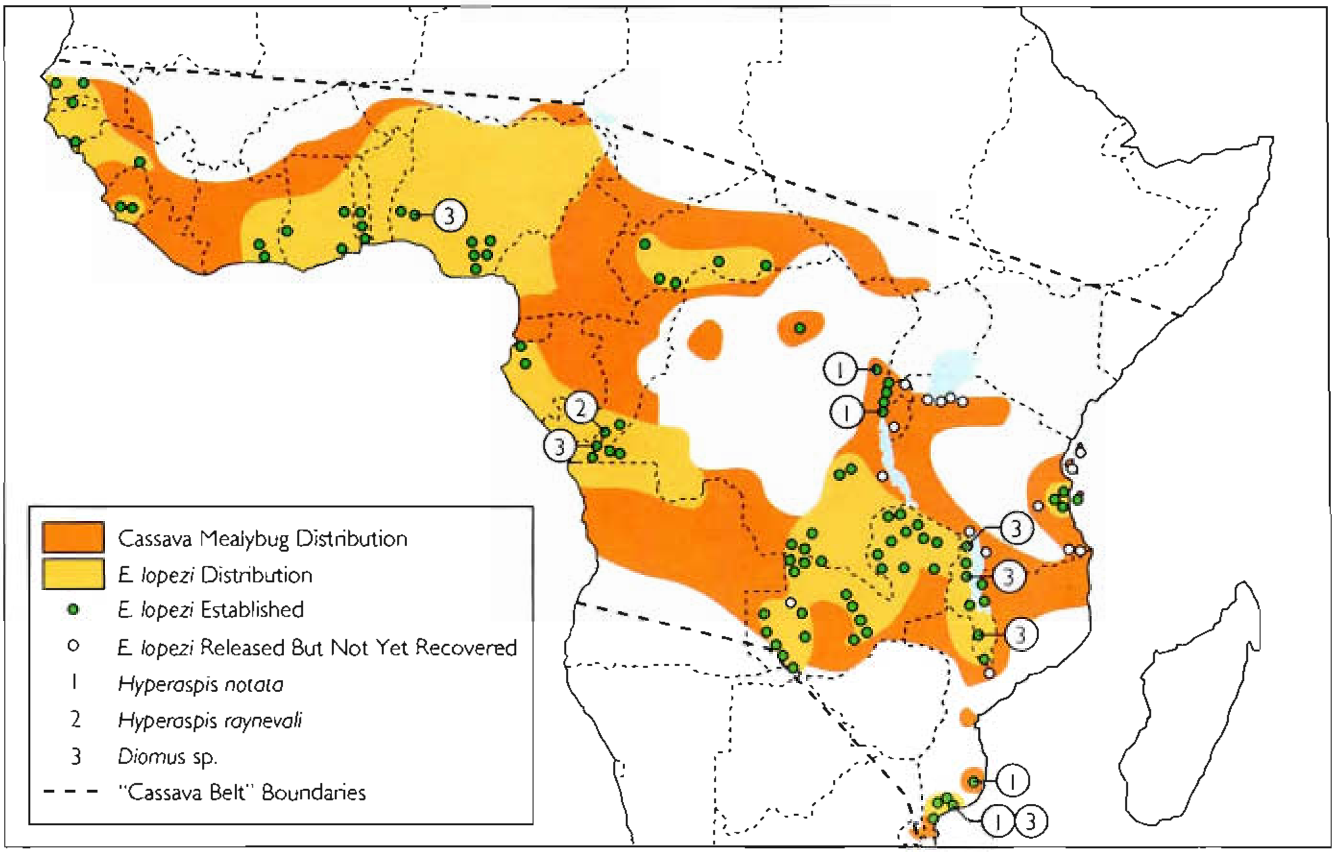
The scientific accomplishments of IITA/CIAT research and the control program include the accumulation of scientific knowledge about the cassava plant and the taxonomy, biology and ecology of the cassava mealybug and its exotic and local natural enemies. Field ecology and plant pest interactions have been studied and sampling methods have been developed to provide a basis for economic and biological impact assessment.

A computer simulation model of the cassava crop system has been developed. The model includes the effects of temperature, solar radiation, nitrogen and water on plant growth. A simulation model of the cassava mealybug has also been established and linked with the crop model. Yet another model concerning the highly successful parasitoid *E. lopezi* has been developed and superimposed on the mealybug model. The evolutionary ecology related to the host-finding behavior of *E. lopezi* has been studied to explain under what circumstances and why it is an efficient parasitoid.

Establishment and dispersal of the released natural enemies have been extensively studied. The map on page 19 illustrates release sites. establishment and spread of *E. lopezi* in Africa. *E. lopezi* was first experimentally released at IITA in November 1981, at the beginning of the dry season, and one year later in nearby Abeokuta. At the end of 1984, three years after the first release, *E. lopezi* was found in 70 percent of all fields on more than 200,000 square kilometers in south-western Nigeria, to the northern limit of regular mealybug distribution. This dispersal rate is among the fastest recorded for microhymenoptera.

Mass-rearing. Hydroponic culture techniques for cassava production have been developed as a necessary first step in the mass rearing of cassava mealybug. Efficient and reliable mass rearing technologies for the cassava mealybug and its natural enemies have been achieved and costed. These technologies incluoe the mechanized insect production system and the so-called "cassava tree", a vertical structure that holds in its perforated central cylinder a number of cassava cuttings.

Aerial Release. IITA had to develop an aerial release and automatic packaging system for natural enemies, since the African cassava belt covers an area one and a half times the size of the United States of America. The system has been tested in Côte d'Ivoire, Ghana, Nigeria, and Zambia. Successful establish-



ments of *E. lopezi* and *Diomus* sp. in the release sites have demonstrated the potential of this method for large-scale and remote-area releases. This airplane, for example, permitted natural enemies to be air-released successfully over remote cassava fields in Zambia less than 24 hours after they had been packaged at IITA in Ibadan, Nigeria.

New indigenous capacity. A major effort to train biological control experts at different levels (extension, M.Sc. and Ph.D.) has been an important component of the biological control program. As of December 1989, 408 trainees, mostly staff members of national plant protection services, had received short-training at IITA. Degree-related training is carried out at IITA and at the International Centre of Insect Physiology and Ecology (ICIPE), in collaboration with universities in Africa, Europe, and the United States. To date, 24 M.Sc. and 12 Ph.D. fellowships have been awarded for research supervised by scientists of IITA's Biological Control Program.

Following governmental requests, 14 African countries have received financial and technical assistance channeled by donors through IITA for the initiation of their own biological control programs, while seven other countries have received technical assistance alone. In seven countries, IITA was instrumental in identifying bilateral funding for the future consolidation of national biological control programs which conduct pre-release surveys and post-release monitoring surveys. These surveys are usually undertaken initially with the assistance of IITA. As these scientists gain experience, their national programs will be able to help develop indigenous capacity to undertake integrated pest management programs.

Impact

By 1990, one of the mealybug's natural enemies, *Epidinocarsis lopezi*, had been established in 25 sub-Saharan African countries over areas of about 2.7 million square kilometers, effectively in all zones occupied by the mealybug and the cassava host plant.

Detailed monitoring of releases in Ghana, Malawi, Nigeria and Zambia have shown that mealybug populations are being brought under control. Mealybug populations now fluctuate below damaging levels in many countries as a result of the control exerted by the introduced natural enemies. Losses due to the mealybug can be expected to continue to decrease as the natural enemies spread further.

The expected common phenomenon in biological control is that the beneficial insect will cover a more limited range of ecological conditions than its host. This assumption was defied, however, with the success of the parasitic wasp *E. lopezi*.

A benefit-cost analysis of the project has been carried out by an economist at the University of California, Berkeley (R. B. Norgaard, *American Journal of Agricultural Economics*, vol. 70, pp. 366-71, May 1988). The analysis was based on a reasonable, least-favorable case over a 25-year period that incorporated the features which the experts felt might threaten the success of the project. The result was a benefit-cost ratio of 149:1 over 25 years, which ranks the program among the most successful agricultural research projects ever evaluated.

Inland Valley Farming Systems

In the upper reaches of major and minor watersheds throughout Central and West Africa, small inland valleys collect surface and subsurface moisture from adjacent, heavily farmed uplands. Individually, these shallow, narrow declivities—as long as 25 kilometers, but as little as 10 meters across where they begin, widening to several hundred meters in their lower reaches—are agriculturally insignificant. Taken together, however, totaling tens of millions of hectares of relatively fertile and well-watered soils in West Africa alone, inland valleys represent a major potential for producing the additional food—especially rice—that tropical Africa needs.

Full responsibility for West African rice improvement in the CGIAR system will be transferred from IITA to the West Africa Rice Development Association (WARDA) by the end of 1990. To focus specifically on the clear opportunity for increased crop production in the inland valleys throughout tropical Africa, IITA, with WARDA's participation, has set up the Inland Valley Systems Research Group, which includes specialists in resource and crop management, in economics, and in crop improvement. The group's mandate: to identify and develop improved cropping systems that will permit sustainable, increased food production by small-scale farmers in those complex and difficult, but richly promising, environments.

Despite their agricultural potential, inland valleys traditionally have been neglected, by agricultural researchers and policy makers as well as by farmers, in favor of the more readily exploitable uplands and vast lowland areas of river floodplains and mangroves. In recent years, however, as populations have grown relentlessly, upland farmers have been forced to dig deep into their agricultural capital—their soil's fertility—to produce more food. The fertility of vast areas of upland has been substantially decreased in the attempt to increase food production faster than population by decreasing the soil-restoring fallow periods between crops. The strategy has defeated its own purpose, contributing instead to a recent decline in per capita food production in West and Central Africa. Increased, sustainable cultivation of inland valleys, which generally have better soils and more available water than adjacent uplands, promises to relieve the pressure on overexploited upland soils while adding significantly to Central and West African food production.

The availability of water makes inland valleys especially well suited for producing rice: in Southeast Asia, similar wetlands, carefully farmed, have sustained continuous rice production for centuries. Agricultural scientists estimate that rice yields under inland valley conditions could reach 2.3 tons per hectare, as opposed to potential upland yields of 1.5 tons. The demand for rice in West Africa has increased during recent decades at an annual rate of more than 5 percent; while production has increased at an annual rate of only 3 percent. To keep up with demand, as domestic production has dropped from 80 percent of consumption early in the 1960s to about half of consumption 20 years later, rice imports by West African countries have increased at an annual rate greater than 10 percent, adding to the region's already substantial foreign trade deficit.

Despite their agricultural advantages, and despite the clear need for greatly increased African food production, the productivity of inland valleys remains largely potential. Only 10 to 25 percent of inland valleys are cultivated at all, according to recent estimates; and on some of those in Nigeria, IITA researchers have monitored rice yields of only 1.2 tons per hectare—about half the potential yield. In many of the cultivated valleys, moreover, the researchers have found erosion, decreased soil fertility, and other signs that current cropping practices in these environments cannot be sustained.

The challenge for IITA's interdisciplinary Inland Valley Systems Research Group is to identify or design farming systems that are at once appropriate to inland valley

Ecologically sustainable agriculture in inland valleys depends on successful water control.

ecologies and consonant with the preferences and practices of farmers. It is not a simple assignment: while inland valleys occur in all the ecological zones of West and Central Africa, they are very diverse, both physically and in the way they are farmed, from zone to zone and even within zones. The only traits common to virtually all inland valleys in West Africa are soils that are hydromorphic, or waterlogged, at least some of the time, and conditions that are hospitable to the vectors of debilitating or fatal diseases of humans and animals, including schistosomiasis; onchocerciasis, or river blindness; dracunculiasis, or guinea worm; and malaria. Water management and the control of disease vectors are therefore basic, and often at least partially linked, elements in any plan to exploit the agricultural potential of inland valleys.

In most other ways, inland valleys are not alike. Some inland valleys slope gently, almost imperceptibly, one foot in a hundred; others are five times steeper. The formation of the underlying rock determines whether a valley declines smoothly or in steps; and whether a valley's profile, or cross-section, is narrow-bottomed with steep, convex slopes, or wide-bottomed, with gentle, concave slopes. Watershed areas vary, according to a valley's size and shape, from 100 hectares to 2,000.

Both among and within inland valleys throughout West Africa, soils vary in structure and depth, generally resembling the soils of the surrounding uplands from which they derive. Sedentary soils form the upper slopes, while soils washed from the upper slopes make up the parent material of soils farther down. Differences in valley shape, water regime, and parent rock produce valley-bottom soil textures that range from sand to clay, and inherent fertility levels that range from moderate to very low.

The hydrologic characteristics of an inland valley are determined by amount of rainfall, depth and texture of soil, area of watershed, and shape of valley. Some valleys hold standing water all year round; others are never flooded. A valley with plenty of water for agriculture may lie next to a drought-prone valley similar in every respect excepting the area of its watershed. Or, the same valley may support flooded rice one year but not the next because rainfall in the region is variable. Within any valley, the moisture level increases continuously from the upper slopes to the bottom. In most valleys the water table will rise above the surface of the valley floor during part of the year.

Social and economic factors—including systems of land tenure, water-control and soil-management practices, and national and regional agricultural and economic policies—operate with ecological conditions to shape the agricultural uses of inland valleys. In some regions, inland-valley fields do not belong to the individual farmers who cultivate them, but to absentee landlords, or to an entire village collectively. A farmer's soil and water management practices, as well as his or her readiness to change or improve them, may depend to a large extent on the form of land ownership. And a farmer's estimate of the potential profit from a new high-yielding rice variety—and therefore his or her decision to adopt or reject it—is conditioned by the availability, sometimes at almost any price, of fertilizer and other inputs in the local market.

All these factors impinge on the farmer, who is the ultimate arbiter of improved practices. The typical inland-valley cultivator is a small-scale farmer who also cultivates three to six times as much upland area. He or she is likely to be producing enough food for the family, plus at best a modest surplus for the regional or national market. Inland-valley farming both complements and competes with upland activities. A cash crop of rice in the valley, for example, may compete for labor and all other inputs with the family's subsistence crop in the upland fields.

The competition becomes more complicated when, as is often the case, rice in the valley field rotates with dry-season crops, such as cassava and sweet potato; vegetables such as okra and tomato; and cowpea. Farmers grow these crops either singly or in mixtures, with each crop requiring different management, although synergies exist in some cases. Farmers who follow rice with cassava, for example, plant their cassava in large mounds, which are flattened before the next rice is planted. IITA researchers hypothesize that this soil preparation helps to control weeds during the rice season.

Much earlier research and development on rice in Africa, beginning in the 1930s on lowland environments and much later extended to inland valleys, has been beguiled by the possibility of replicating the ancient Asian system of intensive, sustained paddy-rice cropping in apparently similar African settings. The failure of this effort to recognize the critical physical, ecological, and socioeconomic differences between Asian and African inland-valley farming systems, and the consequent ineffectiveness of Asian systems in raising food production in West Africa, has been instructive.

The first challenge for IITA researchers is to understand inland valley farming systems in the interacting social, economic, and agricultural contexts in which small-scale farmers actually operate in West and Central Africa. With this understanding, researchers will be able to identify the factors that limit use of inland valleys for food production. This process will permit the development and assessment of improved components and cropping systems that promise to work in the real world.

Within this larger context, the second challenge for IITA's researchers is to quantify and analyze, and finally to understand, actual inland-valley agricultural and ecological systems in all their ingenious complexity. The Inland Valley Systems Research Group will enlist researchers from the relevant IITA programs in a long-term collaboration to develop accurate economic and ecological models of this diversity. With these models, and drawing on the actual experience of inland valley farmers, the researchers will design practical technologies for reaching realistic, sustainable production goals.

Decentralization to the Savanna

IITA announced in July 1989 it was moving part of its cowpea program—seeds, scientists and lab facilities—from Ibadan, in the humid lowlands, to Kano, nearly 900 kilometers away in the dry savanna of northern Nigeria. Barely one year later, in time for field experiments to be planted after the first rains of the season, the new Kano research station has become a reality. The transfer is the first in a process of decentralization that will see parts of IITA's crop improvement programs moving from Ibadan headquarters to research stations in the different agroecological zones of tropical West and Central Africa. More than changes in climate and scenery, decentralization involves significant changes in IITA's research philosophy and objectives.

"Decentralization of research is a logical stage in the evolution of IITA," the Institute's *Strategic Plan: 1989-2000* observed in 1988. The planners cited the scientific achievements of the first two decades of research at Ibadan, especially in developing broadly adapted varieties of important crops with resistence to major pathogens and pests. These successes, the plan concluded, "now permit a significant decentralization of research from Ibadan headquarters to the zones where the commodities studied are important food crops."

Decentralization is a calculated strategy for promoting scientific research that will have practical impact—that will lead to real improvements in national research systems and, ultimately, in farmers' fields. The strategy is based on an axiom born of experience: science that is grounded in the real world of the farmer—his soils and climate, his traditional, locally adapted technology and cropping practices—will be more responsive to the farmer's needs, more likely therefore to yield improvements that the farmer will adopt and that will ultimately increase his productivity, than will science based in far-off Ibadan.

In the case of cowpea, for which IITA has global responsibility in the international agricultural research system, two decades of science at Ibadan have produced a paradox. On the one hand, IITA researchers have developed cowpeas that, even without fertilizer, can double the yields of traditional varieties; that combine multiple resistance to important diseases including viruses and other pests; and that have the medium or short growing duration, seed color and erect plant stature favored by some farmers. But these improved varieties still require chemical insecticides, especially the erect types with uniform growing duration (that is, determinate) which are planted as a sole crop.

All of those improvements were geared for two possibilities: an intensive cropping system of cowpea grown immediately following maize in the humid-forest/moist-savanna transition zone around Ibadan, and a pure crop in northern savannas in rotation with millet and sorghum. The major goals were the identification and incorporation of disease and insect resistance

Moving to the dry savanna, where cowpeas are traditionally intercropped with a cereal, IITA's cowpea research should be better able to respond to farmers' needs.

into short-season, erect, determinate cowpeas for grain production in monocrops with two to three insecticide sprays. The main beneficiaries were commercial growers, who can afford chemical insecticides to support the improved varieties in large-scale monocultures.

IITA is shifting the emphasis to improve cowpea productivity in traditional cropping systems, which involve cowpea-cereal mixtures and are widely practiced in the Sahel and dry savannas of West Africa. For this, Kano is the ideal site: in the dry savanna zone of Nigeria, the heart of the world's prime cowpea-producing environment. Here, small-scale Nigerian farmers grow cowpea on several million hectares to provide essential food and fodder, and a surplus of grain for sale. Beyond its importance as food and fodder, cowpea is a legume which fixes atmospheric nitrogen in the soil through the medium of symbiotic bacteria on its roots. It can produce the equivalent of 30 to 70 kilograms of nitrogen per hectare per year, making it an important contributor in sustainable agriculture for the savanna.

Resource-poor farmers around Kano contend with a very different, much more hostile agricultural environment than that of the transition zone. Most cowpeas here grow prostrate, not erect; are sensitive to photoperiod or daylength and therefore are late-flowering; and, being indeterminate, their growing duration is not fixed, but depends on exposure to sunlight and rainfall. The farmers grow them because they are well adapted to intercropping---in this environment the predominant farming system is some kind of cereal-legume intercrop.

In the moist savanna, cowpea is commonly grown with sorghum, millet and groundnut. In drier savanna, cowpea-millet is the major intercrop. In both cases crops are sown in relays, the millet usually first, the legumes last. Three or four crops are usually in the ground at the same time for at least part of the growing season.

For these complex traditional cropping systems, the erect, early, determinate cowpeas developed at Ibadan are less suitable. Savanna farmers need cowpeas that spread out close to the ground and flower late in the season, so they do not compete with the earlier cereals for sunlight or soil moisture. Because they especially value the cowpea's stems and leaves for cattle feed, farmers favor indeterminate types, which continue to produce vegetation after they have filled their grain, as long as the soil has sufficient moisture.

These cereal-cowpea intercrops are typically grown on soil of very low fertility and poor structure. The organic-matter content is virtually zero. The fields of the new station's research farm at Minjibir, 45 kilometers from Kano, take on a desiccated look during the dry season. The nitrogen added to the soil by cowpea is sufficient to support the cowpea's growth and to contribute some nitrogen for the intercropped cereals in the following season.

After the grain harvest, all leaves and stems of both cereals and legumes, which might improve the soil, are instead removed from the fields for use as livestock feed or as building materials. Commercial fertilizers are as unaffordable as chemical insecticides and herbicides. Aside from the manure produced by his few animals, the resource-poor farmer has nothing to restore his soil. Because of the infertile soil—as well as pests such as thrips, which prevent fruit set, and low residual soil moisture late in the growing season—the farmers' locally selected, prostrate cowpeas generally produce very little grain. Average grain yields of traditional varieties in Nigeria are estimated at about 100 to 300 kilograms per hectare, about 60 percent of the Latin American average and less than 40 percent of the U.S. average.

For IITA's cowpea scientists, the move to Kano is part of an attempt to understand by looking at what the farmer actually does, then asking what can be done within the farmer's constraints to maximize the productivity of both cowpea and the cropping system as a whole.

The emphasis is now on developing prostrate, indeterminate plant types adapted to intercropping. Cowpeas will be bred for both fodder and grain, for resistance to the insects and diseases of the savanna; and for increased yields without insecticides or other purchased inputs. And at Kano, pathologists and breeders will carry the battle against striga and alectra to the parasitic weeds' home ground.

The Kano station is strategically located to encourage collaboration between IITA researchers and their counterparts in both national and international research systems. The new IITA station is housed within the Kano branch of the Institute for Agricultural Research (IAR), which has its headquarters at Ahmadu Bello University in Zaria. IITA's scientific staff at Kano, initially including a cowpea breeder and two plant physiologists, will work closely with agronomists, socioeconomists, pathologists and entomologists from IAR.

The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), which has global responsibility in the CGIAR system for sorghum and millet, also has a Kano facility with IAR. Because cowpea is only part of the millet-sorghum-cowpea system, the success of the effort depends on close cooperation with all involved. While improvements in cowpea might be possible just by incorporating disease and pest resistance, the goal is to improve productivity of the whole system: cereals and legume.

IITA is also establishing a station in the humid forest zone of Cameroon south of Yaounde, primarily for research on resource management and cassava. For its other principal crops, IITA will establish two additional research stations in appropriate agroecological zones of tropical Africa: a moist savanna station, for work on maize; and a cowpea station, in collaboration with the Southern African Development Coordination Conference (SADCC), for the southern African region.

Profiles from IITA's First Generation of Doctoral Fellows

Professor Olaolu Babalola, a soil physicist, is head of the Department of Agronomy at the University of Ibadan in Nigeria. Nematologist Barbara Hemeng is a senior lecturer at the University of Science and Technology in Kumasi, Ghana. Dr. Mohamed Tejan Dahniya is an agronomist and the director of the Institute of Agricultural Research of the Ministry of Agriculture, Natural Resources and Forestry, at Njala in Sierra Leone.

The common bond between these three African agricultural leaders is the crucial role that IITA training has played in determining the direction and success of their careers.

IITA's founders recognized early on that agricultural progress in tropical Africa depends on greatly increased numbers of African research scientists and other agricultural professionals, as much as it depends on improved crop varieties and farming systems. Among the national agricultural research services and other African national institutions with which IITA collaborates, and which bear the ultimate responsibility for selecting, adapting and transferring improved technologies, virtually all are severely hampered by the lack of trained agricultural professionals. Training in Africa for African agriculturalists at all levels, from extension agents and lab technicians to policy-makers and officials in national programs, therefore, has been a central tenet of IITA's mandate from the very beginning.

In almost 25 years, IITA scientists and professional staff have trained more than 6,000 African agriculturalists. Of these, most have participated in a variety of group training courses and programs, both at Ibadan and in collaborating African countries. More than 400 trainees have come to Ibadan for research and field experience leading to their M.Sc. and Ph.D. degrees.

For Margaret Hemeng, a fellowship at IITA for a Ph.D. in nematology from November 1985 to March 1988 was the opportunity of a lifetime. Born in Kumasi, Ghana, Hemeng finished secondary school in Ghana, then continued her studies in England, earning a BSc degree with honors in zoology and botany, followed by an M.Sc. in plant pathology. With these credentials she returned to Ghana in 1971 as a research officer at the government's Crops Research Institute.

"While I was doing my master's project in plant pathology, I had already become interested in nematology," she recalls, "but CRI needed a plant pathologist." Her first professional opportunity to pursue her abiding interest in nematodes – the phylum of roundworms or threadworms, abundant in water and soils and in many plants and animals, including man -- came in 1976, soon after she had become a lecturer at the University of Science and Technology in Kumasi. UST received notice of a series of research planning conferences, part of a long-term international nematode project sponsored by USAID, to be held at IITA. Hemeng was invited to report to the first conference on everything that was known at UST about the root-knot nematode in Ghana.

Subsequent conferences at IITA during 1978 and 1981 further whetted her appetite for nematology, but back home she was frustrated by her lack of advanced education or any way to get it. "I didn't even know enough taxonomy to identify which nematodes were attacking which crops," she says. "We don't have a research library here in the whole country." Although she was already past 40, and married with two young children as well as involved in teaching full-time, she resolved that if she couldn't become a nematologist in Ghana, she would go somewhere else.

"I went to the library and got a directory of universities," she says. "I wrote all the universities in the world" without finding what she needed. Finally she wrote to F. E. Caveness, a renowned nematologist at IITA, whom she had known from "so many years" of participation in nematode conferences at Ibadan. Caveness offered Barbara Hemeng a deal: he would sponsor her for advanced training at IITA and serve as the academic advisor for her graduate degree studies; Hemeng would work on "Deforestation and cropping effects on soil and root nematodes", part of an IITA/United Nations University study on deforestation.

It was an offer Hemeng could not refuse, even though it meant being away from her home and family for months at a time. Hemeng set up a lab and living quarters in Benin City, in south-western Nigeria. With two colleagues, she spent most of her time for more than two years "in the bush", collecting data in a forest preserve and making biannual reports to Ibadan.

In March 1988 Hemeng returned to Ghana, her home and family, and her teaching position at UST in Kumasi. She brought with her 28 months' worth of data and the conviction that she had the raw material for a significant contribution in nematology. "Dr. Caveness knew," she says, "that no one else in the world had done this work."

Two years later Hemeng is still analyzing and writing up her data. The analysis has to be done whenever she can borrow time on a computer at the government's Crops Research Institute. The lack of an adequate research library at UST, or anywhere in Ghana, delays the literature search that will be the foundation of her thesis. Having persisted so long and come this far, however, Barbara Hemeng is not about to give up; she fully expects before long to submit her completed dissertation to UST.

In comparison with the obstacles she faces in Kumasi, Hemeng's experience at IITA was like the best of all possible worlds. "For research, IITA has the equipment, and the people to advise you. They've got a very good research library where you can do your literature review; you can get whatever references you need within two days.

"There are so many scientists there–all the sciences are interrelated. Everyone is very busy but also very friendly; they are willing to give you any information you want on any aspect of your research. The scientists come from different countries, with different characters: it's almost like you've been through the whole world. The contacts and interaction I had there didn't stop when I finished my work. I'm still communicating with them: that's been the most important aspect of my IITA training."

Her long-standing IITA connection is a matter of considerable pride and practical value. A Hemeng lecture on agroforestry to students at the UST School of Agriculture quickly turns into an inspirational description of the opportunities for research and training at IITA. Even Hemeng's undergraduates get an early dose of IITA training: she has sent some of her best UST students to Ibadan with modest research projects under the guidance of IITA scientists. Hemeng hopes that this brief experience at Ibadan, which counts toward the bachelor of science degree in agriculture, will give her students an insatiable taste for topflight scientific research and the ambition to become Ghana's future researchers.

Mohamed Dahniya had already left Sierra Leone to get an M.Sc. degree in agronomy at the University of Illinois, when the opportunity to pursue his doctoral research at IITA brought him back to Africa. Born in Freetown, Dahniya was one of 10 children. Their father, a civil servant, sent six (three brothers and three sisters) to university.

One of the first students at Njala University College, a branch of the University of Sierra Leone founded in 1964 with USAID funds, Dahniya got his B.Sc. in agriculture in 1968. A USAID fellowship took him to the University of Illinois, where he received an M.Sc. in agronomy in 1971.

"My research in the U.S. was in maize," says Dahniya. His thesis title: "Incorporated maize organic material effects on subsequent crops". "I became interested in root and tuber crops–cassava and sweet potato. The best place to study them was in Africa." From IITA publications that had found their way to Illinois, Dahniya heard of the new international institute in Ibadan, Nigeria, which had a research program in roots and tubers getting under way.

Dahniya came back to Sierra Leone as an assistant lecturer in the agronomy department at Njala, with time out in 1972 to get a postgraduate diploma in agricultural meteorology in Israel. After attending annual root-crops meetings at IITA in 1975 and 1976, he registered in October 1976 as a doctoral student in the agronomy department at the University of Ibadan and signed on at IITA to do his thesis research on "Defoliation and grafting studies of cassava and sweet potatoes."

The subject has special relevance for Dahniya and for West Africa. "In Sierra Leone we eat quite a lot of leaves from both cassava and sweet potato," he explains. "I wanted to know the result of continual leaf removal on tuber production."

With his Ph.D. degree, awarded in 1980, Dahniya became a senior lecturer, then an associate professor, in the agronomy department of Njala University College. He has served as head of the departments of agronomy and crop sciences. Most recently, in 1988, he became director of the Institute of Agricultural Research in Sierra Leone's Ministry of Agriculture, Natural Resources and Forestry.

As his career in Sierra Leone has progressed, Dahniya has maintained close ties with IITA. He comes back to Ibadan at least once a year, for IITA's annual root crops collaborators' meeting, which draws cassava and sweet potato researchers from many African countries. He sends a steady stream of students and researchers from Sierra Leone to Ibadan. "The undergraduates go to do projects," he says. Of three undergraduates from Njala at Ibadan in 1990, two are working in the root and tuber program and a third in sustainable agriculture.

"Staff members get a good bit of research experience at IITA, not just in their own area of specialization but in quite a few related areas," Dahniya says. "Sometimes I ask for a particular training course. This year I sent the training officer from IAR for two months." He has also proposed sending a graduate to Ibadan to learn the method for evaluating the cyanide content of cassava.

The cooperation works both ways: at Njala, IITA supports two in-country courses that train extension supervisors in cassava and sweet-potato agronomy and in nutrition. IITA also cooperates with IAR in a root and tuber improvement program to develop cultivars that are adapted to Sierra Leone's environments, resistant to major diseases and pests, high-yielding, nutritious and attractive to consumers. IAR also adapts and distributes other improved IITA varieties in Sierra Leone. In 1990, IAR got half a ton of streak-resistant maize from IITA for multiplication and distribution to Sierra Leone farmers fighting a streak outbreak.

For Olaolu Babalola, a lecturer at the University of Ibadan early in the 1970s, the opportunity to do research in soil physics at IITA made all the difference between achieving his ambitions in Africa or going abroad for the second time as a student. Babalola's mother is illiterate. His father, a farmer and carpenter and an influential person in his village, near Ife town, can read and write. Their seven sons and one daughter, Babalola says, were all educated.

Babalola's initiation into agriculture was fortuitous: he was one of four students from his high school selected for a job as an assistant technical officer with the Nigerian Department of Forestry. A Commonwealth scholarship in forestry was his ticket to Vancouver, British Columbia, for a bachelor's degree. A United Nations fellowship then took him to Oregon State University in the U.S.A. for a master's degree in soil physics.

Required to return to Nigeria and the Department of Forestry as a condition of his fellowship, Babalola faced five years in a reforestation program in the remote northern part of the country. "It was too quiet in the north," he says. ""There were no suitable partners for me to marry." Feeling the urge to settle down and start a family, he "bolted away" after one year and took up a career as a lecturer at the University of Ibadan.

"I realized that to remain in the profession I had to have a Ph.D.," he recalls. "The problem was that there was no Ph.D. program in soil physics in Nigeria–or anywhere in West Africa." His only choice, it seemed, was to desert Africa again to study in England or the United States. Instead, through the intervention of Rattan Lal, a soil physicist at IITA, Babalola was able to do his research at IITA while continuing to lecture at the University of Ibadan, where he was also registered as a doctoral student under the supervision of an agronomist. In fact, his real supervision came from IITA.

"I found IITA a far better place to work than a university," he says. "At IITA I was part of an ongoing program, and Lal was as interested in what I was doing as I was. At Oregon or Vancouver, a student selects a topic and works alone at his or her own pace. At IITA, I was given a certain time to achieve a real research goal. We shared information: I discussed my work with farming systems people and collaborated with an agroclimatologist on my research design."

Once he had finished his Ph.D. and had joined his university faculty full-time, Babalola found that his increasing academic work prevented him from continuing research at IITA. But in his role as teacher and advisor he has been able to steer new generations of promising students–undergraduates as well as graduates–toward IITA, carefully matching his university's academic goals to the practical research objectives of IITA's programs.

"IITA has a research set-up that the university lacks," Babalola says. "I can tell an IITA scientist that we are working on something and we have student who is interested in a particular line of research. I can ask the scientist: does this fit in with your program?"

Like Barbara Hemeng in Ghana and Mohamed Dahniya in Sierra Leone, Olaolu Babalola in Nigeria is part of what has become a tradition in training in African agricultural research. The product of that tradition is a growing African network of leading specialists, trained in their tropical homeland to address its unique and urgent agricultural needs.

IITA Today

About IITA

In 1967 IITA was established as an international research institute with headquarters on a 1,000-hectare farm at Ibadan, Nigeria and with links with national programs in many countries of sub-Saharan Africa. It became the first African link in a worldwide network of international agricultural research centers known as the Consultative Group on International Agricultural Research (CGIAR). The Federal Republic of Nigeria provided 1,000 hectares of land for the Institute's headquarters and experimental farm at Ibadan, while the Ford and Rockefeller foundations provided the initial planning and financial support.

Objectives. IITA has four objectives:

1. To develop systems for the management and conservation of natural resources for sustainable agriculture in the humid and subhumid tropical zones.

   There is global concern that Africa's growing population is placing increasing pressure on basic natural resources and threatening the viability of traditional farming systems.

2. To improve the performance of selected food crops that can be integrated into improved and sustainable production systems.

   This is the shared goal of many of the institutes in the CGIAR system. IITA conducts varietal improvement research on six crops: cassava, yam, plantain, maize, cowpea and soybean.

3. To strengthen national agricultural research capabilities in order to accelerate the generation and utilization of improved technologies, by means of training, information and other outreach activities.

   The objective here is to enable IITA's partners in national research systems increasingly to meet their own technology requirements.

4. To improve food quality and food storage, processing and marketing, in order to encourage more efficient use of available food supplies.

   For a number of IITA commodities, particularly roots and tubers, the lack of efficient technology for storage, processing and conversion to commercial products is a serious barrier to their increased use as both food and feed.

IITA Trustees and Senior Staff, April 1990.

With a geographical mandate covering tropical regions worldwide, IITA focuses on the lowland tropics of West and Central Africa. IITA conducts research and training activities at its headquarters and at substations in West and Central Africa, and in conjunction with regional and national programs in many parts of Africa. As a means to enhance the practical relevance of its crop improvement research to farming conditions, IITA has begun to decentralize its research from its headquarters to locations in the various agroecological zones where its mandated crops are grown. (See "Decentralization to the Savanna" in the Research Highlights section of this volume.)

IITA programs comprise:

- **Resource and Crop Management**
  (emphasizing farming systems with major IITA crops and soil resources)

- **Root, Tuber and Plantain Improvement**
  (focusing on cassava, yam and plantain)

- **Grain Legume Improvement**
  (focusing on cowpea and soybean)

- **Maize Research**

- **Rice Research**
  (activities being transferred to WARDA during 1990)

- **Biological Control**
  (emphasizing environmentally sound integrated pest management)

- **International Cooperation and Training**
  (emphasizing the strengthening of national agricultural research systems)

- **Information Services**
  Library
  Publications
  Public Affairs

- **Research Support Units**
  Genetic Resources
  Virology
  Biometrics
  Analytical Services
  Farm Management

The main conduits for sharing the results of IITA research with national programs are training, germplasm exchange and publications/information exchange.

Training. The training program is one of IITA's principal means of achieving "transfer of technology" in agriculture from international to national levels. Training can help in building African capabilities for agricultural research and food production by increasing the corps of competent research workers for the humid and subhumid tropics. To date, over 6,000 trainees have participated in the range of training activities, including group courses, doctoral or master's degree programs and short-term study projects.

Germplasm. The genetic resources unit is involved in collection, documentation, storage and distribution of germplasm of IITA-mandated and other important food and agroforestry crops. Over 40,000 accessions of germplasm are stored at IITA, including the world cowpea collection of 15,000 accessions from more than 100 countries and 11,500 accessions of rice, chiefly from Africa. Seed samples and information on them or the characteristics of the species are made freely available on request. During the first 12 years of its existence (1978-1989), IITA distributed over 41,000 samples to non-IITA users in over 80 countries.

Information. Information services together with the research programs provide information in many forms to scientists in user countries. Publications are distributed on a regular basis with a mailing database of over 8,000 addresses. Results of collaborative and other research are disseminated through network newsletters and monographs. IITA's library facilities include a collection of over 35,000 books and periodicals, a computerized bibliographic and database service, microfilm and CD-ROM facilities and a scientific literature service for selective dissemination. Interpretation and translation services support meetings and training activities.

Through these means IITA maintains vital links with national agricultural research programs. By testing IITA's innovations, adapting them to local conditions, and carrying them to farmers, national programs can translate research into increased food production.

The Institute. IITA employs about 180 scientists and professional staff members from over 40 countries and about 1,300 support staff mostly from Nigeria. Half the staff are located at headquarters, where 300 hectares of the 1,000-hectare campus have been developed for experimental fields. An 80-hectare research station lies in the humid coastal zone at Onne, in southern Nigeria. A 30-hectare station was opened in 1990 in the dry savanna zone at Kano, northern Nigeria, in collaboration with Ahmadu Bello University's Institute of Agricultural Research. A station at coastal Cotonou, Republic of Benin, houses the Biological Control Program. A 1,000-hectare, high-rainfall, humid forest station is being established at Mbalmayo in Cameroon in collaboration with Institut de la Recherche Agronomique (IRA). A moist savanna station is being planned for Côte d'Ivoire in collaboration with Institut des Savannes (IDESSA). Eight major collaborative projects were under way in western, central and southern African countries at the beginning of 1990, while other projects were being conducted on a more limited scale throughout tropical Africa.

IITA is a nonprofit, international agricultural research and training institute supported primarily by the Consultative Group on International Agricultural Research (CGIAR). Founded in 1971, CGIAR is an association of about 50 countries, international and regional organizations and private foundations. The purpose of the research effort is to improve the quantity and quality of food production in developing countries. The World Bank, the Food and Agriculture Organization of the United Nations (FAO) and the United Nations Development Programme (UNDP) are co-sponsors of this effort. (See note on page 99 of annexes.)

Resource and Crop Management

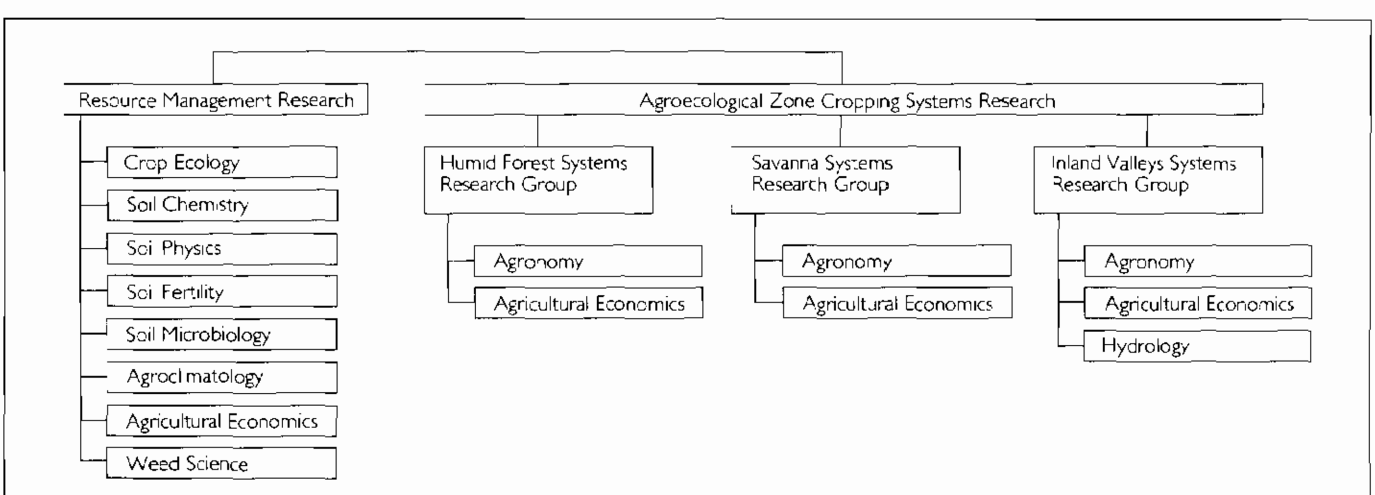
The twin challenge for agricultural research in tropical Africa is to enable farmers to produce enough food for a growing population, while sustaining the natural resource base so that future food production will not be curtailed. IITA's Resource and Crop Management Program concerns itself with both sides of the food production equation—crop productivity and resource sustainability—in its research to improve smallholder farming systems in the three main agroecological zones: the forest (humid tropics), moist savanna (subhumid tropics) and inland valleys (wetlands, or lowland areas which are flooded during the rainy season).

Traditionally, farmers in the African tropics have solved the sustainability problem by permitting farmland, which loses its productivity rapidly under cultivation, to revert to natural vegetation and regain fertility during fallow periods lasting from 5 to 20 or more years. The farmers would turn to earlier fallows ready to be exploited again or to virgin areas, in a pattern of shifting cultivation that would avoid permanently degrading the resource base while keeping food production at as high a level as possible. Agriculture was thus "sustainable" in the long term over a broad cropping area.

However, the rapid growth of population and demand for cropland in recent decades has upset this balance. Population in sub-Saharan Africa has more than doubled since 1960, and will double again before the next quarter century. In order to meet rising demand for food and other agricultural commodities, the land under cultivation has had to increase substantially, often at the expense of restorative fallows. Many new areas have been opened for cultivation using techniques which can lead to serious degradation of the productive capacity. As a result, the sustainability of the system is being threatened. There is an urgent need for new or improved techniques or systems of land development and management that will enable production to be increased, prevent degradation and yet be compatible with prevailing farming systems so that farmers will readily adopt them.

IITA's Resource and Crop Management Program is thus organized (see diagram below) to conduct research which addresses these issues in two major activities, in partnership with scientists in African national research systems:

- Resource management research to study the natural resource base and develop existing or new technologies for smallholder farming systems.
- Crop management research to synthesize the products of resource management research and crop improvement research (conducted by crop-focused programs at IITA) into sustainable and more productive cropping systems, which are compatible with the resources and objectives of the smallholder. This synthesis is in essence the goal of the concerted efforts of all IITA programs.



Agroecological background

Within the general framework of the main climatic/vegetational zones of forest, moist savanna and inland valleys, the two most important variables are soil type (chiefly acid and nonacid) and population density (high, medium and low).

Soils. A simple categorization of tropical African soils would include four general groupings:

- Highly weathered acid soils.
- Highly weathered nonacid soils.
- Nonacid soils from basic and volcanic materials.
- Nonacid hydromorphic and alluvial soils.

They have varying management requirements and different tolerances for intensified or continual use.

The humid forest zone of West and Central Africa, which includes over 55 percent of the land area of the countries of IITA's primary focus, has mostly highly weathered soils that are strongly leached and acidic. They degrade rapidly when cleared of natural vegetation. The central problem for agriculture here is to maintain soil fertility.

The moist savanna (subhumid) zone also has highly weathered soils, which are generally less leached and acidic. They are, however, susceptible to compaction and erosion. In some areas, originally nonacid soils have acidified, often as the result of use of acid-forming fertilizers. In the highlands of western Cameroon and East Africa, less-weathered soils derived from volcanic ash and ferromagnesium rocks are productive.

Labor required to clear land for cropping is becoming harder to mobilize in many areas.

Throughout both humid and subhumid areas of West and Central Africa, hydromorphic and alluvial soils are associated with swamps, lakes and rivers in the distinctive agroecological zone of inland valleys.

Population pressure. Serious degradation of the resource base appears to be occurring under different traditional farming systems in many places where population densities are either high or low.

In densely populated areas, fallow periods have often become significantly shorter, resulting in accelerated leaching of nutrients, rapid oxidation of organic matter, increased weed populations, erosion and decreased moisture retention. The farmers' options for coping with these problems may be overwhelmed by the rapidity and extent of the changes, and, in extreme cases, irreversible degradation of the land and soil may result.

Paradoxically, there are other rural areas in which too few rather than too many people make it difficult to maintain productivity. Substantial labor is required to clear land, to keep weeds under control, and in sloping areas, to construct ridges or terraces to prevent soil erosion. In many cases, the migration of large numbers of young males to urban areas, together with increased primary education for children, has removed a significant portion of the agricultural labor force. As a result, it is increasingly difficult to mobilize sufficient labor to clear trees from land that has been under fallow for long periods, to carry out essential tasks such as weeding and planting at the optimal times, and to maintain ridges or other soil conservation measures. Thus, productivity may decline as lack of labor compels the repeated use of the same land, elimination of restorative fallows, and the neglect of tasks needed to maintain the resource base.

Potentials and limitations. Each of the main agroecological zones has different crop production potentials and constraints. In the humid forest, production potential is greatest for root crops, tree crops and plantains, and in general multistory cropping systems are most appropriate. The acidic soils in these regions contain few nutrients. Toxic elements that can inhibit crop growth are found in much of the subsoil. Many of the important nutrients of the system are present more in the biomass than in the soil, and thus manipulation of the biomass is important in preserving productivity and making the best use of the productive potential.

In the moist savanna zone, the productive potential for cereal and grain legume crops is greater than in the forest, and soil constraints are generally not as serious. However, poor soil structure and other physical soil problems remain important. There is also significant risk of erosion in many areas. Some of the main soil types in the savanna and transition zones may be subject to acidification when intensively cultivated. Erratic and unpredictable rainfall, and resulting periods of drought stress, are significant problems for crop production, and integrated soil and water management is often needed to achieve increased yields.

The wetlands include coastal plains, inland basins of many of the river systems, river floodplains, and inland valleys and swamps. They form an estimated 10 to 20 percent of the humid and subhumid lowlands of West and Central Africa, the region of primary focus for IITA. In many instances, their production potential has not been developed. The inland valleys are often especially suitable for smallholder development and for production of rice and associated crops. In general, sustainability of production is much less a problem in these wetland areas than in most upland regions. However, soil toxicity and the threat of pests for both crops and people can be serious obstacles to development, as can the socioeconomic factors that reduce the availability of resources needed in developing inland valleys.

Resource Management Research

Research to guide management and conservation of the natural resource base involves the search for sustainable crop production systems. This task is fundamental in African agricultural development and is enormously complex.

Resource management research entails three conceptual stages of activity.

- Measurement and analysis of the components of the resource base (physical, chemical, biological, socioeconomic).
- Analysis of the determinants of stability/degradation of the resource base through study of the dynamic interactions among those components (for example, transport and storage of water and soil nutrients).
- Design of resource management systems through use of principles identified in the analysis of stability and degradation (that is, modification of existing practices or design of new ones which can stabilize or increase crop output while avoiding degradation of the resource base.

IITA research activities in resource management are conceived under five headings, and are developed and linked with modelling, as illustrated in the diagram in the righthand column:

1. Resource characterization: description and mapping of the biophysical and socioeconomic characteristics of the IITA mandate area.

- Intensive studies: surveys of fallow management systems (crops, fallow vegetation, soil characteristics, field size and household characteristics of fallow-based farms).
- Extensive studies: climatic-elevational map of mandate area (climatic data from available stations in West and Central Africa; elevation map; construction of climatic surface).

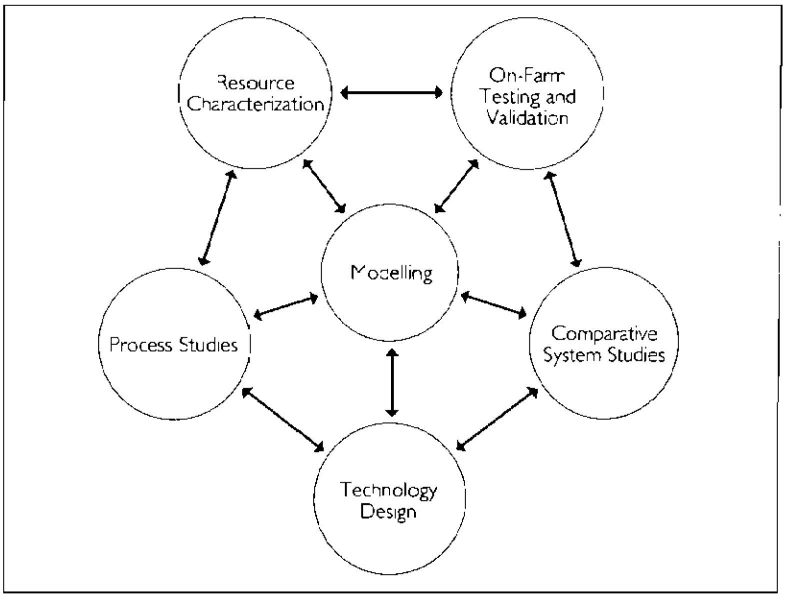
2. Process studies of the resource management components contributing to sustainability, often in collaboration with advanced laboratories and institutions in developed countries.

- Biological regulation of nutrient cycling in alley farming as compared with monocrop systems (rates of input and decomposition of crop residues and hedgerow prunings; rate of nitrogen fixation; among others).
- Interplant competition under different types and intensities of management (weed seedbank changes through clearing and cropping sequence; weed growth and response to management; among others).
- Crop growth modelling in collaboration with the commodity improvement programs.

3. Design of technologies for managing natural resources and overcoming constraints in production and sustainability.

- Cropping systems incorporating trees (improvements in the physical and chemical characteristics of soil; increased stability of yield; multiple outputs).
- Cropping systems incorporating herbaceous legumes (improved weed management; control of erosion; increased soil fertility).

4. Comparative studies of whole cropping systems to



investigate interactions among resource management components.

- Comparison of traditional, tree-based and herbaceous legume-based fallow management systems (interaction between weed management and soil fertility; competition between fallow species and crops; labor requirements).
- Comparison of whole cropping systems.

5. Testing, validation and adaptation of resource management technologies.

- On-farm experiments in collaboration with the crop management research groups and national agricultural research agencies (e.g. with alley cropping technologies).
- Use of modelling to determine environmental adaptability of technologies (e.g. alley cropping, tillage practices) in relation with long-term sustainability.

Resource Management Achievements

From the results of about two decades on African soils and the ecological and social setting in which African farmers cultivate their crops, IITA has learned that the essential principle for preventing or retarding soil degradation is to:

- Maintain a cover of organic matter on the topsoil. This mulch mimics and replaces the effects of the forest ecosystem in protecting and regenerating the productive capacity of the soil. The mulch protects the soil from structural damage from rain and excessive temperatures, supplies organic matter to replace that lost in microbiological processes, encourages beneficial activity by earthworms and other soil fauna and reduces nutrient leaching and acidification.

A cover crop of egusi melon helps in controlling weeds in this intercropped field of maize and yam.

Other important principles arising from the research include:

- Limit use of heavy equipment, in order to avoid soil compaction, and select or design equipment to use which will exert a low pressure on the soil.
- Loosen compacted soils where they occur and restore their structure.
- Propagate mixed cropping with shallow- and deep-rooting species, for efficient use of soil nutrients, as opposed to continuous monocropping.
- Use fertilizer judiciously in order to balance soil nutrients and replace losses, but avoid overuse with concomitant problems of soil acidification and toxification.

The major research products are considered to be prototype technologies which are intended to be developed or finished through adaptation by national agricultural research systems in Africa, which will in turn extend them to farmers. They include:

- Alley farming. A means of sustaining soil fertility and an alternative to fallows, alley farming is an agroforestry system in which multipurpose trees (usually legumes) are planted in rows while food crops are planted in the "alleys" between the trees. Soil nutrition is improved through nitrogen fixation by the tree species and application of tree prunings for their organic matter.
- Mulches and cover crop systems. Fast-growing leguminous cover crops are planted to provide a constant soil cover before, during and after the cropping phase, in order to retard soil degradation and, in many cases, to suppress weeds.
- Land clearing and development. When land must be cleared by machine, soil disturbance and subsequent erosion can be kept to a minimum with such implements as the shear blade, which cuts the vegetation at ground level. Minimum or zero tillage with the use of cover crops, mulches and herbicides is required when land is cleared in this way.
- Tillage method. Studies at IITA and elsewhere have shown the advantages of minimum or no-tillage farming.
- Fertilizer and soil additives. Appropriate fertilizer regimes have been developed which should enhance crop growth and not cause soil acidification or toxicity problems.
- Improved fallows. Some research has been done to improve fallow management practices that would be more efficient in restoring soil fertility than are unmanaged bush fallows.

Conducted mainly at its humid forest station at Onne in south-eastern Nigeria, IITA's research on acid soils has followed two different but complementary approaches to soils management.

The first entails soil amendments, in this case by the use of lime and related materials, to combat acidity and aluminum toxicity in the soil. Experiments over a number of years have shown that even low applications of lime result in reduced acidity and toxicity, permitting significant yield improvements in crops such as maize. Additions of lime to experimental fields increased the effectiveness of magnesium fertilizer applications in 1989 experiments.

Lime and other related fertilizers are not, however, always available within the forest zone of West and Central Africa. Although large quantities of nitrogen fertilizer are produced in Nigeria, it cannot readily be found even within Nigeria, because of its high price and transport difficulties. IITA is embarking on a study with the International Fertilizer Development Center (IFDC) in Togo to examine availability and potential of the raw materials in the region. Another problem, in the case of lime, is that many soil nutrients can be lost through leaching because they are released as a result of changes in soil acidity.

Both these problems are addressed in IITA's second approach to acid soil management, by enrichment of the soil with organic matter through use of fallow species, including trees. The 1988/89 IITA annual report describes IITA's success with alley farming, a particular application of this approach in the transition and savanna zone environments. Similar experiments have been conducted with trees, shrubs and herbaceous fallows at Onne, in the humid forests of coastal south-eastern Nigeria.

Herbaceous legumes such as *Pueraria* seem to perform equally well in alley farms in both zones, whereas the most widely used tree species, *Leucaena leucocephala*, does not perform well in the humid forest at Onne. As a result of recent research on herbaceous alternatives to *Leucaena*, IITA has identified a number of successful species. Among the most promising are *Acio barteri* and a shrub, *Flemingia congesta*. These species help to increase yields of interplanted maize and cassava in acid soils by improving the soils chemically and physically, improving the microenvironment and reducing weed infestation. Another shrub, *Tephrosia candida*, shows great promise as a fallow species for the reclamation of degraded land. *Tephrosia* is being tested on land where yields have declined over several years.

Acio baterii, indigenous to West Africa, is valued as a fuelwood and as a "living stake" for support of yam vines. In parts of south-eastern Nigeria, it forms a component of a managed fallow system which has evolved out of the mixed-species bush fallow system more common in the area. In some instances, farmers of Imo State manage the tree in rows analogous to the hedgerows used in alley farming.

In collaboration with Nigerian scientists and the International Council for Research and Agro-Forestry (ICRAF), IITA is preparing a survey to identify other indigenous trees for multipurpose use in agroforestry.

The interactive effects of our two approaches to soil management will be studied during the next four years. Much of this comparison between conventional soil amendment (utilizing lime and fertilizers) and soil organic matter "manipulation" (utilizing trees and herbaceous fallow species) will be conducted at the new IITA humid forest station at Mbalmayo, 40 kilometers south of Yaounde in Cameroon. A soil chemist and soil physicist have already begun to prepare for surveys of local farming systems and the natural resource base of the forest environment.

Weed control is another important focus of resource management research. A weed is a plant out of place. Plant species which play a useful role during fallow periods by helping to enrich the soil may, during cultivation periods, compete with crops and become serious pests. Since the small farmer usually has to control weeds by hand, weed control is often the biggest demand on his or her labor.

Weed control practices which reduce labor demand are high among IITA research priorities. The two main alternatives are the use of herbicides and cultural practices for biological control, both of which are being researched by IITA scientists. Cultural practices offer the better long-term solution because the cost of herbicides limits their potential use by small farmers.

Speargrass, *Imperata cylindrica*, is one formidable weed which can be controlled by both chemical and biological means. Found in intensely cultivated areas in the forest zone as well as throughout the African savanna, speargrass is able to take over cultivated areas and force farmers to abandon their fields. Subsequently it can maintain itself as the sole plant species in such areas almost indefinitely. In a survey in Oyo State, Nigeria, such abandoned fields were found in 31 out of 39 villages. *Imperata* is able to succeed because it has a rhizome or underground stem which stores large amounts of carbohydrate. This food fuels the spread of the grass and helps it to survive and regenerate when the biomass above ground is destroyed, such as during dry-season fires. A common feature of *Imperata*-infested areas is a regular fire cycle which assists in the maintenance of the speargrass.

During 1989 IITA tests showed successful control of *Imperata* chemically, with a number of herbicides and biologically, with hedgerow trees or herbaceous legumes. Most promising for control are the herbaceious species: the shading effect of *Puerana* reduced the *Imperata* rhizome biomass by 80 percent within a year. The herbaceous species are relatively resistant to fire, can easily be established in speargrass areas where the fire cycle is frequent, and require less labor to maintain than do tree species. IITA will therefore concentrate research on this promising means of *Imperata* control with the prospect of rehabilitating large areas of currently uncultivatable land.

Crop Management Research

Research to guide management of different cropping systems concerns itself with adaptation of new or improved farming practices which are intended to increase productivity in those systems.

Research of this kind requires the cooperation and interaction of scientists in many disciplines, who work together from the stages of initially defining the objectives and problems, to developing new technologies, testing them under field conditions, combining individual technologies into viable systems, and validating their suitability under varying conditions. IITA contact and cooperation with scientists and extension workers from national programs as well as with farmers are an essential part of this effort. In addition, IITA needs to study and understand the agroecological setting, the farming systems and constraints in production, all of which vary across the areas of research concern. IITA also needs to know what changes are occurring over time. This is critical in setting research priorities, selecting suitable research sites, and targeting technological innovations to the appropriate places and farmers.

Crop management research entails three linked activities:

- **Diagnosis:** characterization of mandated cropping systems areas, description and analysis of constraints and impact of new technology.
- **Validation and adaptation:** on-farm screening, testing and evaluation of technologies generated during experiment-station research. Adjustment or adaptation of existing technology to a particular set of environmental conditions, either agroecological or socioeconomic, through on-farm research.
- **Feedback:** relevant information from farm-level characterization, diagnosis and adaptive research reported back to scientists who are developing resource management technologies or breeding improved varieties at IITA's research stations.

Different scientists representing varied disciplines have been teamed to develop and implement the research agenda for specific types of farming systems, associated with particular crops and agroecological zones. At first known as crop-based systems working groups, these groups have been renamed for their agroecological zone. They will focus on the main crop system in each zone as follows:

- Humid Forest Systems Research Group (cassava-based crop systems).
- Savanna Systems Research Group (maize-based crop systems).
- Inland Valley Systems Research Group (rice-based crop systems).

IITA research activities in crop management are organized in a farming systems perspective according to three agroecological zones, with three corresponding multidisciplinary groups of scientists.

Humid Forest Systems Research Group

- Characterization of cassava systems in Africa.
- Adoption and impact of IITA cassava in West Africa.
- On-station study of resource use and productivity in cassava-based intercropping and rotation systems.
- Collaborative adaptive trials with national institutions in Nigeria, Ghana, Cameroon, Zaire and Sierra Leone (e.g. effect of lime and improved cassava varieties on cassava and groundnut intercropping systems in Bàs-Zaire and use of improved varieties and alternative spacing on rice and cassava intercropping systems in Sierra Leone and Liberia).

Savanna Systems Research Group

- Characterization of maize-based farming systems in the savanna of Nigeria and Côte d'Ivoire.
- Diagnostic study of the impact on striga infestation of intensifying maize-based cropping in the northern savanna of Nigeria.
- Development of cultural control methods for striga.

Inland Valley Systems Research Group

- Characterization and classification of inland valleys in West and Central Africa.
- Quantification of yield losses from weeds.
- Development and testing of methodology for selecting upland crop varieties for the inland valleys.

Crop Management Achievements

Available technologies that have been identified over the past five years include:

- Cassava varieties with durable disease resistance and well adapted to the cassava/maize system.
- Soybeans adapted for growing in the second season and in association with cassava.
- Maize varieties with durable disease resistance and appropriate for green maize, but not where maize requires storage for an extended period of time.

Feedback on farm-level problems from the systems research groups is helping to set the right emphasis in the research agenda of resource management researchers and breeders.

Examples include problems in establishing leguminous trees in alley cropping systems; the relative contribution of trees and herbaceous legumes in improved fallow management systems, besides continuous cultivation systems; weed control problems in no-tillage, cassava-based systems in which herbicides are not used.

During 1989, the Humid Forest Systems Research Group launched the first major activity of the Collaborative Study of Cassava in Africa (COSCA). Led by IITA and funded by the Rockefeller Foundation, the study involves scientists from the Côte d'Ivoire, Ghana, Nigeria, Tanzania, Uganda and Zaire in a survey of cassava production in their countries. Scientists from Centro Internacional de Agricultura Tropical (CIAT), the U.K. Natural Resources Institute and the International Child Health Unit of Upsala, Sweden are also collaborating in the survey.

COSCA's broad objective is to improve the relevance and impact of cassava research by the international agricultural research centers and national agricultural research systems in Africa. The study entails collection of data on cassava cropping systems in Africa, type and extent of use of various processing techniques, marketing systems, present and future demand in rural and urban areas, and relationships between consumption and consumer nutrition. The participating countries produce about 70 percent of the cassava of sub-Saharan Africa.

COSCA gathered general, mostly qualitative information from group interviews in selected villages. Information specific to households, farms or processing units will be collected from individual households. Preliminary analysis of village-level data reveals, contrary to general expectation, that virtually all small farmers in the high-density population areas of the humid forest zone harvest their cassava 12 months or less after planting. In low-density population areas, about 95 percent of the farmers harvest their cassava at 12 months or less. In comparison with past practice, farmers thus appear to be using varieties which require shorter growing periods and to be harvesting their crop sooner, without keeping it stored in the ground. Furthermore, where access to the market is good, up to 44 percent of farmers harvest their cassava after less than 12 months.

Cassava intercropped with the soybeans being harvested ensures food security for this family when other food crops are not available.

As market access improves, the fallow period seems to be declining substantially, from about 6 to 3 years, while farmers are increasing their weedings from 2 to 3 times. All the villages surveyed in Côte d'Ivoire and Ghana, and 97 percent of those surveyed in Zaire, are not using any improved cassava varieties. In Nigeria, by contrast, where IITA varieties have been widely disseminated, about 90 percent of the villages surveyed are using improved varieties.

The survey also reveals that small-scale cassava growers actively experiment with new varieties, abandoning old varieties when they prove unsuitable and adopting new ones. When bitter varieties are abandoned, it is usually because of their susceptibility to weed competition, their late maturity or their low yields. With sweet varieties, it is their low yield, their late maturity or their poor storage qualities.

During 1989 the Savanna Systems Research Group, together with the Institute of Agricultural Research at Zaria, Nigeria, completed their characterization of the agroecological and socioeconomic factors in maize cropping systems in the northern Guinea savanna, or moist savanna, of Nigeria. The recent dramatic expansion of maize in the area was the stimulus for this focus. In the mid-1970s maize was a minor crop grown mainly in backyards. At that time it was significant as a cash crop in only one of the villages in the survey, and a major food crop in only one-third of them. Currently, maize is one of the three most important food crops and one of the three biggest cash crops in nearly nine out of ten of the sampled villages. Almost all of this new maize is reported to derive from improved IITA varieties.

The savanna group also discovered that agricultural production in the area had intensified. Fallow periods have been eliminated in 6 out of 10 villages and declined in another quarter of them. Fertilizer is commonly used in all villages. Ox-driven plows are frequently used in land preparation and, in about half of the villages, ox plowing has often been adopted in conjunction with the elimination of fallows and the increase in maize cultivation. Concurrently, in response to the increased profitability of farming, farmers have also expanded the size of their farms and diversified their crops. In addition to maize, rice has become a cash crop, while production of such cash crops as pepper, cowpea and sugarcane has grown.

Population increases in general, increases in population density in particular and access to markets appear to have been the chief causes for the changes. The savanna group will concentrate on the economic sustainability of the system; that is, what will be the impact on maize production of the expected removal of the government's subsidy on fertilizer, and the impact of devaluation of the Nigerian currency on incentives for such cash crops as cotton and groundnut, which compete with maize. IITA scientists will also look at the long-term sustainability of soil productivity; in particular, the effects of replacing traditional soil maintenance practices with increased use of inorganic fertilizers, and their implications for research on soil fertility maintenance.

Expansion of maize farming has brought an increase in ox-driven plowing in the moist savanna.

In an analogous survey in the forest zone of Nigeria, farmers identified their preferred characteristics of maize. Their top priority is increased yield, combined with bigger cob size. Eating quality appears to be important mostly for green maize. Improvement in storage quality does not have as high a priority as yield. Early maturity of the crop is not an important characteristic. It is unlikely that farmers in the forest zone, where land is freely available, would want to adopt high-yielding varieties which require fertilizers and other inputs to a high degree. Other ways of increasing yields would seem to be the alternatives for IITA research: durable resistance characteristics to drought and pests.

During 1989 the Inland Valleys Systems Research Group made an exhaustive review of agronomic and socioeconomic research on inland valleys in Africa. The group formulated several hypotheses about land use for future research. For example, the lower the rainfall in a given area, the more likely that inland valleys are used for agricultural production. Also, changes in land use in inland valleys are principally determined by increases in population pressure and improvement in transport infrastructure. Some of the hypotheses relate to the quantification of constraints in different forms of land use, with respect to sustainability, productivity and farmer welfare. For example, ecologically sustainable agricultural production in inland valleys depends primarily on water control. Also, in some categories of inland valleys, the productivity of labor is greater in upland fields than in inland valleys.

Research Strategies for Resource and Crop Management

Building on the principles and accomplishments of past work, the IITA Resource and Crop Management Program will continue to focus on prevention of soil degradation while intensifying use of land and other resources to increase production. Systems which have shown promise for the forest/savanna transition zone will be further developed and new technologies suitable for the acid soils of the forest zone will receive increased attention. The results of past resource management research will be more closely integrated with the results of commodity improvement programs through the zone-based systems research groups.

The program's research priorities are described in the inset panel "Research Directions" on the opposite page.

Research Directions

Resource Management Research

• Description, measurement, classification and mapping work on the biological, physical, chemical and socioeconomic characteristics of the IITA mandate area will be expanded with adoption of a geographical information system (GIS) and a large capacity for satellite image analysis. Climate-elevation maps will be constructed into which will be incorporated the results of intensive studies such as surveys of fallow management systems.

• Quantification of fundamental relationships among factors contributing to the sustainability of food production systems will be expanded. Such process studies (e.g. biological regulation of nutrient cycling, physical factors affecting soil fertility, factors regulating interplant competition) will continue on non-acidic and high-phosphate acidic soils. The new humid forest station at Mbalmayo, Cameroon, will provide scope for expansion of interdisciplinary research on low-phosphate acid soils.

• Indices will be developed for measuring the sustainability of small farmer cropping systems.

• Technology design activities will be intensified. The prototype alley cropping system will be further adapted for small-scale farmers by adding economic tree crops or using hedgerow trees which have direct benefits.

• For the humid forest zone, development of multipurpose agroforestry systems which combine improved soil and weed management will continue.

• Efforts to develop economically viable and sustainable fallow management sytems incorporating herbaceous legumes will be intensified.

• Long-term comparative studies will assess capacity for sustainable crop production in traditional and improved resource management systems.

• On-farm testing and validation of IITA technologies will expand, emphasizing adaptability of alley cropping in different socioeconomic conditions, in collaboration with the Alley Farming Network for Tropical Africa (AFNETA).

• Development of systems simulation models will emphasize intercropping, nutrient cycling in alley farming systems and economics/ecology of inland valleys, and will provide a comprehensive description of agricultural production systems.

Humid Forest Systems Research Group

• The Collaborative Study of Cassava in Africa (COSCA) will characterize African cassava production systems including types of varieties, processing, marketing and consumption, initially in 16 agroecological zones of 6 countries.

• Strategic on-station studies of resource use and productivity in cassava-based intercropping systems will be conducted.

• Studies of the adoption and impact of IITA cassava varieties in West and Central Africa will be expanded.

• On-farm collaborative studies will be expanded with national institutes, on the modifications of alley cropping systems to improve sustainability of intercropping with cassava.

Savanna Systems Research Group

• Maize-based farming systems in the moist savanna of West Africa will be characterized and classified. Constraints affecting their sustainability will be identified and quantified.

• The influence of intensification of maize farming on striga infestation will be studied.

• Cultural methods for control of striga as well as improvement of soil fertility will be developed and tested on farm with national institutes.

Inland Valley Systems Research Group

• Inland valleys in West and Central Africa will be classified and characterized, involving estimation of the percentage and location of those valleys which are used for agricultural production, identification of factors which discourage utilization of inland valleys for agricultural .production, and classification of the valleys into different categories.

• Constraints in land use in inland valleys will be identified and quantified in respect of sustainability, productivity and farmer wellbeing. The quantification will include yield losses owing to weeds, a major constraint in increasing rice production.

•Models will be developed of biological, physical, chemical and socioeconomic processes in the principal categories of inland valleys. Together with national institutes, the models will be validated and tested with a view to applying the results in other categories of valleys and countries of West and Central Africa.

• Improvements in land use and management practices for different categories of inland valleys will be designed and tested.

• Selection methods of upland crop varieties for inland valleys will be developed together with the commodity improvement programs.

In summary, the Resource and Crop Management Program integrates the results of resource management and commodity improvement research within crop management research, through the work of the zone-based systems research groups for the humid forest, moist savanna and inland valleys. Those groups ensure linkages and feedback between resource management and commodity scientists who work with economists in the study and improvement of smallholder production systems. The groups' linkages also extend to scientists in national agricultural research systems, through whom IITA responds to the needs of its ultimate clients, the farmers.

International Collaboration

The program collaborates extensively with developed-country institutions, international agricultural research centers and national agricultural research systems.

IITA agroclimotologist S. S. Jagtap shows how computer-assisted models contribute in resistance breeding.

Developed-country institutions. Long-term collaborative research with the University of Hawaii at Manoa focuses on making the most effective use of alley farming systems. The objectives include research and training to ensure effective nitrogen fixation in legume-based alley cropping systems, to realize maximum benefits from mycorrhizae for enhancing tree-legume effectiveness in these systems, and to develop computer-based information systems as a resource for national research/extension activities on alley cropping systems. The target is the acid, infertile and highly weathered soils of tropical Africa.

Cooperative long-term research with Michigan State University seeks to quantify root competition for nutrients and water between associated crops in alley cropping systems. The long-term goal is to quantify the underground processes of both hedgerow and alley crops grown in alley cropping systems, so that alley cropping may be adapted to more acid soils and to the subhumid tropics.

A collaborative project with the Institute for Soil Fertility in the Netherlands seeks to quantify the role of soil organisms in soil management for food production in the humid tropics. A long-term project with the Katholic University of Leuven, Belgium, will study the dynamics of soil organic matter and its relationship with food crop yields and soil productivity.

Collaboration with other international organizations. IITA co-sponsors the Alley Farming Network for Tropical Agriculture (AFNETA) with ICRAF and the International Livestock Center for Africa (ILCA), which involves scientists of most African countries. Its general objectives are to promote and support alley farming research, including on-farm testing, use and extension of the concept across diverse environments.

Collaboration with ICRAF in a joint project with Oregon State University involves the stationing of an ICRAF scientist at IITA to evaluate multipurpose tree species for agroforestry systems in the humid lowland zone of West Africa.

Collaborative research activities are planned with IFDC in soil fertility management for sustainable agricultural production in the humid forest and inland valley ecosystems. An IFDC scientist will be stationed at the IITA station in Mbalmayo, Cameroon.

IITA participates in the West Africa Farming Systems Research Network, which sponsors the farming systems research course at the University of Dshang, Cameroon.

IITA is collaborating with the West Africa Rice Development Association (WARDA) in rice-based farming systems research in:

- Characterization and classification of land resources for cropping in general and on rice cropping in inland valleys in particular.
- Resource and crop management research on rice-based cropping systems in inland valley bottoms and uplands in West Africa.

Cooperation with national programs. The Resource and Crop Management Program's networking activities with national research programs are based primarily with AFNETA, a group on cassava-based systems research which has existed since 1985, and a group on maize-based systems research (COMBS) launched in November 1989. Each group holds an annual workshop where ongoing collaborative projects are reviewed and plans made for new ones. The collaboration mainly concerns on-farm adaptive research, focusing on soil fertility management and weed control.

Root, Tuber and Plantain Improvement

Cassava, yam and plantain, widely grown by small farmers, are the staple foods of hundreds of millions of people in the humid and subhumid regions of tropical Africa. Of the three crops – cassava, a tuberous root – is by far the most important, providing more than half the food energy consumed by more than 200 million people. Plantain is eaten as a staple food by about 60 million people.

The IITA Root, Tuber and Plantain Improvement Program is organized (see diagram below) to conduct research mainly on cassava, yams and plantains which addresses problems of crop improvement, including breeding for pest resistance and quality factors, and postharvest processing. It works with national programs to adapt technological advances to their specific needs.

Cassava

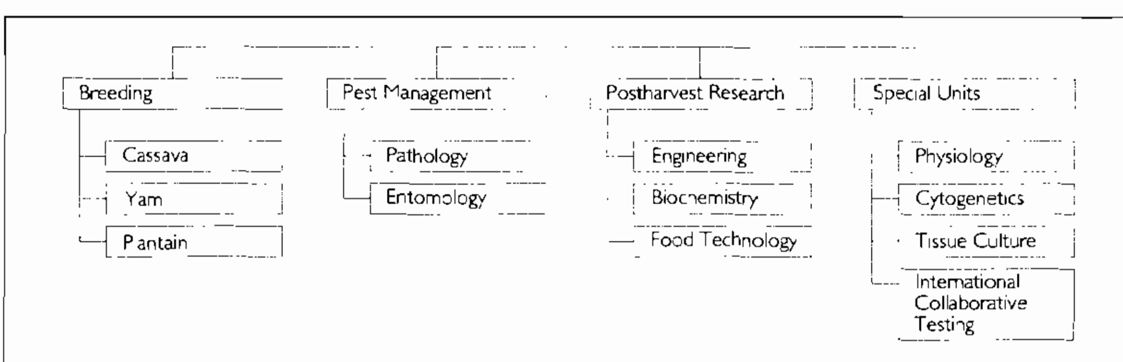
IITA cassava scientists have developed high-yielding, pest-resistant cassava varieties with good eating quality characteristics that are being adapted to the humid forest, forest-savanna transition, moist savanna and mid-altitude agroecological zones. They have set up 30 test sites in those different zones in Nigeria with the help of national colleagues. By 1990, IITA varieties had been released to national programs in nine countries for further testing and release to farmers: in Cameroon, Gabon, Liberia, Nigeria, Rwanda, Seychelles, Sierra Leone, Tanzania and Zaire.

Scientists from those countries have confirmed that the new varieties are resistant to the two most destructive disease pests: cassava mosaic virus disease and cassava bacterial blight. The Catholic University of Leuven in Belgium has also conducted tests of IITA cassava clones, or plant material which is one stage short of being produced as a variety. Involving the use of bacterial strains from many countries all over the world, those tests have confirmed stable resistance of IITA clones to cassava bacterial blight.

While the major disease problems have been overcome through breeding for host-plant resistance, the spread of the cassava mealybug (*Phenacoccus manihoti*) and the cassava green spider mite (*Mononychellus tanajoa*) throughout Africa's cassava belt has posed a major challenge in recent years. Significant success has been achieved in biological control of the mealybug in many cassava-growing areas of Africa and a similar approach is being investigated for the mite. (See Biological Control Program article.) But the ultimate goal is integrated pest management involving host-plant resistance.

The mechanisms for insect resistance/tolerance that are observed in such IITA cassava clones as TMS 91934 are being investigated. The presence of trichomes, or minute hairs, on the young cassava shoot seems to discourage attack by the cassava green spider mite. The trichomes appear to physically inhibit feeding by the pest. Several high-yielding varieties with such pubescence or hairy development have been identified. Hybrids between cassava and its wild relatives, in particular *Manihot tristis* and *M. anomala*, are attracting interest as improved clones with the resistance character of pubescence.

Although cassava as a crop is adapted to many different environments, the evidence suggests that

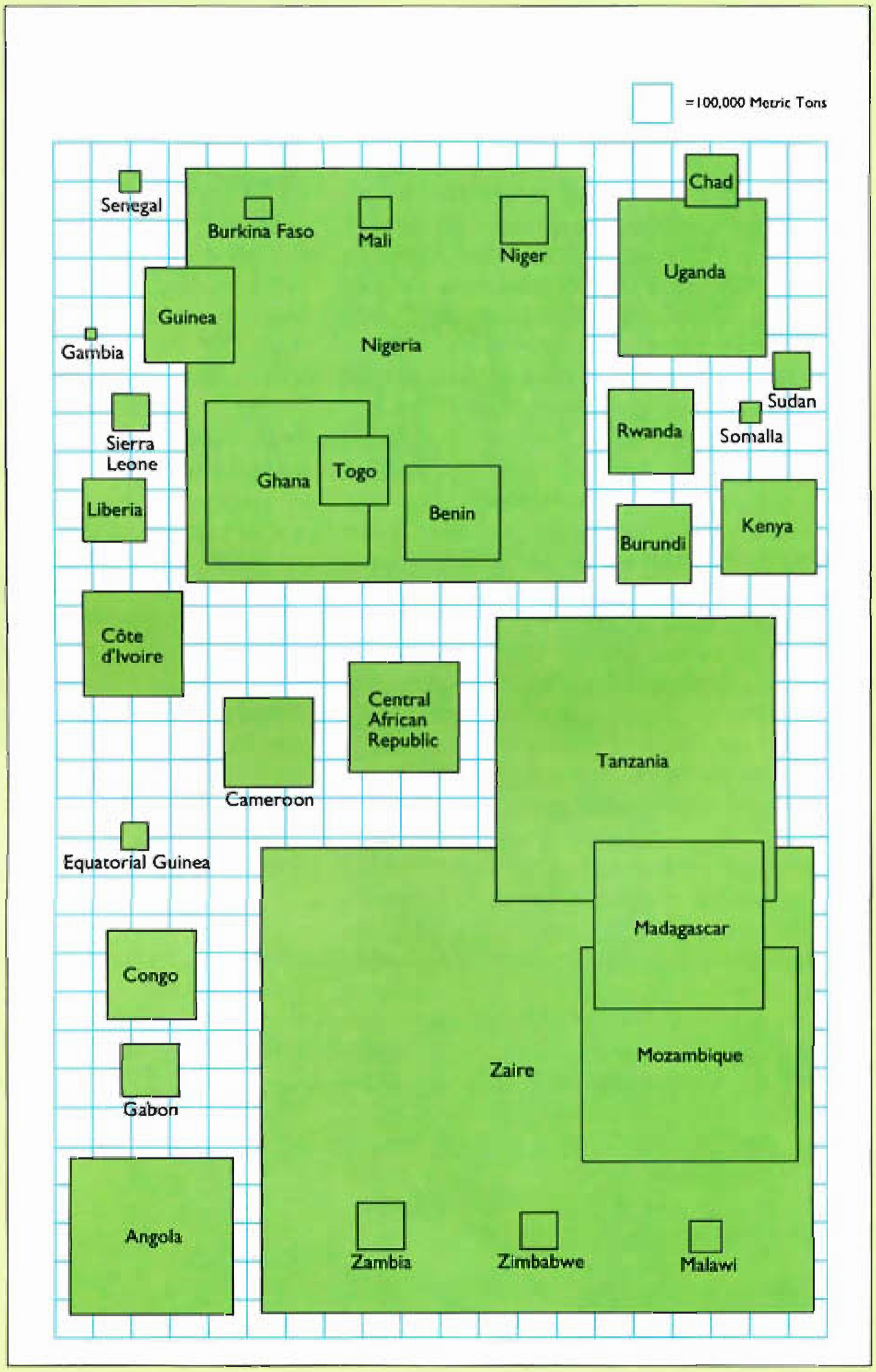


Cassava in Africa

Cassava is the single largest source of calories produced throughout tropical Africa. West and Central Africa each account for about one-third of cassava production in Africa; Zaire and Nigeria are the continent's leading producers (see figure). About three-fourths of the cassava in West Africa is grown in the forest and moist savanna zones. Data on production of root crops in Africa are especially suspect, but production of cassava has undoubtedly increased in West and Central Africa, although perhaps not as fast as population. Almost no export/import trade in cassava products is recorded, but some trade does take place across land borders.

Cassava is more productive under poor soil conditions than are most other crops, and for this reason it often is planted last in the cropping sequence, just before the land reverts to fallow. Production of cassava roots requires relatively little labor compared with that of rice or yams; moreover, the timing of these labor inputs is very flexible since the root can be left in the ground for periods of several months or even a few years in some cases before harvesting. The ability of cassava to withstand drought once the plant is established has also encouraged its use as a famine reserve crop in drier parts of Africa. Tolerance of poor soils and low and flexible labor requirements help explain why cassava production has historically increased in areas where the best land and most of the available labor are devoted to cash crops (for example, cocoa) or labor-intensive food crops (yams). As population pressure leads to increased use of marginal lands, the area planted to cassava is likely to expand.

The labor required for processing the roots into gari, one of the most widely consumed cassava products in West Africa, is very high and equals the total labor input for production of the roots themselves. This processing is usually done at the household or village level, almost exclusively by women and children. The end product is suited for low-income urban consumers because of its low cost per calorie (slightly lower than that of maize) and because it requires almost no further processing. The low protein content of gari is augmented by the soups and meat with which it is usually eaten.



individual cassava varieties often have a narrow ecological adaptation. Multilocational trials conducted over a wide range of agroecological conditions in Nigeria have shown differential responses of cassava clones (genotypes) to the various edaphic, climatic and biotic factors encountered in those environments. Such interactions between genotype and environment (GxE) often complicate the selection of desirable genotypes and thus hinder progress in varietal development. In order to avoid this hinderance, the selection process is being conducted from early generations directly in the specific target environments.

Reproductive biology. New discoveries at IITA about the reproductive biology of cassava may offer a key to rapid dissemination of improved varieties and, eventually, to the agronomy of cassava through true seeds. Some cassava varieties can develop viable seeds even when the normal fertilization process is prevented, in a form of vegetative reproduction called apomixis. IITA breeders have observed that first-generation hybrids between an improved clone and wild *Manihot* relatives (known as interspecific hybrids) all resembled the cassava parent.

In order to investigate this unexpected outcome, the female flowers of a number of clones were covered with cloth bags before the opening of the perianth and kept bagged for some five days, by which time the stigmas had ceased to be receptive. Despite the bags, which had effectively prevented the opportunity for fertilization with pollen from African honeybees or any other external source, many flowers set fruits with viable seeds which produced normal plants.

IITA aims to breed high-yielding cassava varieties which consistently produce true seeds by this process (obligate apomixis) such that their progenies are identical with the mother plant. Such true seeds could serve as a cheaper and more convenient means of disseminating and propagating improved cassava varieties.

Another exciting and promising finding among the interspecific hybrids produced at IITA has been cassava polyploids—plants with a multiple of the normal number of chromosomes. (See inset story on "Cassava Polyploidy".) It is still early to substantiate the advantages of polyploidy in cassava, but it is clear that polyploids grow vigorously, quickly establish a ground cover which helps control weeds, and yields as well as the best improved varieties. Apomixis and polyploidy offer plant breeders new opportunities for developing improved varieties.

Polyploidy—A Cassava Breeder's Bonanza?

During the past two decades of patient plant breeding, IITA scientists have developed improved cassava varieties that are winning growing acceptance by farmers in Africa's vast cassava belt. Recently, while crossing cultivated cassava species with wild members of the same genus, *Manihot*, the Institute's breeders have discovered spontaneous cassava polyploids—plants with multiples of the normal chromosome number (2n = 36)—among some of the resulting interspecific hybrids. The natural polyploids, which are characterized by enormous vigor and variation in form and structure, offer hope for further increases in yields, broader adaptation and new breeding possibilities, for the most important food crop of tropical Africa.

Cassava, a starchy root, provides more than one-third of the total food energy in the region's diet, more than twice as much as either maize or yam. For more than 200 million people in sub-Saharan Africa—40 percent of the population, including many of the poorest—cassava is the staff of life. Farmers appreciate cassava because it tolerates drought, pests and diseases and poor soils; requires relatively little labor; and can be left in the ground, ready for use when needed, for a year or more after maturity.

For reliable harvests, farmers propagate cassava vegetatively: by planting sections of last season's stems, they can assure themselves of virtually identical clones of the parent plants. But cassava breeders, who produce new, improved cassava types by combining characteristics from genetically disparate parents, must take a slower, less certain route: they rely on cassava's readiness to reproduce sexually and to set true seed. For example, by sexual crossings of cultivated cassava with a single related species, *Manihot glaziovii*, a tree form introduced into Nigeria from South America a half-century ago as a source of rubber, breeders have transferred such valuable traits as low cyanide content and resistance to mosaic virus and bacterial blight into African cassava varieties.

Seeking further improvements, IITA scientists during the 1980s crossed several varieties of cultivated cassava with both *M. glaziovii* and *M. epruinosa*, a more recent acquisition from Brazil. Among the hundreds of progeny from their crosses, the scientists identified a few anomalous plants with unusually broad, thick leaves and large, widely spaced stomata, the respiratory openings in the leaf surface that permit the exchange of carbon dioxide and water in photosynthesis. Closer examination of single cells and pollen spores confirmed that the anomalous plants were polyploids: either tetraploids, having twice the normal diploid number, 2n, of chromosomes in each somatic cell; or triploids, with 3n chromosomes.

Natural polyploids originate most commonly as accidents during sexual reproduction, when one or both parents contribute gametes with the unreduced (2n) number of chromosomes. The IITA tetraploids were attributed to matings between cultivated cassava and related wild parents—both diploids, with the normal (2n) chromosome number—that had both produced unreduced (2n) gametes. The triploids, by this reckoning, resulted from matings between n gametes from one parent and 2n gametes from the other.

Natural polyploids can also arise asexually, from a failure of mitosis, resulting in a replication of the chromosomes in a somatic cell without the subsequent, normal division into daughter cells. Such asexual polyploids are rare: among more than 200,000 plants, the IITA cassava scientists have found only two asexual individuals, both tetraploids, arising from adventitious buds on two different plants. (See accompanying diagram.)

In IITA's experimental fields, polyploid progeny, with genes from both cassava and its wild relatives, grow up to be cassava types, able to hybridize freely with cultivated cassavas to produce improved varieties. But some polyploids, which have the vigor associated with hybrids in addition to their other qualities, may achieve variety status without further improvement. In uniform yield trials in a variety of Nigerian environments, from the high-rainfall, acid-soil area to the dry savanna, an IITA tetraploid yielded an average of 19 tons per hectare, rivaling one of the country's leading improved cassavas. The same tetraploid displayed resistance to mosaic virus and bacterial blight, and produced tubers of acceptable food quality.

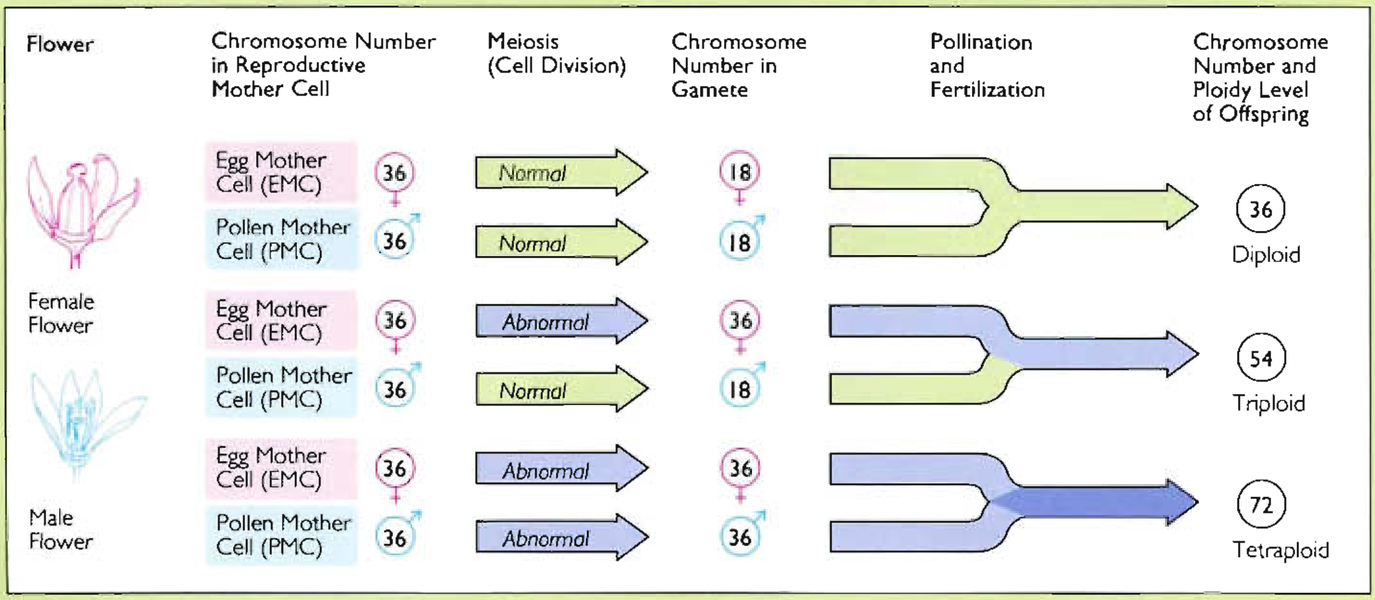
As parent material for further improvement, natural polyploids, with their multiplied genetic complement, offer breeders greater variety of form and structure than the diploids, suggesting the possibility of breeding radically new cassava varieties adapted to diverse environments.

Despite their complete complement of genes from their wild parents, the polyploid progeny of cultivated and wild *Manihot* parents turn out to be all cassava types. Thus they require relatively few backcrosses to recover and stabilize desirable traits, allowing breeders to accelerate the transfer of useful genes from wild *Manihot* species to cultivated cassava.

Sexual Polyploidization in Cassava

The reproductive cells in the flower buds, known as pollen mother cells (PMC) in the male bud and egg mother cells (EMC) in the female bud, undergo the process of meiosis by which the chromosomes are separated during the formation of sex cells and their numbers are reduced from the diploid condition (36 chromosomes) to the haploid (18 chromosomes). If the reduction process fails, the resulting sex cells retain the original diploid number of chromosomes (36).

Following pollination, fertilization marks the event in which the female and male nuclei (gametes) in the sex cells join to form a zygote. If a normal male gamete (having 18 chromosomes) fertilizes a normal female gamete (18 chromosomes), the resulting zygote is diploid (36 chromosomes). If one gamete is a haploid (18 chromosomes) whereas the other is diploid (36 chromosomes), a triploid zygote (54 chromosomes) is produced. A tetraploid (72 chromosomes) results from the union of two diploid gametes.



Cassava plantlets are also being produced through somatic embryogenesis, whereby embryos are generated from non-reproductive cells of the plant. Somatic embryos have been obtained in vitro from young leaves of several IITA cassava clones in a liquid culture medium. At least 10 to 15 somatic embryoids have been obtained per leaf. Different procedures are being investigated in an effort to generate plantlets from the embryos.

Embryo rescue. Making use of exotic gene sources to improve cassava is an important task of IITA research in biotechnology. Immature embryos resulting from interspecific crosses have a tendency to die prematurely owing to incompatibility between the embryos and material tissues. IITA scientists have already established procedures for the culture of fairly mature embryos of cassava and wild *Manihot* species on artificial growth media. These techniques are being adapted for rescue of very young embryos resulting from important interspecific crosses.

Multiplication. IITA scientists recently developed a technique for rapid multiplication of cassava varieties to cut down on growing time and help speed up adaptive research. The technique entails treatment of ministem cuttings with a fungicide suspension and sprouting in perforated polyethylene bags before

Props for Progress: A Better Cassava Stick

Mrs. Misitura Raufu, whose business card reads CASSAVA TREE SUPPLIER, doesn't need statistics to tell her that small-scale farmers have adopted IITA's improved cassava varieties. Mrs. Raufu, assisted by her mother and several children, has been doing business at her jerry-built roadside stand, just across the main highway from IITA's Ibadan headquarters, for four years. She knows what farmers want: her inventory—bundles of cassava stems, called sticks, 40 to 50 sticks to a bundle, that farmers cut into shorter pieces to plant—is all guaranteed "IITA cassava".

And how's business? "Look," she says, leafing through her invoice book and displaying a recent sale: 600 bundles at 5 naira, for a total of 3,000 naira (about US$375). In 1990, between the first rains in March and the end of June, halfway through the planting season, Mrs. Raufu estimates that she sold about 3,000 bundles. Many competitors offer the same product, up and down the highway and along virtually every back road in the region.

The informal trade in IITA cassava sticks began spontaneously several years ago, when IITA enlisted some local farmers in on-farm trials of improved cassava varieties that had performed especially well on IITA's research plots. As the crop grew, the farmers—and their friends and neighbors—could hardly fail to notice the marked superiority of the IITA cassava to the local varieties. The resulting demand for planting sticks of IITA cassava was far greater than the Institute, which is not set up to distribute varieties directly to farmers, could begin to satisfy.

Entrepreneurial Nigerians like Mrs. Raufu have been quick to seize the opportunity for profitable public service. Since she could produce clones of IITA's improved cassava in infinite multiples, all she had to do was get hold of a single stick and she was in business. Four years later she is able to produce most of the sticks she needs on her own farm, buying from other farmers if she runs short. Indeed, she's beginning to worry that some of her customers are stealing a leaf from her book, harvesting enough cassava sticks for their own needs and a surplus for market.

transplanting. No costly and bulky soil is needed as a sprouting medium. The sprouted cuttings can be shipped in sealed polyethylene bags which meet phytosanitary regulations in inter-country exchanges.

Utilization. Eating and nutritional qualities have been a focus of IITA research in recent years. IITA has improved clones with reduced cyanide content, a more mealy texture when cooked and other appealing characteristics. Mealiness results from marked changes in texture after boiling, as a result of a process which is being investigated.

Cassava clones have also been improved for production of flour for breadmaking. The goal is cassava varieties and processing technologies that can produce an acceptable bread from composite flours with a large proportion of cassava. Suitability of cassava flour in bread-making depends on certain properties of cassava starch. Detailed studies at the molecular level into differences of starch from IITA cassava clones are being conducted with the Food Science Department of the University of Manitoba, Canada. With another collaborator, the Catholic University of Leuven, IITA has identified new clones that can substitute for up to 20 percent of wheat flour in composite-flour breads. Rapid and effective methods for screening of additional clones have been perfected.

In 1988, IITA cassava breeders developed improved varieties with yellow root flesh, for use in traditional foods. The West and Central African roasted cassava dish "yellow gari" and other popular dishes such as "fufu" can be prepared more conveniently and less expensively with yellow cassava. Normally white, gari turns yellow if red palm oil is added to the cassava during roasting. Oil from the red oil palm is rich in carotene, a plant pigment that changes to vitamin A in the body. It makes yellow gari more nutritious than white gari, and as much as one-third more expensive. The yellow-flesh cassava developed at IITA combines high carotene content with good cultivation characteristics, resistance to pests and diseases, and a high yield; and it makes yellow gari without palm oil.

A survey of traditional cassava postharvest systems in Nigeria has revealed tremendous losses (about one-half of the potential product) and very high labor input, particularly by farming women. The results point to an urgent need for research into and development of processing facilities, especially frying stoves and drying areas. Postharvest equipment was subsequently developed and field-tested and has contributed to a 12-percent reduction in production losses and 70-percent reduction in labor input. Contributing to the increase in system efficiency are improvements in technology and the processing system, attitudinal improvement among operators and technical training. Some 362 units of 11 types of postharvest equipment have been fabricated and distributed in 16 countries in West and Central Africa. Further improvements are under way, including standardization of designs and operating procedures.

More yams for the marketplace – one benefit of improvements in production of yam planting material.

Yam

The six West and Central African countries from Côte d'Ivoire to Cameroon produce over 90 percent of the world's yams, a staple food for tens of millions of their people. This highly labor-intensive crop is gradually expanding into the transition zone between humid forest and moist savanna, as arable land becomes scarcer (because of shortening fallow periods) in yams' original humid-forest home. The importance of the crop, and the promise of significant improvements in yield, more than justify continuing yam research.

The goals of IITA's yam breeders are to produce plants that require less laborious staking; to improve the yam tuber's shape and make it easier to harvest and handle; to in-build genetic resistance to major diseases and nematodes; and to make yams look and taste better to consumers and keep longer before spoiling. The growing acceptance by urban consumers of smaller but uniform tubers (1 to 2 kg) should serve to lighten the burden of the yam farmer in future, as cultivation of such tubers does not entail use of tall stakes and large mounds.

Even before 1988, despite the frustrating complexity of yam's reproductive biology, IITA breeders were able to make as many as 10,000 crosses annually to select for promising characteristics.

In 1988, yam breeders succeeded in their quest for high-yielding water yam clones resistant to foliar necrosis, a disease that causes yam plants to lose their leaves prematurely. Field tests in four different agroecological locations produced yields of about 30 tons per hectare, which outperformed local cultivars by far. Many other promising white yam clones have been produced and are being evaluated for further adaptive research.

During the 1980s, IITA scientists made significant improvements in methods for producing high-quality, low-cost and abundant yam planting material, relieving farmers of their traditional need to set aside one-quarter of each crop to use as seed for the next.

Minisett technology has been developed as a cheap and reliable method of producing seed yam. With this technology, farmers can produce 40,000 to 100,000 seed yams per hectare. Further improvements include the use of polyethylene mulch which eliminates staking, conserves soil moisture and nutrients, regulates soil moisture and checks weed growth. The minisett technique has created a big opportunity not only for farmers but for researchers, in making the job of germplasm preservation easier.

Five virus-free white yam cultivars were sent to 21 countries, a milestone reached because of in-vitro microtuber formation. This new technique from IITA has resolved obstacles of quarantine policy in the international distribution of germplasm. It also has permitted germplasm accessions to be preserved in vitro in IITA's genetic resources collection.

Plantain

West and Central Africa produce about 60 percent of the world's plantains. Because of its long history of wide cultivation and distribution of plantain, the region has become a secondary center of plantain diversity. So far, 116 different cultivars have been identified.

Plantain is a particularly useful crop for farmers in the humid forest zone of West and Central Africa. As a backyard crop, plantain coexists easily with established farming systems. It can provide a continuous source of food over the cropping year. It also counteracts degradation of the environment through the prolific leaf mulch cover it produces.

Plantains have long been considered to be disease-free because of their resistance to panama disease (*Fusarium oxysporum* f. *cubense*) and yellow Sigatoka (*Mycosphaerella musicola*). This picture changed dramatically about 15 years ago with the accidental introduction into Africa of black Sigatoka (*Mycosphaerella fijiensis*), a disease which ultimately leads to leaf necrosis. It is so virulent that plants are often severely defoliated at harvest, thereby reducing yields drastically. (See inset story on "Plantain's Reprieve from a Black Plague".)

Plantains are exceptionally susceptible to black Sigatoka. No resistance or tolerance to the disease has been found among all the plantain cultivars in IITA's collection, which is maintained at the Onne High Rainfall Station. Since plantains are mainly grown by family farmers, black Sigatoka is endangering the food security of resource-poor farmers.

Plantain's Reprieve from a Black Plague

When scientists at IITA's substation at Onne, Nigeria, began in 1987 to breed plantains with resistance to black Sigatoka, they expected the effort to consume at least 10 years—the best part of a scientist's career. Even then, the outcome was far from assured. No source of resistance was known in plantains; only in some of its *Musa* cousins, which include common table bananas, starchy cooking bananas and wild types.

In any case, cross-breeding resistance genes into edible plantains would be a formidable challenge: plantains are triploids, with three sets of chromosomes instead of the two carried by most organisms. In theory, breeding is complicated by the fact that each of plantain's three sets of chromosomes derives from a different ancestor. In practice, however, that problem is moot, because triploid plantains are normally seedless, and therefore infertile. They are easy to eat but virtually impossible to breed.

Preparing for the worst—the virtual loss of plantain as a major food source for tropical Africa—the IITA scientists pursued a fallback strategy: adapting black-Sigatoka-resistant starchy cooking bananas, they prepared to offer them to lowland farmers as plantain substitutes. Warned an IITA statement early in 1989: "Time may be running out for plantains."

Just nine months after this gloomy forecast, by the end of 1989, plantain's future was looking much brighter. Years before they had expected any significant success, the scientists at IITA's Onne station were in sight of their goal. Growing in their experimental fields were a few hybrid plants that looked—and, more importantly, tasted—like plantain, and that had inherent resistance to black Sigatoka.

A plantain plantlet – an improved variety which is a product of in-vitro tissue culture.

Pollination of plantain in breeding resistance to black Sigatoka.

The breakthrough was the result of crossing black-Sigatoka-susceptible plantains with resistant diploid wild bananas. To arrange such an unlikely marriage, the IITA scientists needed a triploid female plantain that would set viable seed when fertilized by their diploid male wild banana with genes for black-Sigatoka resistance. Among the 116 different plantain cultivars maintained in IITA's germplasm collection, the scientists at first found several—by mid-1990 they had 28—seed-producing females of the preferred type. Some so-called French plantains that are reported to set seeds very rarely elsewhere turned out to set 50 to 60 seeds per stem when fertilized with viable pollen under Onne's conditions. False Horn plantains, which never set any seed anywhere else, managed as many as 15 per stem at Onne. In 1988, crossing these plantains with resistant wild bananas—disparate members of the genus *Musa*—the scientists were rewarded with viable hybrid seeds.

Using embryo-culture techniques to overcome the seeds' reluctance to germinate, the scientists produced some 100 hybrid seedlings, which were transferred from petri dishes to the fields at Onne. Late in 1989 they announced that four of the resulting hybrid plantain plants combined the physical characteristics of plantains preferred by African consumers with high levels of resistance to black Sigatoka. The resistance not only delays the onset of Sigatoka symptoms; it also slows the progress of the disease, allowing even infected plants to mature and bear fruit normally. By July 1990, several hundred plantain hybrids were growing at Onne, awaiting evaluation for black Sigatoka resistance.

The battle against black Sigatoka is not over yet. The scientists may need at least one more round of breeding to reduce their hybrids' chromosome counts to the triploid number: as the offspring of diploids and triploids, the resistant plants are tetraploids, with four pairs of chromosomes. Because they produce pollen, tetraploids are capable of crossing with other tetraploids, producing seeds that are hard and unpleasant in the eating of the fruit.

Once this consumer-acceptance problem is overcome, the resistant triploid hybrids will be rapidly multiplied by culturing shoot-tips in a medium that induces a proliferation of clones. Finally, IITA and the International Network for the Improvement of Bananas and Plantains (INIBAP) will further multiply and distribute the clones to national programs, which will reproduce them for distribution to smallholders throughout Africa's humid-forest zone.

In starting a plantain breeding program at IITA, germplasm was collected from Asia, the primary center of plantain diversity, and West and Central Africa. Wild banana species resistant to black Sigatoka were collected from many parts of the world.

In the process of breeding plantain with bananas in order to obtain seeds, IITA scientists made discoveries which changed scientific thinking about plantains. The team has identified 20 French plantain cultivars and 8 False Horn cultivars all with variable levels of fertility, overturning the prevalent ideas that French plantains had very low level of fertility (1 to 2 seeds per bunch) and that False Horns were sterile. Up to 219 hybrid seeds per bunch were obtained.

Operational strategy. The plantain research program is focused on the genetic improvement of plantain for black Sigatoka resistance. This should ultimately benefit the family farmers of West and Central Africa who produce the bulk of the plantain crop for their own consumption in their backyards and small fields close to villages.

Genetic improvement involves the use of conventional breeding techniques, integrated with the use of in-vitro culture techniques to surmount specific problems.

Research Directions

Cassava

• Cassava genotypes will continue to be selected for major agroecological zones: humid forest, moist savanna, dry savanna and mid-altitudes. Quality characteristics being defined in the Collaborative Study of Cassava in Africa will be emphasized.

• Cassava germplasm from Centro Internacional de Agricultura Tropical (CIAT) from selected agroecological zones in South America will be crossed onto IITA's improved cassava mosaic virus-resistant varieties and tested for agronomic characteristics in corresponding African zones. The promising material thus identified will be sent out in seed form to national programs for evaluation and further adaptation and use.

• The search for new sources of host-plant resistance to the cassava green mite as a component of integrated pest management will be intensified.

• Crosses between cultivated cassava and its related *Manihot* species will be continued for manipulation of ploidy levels and for exploring possibilities to introgress new genetic sources from *Manihot* species to cultivated cassava.

• Research will continue to improve understanding of the physico-chemical bases for quality of traditional food products prepared from cassava, yams and plantains.

Plantain

• Further research will enlarge understanding of the epidemiology and biology of the causal organism of black Sigatoka disease.

• Breeding of durable host-plant resistance to black Sigatoka in plantain from different genetic sources will be attempted.

• The sources of resistance to banana weevil will be identified and incorporated into plantain breeding populations.

• Investigations into the rapid decline in yield of plantains under farming conditions in West and Central Africa will continue.

Yam

• Selection of genotypes for resistance to necrosis will be emphasized because of its importance for minimum staking.

• The search for increased flowering and better synchronization of flowering will be intensified. More locations with different environmental conditions will be used for flower induction.

• DNA analysis will complement and extend on-going preliminary work on isozyme and storage protein electrophoretic analyses.

The achievements described in the inset story, within two years of starting the plantain breeding program, indicate that other breeding objectives may also be achievable in the near future: breeding for banana weevil resistance, nematode resistance and dwarfism, and against yield decline.

International Collaboration

Germplasm exchange and dissemination of improved lines have intensified in recent years and become prime outreach activities. Dissemination of improved lines was at first delayed, however, by the slow process of multiplying planting material; and delayed further by national plant quarantine regulations. Both obstacles were at least partially overcome by the introduction of tissue culture and reliable indexing techniques, which eliminate viral and other diseases.

Root crops. Several thousand true seed of cassava and over 10,000 disease-free clones in tissue culture form have been shipped to 38 African countries, where those varieties best adapted to local conditions are selected. Among the new releases derived from IITA germplasm are the CARICASS series in Liberia, the ROCASS and NUCASS series in Sierra Leone, CIAM 76-7 in Gabon, Kinuani in Zaire, and NC-Savanna and NC-Idiose in Nigeria. True seeds from local cassava clones outcrossed with IITA improved crosses have been introduced to IITA for evaluation, selection and hybridization with IITA clones in order to combine desirable traits from local germplasm with the high yields and pest resistance of the latter.

IITA and Centro Internacional de Agricultura Tropical (CIAT) have expanded their sharing of cassava germplasm. CIAT has conducted trials with two IITA improved clones. Preliminary results indicate that one, TMS 30572, produces a stable yield under a wide range of ecological conditions in Colombia. Another clone, TMS 30001, was found to be resistant to superelongation disease, a major South American disease of cassava. CIAT has introduced 149 cassava families into IITA, and a CIAT scientist has joined the IITA research team. This will ensure that the germplasm base for the improvement of cassava in Africa is being broadened.

In Cameroon, Rwanda and Zaire, IITA has trained over 20 scientists, 600 technicians and extension agents and 2,600 farmers or representatives of farmers' associations in using root crop technologies. Improved varieties of cassava and sweet potato have been produced and released to farmers by those national programs and by the National Root Crops Research Institute and National Seed Service of Nigeria, using IITA germplasm. Sierra Leone, Liberia, Mozambique, Togo, Malawi, Kenya, Tanzania and Uganda, among other countries, are actively developing their national root and tuber improvement programs and attracting donor support for those programs in collaboration with IITA. IITA scientists have been assigned to cooperative root crop programs in Ghana, Cameroon, Rwanda and Zaire.

The Eastern and Southern African Regional Root Crops Network (ESARRN) has coordinated among the countries of the region and IITA the planning and execution of regional research of common interest. IITA also participates in the Central and West African Regional Root Crops Network (CEWARRN).

IITA participates in the African Plant Biotechnology Network (APBNet) and the International Plant Biotechnology Network (IPBNet) which link the countnes of Africa with advanced biotechnology laboratories.

In 1989 IITA handed over the responsibility for the improvement of sweet potato to a sister institute, Centro Internacional de la Papa (CIP). The links with CIP remain close as IITA continues the process of assisting CIP in implementing its responsibility to Africa for sweet potato germplasm.

IITA has research links with several advanced laboratories in areas which complement on-going research. Mutation breeding of yam and cassava, and somatic embryogenesis in yam, are being investigated in collaboration with the International Atomic Energy Agency, Vienna. Collaborative agreements for research on various aspects of cyanogenesis and cassava detoxification and utilization are currently being planned with universities in Australia, Denmark, Netherlands, U.K. and U.S.A. Somatic embryogenesis in cassava is being pursued with the University of Bath, U.K. as well as research on the processing quality of plantains.

Plantain. To strengthen plantain research, IITA has established linkages the International Network for the Improvement of Bananas and Plantains (INIBAP), with the purpose of testing hybrids of both the Honduras Foundation (FHIA) and IITA in different agroecological environments in Africa and Central and South America.

Phylogenetic studies in plantain are being given a boost with analysis of restriction fragment length polymorphisms (RFLP), in collaboration with the U.S. Department of Agriculture in Georgia, U.S.A. The research aims to evaluate genetic diversity in plantain and improve understanding of the organization of the plantain genome. Studies of postharvest processing quality and starch quality of plantains are being conducted with the Overseas Development Natural Resources Institute, U.K.

Grain Legume Improvement

Protein-rich grain legumes—mainly cowpea and, in recent years, soybean—are especially important in many parts of Africa where diets are otherwise scanty in protein sources. These plants. capable of producing their own nitrogen requirements from the nitrogen in the air, are also a basic component of any sustainable crop system in the savannas of Africa.

The Grain Legume Improvement Program is organized (see diagram below) to conduct research mainly on cowpea and soybean which addresses problems of crop improvement and utilization in the target areas of farmer use.

Cowpea

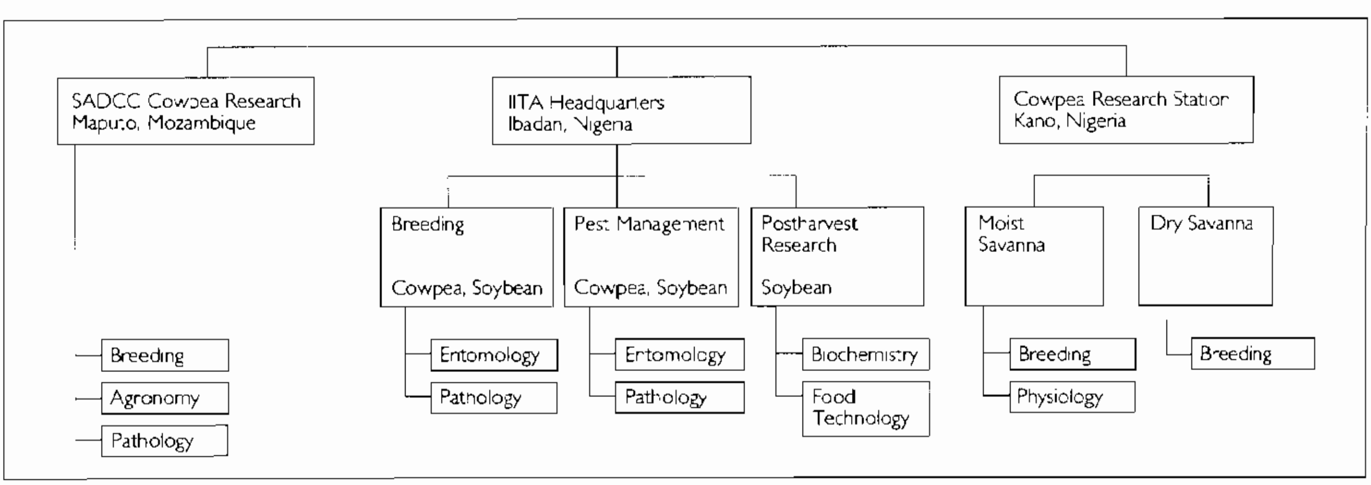
Cowpea in Africa is traditionally considered to be a food legume of the poorest farmer's diet and is mostly cultivated as a subsistence crop. In the mixed farming systems of the Sahelian regions, cowpea is the predominant legume and a major source of human food and fodder for cattle. It is a secondary crop mainly in semi-arid zones, in association with millet, sorghum, maize, cassava and cotton. It is drought-tolerant and can be grown in poor soils. Cowpea is able to fix nitrogen in the soil efficiently at around 30 to 70 kilograms per hectare per year.

Unlike many other legumes, cowpea may be consumed at different stages in its development: as leaves green or dried. green pods, green peas and grain, of which the last is the most popular. Dried cowpea is highly nutritious: 24-percent protein, 20-percent oil and the rest carbohydrates with minerals and other nutrients. Dried cowpea seeds take comparatively less time to cook then many other food legumes, an important consideration in most developing countries where cooking fuel is scarce and expensive.

Research conducted on cowpea by national programs of African countries and IITA has made cultivation of the crop more attractive to both small- and large-scale growers. New varieties with higher yield potential, a range of maturities, and resistance to some diseases and insect pests are being grown in larger areas and different agroecological zones than before. IITA has the global responsibility among international centers to conduct research on cowpea.

Ecologies of cowpea. In the different agroecological zones in which they are grown in Africa, the appearance and growing habits of cowpea differ according to diversity among genotypes, climatic conditions, cropping systems and production problems.

In the Sahel, traditional farm varieties are an indeterminate, viny, spreading type with a growing period of up to 120 days. They are fast-growing, cover the soil surface and produce large quantities of biomass. Millet is the main cereal here; cowpea is cultivated in mixtures with millet. Cowpea is consumed as green leaves, dried leaves, green peas, dry grain and fodder. After harvest, the dried plants are bundled and stored for use as fodder for cattle during the harsh dry-weather period.



In the dry and moist savannas, cowpea is mostly intercropped with millet, sorghum and maize as a secondary crop after the cereal crop is established. Cowpea is grown mostly for dry grain and fodder. With the first rains, farmers often plant an early-maturing cowpea along with a cereal. After the cereal is established, the main cowpea crop is planted for both grain and fodder.

In the lowland humid tropics (humid forest and transition zones) which have a bimodal rainfall distribution of two seasons, cowpea is planted in the second (short rainfall) season, in fields previously established with a cereal or root crop. Cowpea in this region is cultivated mostly for dry grain and is also used to a limited extent as a green leafy vegetable. Early-to-medium-maturing (60 to 70 days) varieties are preferred. Short, compact and upright varieties are considered most suitable.

In the forest zone, cowpeas have traditionally been grown on a trellis for green pods for household subsistence needs. The continuous rain and high humidity which prevails for 9 to 10 months of the year prevent farmers from growing cowpea for dry grain.

However, in all these zones, cowpea faces severe yield loss from indigenous insect pests. Even after screening almost all of the existing germplasm (15,000 accessions), the resistance to some insects is low, resulting in the need for new (unconventional) approaches to stabilize yields under farm conditions without the use of chemical pesticides.

Achievements. Having global responsibility for cowpea germplasm collection, IITA has collected more than 15,000 accessions and maintains them at its headquarters at Ibadan. IITA headquarters lies near the center of origin and genetic diversity of the crop, and within the region that produces most of the world's cowpeas. Since 1986 special efforts have been made to collect wild *Vigna* germplasm which is expected to play a key role in breeding for insect resistance and other characteristics in future.

IITA's early work in cowpea improvement was mainly devoted to basic research in crop physiology and to the identification of sources of resistance to insects and diseases. Sources of resistance to most of the important diseases have been identified and incorporated in breeding lines. Many of the elite lines distributed in international trials since the mid-1970s have high levels of combined resistance to the principal bacterial, fungal and virus diseases.

Late in the 1970s, the orientation of the program evolved to include insect resistance, with the emphasis on insects encountered in Africa. The strategy was to achieve yield stability through resistance to both insect and disease pests. Several lines with multiple resistance to diseases and resistance to one or more insect pests have been developed. Many of those varieties have been released by national programs.

In the Sahel, the Semi-Arid Food Grains Research and Development (SAFGRAD) project team based at Burkina Faso began research on drought tolerance and resistance to striga in 1980. Through their efforts, sources of resistance to those two constraints were identified. A cowpea breeder was based at the International Crop Research Institute for the Semi-Arid Tropics (ICRISAT) Sahelian Centre at Niamey. Several lines with resistance to aphid, bruchid, bacterial blight and *Macrophomina* ashy stem blight are being developed. Crosses have been made for combining striga resistance and drought tolerance. Several lines combining striga resistance and multiple insect and disease resistance were selected in 1989 for further trials after screening in Niamey and northern Nigeria.

From research conducted through the SAFGRAD project and from lines developed at IITA headquarters, several lines have been selected in the Sahelian countries by national programs for further tests or release to farmers for cultivation. VITA-7, SUVITA-2 and TVx 3236 are among the more popular lines released in the Sahelian countries. In 1989, mixed cropping on-station trials without insecticide application showed higher grain and fodder yields than did local varieties. Lines IT87D-549 and IT87D-1491 were selected for on-farm testing by national scientists.

In the savanna, a cowpea research station was established in July 1990 in Kano, northern Nigeria. (See story "Decentralization to the Savanna" in the Research Highlights section.) IITA is working closely with the Institute of Agriculture Research (IAR) at Ahmadu Bello University, Zaria and ICRISAT scientists based at Kano. IITA scientists at the station include a cowpea breeder and two physiologists (one supported by the Tropical Agricultural Research Center of Japan).

Several segregating lines combining aphid, striga and alectra resistance appear promising. Several cowpea lines tested through international trials by national programs in the region have been released for cultivation by farmers. In 1989 on-farm trials with minimal insecticide applications, TVx 3236 showed a moderate level of resistance to thrips and diseases with a consequently improved yield potential. This variety has performed well in both the Sahel and savanna zones. Other lines likewise tested in 1989 in the savanna with minimal insecticide applications have yielded consistently higher than local varieties: IT84S-2246-4, KVx 165-14-1 and IT84S-2231-15. VITA-3, which is resistant to leafhoppers, was released in several Latin American countries where leafhoppers are a major cowpea pest.

In the humid forest and transition zones, IITA has succeeded in developing several lines with high yield potential (2,000 kilograms per hectare) with multiple virus resistance and with multiple disease and insect resistance. Cowpea lines have also been developed with medium (70 to 75 days) and early maturity (60 to 65 days) with a diversity in seed color and plant type suitable for humid tropics, for cultivation during the short rainy season or the dry season in paddy rice fallows. These varieties are for grain production as sole crops using insecticides to control pests. Their yield, with improved management but no fertilizer, is more than 100 percent greater than that of traditional varieties. The improved varieties require less spraying with insecticides because of their short duration and partial resistance. The cash cost of spraying is only a small fraction of the value of the increased output in many countries. Some of the best performers in international trials have been released to national programs: IT82E-18 to Zaire and Mozambique, IT82D-889 and IT83D-442 to Bolivia.

In the mid-altitudes, an IITA cowpea breeder was based in Kenya with the International Centre for Insect Physiology and Ecology (ICIPE) from 1985 to 1987. During that time several local cowpea varieties and IITA lines were identified with superior agronomic character. Among the IITA lines tested in the region, IT82D-889, IT82D-885, IT82D-789 appear to perform better than others. A cowpea project was approved by the Southern African Development Coordination Conference (SADCC) during 1989, with funding from the European Economic Community. Through this project, the needs of southern African countries will be served and varieties suitable for eastern Africa are expected to be developed.

Among the international trials conducted in 1989 over a range of locations, the following cowpea lines consistently performed better than others: extra early maturity IT82E-32, IT84S-2246-4, IT84D-666; medium maturity IT85F-2020, IT83S-872, IT83D-219; bruchid-resistant lines IT81D-1007, IT84S-2246-4, IT85F-2205; aphid-resistant lines IT84S-2246-4, IT85F-867, IT83S-728-5.

Percentage bruchid infestation and yield losses due to bruchids were studied during 1989. Comparisons were made among standard local variety Ife Brown,

The savanna area of Kano, Nigeria, where the two farmers shown here are preparing to plant cowpea, provides a good environment for IITA to adapt improved varieties to the traditional mixed cropping systems.

resistant check TVu 2027 and two bruchid-resistant cowpea lines, IT81D-994 and IT84S-2246-4, which are derived from crosses made with TVu 2027. The results indicated that two months after infestation Ife Brown was 100-percent infested, as opposed to 7.3 to 14.7-percent infestation in the two bruchid-resistant lines. TVu 2027 was 18.4-percent infested. Similarly, percentage loss in weight at 60 days after infestation in Ife Brown was 18.6 percent, compared with the other three resistant lines which varied between 1.7 and 1.8 percent.

Impact. Fifty-one countries worldwide in different agroecological zones have benefited from the numerous cowpea lines developed through IITA. These cowpea varieties have been released to farmers for cultivation by the national programs. Several lines are also utilized by national programs for incorporation of useful traits into the local varieties.

The thrip-resistant cowpea variety TVx 3236 is popular with farmers in the northern parts of Nigeria, Cameroon (savanna), Senegal (Sahel) and Botswana. Along with TVx 3236, the variety ER-7 is frequently cultivated in southern Africa, particularly in Botswana.

Several lines with multiple resistance to diseases have been developed, including Vita-1 and Vita-3 which have already been released. Vita-3, with tolerance to drought and resistance to leafhoppers, is popular in Latin America where leafhoppers are a major pest of cowpea. It is extensively cultivated by farmers in Brazil, Jamaica and Guatemala.

Cowpea strategies. The aim of cowpea research at IITA is to reduce the risks in cultivation for the farmer, thereby increasing the farmer's productivity and income.

At IITA cowpea research focuses on the crop in its agroecological context, as part of a cropping system with particular requirements for resistance to insect pests and diseases. From 1988 the main breeding objectives have emphasized:

- Morphological and physiological adaptation for intercropping with cereals.
- Multiple pest and disease resistance for incorporation into locally adapted varieties.
- Improved drought tolerance in cowpeas, especially for the millet cropping system of the semi-arid zones.
- Resistance to post-flowering pests.
- Pest resistance characters from wild *Vigna* species.

Because conventional breeding and sources of genes from cowpea collections have not been successful against insect pests in some cases, the program is relying increasingly on biotechnology research on the wide crosses. In 1989 wild *Vigna* species were screened for resistance to major pests of cowpeas. Several species appear to have high level of resistance: *V. vexillata*, *V. luteola* and others to cowpea aphid and bruchid; *V. vexillata* and *V. oblongifolia* to the *Maruca* pod borer. Some *V. oblingifolia* appear resistant to pod sucking bugs.

International collaboration. IITA works closely with many national agricultural research systems in sub-Saharan Africa and other tropical regions of the world, in the development and adaptation of new technology for cowpea production. IITA collaborates with advanced laboratories in specific problem areas for basic research and has initiated contract research for solving some of the difficult crop protection problems. These include resistance to post-flowering pests of cowpeas through interspecific hybridization; resistance to striga and alectra; resistance to root knot nematode and cowpea aphid biotypes in the tropics.

In Nigeria, IITA has contracted research on resistance to *Striga gesnerioides* and *Alectra vogelli* to IAR and resistance to root knot nematodes to the University of Ibadan. IITA collaborates on resistance to bruchids, *Callosobruchus maculatus* and *Bruchidius atrolineatus* with the Federal University of Technology, Akure and School of Biological Sciences, Imo State University, respectively. In Niger, IITA works with Institut National de Recherches Agronomiques du Niger on *Macrophomina* ashy stem blight resistance; and in Zambia, with Msekera Regional Research Station, Chipata, on cowpea aphid-borne mosaic virus, among others.

With advanced laboratories in Italy (Università degli Studi di Napoli and Istituto del Germoplasma, Bari) and the U.S.A. (Purdue University), IITA has recently focused on biotechnology research for resistance to post-flowering insect pests and cowpea bruchid resistance. The Italian government has supported this basic research. IITA has contract research arrangements for the biotechnology research with Purdue University. IITA also collaborates with the University of Durham, where the mechanism of bruchid resistance in TVu 2027 and cowpea trypsin inhibitor gene (CpTI) were originally identified. TVu 2027 was identified as resistant to bruchid by IITA in 1974.

ICIPE in Kenya has worked with IITA in the development of diet for *Maruca* pod borer under a research contract for a period of three years, funded by the German Technical Cooperation (GTZ). IITA has also collaborated with ICIPE in the identification of a mechanism of resistance to *Maruca* pod borer in TVu 946, and research on integrated pest management in cowpea mixed cropping with other cereals. In the U.K., IITA has contract research arrangements with Wye College for cowpea aphid biotype resistance research and identification of geographical races of this pest in the tropics. With the University of Bristol, Long Ashton Research Station, IITA collaborates for striga research which has resulted in the identification of B301 striga and alectra resistant cowpea by the Long Ashton group. B301 is the only line which appears to be resistant to virtually all the strains of striga and alectra in West Africa. IITA has collaborated in the past with the Plant Environment Laboratory, Department of Agriculture, University of Reading, in cowpea physiology research.

Collaborative attempts are being made to transfer the coat protein gene of cowpea aphid borne-mosaic virus to cowpeas, by innovative biotechnology techniques, giving a novel approach for the control of several strains of the virus. This work could possibly provide for control of other potyviruses affecting cowpea. (A total of eight potyviruses are reported from cowpea from all over the world.)

In the near future collaborative studies will commence with the bean/cowpea collaborative research support project of Michigan State University and with the Boyce Thompson Institute, U.S.A., to identify fungal, bacterial and virus pathogens involved in control of cowpea pests.

The results of these cumulative efforts should ultimately help in solving some of the more difficult cowpea production problems and make the crop less risky and more profitable to farmers in the tropics.

Soybean

From the beginning, IITA has attached great importance to improvement of soybeans for the tropics, and more recently to research on soybean processing and its utilization in human diets. As a nitrogen-fixing legume and cash crop in substantial demand, soybean has great potential as an important component of substainable farming systems in the moist savannas of Africa. And although the crop is not yet widely grown by small-scale farmers there and has traditionally been little used in Africa for food, it also has very great potential as a source of inexpensive protein in human diets, of valuable cooking oil and of animal feed.

Improved soybean varieties must resist the major disease and insect pests and have growth cycles which fit agroecological conditions and the main features of local farming systems. The second research aim is to develop appropriate technologies for convenient home and village utilization. If people know what foods soybean can be used in and how to make them, this nutritious legume (40-percent protein and 20-percent oil) can generate a strong demand in the marketplace so that farmers will continue to produce soybean for the benefit of all.

Ecologies of soybean. The best agroecological environments for soybean production are similar to those for maize and sorghum. In all environments, however, soybean has faced the two paramount problems of poor nodulation with soil bacteria and poor seed longevity. These problems are described in the "Achievements" section below.

The moist and mid-altitude savannas are the most favorable zones for soybean production in West and Central Africa. Because of the relatively short rainy season, crop management and seed storage face fewer problems than in the wetter zones. Improved varieties need to have a maturity range from 75 to 130 days in order to stay within the normal range of rainfall distribution. In these agroecological systems, maize and sorghum are the main crops and soybean is planted with them in rotation or is intercropped. Soybean production in these zones has been expanding rapidly in Nigeria, Ghana, Côte d'Ivoire and Zambia over the past five years.

The transition zone between humid forest and moist savanna is also suitable for soybean production. Recent investigations show that soybean yields in this zone are higher than those of cowpea and groundnuts. However, the bimodal rainfall pattern with two seasons makes maturity range an important factor. Some farmers plant within one or each rainy season, while some plant one crop across both seasons.

Cowpea and soybean are screened for resistance to insect pests and insect-borne diseases in this screenhouse designed by IITA.

The humid forest agroecological zone is the most challenging for soybean improvement, because of acid soils and weathering of the bean on the plant before harvest. Harvests from an intercropping system with cassava have shown encouraging results, however.

Inland valleys can also be promising for soybean production, as shown in intercropping trials with rice. Early maturity (75 to 90 days) is a particularly important characteristic in this zone.

In all zones, apart from the immediate goals for research already described, the long-term issues for research concern crop rotation, intercropping and alley farming systems. The effects of soybean on maintenance of good soil physical and chemical properties, and its effect on yields of associated crops, are at the heart of that concern, together with the socioeconomic effects of soybean cultivation on the farm families. In the savanna and transition zones it is not yet known whether soybean has any effect on striga populations in associated cereal cropping systems. In the humid forest and inland valleys, tolerance of acid soils is an important character for study.

Achievements. When IITA began to collaborate with Nigerian scientists in the 1970s in soybean research, the two most critical weaknesses in the exotic high-yielding varieties which they were testing were: (1) the inability of the plant to utilize nitrogen from the air, and (2) the low rate of germination of the seed after it had been stored between cropping seasons. Both were subsequently overcome by breeding and a "tropicalized" soybean was created.

The first problem concerned the way soybeans, like other legumes, use nitrogen from the air. The roots of legumes are normally invaded by rhizobia, harmless bacteria from the soil which capture atmospheric nitrogen and convert it into a form which is useful for the nutrition of their host plant. Hence, legumes need little or none of the nitrogenous fertilizer which is so important for cereal crops, for instance, to the obvious advantage of the farmer. Compatibility between host plant and colonizing bacteria determines whether the plant roots form nodules where the bacteria can reside. Nodulation with rhizobia in the roots is crucial for the soybean to acquire the nitrogen it needs.

The second problem concerned the rapid loss of the seed's germinating ability in the warm, moist storage conditions so common on African farms. Very few seeds remained viable, or alive and able to grow, between harvest in one year and planting in the next.

An IITA team consisting of a breeder, physiologist and microbiologist began to work on those problems during the 1970s. Genotypes with traits for overcoming both nodulation and seed storability were found, but other characteristics had to be improved before they could be combined in successful varieties for Africa. Pods and leaves were vulnerable to insect and disease attack. Pods tended to "shatter" before harvest, scattering their seeds. Under storms or strong winds, stems fell over or lodged. Seeds were not uniformly cream-colored.

Soybean is beginning to fulfill its promise as more farmers grow the crop and consumers learn how to process and use it.

By 1983 IITA had developed several varieties with improved nodulation and seed longevity and other agronomic characters. Subsequent research concentrated on resistance to shattering, foliar pathogens and pod sucking bugs, and on a uniform cream seed color. By 1989 significant progress had been made it improving genetic backgrounds of varieties for Africa with multiple resistance characteristics. Soybean yields of up to 2,500 kilograms are now obtainable with IITA varieties which have been released in Nigeria and other West African countries. In 1989, 23 African countries requested improved seeds from IITA to test for adaptability to their local environments.

Improved cultivars with a short maturity period of 90 days, which are suitable for intercropping with sorghum in the dry savanna, began trials with ICRISAT at Kano in 1989. Several lines were identified with a high level of resistance to the diseases of frogeye leaf spot and bacterial pustules, both of which are spreading and becoming economically significant in the region. Over half the potential yield of one susceptible local cultivar, Samsoy 1, was lost to frogeye leaf spot in trials, while the improved resistant variety TGx 996-26E maintained its high yields under heavy disease pressure.

Consumer aspects came under IITA's purview in 1985, when a food technologist joined the soybean team. The importance of improving the protein content of African diets has been the guiding principle of this research. Soybean utilization work has focused on improvement of technology for household and small-scale uses, as well as the food products made with such technology.

New methods of processing soy milk to eliminate burning hazards and reduce the labor requirement have been successfully introduced, leading to commercial adoption of the technology. Soy flour has been used to improve the protein content of low-protein traditional foods without increasing the cost or the cooking time and without changing the appearance or taste of the foods.

For example, work in 1989 with soy milk residue and flour has given gari (a traditional food made from cassava) a 10-percent protein content as against less than 1-percent protein in the traditional gari. Several recipes utilizing soy milk residue were developed, and work continues on developing other uses for the home and small-scale industry. Tofu was produced using local plants as a coagulating agent. "Soyamusa", a new extruded, inexpensive soy-plantain baby food has been developed. Screw presses constructed in Africa that can process soybean are now available and their performance is being evaluated.

Research Directions

• Emphasis is being given to problems of the savanna zone: the dry savanna for cowpea and moist savanna for soybean.
• Understanding of the biology of striga and its control are major objectives of a new IITA cross-program project with a twofold approach: to reduce the striga population and improve host-plant resistance to striga in maize and cowpea.

Cowpea

• Development of locally adapted cowpea genotypes will continue, for mixed cropping systems in the savanna with millet and sorghum, with emphasis on stable resistance to insect pests and diseases.
• Improvement of cowpea grain types and a range of maturities will continue, which meet the diverse needs of producers and consumers of cowpeas in the tropics of Africa.
• Strengthening of national programs and regional networks for cowpea in West and Central Africa continues to have a high priority. Technologies for incorporating resistance to insect pests and diseases into local cultivars will continue to receive special emphasis.
• Collaboration with the Semi-Arid Food Grains Research and Development (SAFGRAD) cowpea network will strengthen understanding of small-scale farmers' systems and will result in approaches relevant to their needs. Strong support will also be given to the Southern African Development Coordination Conference (SADCC) cowpea project.

Soybean

• Development of varieties that are suitable for farmers in tropical Africa will seek to combine the following traits: stable and high yield, promiscuous nodulation, resistance to the major diseases and insects, good seed storability, and resistance to lodging and shattering, with a range in maturities from 80 to 130 days.
• Identification of the different strains of *Cercosporo sojina*, the causal organism of *Cercospora* leaf spot on soybean, and of sources of resistance will continue and the mode of inheritance of resistance will be determined.
• Development of improved small-scale and home-use technologies for incorporating soybean into traditional foods proceeds with the Institute for Agriculture and Training (IAR&T) at Ibadan, Nigeria. Simple low-cost processes are also being developed for soybean products that simulate meat, fish and African cheese.
• Collaboration with the Institute for Agricultural Research (IAR; Zaria, Nigeria) and the International Crop Research Institute for the Semi-Arid Tropics (ICRISAT) will emphasize sorghum/soybean intercropping and crop rotation systems.
• Studies of the production, utilization and marketing systems used by soybean farmers in Nigeria will give direction for setting goals and objectives for IITA soybean research.

Research strategy. A multidisciplinary team at IITA works together with scientists in national programs to develop improved varieties and production and utilization technologies. The interaction with each institute or university is unique and diverse, according to need.

In its genetic improvement work, the team concentrates on incorporating resistance to pod shattering, lodging and pod-sucking bugs into elite varieties which can nodulate freely and whose seeds retain their viability in farm stores.

Improved cultivars have been sent to IITA from strong breeding programs in Côte d'Ivoire, Zimbabwe, Brazil and Thailand. Some national programs are evaluating IITA breeding lines for traits that are important to them and for which they have a comparative advantage in conducting the research. Some programs request a large sample (100 kilograms) of one or two varieties for on-farm testing. Often they wish to promote soybean production and utilization but do not have an active cultivar testing program. Some request seed of all IITA breeding lines, while others would like to receive 10 to 15 varieties for a replicated yield trial.

IITA maintains a soybean breeding capability, including a germplasm collection. When soybean becomes widely grown and consumed by African farmers, or if significant production problems appear, this capability is ready to be used in conjunction with national program efforts.

Processing and utilization have gained priority as research topics at IITA, in the conviction that consumers will increase demand for soybeans once they know what foods to prepare with soybean and are able to process them. Early in the 1980s IITA held workshops with Nigerian and American scientists and producers on tropical soybean production and utilization. The participants established that the need to disseminate new home-level and small-scale processing techniques was urgent. In subsequent years a project was launched together with the Institute for Agricultural Research and Training (IAR&T), Nigeria, and a soybean utilization specialist was provided to IITA from Japan.

Other soy-based foods on the IITA research agenda are weaning foods; meat, fish and dairy substitutes; biscuits and breads made from composite flours including soy flour; and various uses for soy milk. The soybean research team is also developing methods and equipment to improve processing of soy oil, flour and milk.

International collaboration. In breeding, collaborative projects are concentrated in Nigeria, taking advantage of the favorable range of soybean-growing environments and ready consumer acceptance. With the National Cereals Research Institute, IITA is evaluating effects of acid soils on its breeding lines, and seed storability in the savanna. Resistance to insect and disease pests is being investigated by University of Ibadan students, while socioeconomic studies of soybean production have been undertaken at the University of Agriculture, Makurdi.

In other countries, the Institut des Savannes (IDESSA) in Côte d'Ivoire is evaluating breeding lines under high-input production, utilizing cultivars received from Brazil. Long Ashton Research Station of the U.K. and IAR, Nigeria have collaborated in studying striga on cowpea for the past seven years, and have succeeded in identifying B301 as a cowpea cultivar highly resistant to striga strains in West Africa.

Similarly, much of IITA's soybean utilization research is conducted in Nigeria. IAR&T is developing traditional foods with a soybean component in a collaborative project with IITA, funded by the International Development Research Centre (IDRC). Baby foods are being developed with the National Horticultural Research Institute (NIHORT) and University College Hospital at Ibadan, and the Federal Institute for Industrial Research, Oshodi (FIIRO). A Japanese postharvest technologist has been provided by the Japan International Cooperation Agency (JICA) to adapt soy food products to the requirements of Africa. Two companies, in Ghana and Nigeria, have teamed up with IITA to design and build screw presses for soybean oil extraction. Two other Nigerian companies are evaluating those screw presses.

Soybean has become an attractive crop in tropical African countries. The main obstacles to successful cultivation have been overcome with patient research by IITA and collaborating partners over the past 20 years. Soybean is relatively high-yielding and easy to grow in comparison with other legumes. Consumers are beginning to find uses for soy products at home as a food and at a commercial level as vegetable oil, livestock feed, baby food and other food products.

Maize Research

IITA conducts a full-scale improvement program for maize because of its importance as a source of food and feed, because of its high labor productivity, and because of its potential for rapid impact. Recent years have seen a significant expansion of maize production in West and Central Africa. Maize is expected to become increasingly important as population growth and urbanization intensify demand for easily transported and storable food grains, and as demand for livestock products increases.

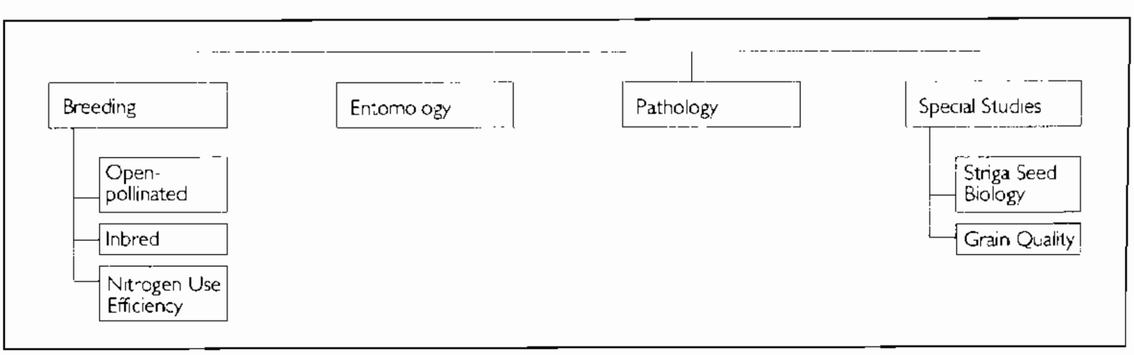
IITA's research strategy for maize focuses primarily on the lowland moist savanna and humid forest zones of West and Central Africa. IITA collaborates with CIMMYT in a germplasm development program for those zones, which includes work on both open-pollinated and hybrid varieties and efforts to maintain stable resistance to streak virus, downy mildew and lowland rust and blight. A maize research station is being established in the West African moist savanna for the development of germplasm with emphasis on resistance to the parasitic weed striga. At Ibadan headquarters, methods to screen germplasm for resistance to pests and pathogens and tolerance of other stresses is being refined. (See diagram below.) In addition, maize scientists are actively involved in the savanna systems research group. Collaboration with and support to West and Central African national maize improvement programs continues, as does active participation in regional maize research networks.

During 1989, IITA maize scientists studied key aspects of the diseases downy mildew and maize streak virus, including host-plant/pathogen interactions, survival mechanisms and surveys on incidence and distribution in Nigeria. Research on the parasitic weed striga was aimed at improvement of resistance/tolerance levels in both open-pollinated and hybrid maize varieties. Significant improvement in resistance to the stem borer *Eldana saccharina* was demonstrated in selected lines. Nitrogen-use efficiency of key IITA varieties was studied, and work began on characterizing some of the physical and chemical properties of maize grain in relation to consumer preferences.

Ecologies of maize

The moist savanna, where maize has spread since the 1970s, has the greatest potential for maize production of all agroecological zones in West and Central Africa. Maize has increasingly replaced sorghum in this region. Improved maize varieties have spread in several states of Nigeria's moist savanna through active promotion by Agricultural Development Projects, which have used IITA varieties to make improved seed, including hybrids, available to farmers, together with fertilizer. Without applications of fertilizer or organic manures, however, low soil fertility limits continuous maize cultivation. The parasitic plant striga also looms as the foremost pest threat to stable yields in the savanna. This zone holds IITA's highest priority for development in the region, with the emphasis on yield improvement by farmers who can use improved varieties, good husbandry and a few purchased inputs.

The humid forest, where maize was first introduced in Africa, is characterized by high rainfall and humidity at elevations below 800 meters above sea level. It includes the coastal rainforests of West Africa and the equatorial rainforest of Central Africa. The complex ecosystem of this zone presents the maize farmer with a series of challenges: disease and insect attacks, low light intensity during the growing season, acid soils and



high humidity that makes grain drying and storage difficult. Rapid urbanization in this zone has nevertheless stimulated the demand for "green" or fresh maize ("corn-on-the-cob") as well as for dried grain.

The mid-altitude zone—from 800 to 1,500 meters above sea level—in some parts of West and Central Africa is ideally suited to maize. With good management, farmers can achieve and sustain even higher yields in this zone than in others, because of its rich volcanic soils and intense solar radiation yet cool nighttime temperatures.

Achievements

Most African farmers who grow maize cultivate their land with minimal resources which, combined with various stresses, produce yields of less than one-quarter of their potential. IITA's maize research program has sought to breed maize varieties for these farmers which are (a) resistant to the main disease and insect pests affecting the crop and (b) better adapted than their present cultivars to the growing conditions and which thus will produce higher yields. The program's end product of improved germplasm must be useful for national researchers, who adapt it into varieties suitable for local conditions in each agroecological zone, ultimately for the farmers themselves. Within this frame the program has achieved notable successes, some of which are described in the following pages.

Diseases. Of all pests, diseases pose the most critical threat to tropical maize development. Since the 1970s IITA has focused research with national programs on five major diseases: maize streak virus, downy mildew, stem/ear rot fungi, rusts and blights. The focus of the maize program's early breeding efforts was on combining the potential for high yield with significant resistance to lowland rust and blight, the two most important maize diseases at that time. Building on germplasm identified by Nigerian research and CIMMYT, IITA breeders developed two open-pollinated varieties. Because of their resistance to those foliar diseases, the two varieties were quickly and widely adopted throughout Nigeria. As a result lowland rust and blight are no longer an immediate danger to improved maize crops.

As the doubly resistant varieties were winning acceptance throughout Nigeria and in several other African countries, in the mid-1970s the maize scientists added maize streak virus to their agenda, then downy mildew, and striga a few years later. In 1977, the program also began to tailor varieties for the mid-altitude zone.

IITA maize scientists have received accolades for

Maize has expanded rapidly in the moist savanna of Nigeria, as farmers have adopted improved IITA varieties.

10 years of effort in conquering maize streak virus, one of the main pests of maize in Africa. They devised novel screening techniques and a breeding strategy which identified a highly stable type of resistance, innovations which led to success and earned IITA the King Baudouin Award for International Agricultural Research in 1986. IITA organized an accelerated breeding campaign with CIMMYT and African national scientists to incorporate the resistance genes into improved varieties. By early in the 1980s, high-yielding, streak-resistant varieties—both open-pollinated and hybrid—with different maturing rates and grain types, were ready for farmers in all the maize-producing zones of Africa.

Maize pathologists are gathering fundamental knowledge on downy mildew, a devastating fungal disease. Limited to a few areas at present, downy mildew appears to have a potential to spread together with expanding maize cultivation which must be assessed. Besides undertaking studies on the causal organism and the disease cycle, the pathologists have begun to investigate the interactions between host plant and pathogen. IITA pathologists are also working with Nigerian scientists to improve screening techniques for identifying resistant germplasm.

Scientists from IITA and the Institute for Agricultural Research and Training (IAR&T) at Ibadan, jointly conducted a survey on the incidence and distribution of downy mildew disease in 1989. They investigated survival mechanisms of this fungal disease and potential sources of inoculum, as a step in building an understanding of its epidemiology and its potential to spread into new maize areas or to develop more virulent strains. IITA scientists, with colleagues from the University of California at Davis, plan to apply the biotechnology technique of restriction fragment length polymorphism (RFLP) analysis, a new tool for examining such genetic variability.

Striga. The parasitic plant striga, or "witchweed", is becoming a serious pest as maize production expands from the humid forest into savanna areas, the home of striga. The striga genus co-evolved with the native African crops of sorghum, millet and cowpea, which may have thus developed some tolerance of the pest. Maize has little natural resistance since it was introduced into Africa less than 500 years ago and was grown mainly in the forest zone, where striga does not occur. Up to 90 percent of a maize crop can be lost to striga in severely infested fields.

Over the past decade IITA scientists have screened thousands of maize varieties or lines for striga resistance, and have identified some moderately resistant types. They have succeeded in artificially infesting large test plots where different maize lines are screened for resistance. They have begun to develop moderately striga-resistant varieties for tropical Africa using genes from temperate-zone maize. In 1988 IITA scientists began studies with colleagues from University College, London on the physiological basis for resistance.

Insect pests. The main insect pests of maize in Africa are: stem borers, which attack the growing maize plant itself; leafhoppers, which are vectors of viruses that attack the plant; and the various enemies of stored maize, chiefly the grain weevils. To combat these pest problems, maize entomologists work at understanding their biology, their population dynamics and their complex interactions with the plant. In quest of maize plants with built-in pest resistance, the researchers devise methods for multiplying and raising large populations of the pests, for infesting maize plots under controlled conditions, and for keeping accurate scores on how well the test plants survive.

Stem borer resistance poses an unusually difficult challenge to maize breeders. In 1989, after improving the screening method against *Eldana*, one of several important stem borer pests, IITA scientists screened numerous maize lines for resistance and could demonstrate significant improvement in resistance levels.

Maize, as a crop new to the savanna which is the home of striga, has little natural resistance to the pest and must be bred for durable resistance.

On-farm trials with Beninois scientists have confirmed that resistance to weevils needs to be improved for the humid forest zone. The scientists' strategy defines three lines of defense: a better husk cover and physical and chemical characteristics of the kernels. The Natural Resources Institute, U.K. will help IITA to test for resistance and to elucidate the possible chemical and physical factors associated with resistance.

IITA entomologists conducted a survey on the insect vectors of maize streak virus, *Cicadulina* leafhoppers, in different Nigerian agroecological zones. They studied the grass hosts of the virus and the capacity of the virus to be transmitted from these grasses to maize. They need such information in order to understand how the virus survives the dry season, when there is little or no maize, and where reinfection comes from, at the beginning of each new rainy season. These studies should also be able to show whether new strains of the virus are appearing in wild grasses which could jeopardize currently resistant maize varieties. So far none has been found.

Maize is increasing in popularity as a food for urban populotions, o trend which influences farmer acceptance of different varieties and, hence, breeding research objectives.

Entomologists also began to study the feeding behavior of the leafhopper, in order to improve understanding of host-plant/vector/virus interrelations.

Fertilizer. Maize farmers in Africa are aware of the benefits of fertilizer and use it when they can find and afford it. The recent spread of maize in the savanna was facilitated by availability of subsidized chemical fertilizers, especially nitrogen. However, fertilizer prices are increasing and distribution systems often favor large-scale farmers. Furthermore, maize root systems tend to develop poorly in tropical soils, so that their recovery of nitrogen from fertilizer is often inefficient, sometimes as low as 20 percent of total nitrogen applied.

IITA scientists have begun to look at the possibilities for breeding African maize for improved efficiency in nitrogen uptake and use. They have evaluated the yield performance of certain improved maize varieties under varying conditions of soil nitrogen fertility. It is clear, however, that high yields from any maize variety cannot be sustained without some form of nitrogen enrichment of the soil. Economical ways to improve soil fertility and soil nutrient retention are being researched by the IITA Resource and Crop Management Program. These methods need to be combined with maize varieties that are designed to increase the efficiency of nitrogen use.

In 1989, scientists measured dry matter production and nitrogen uptake and distribution in the plant, in several maize varieties, in order to identify mechanisms associated with efficient nitrogen use. Grain yield of different varieties declined as the nitrogen level decreased; however, varieties which yielded well with high nitrogen levels also tended to be the better yielders under low nitrogen. Different results had, however, been found earlier among varieties tested in IITA's outreach program in mid-altitude Zaire and in savanna trials in Burkina Faso.

Eating quality. Little work on quality characteristics for human consumption has been done in developed countries because maize is used there mainly as an animal feed. However, looking toward the future when maize will be a major food source for the urban population in Africa, urban preferences will influence quality characteristics in the maize supply. Already, consumer taste and texture characteristics greatly influence differential market prices for maize. IITA scientists in the Republic of Benin have found that farmers like the high yields and disease resistance of IITA varieties, but are used to different grain textures. Hence, the research is important for farmer acceptability of the new improved varieties.

IITA scientists began to characterize some physical and chemical properties of maize grain and to study their relationship with consumer preferences. The ratio of sugar to starch, and the hardness of the kernel, are important eating characteristics of green maize. In the dry grain of mature maize, soft floury kernels are preferred in many areas while hard kernels are preferred in others, depending on the type of dish being prepared. Research on genetic control of this characteristic, and its relationship with protein content of maize, has commenced.

Breeding. The "pay-off" from the work described above is the development of new, improved varieties. IITA breeders must always be engaged in pioneering work against new challenges, such as striga, as well as conduct regular programs of "maintenance" breeding to keep up the levels of resistance to such disease pests as streak virus, downy mildew, rusts, blights and stem/ear rots.

Breeders can develop two types of maize: open-pollinated varieties, which farmers like because they can propagate the seed on-farm from year to year; and hybrid varieties, whose advantage is a higher yield but for which seed must be bought anew each year. IITA's maize program works on both types, because both are important in the development of small-scale maize farming. They also form complementary components in maize breeding strategies: hybrid varieties can be developed out of open-pollinated "base populations." From open-pollinated populations come the "inbred" lines with specific genetic traits which are used in developing new hybrids as well as in "fixing" desirable genes into unchanging forms, as a genetic resource. Inbred lines can in turn be combined to form new open-pollinated varieties.

The use and commercialization of hybrid maize can be a milestone in maize development in any country, because it contributes to the profitability of the local seed industry, which is so important for sustaining a source of high-quality hybrid and open-pollinated seed for farmers. By 1984, hybrids produced at IITA had helped to establish two successful Nigerian seed companies.

IITA maize breeders in 1989 reviewed work on inbred lines and hybrids and corrected deficiencies in certain traits. They tested 3,000 experimental hybrids in order to diversify the germplasm base.

Research strategy

Research strategy must respond to changing needs and possibilities, tailoring its research priorities according to pest and environmental problems and to consumer needs in each agroecological zone. For example, the advantages of easy cultivation and high productivity could lead to overproduction and depressed prices for maize for human consumption. Hence, future strategies should entail alternative use of maize as livestock feed or industrial applications. (See table on maize breeding objectives on this page.)

In the moist savanna, breeding for resistance to striga ranks as the highest priority. Basic research is needed on host-parasite relations, resistance mechanisms and resistance screening methods. And looking ahead, the potential for downy mildew to spread with expanding maize production calls for preemptive research measures to contain such a threat.

IITA is establishing a research station for maize research in the moist savanna zone. Other IITA research programs with an interest in the zone will also use the facilities. An adjunct CIMMYT breeder will work there to adapt susceptible germplasm to resist African pests.

Breeding objectives for maize in West and Central Africa

Agroecological Zone	Cropping System	Breeding objectives: Biotic	Breeding objectives: Abiotic
Humid forest	Maize/cassava	Downy mildew, stem borers, ear and stalk rots, streak virus, storage weevils, curvularia, rust and blight	Nitrogen use efficiency, intercropping characteristics
Moist savanna	Maize monocrop, Maize/sorghum, Maize/cowpea	Striga, hybrid vigor, streak virus, downy mildew, stem borers, rust and blight	Nitrogen use efficiency, drought
Mid-altitudes	Maize intercrop, Maize/legume	Blight, rust, streak virus, hybrid vigor, ear and stalk rots, stem borers	Acid soil tolerance

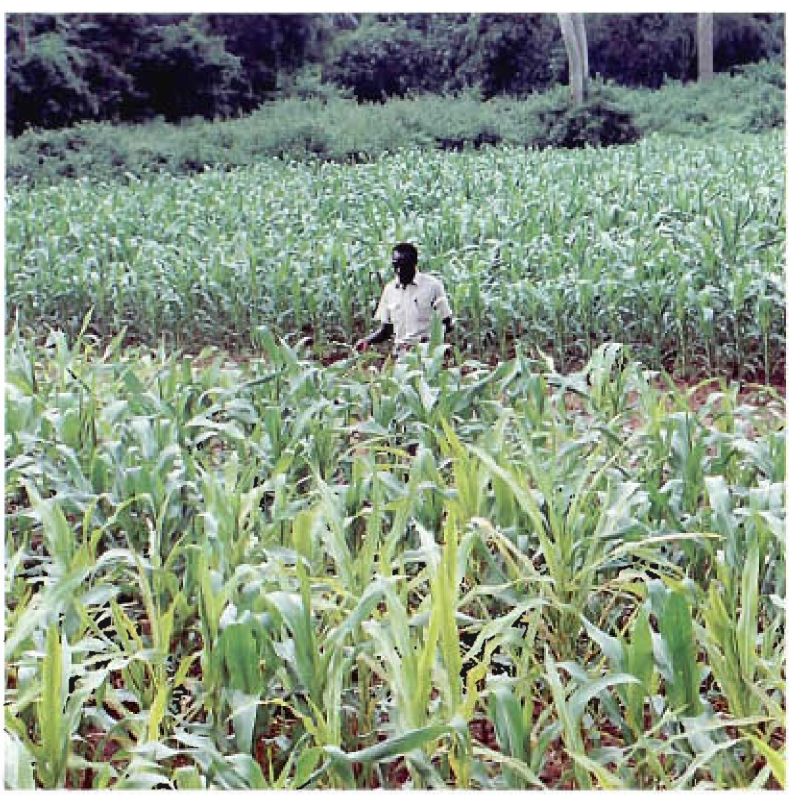
For the humid forest, IITA scientists will continue their research at the Ibadan campus headquarters. The first priorities are resistance to insect pests (stem borers and storage weevils), downy mildew, and ear and stalk rots. The possibilities of improving green maize will be further examined. Also, maintenance breeding against streak virus and lowland rust and blight must continue.

The highest research priorities for the mid-altitudes are development of higher-yielding varieties with resistance to mid-altitude rust and blight and streak virus.

IITA scientists aim at developing "durable" resistance that won't break down after a few years. Durable resistance is often based on the interaction of many genes in complex forms which pests have difficulty in overcoming, even with their own natural mechanisms for adapting to new situations. A durable resistance to a pest can give stability to the farmer's maize yield, which is crucial for the small farmer whose resources leave little margin for risk-taking in selecting a crop to plant.

With the deeper understanding gained from those efforts comes the ability to breed improved maize germplasm and to help scientists in national maize programs in improving varieties to meet their own particular needs. IITA scientists develop and test improved germplasm and distribute it to researchers in African national systems and to others for adaptation to local cultivation needs. They also tap the resources of advanced laboratories for primary research technologies needed in the adaptive process.

Maize plants in the foreground show symptoms of downy mildew, which has a high priority in humid forest research at IITA in the hands of Dr. O. M. Olanya and others.



The effort also enlists scientists from other IITA programs. Colleagues in the International Cooperation Program, for example, work with national research systems in training scientific manpower. Scientists in the Virology Unit investigate maize viruses. Maize scientists contribute improved germplasm and their disciplinary research to the Savanna Systems Research Group in IITA's Resource and Crop Management Program. In turn, the group feeds back the results of its trials under actual farming conditions. This information guides the maize scientists in returning full circle to defining their future research objectives.

IITA and CIMMYT are addressing the major germplasm issues of Africa as a whole. IITA concentrates on West and Central African problems while CIMMYT takes the lead in East and Southern Africa. They exchange and test germplasm and information between the two regions to ensure that all African countries have access to the best available materials.

International collaboration

IITA's most active partnerships with national research systems have been with Cameroon, Nigeria and Zaire. IITA also participates with 26 national maize programs through the Semi-Arid Food Grains Research and Development (SAFGRAD) maize network, and posts a coordinator with SAFGRAD project headquarters in Burkina Faso. Within the international research system, IITA's maize research program shares research findings and genetic materials with CIMMYT in Mexico and other institutions.

The devastating Sahelian drought early in the 1980s galvanized the 26 national programs bordering the West African Sahel desert and dry savanna areas, with donor agencies and technical support institutions, to link their research systems in the struggle to keep agriculture alive in those areas. Countries take on research responsibilities according to their capacity, in such areas as resistance to drought, streak virus, striga and stem borers, and improved grain quality and storability. For these dry savanna areas where maize is intercropped with cowpea, IITA has contributed maize and cowpea germplasm, training and technical advice and support. Many member countries have seen their capacity to utilize and generate new germplasm grow as a result of SAFGRAD activities.

In Cameroon, the National Cereals Research and Extension (NCRE) project houses an IITA maize

Research Directions

- Priority is being given to problems of the moist savanna zone, the most favorable lowland environment for maize. A station for maize research in the moist savanna zone is being established.
- Understanding of the biology of striga and its control are major objectives of a new IITA project with a twofold approach: to reduce the striga population and improve host plant resistance.
- Strengthening of national programs and regional maize networks in West and Central Africa continues to have a high priority. Transfer of technologies for screening for resistance to maize streak virus will continue to receive special emphasis.
- Close collaboration of the maize program with IITA's Savanna Systems Research Group is strengthening IITA's understanding of small-scale farmers' systems.
- Development of locally adapted populations, inbred lines and hybrids will continue emphasizing: stable resistance to foliar and ear diseases and to maize streak virus; resistance to stem borers and storage insect pests; grain types and a range of maturities to meet the needs in the lowland and mid-altitude tropics.

breeder who develops new varieties with local scientists for the western mid-altitude plains, a major maize-producing and -consuming part of the country. NCRE has developed high-yielding open-pollinated varieties for the area resistant to highland blight and rust. Hybrid maize is also expected to make an impact there, since NCRE has produced inbred lines with excellent combining ability.

Since IITA varieties resistant to maize streak virus have not yet been widely introduced in Zaire, the disease continues to damage the maize crop there. An IITA breeder and entomologist in a bilateral aid program have helped scientists in the national maize program to select and test streak-resistant varieties on farms. Those varieties have begun to enter the national seed multiplication process. IITA and Zairean scientists have also constructed a leafhopper rearing facility, needed in continuing the selection of future resistant varieties for Zaire.

Substantial facilities at IITA headquarters are an asset to national program scientists who use them on visits or research attachments to enhance their own work. The process flows two ways: visiting scientists and collaborators in turn add insights from their own experience to ongoing IITA work, providing an extra dimension to research accomplishments at IITA.

During 1989/90, a Ghanaian breeder took the opportunity, as a visiting scientist at IITA, to utilize IITA materials and facilities to strengthen maize work in Ghana. Dr. Baffour Badu-Apraku, who received his doctorate from Cornell in 1986, has since that year headed Ghana's maize program based at the Crops Research Institute, Kumasi. He is happy that his year-long stay at IITA has produced substantial results.

Within two experimental generations, Ghanaian maize varieties have been improved with resistance genes to maize streak virus. Also, inbred lines from IITA and Ghana have been matched to produce better Ghanaian hybrids.

On his return to Kumasi, Dr. Badu-Apraku will work in transferring the maize streak resistance technology to the Ghanaian program, with the use of leafhopper-rearing facilities that IITA is helping to set up. He is also keen to combine eating quality characteristics of local "dent" varieties (soft-textured kernels which are preferred in Ghanaian-style cooking) with high-yielding improved varieties.

The value of the mutual support among IITA and its collaborators is reflected in a letter received from the recently retired head of Nigeria's maize research program, Dr. C. E. Ago:

I took over leadership of maize at the National Cereals Research Institute in 1981. The eight years which followed were the most dramatic for any crop in Nigeria. National production rose from about 1 million tonnes to about 4.0 million tonnes. National average production rose from about 500 kg/ha to about 2.0 t/ha. The hybrid maize program was executed to an admirable point. Seed companies were functioning. A national seed law was in place. A national varietal release mechanism was in place. The nationally coordinated research program designed along the lines of the national maize breeders meeting was functioning. In all these, we cooperated closely with others in order to make these happen. I like to feel I made a small contribution. And I urge you to keep up the good work. Please express my personal thanks to the program at IITA for all its help when I was in maize. I wish you success in your future endeavours.

Yours sincerely,
C. E. Ago

Rice Research

Africa produces only half as much rice as it consumes, a shortfall which must be made up with imports. Yet the potential for expansion and intensification of rice cultivation is great. With an estimated 203 million hectares of land suitable for rice, African farmers cultivate only some 4.9 million hectares, or 3 percent of the total.

Demand, primarily from urban consumers, is increasing faster for rice than for other staple crops: Africans consume about 5 percent more rice each year than during the previous year. With improved rice varieties, improved cultivation methods and greater exploitation of available land, Africa should be able to make up this rice deficit and more, and provide for the expected growth in consumption needs.

To harness the potential of African rice, IITA began in 1970 to develop technologies for efficient and sustainable production in different growing environments. With the strengthening of the research program of the West Africa Rice Development Association (WARDA), IITA has since 1987 been gradually transferring rice research activity to its sister institute, with the goal of completing the handover by the end of 1990. IITA decided to phase out of rice improvement as a way to rationalize resources in the Consultative Group on International Agricultural Research (CGIAR) system and to permit a sharper focus on its other mandate crops.

WARDA scientists are being thoroughly familiarized with the IITA rice germplasm collection, production technologies and benefits of research experience gained over the past 20 years. IITA scientists have continued germplasm collection, breeding trials and cropping system research during the current interim period so that momentum is not lost during the transition. Scientists from both institutes have jointly visited each other's trials and worked out a cooperative long-term plan, contributing to a smooth transition.

Strategies. Rice breeding work since 1987 has been tailored to the needs of the transfer of IITA's germplasm and research results to WARDA. Earlier strategy had been based on breeding of pest- and disease-resistant varieties that would respond to improvements in crop management with higher grain yields than possible with traditional varieties. The target ecosystem for rice had been the inland valleys of West and Central Africa. Since the International Rice Research Institute (IRRI) works on global rice problems, IITA had sought to complement those efforts by focusing on resistances to constraints that are more important in, or in some cases wholly restricted to, Africa. IITA rice scientists participated in the interdisciplinary Rice-based Systems Working Group (renamed the Inland Valley Systems Working Group in 1989: see Resource and Crop Management Program article).

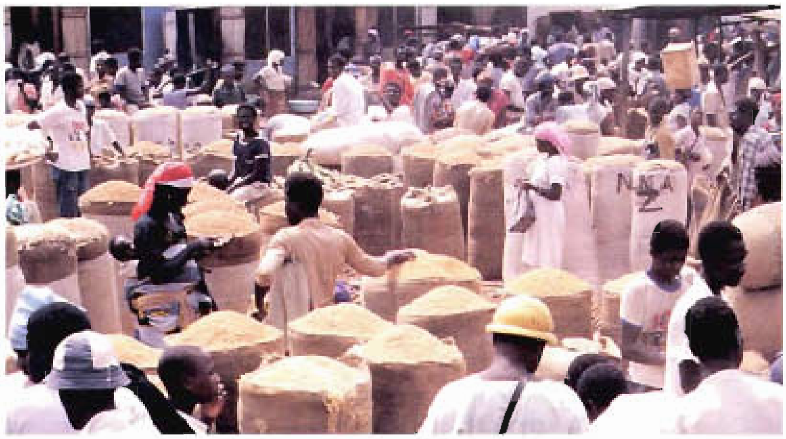
IITA has continued to collaborate with scientists in national programs in West and Central Africa in strengthening and broadening research into different environments. These linkages, built up over the past two decades, are an invaluable part of the corpus of work being given to WARDA, and must be sustained during this interim period. Examples of past collaboration are given in later paragraphs.

Central to IITA strategy in working with national programs has been the facilitation of timely and purposeful exchanges of germplasm. The rice program has supported the International Network for Genetic Evaluation of Rice (INGER-Africa), an IRRI project which distributes advanced germplasm for testing in Africa.

The program has also responded to special requests for germplasm at different "unfinished" stages in the breeding process. Some examples are: crosses to combine particular traits; early-stage experimental materials, such as segregating populations; and larger volumes of seed for pre-release multilocational testing and seed multiplication. These activities provide national program breeders with access to the world's best rice germplasm, in the forms most useful for their needs.

Achievements. The IITA Rice Research Program will close at the end of 1990, as all rice improvement work is transferred to WARDA. So it is timely that some of the achievements of 20 years of rice research at IITA be summarized in these pages.

With its first experiments in breeding upland rice during the mid-1970s, IITA found that Asian varieties adapted poorly to the acid, nutrient-poor African soils, and they succumbed to diseases. So the rice program assembled and began building on a base of traditional African land race germplasm, as well as excellent lines from the Institut de Recherches Agronomiques Tropical (IRAT) and some valuable Brazilian materials which had evolved in or been selected for similar ecosystems. IITA breeders selected for a shorter, higher-tillering plant type in order to improve the yield potential, and for longer grains of higher market value, while at the same time preserving the excellent stress and disease resistance of the source material. IITA scaled down its upland work after the strategic review recommended, in 1987, that it concentrate its resources on the inland valleys.



The rice in this Nigerian market place is evidence that a beginning has been made in filling the region's rice deficit.

Perhaps the greatest impact of the upland rice work has been the spread of the varieties ITA 150 and ITA 257 across the forest and moist savanna belts of Nigeria. Through aggressive seed production programs by the Federal Government and State Agricultural Development Projects, seed has reached the farmers and the varieties have met with an enthusiastic reception. ITA 257 has taken on such colorful local names as "Canada", "three-month rice" and "Wanikiran" (meaning "antelope" in the Tiv language, for its rapid maturation and brown husk color resembling antelope skin). ITA 257 is also well accepted in Sierra Leone, one of West Africa's most rice-dependent countries. The short-duration growth cycle of ITA 150 and ITA 257 results in quick returns on investment for farmers and improved total income, because the two varieties are ready for harvest when prices are at their annual peak in July/August, well before the lowland rice crop reaches the marketplace. Their excellent eating quality also earns price premiums.

IITA's previous priority environment for rice, the inland valleys—which stretch from the humid forest northward to the savanna—present many challenges, not all of which can be solved with better breeding. Inland valleys are ubiquitous in West and Central Africa, and are under-utilized at present. With good water supply yet sufficient drainage, these valleys are ideally suited to rice. Yet they are also characterized by lack of water control, rough tillage, uneven stand establishment and heavy weed infestations. For this environment, IITA selected for a plant type that would help the plant to compete with weeds and tolerate physical stresses. Such varieties have good seedling and vegetative vigor, moderate to high tillering and moderately long, erect leaves, and medium to tall height; yet they have stiff, erect stems that resist buckling or blowing over. Breeding efforts aimed to combine resistances to three major constraints—blast fungus, yellow mottle virus and iron toxicity—with high yield and good plant type.

IITA's breeding program for the inland valleys began early in the 1980s, and was proposed for priority by IITA's strategic review in 1987. Excellent varieties are just now reaching the final testing stages in national research programs. They are poised to make a significant impact in this agroecological zone over the next decade, and also will enable WARDA to begin its work in the area with superb elite materials.

Despite its high productivity, the limited extent of irrigated rice cultivation in the region led IITA's strategic review of 1987 to recommend reduction in that area of research. Finally, tolerance of rice yellow mottle virus and gall midge has been incorporated into varieties of the "green revolution" high-yielding type, long proven to be appropriate for this form of cultivation.

Work on irrigated paddy varieties began before its upland work, early in the 1970s, and has achieved an exceptional record of success. The best of them have world-class yield potential. For example, in 1983, ITA 212 was among the top few varieties in global yield trials conducted at 30 locations all over the world by INGER. In addition to their high yield, farmers prefer them for their better blast resistance and slender grain shape, which brings higher prices. Five of the irrigated varieties have been released by the Government of Nigeria and are widely grown in irrigation projects. They are also rapidly spreading into other West and Central African countries. ITA 222 and ITA 306 are spreading in Cameroon. ITA 306 is commercially grown in Ghana. ITA 212 is important in the Republic of Benin. Also notable in irrigated paddy rice breeding was the 1977 release of "Suakoko 8" in Liberia, the first African improved variety to show resistance to iron toxicity. An IITA collaborative project with the Central Agricultural Research Institute (CARI) of Liberia developed it. Several varieties with iron toxicity resistance but better plant type than Suakoko 8 have since emerged, most notably ITA 247, ITA 249 and ITA 328.

from collaborative research with CARI, WARDA and Nigeria's National Cereal Research Institute (NCRI).

To exploit the research results to the fullest, IITA has collaborated with INGER-Africa since 1985, supplying logistical needs for the program. INGER-Africa helps to systematize the flow of advanced germplasm, as well as to foster awareness and communication among the small and scattered national rice breeding projects of sub-Saharan Africa.

1989/90 Highlights

Breeding. In upland rice breeding, final-stage multilocational yield testing of the most advanced material ensures that the best lines have been identified and adequate amounts of seed secured for efficient transfer to WARDA. Data gathered from international trials over the past three years confirms the outstanding performance of five lines in particular: ITA 301, ITA 305, ITA 315, ITA 317 and ITA 321. These varieties are now being considered for release in many countries.

Final-stage testing of advanced germplasm for the inland valleys has also identified several highly promising lines. Five new lines were given ITA numbers in 1989/90, namely, ITA 340, ITA 342, ITA 344, ITA 346 and ITA 348. The designation of an ITA number indicates "elite" status based on outstanding performance over years and in many testing locations. In addition, about 150 advanced lines were distributed to national programs for their own testing, through INGER-Africa and also by special request of collaborating scientists. Lines were also submitted for worldwide testing through the global INGER network. This year represents the first widespread distribution of IITA's rainfed lowland material, which is indicative of the current maturation of this relatively new breeding project. The payoff is just beginning, and WARDA will benefit in utilizing these new materials.

Breeding for the irrigated paddy zone focused on rice yellow mottle virus resistance, a growing threat. Progenies of eight new crosses combining resistance to rice yellow mottle virus with good plant type were identified as promising during the 1989/90 crop year. Resistance comes from the donor parents ITA 235 and CT 19. About 80 advanced lines were submitted to INGER-Africa for regional testing under virus pressure. Five particularly promising lines will be considered for ITA status after another season's testing. These lines will help WARDA in starting work on the virus.

African gall midge. A severe outbreak of African gall midge, a tiny, mosquito-like insect, destroyed thousands of hectares of rice in Nigeria during 1988, driving many farmers out of the rice-growing business altogether. The pest continued to spread in 1989, devastating even larger areas. During 1989/90 IITA conducted studies on the pest's life cycle, its biological control and identification of resistant lines for WARDA's future breeding use, in collaboration with scientists from NCRI, several Nigerian universities and local agricultural development project staff in affected areas. The project has confirmed that several wasp-like species are extremely effective in parasitizing the gall midge and look promising as biocontrol agents. Through training of local extension agents, farmers have learned how best to avoid the pest, as well as to help IITA and NCRI staff to collect detailed survey data and to run multilocational trials. This project helped maintain contacts with the Nigerian program so that WARDA will have a strong ongoing linkage to take over from 1991.

INGER-Africa. Ten types of nurseries were composed and distributed in 1989/90, tailored to upland, rainfed lowland, irrigated, and mangrove swamp rice ecologies, as well as special sets for blast and yellow mottle virus diseases. In 1989, INGER-Africa organized a monitoring tour to East Africa, which visited Madagascar and Kenya, followed by a workshop in Nairobi. In 1990 the tour visited the mid-altitude, cold-affected environment of Rwanda and planned to visit Burkina Faso, Côte d'Ivoire and Mali. IRRI and WARDA have made plans for the transfer of INGER-Africa to WARDA.

USAID/IRA collaboration. IITA has contributed the work of a breeder and agronomist to a bilateral project, National Cereals Research and Extension (NCRE), between the U.S. Agency for International Development (USAID) and the Institut de Recherche Agronomique (IRA) of Cameroon. Their goal is to breed high-yielding varieties and more cost-efficient crop management technologies for the country's irrigated rice development projects, and in the process to train Cameroonian researchers to high scientific standards. Cold tolerance is a major objective in the mid-altitude projects in the southwest, while blast and bacterial leaf blight are the primary concerns in the northern lowland areas. Several superior varieties have been identified and are being disseminated to farmers. The costs and benefits of green manures–as internal sources of nitrogenous fertilizer–and different crop rotations have been assessed. Some improved machines such as automatic transplanters were tested and found promising. IITA's involvement in the NCRE project will finish at the end of 1990.

Biological Control

The Biological Control Program originated at IITA in 1979 as an urgent experiment to combat the cassava mealybug and the cassava green mite, two recent and decidedly unwelcome immigrants from South America. Uncontrolled, the two pests were spreading rapidly in Africa's cassava belt—an area larger than the United States of America—threatening yield losses as high as 80 percent to the sub-Saharan region's most important crop, the staple food of some 200 million people.

The conventional, chemical response—frequent dousings with potent insecticides—would have been ecologically brutal, socially unacceptable, economically expensive and practically impossible.

A biological alternative, enlisting nature's own agents and mechanisms to keep pest populations in tolerable balance, appealed as an effective solution. IITA's scientists already knew that, on their home ground in South America, mealybug and mite populations are naturally controlled by biological antagonists, including parasitic wasps and ladybugs.

Arduous field research in South America, all the more difficult because the mealybug is present at low levels in the coevolved ecosystem of that region, had identified that pest's primary natural antagonist: *Epidinocarsis lopezi*, a parasitic wasp. The successful establishment of this wasp in Africa promised prompt, self-perpetuating and self-regulating mealybug control.

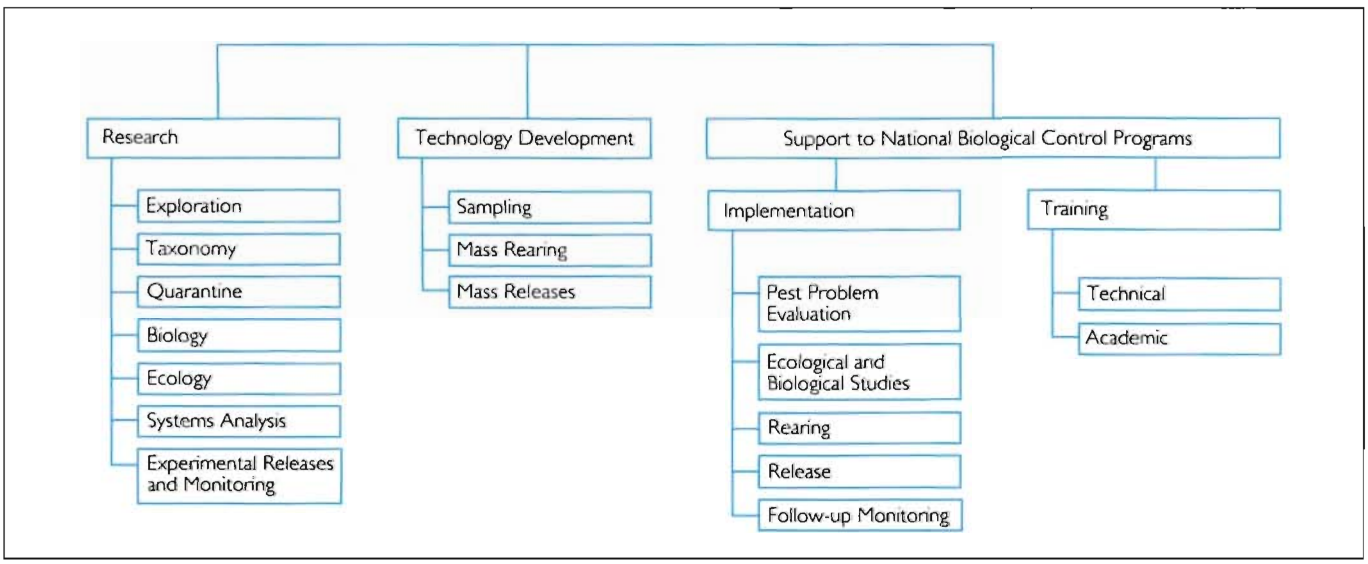
The biological strategy was also attractive because of its logistical efficiency. To succeed, *E. lopezi* required no effort from networks of extension agents, nor from individual farmers. IITA's biological controllers needed many thousands of laboratory-bred wasps, to broadcast from airplanes or release on the ground with governmental cooperation in the affected countries.

For a natural enemy of the cassava green mite, IITA and cooperating governments appear to have established the exotic phytoseiid *Neoseiulus idaeus* from Brazil, in the Republic of Benin in West Africa and in Kenya in East Africa.

Program achievements

Biological control of the cassava mealybug worked from the start: the introduced wasps, multiplied at IITA and released in cassava-growing regions, readily established themselves in the African environment and promptly set about reducing mealybug depredation by half or better, in many areas to virtually subeconomic levels. (See story on 1990 King Baudouin Award in the Research Highlights section.)

The early success of the campaign established biological control as a key element in IITA's research. The



application of biocontrol strategy to other crop/pest problems rests on a full understanding of the ecology and life cycle of the pest and its antagonists. The biocontrol project became a full IITA program in August 1988 and moved to new quarters in the IITA station at Cotonou, Republic of Benin in November 1988.

To the original pair of enemy targets, the program is now, through such ecosystem analysis, exploring opportunities to add the complex of cowpea pests, the banana and plantain weevil, the larger grain borer (a storage pest of maize), the mango mealybug (see inset story "Practice Makes Perfect") and polyphagous grasshoppers, which are a pest of a number of crops in the savannas. The potential for control of the parasitic weeds striga and *Imperata* is being explored.

In all cases, biological control will be used as one among other components—host-plant resistance, cultural practices—to develop an environmentally sound, integrated pest management approach.

New research facilities on a 50-hectare site at the IITA Benin station include laboratories and offices for scientists, their students and technicians, and visiting scientists; a library, an insect/mite museum and a communication center; and six air-conditioned "teflon greenhouses", an insectary and mechanized units for mass rearing of insects. Meeting and training facilities adjoin the new complex, which have been planned for shared use with kindred organizations for research on pests of crops outside IITA's mandate (including plantation crops, cash crops). Africa now has an environmentally safe facility to conduct biological control research for all of its major pests.

A unique technology of the IITA insect-rearing system is the artificial cassava tree, an armature on which up to 180 cassava plants grow in a nutrient water solution. The device was developed by the program's scientists to simulate ideal natural conditions for the mass rearing of the mealybug and mite pests and their antagonists. Its inventors refined the system in 1988 by eliminating all mechanical and electrical components, substituting a drip-irrigation system that increases plant growth while it reduces the need for labor and the chance for error. This rearing technology can be adapted to different environmental conditions, including climatized greenhouses or plastic shelters. The program had distributed several such "cassava trees" to 14 national programs by 1990, enabling cassava-growing countries to begin arming themselves for biological control of the mealybug, the cassava green mite and other pests.

Since its initial success, the program has maintained its biological offensive against the cassava mealybug. By 1989, natural enemies of the cassava mealybug had

IITA had to invent this "cassava tree" to produce cassava leaves as part of its mass-rearing system for mealybugs and their natural enemies.

been released in about 150 sites in 19 countries of western, central, eastern and southern Africa. The principal one of them, the wasp *E. lopezi*, has made itself at home over more than 2.7 million square kilometers in 24 countries of the continent's cassava belt. The distribution of this parasitoid greatly exceeds that of any other ever introduced into Africa for biological control purposes. IITA scientists have identified other natural enemies of the mealybug in South America, and have successfully introduced some of them into the African environment. One of the program's most important contributions to research strategy is that it has made evaluation of campaign effectiveness into a feature of its regular activity. Some ecological pockets remain, where control has not been satisfactory, which are being studied and subjected to alternative solutions. In other areas, scientists are becoming familiar with the principles of biological control. They differ from chemical control in that the aim is to reduce (not eliminate) pest numbers to an equilibrium such that economic damage is kept minimal.

The results from the work of the biocontrol team for cassava green spider mite (*Mononychellus tanajoa*) are promising. This exotic pest was first seen attacking cassava in East Africa early in the 1970s, from where it quickly spread to 27 cassava-belt countries where it has been causing losses of up to 80 percent of yield. Since 1984 the team has made experimental releases of nine predator species and various strains in ten countries of the African cassava belt, covering different agroecological zones. Since early in 1989, populations of two phytoseiid species imported from Brazil have been released and recovered throughout the wet season for some, but not all, release sites. This pattern has persisted in Benin since April 1989. Subsequent wet and dry season recoveries have also been made of the phytoseiids from Brazil released during the wet season in 1989 in Kenya.

Training. The program has also trained biocontrol professionals at three levels of competence. At the most basic level, laboratory and field technicians are taught the basic methods of biological control, entomology and general crop protection. Their training emphasizes techniques for surveying pest damage, and for sampling pest populations before and after release of their natural enemies. Promising candidates for master's degrees in biological control or pest management, recruited from the technical training courses or directly, are sent to selected universities in Africa or overseas. And doctoral candidates, including top-ranking students from the master's program and other well-qualified applicants, cap their university studies with thesis research in Africa.

Trainees at a recent biological control course at Cotonau examine host-plant cassava leaves as part of their curriculum in control methods.

By 1988, more than 250 biological control specialists from 35 African countries had received IITA training. During 1989, a total of 128 trainees took courses at IITA and also in Zaire, Tanzania and Mozambique; 16 fellows pursued M.Sc. or Ph.D. programs.

Benefit:cost ratio. IITA's experience testifies that biological control strategies, well conceived, well planned and well executed, can work against major pests of important crops in Africa's diverse environments—and can repay their costs many times over. Assuming the rapid spread of both the cassava mealybug and *E. lopezi* throughout the entire cassava belt, an independent review team recently estimated the annual gain in cassava yield from control of the mealybug at 10.2 million tons.

"Reasoning that the benefits will continue for years, decades and even centuries, as seems likely," the reviewers concluded, "the benefit:cost ratio of the IITA project will become very large"—and is estimated at 149:1 over 25 years for the mealybug project.

Operational strategies

The objectives of biological control research are being expanded to include the pests of other crops in IITA's mandate, and weeds, as biological control science becomes a component of integrated pest management in the IITA research agenda. Biocontrol work will be integrated with the search for host-plant resistance in commodity improvement work, with weed control strategy and with work on other fronts of pest management as contributions to reduction of the risks for family farms.

The IITA Medium-Term Plan (1989-1993) envisages a gradual decrease of research and control activity with mealybugs as the present campaign reaches its successful conclusion, probably by the end of 1991. Research and practical action to control green spider mite are expected to continue throughout this five-year period, but the nature of IITA's involvement will gradually change. The implementation of biocontrol campaigns will be transferred to national biological control programs and IITA will concentrate on research and research training.

The Biological Control Program scales its research activities and operations according to the character and dimensions of the problem in its geographical area. The selection of pests and the problems to be tackled depends on their economic importance.

IITA's biocontrol scientists take a phytosanitary approach to pest control problems—their assumption is that a vigorous plant in a healthy environment is less susceptible to damage by the pest. They proceed from this point of departure to develop a full understanding of the plant within its ecosystem. The objective is to produce a holistic solution to the pest problem and apply control measures that accord with the greater environmental and economic objectives of the concerned government.

Against each pest, the program organizes a group of appropriate specialists for a three-pronged attack that includes research, training and support of national biocontrol programs. Researchers study the plant's

Practice Makes Perfect: A New Mealybug Threat Is Contained

A new mealybug was accidentally introduced into West Africa during 1981-1982. It quickly spread through Ghana, Togo and—since 1986—the Republic of Benin. It has recently invaded also Côte d'Ivoire, Nigeria, Gabon, Congo and Zaire. Reported from 45 species of crop plants, ornamentals and wild plants, its main target is the mango tree. Where populations of this mealybug have been high, the heavy accumulation of honeydew and the resulting black cover of sooty mold has stopped further plant growth, flowering and fruiting, and has often led farmers to fell their trees.

After an initial misidentification, the species was newly described as *Rastrococcus invadens* Williams (Homoptera, Pseudococcidae) with a south-east Asian origin. Intensive search by the CAB International Institute of Biological Control (IIBC) in India led to the discovery of a promising parasite wasp, *Gyranusoidea tebygi* Noyes (Hymenoptera, Encyrtidae).

Studies on the bioecology of *R. invadens* in Africa began with a Food and Agriculture Organization (FAO)-financed project at the Plant Protection Services in Cacaveli, Togo and at the Plant Protection Services in Porto Novo, Benin. Both services are supported by the Gesellschaft für Technische Zusammenarbeit (GTZ). At an FAO-sponsored workshop in Lomé in October 1987, the groundwork laid earlier by IITA's Biological Control Program against the cassava mealybug was recognized as a model for action against *R. invadens*. A regional project for the biological control of this new pest was set up and, with the agreement of the Inter-Africa Phytosanitary Council of the Organization of African Unity, the introduction of natural enemies was recommended by the workshop participants. Close collaboration between IITA's biocontrol program and IIBC in training, the introduction of natural enemies and research was also recommended. In all the countries concerned, the expertise to carry out research and operational aspects in the fight against *R. invadens* was already in place in national biological control programs, which had been set up and trained during the cassava mealybug project.

Releases of *G. tebygi* reared at the Cacaveli insectary started at the end of 1987 in Togo. The parasitoid proved to establish on *R. invadens* wherever it was released. By the end of 1988 it had penetrated into the border area of Benin's Mono Province, and pest populations soon collapsed in Togo.

At IITA, a special project on biological control of mango mealybug, separately funded by the Swiss government, had been added in the biocontrol program late in 1987. It has extended its activities into several countries, as described here.

Research Directions

• Expansion of the current cassava simulation model to include different ecological zones, effects of soil and plant nutrition, different cassava varieties (local and IITA improved) in different cropping systems (monocrop and intercropping), the mealybug and its natural enemies, and hyperparasitoids. The model will consolidate all our knowledge on the cassava mealybug system in Africa.

• Evaluation of the impact of two Brazilian strains of phytoseiids which are showing some success in the field against the cassava green mite. Establishment in the field can be declared if these exotic populations survive the next dry season (November 1990 - February 1991).

• Development of a demographic simulation model of the insect pest of cowpea, the bean flower thrip (*Megalurothrips sjostedti*) which will be incorporated into the cowpea model as a means of assessing plant-pest interactions. Other studies of the effects of the pest on the plant and on the pest's egg-laying behavior will be undertaken.

• Analysis of the mango mealybug's population dynamics, the results of biological control experiments on mango trees and the impact of the released parasitoid on the mealybug and on the mango market.

• Development of growth models for maize and two stemborer pests, together with a series of pest-plant field ecological studies and pest population studies.

• Development of a biocontrol campaign for the larger grain borer *Prostephonus truncatus*, an important pest of maize.

• Development of a survey of the banana and plantain weevil and its interactions with its host species.

• Collaboration with IIBC in the assessment of alternatives to chemical control for locust and grasshopper in Africa.

• In Nigeria, the quarantine authorities were informed of the presence of *R. invadens* in the south-east of the country and were assisted in a survey to determine the spread of the mealybug. Throughout 1989, numerous shipments of *G. tebygi* were sent to the National Horticultural Research Institute for release in all infested areas covering the southern half of the country.

• In Ghana, the Quarantine and Plant Protection Services of Pokoase were supplied with *G. tebygi* and assisted in releases over all infested zones. The exotic parasitoid quickly established itself and spread. A marked reduction in mealybug population densities followed.

• In Gabon and Zaire, *G. tebygi* was released during 1989 in collaboration with the national biological control programs.

• In Benin, *G. tebygi* was reared from January 1988 in newly constructed biocontrol facilities. In May 1988 the parasitoid was released for the first time at Calavi. In November-December 1988, the Plant Protection Services at Porto Novo made more releases covering all infested areas of the country with wasps, which came partly from the IITA biocontrol program and partly from a newly established insectary at Porto Novo. *G. tebygi* has become established throughout Benin even in remote fields. During 1989 it drastically reduced mealybug populations in the south, so that mangos could be harvested abundantly again after several years of almost total crop failure.

Parasitic **Gyranusoidea tebygi** *lay their eggs in mango mealybug larvae on a mango leaf.*

In summary, preliminary results show excellent control. Mango mealybug populations have been reduced to negligible levels and mango production has been restored following two years (1987-1988) of crop failure. Nevertheless, the mango mealybug is still spreading and releases are continuing in affected areas.

As in the biological control of the cassava mealybug, the mango mealybug project is characterized by highly coordinated international collaboration in a clear-cut and simple approach, leading to ecologically and economically sound pest control.

physiology and growth patterns, the better to understand the plant's vulnerability to the pest. They study the biology and ecology of the pest, in both field and laboratory, and of the pest's natural enemies, both exotic and indigenous. Developing appropriate sampling methods and computer simulation models, the researchers investigate the agricultural and ecological contexts in which plant and pest coexist, and assess the economic costs attributable to the pests and the net benefits to be derived from biological control, or from other forms of integrated pest management.

Models of the crop-pest problematique have been developed for cassava and cowpea. Models for maize and for the intercropping system of cassava + maize + cowpea are being developed. These models open the way to a scientific understanding of the systems involved, which leads to development of pest management/control strategies and, eventually, to assessment of the effectiveness of the control effort.

International collaboration

The control strategies for cassava mealybug and cassava green spider mite are examples of how the IITA biocontrol program trains future leaders and technicians of national crop protection programs. Training goes hand in hand with a two-phased approach to control programs: preliminary research activities and program operations. The IITA program works with national staff toward the eventual transfer of all operations to a national or regional program responsibility.

A "pioneer" staff is trained to take on different tasks as described in preceding paragraphs. The first task in the research phase is a survey of ecological conditions in the infested target areas for pest control. The densities of pest populations and conditions which promote or inhibit the survival of pests and natural enemies are investigated. Exotic predators are selected and are released in the field in an experimental effort to assess the likelihood of success for a large-scale program. After a trial period of varying length, according to ecological conditions, the IITA-assisted national team follows up the releases with another survey, to determine whether the introduced predator species has established itself and how much of a dent it has made in the pest population.

The operations phase of the pioneering campaign begins with trial rearing of natural enemies, after the national government has confirmed its commitment to a biocontrol program with budget and manpower allocations. A small-scale rearing operation serves to familiarize the new staff with the production process and the problems they are likely to face in sustaining a full-sized production effort.

The IITA biocontrol program provides the mother stock of natural enemies and new cultures periodically as required in order to maintain fitness of the populations being reared. For emergency releases requested by countries, and for compaigns against cassava green mite for which natural enemy rearing is problematical, the IITA program is ready to provide regular assistance. The IITA program has thus assisted national programs across the African cassava belt. The next countries slated to receive assistance in starting up rearing activities are Burundi, Gabon, Ghana, Tanzania and Zaire.

Locusts have been targeted for IITA research into biological alternatives to chemical pest control.

International Cooperation

The special role of international cooperation at IITA is to strengthen the capacities of African national research systems to select, adapt and generate improved technologies for their own agricultural development. The best cultivars or technologies from IITA cannot be delivered to farmers' fields without the participation of the national programs at every stage, from the early definition of problems to the fine-tuning of solutions for local use.

Cooperation strategies . . .

The principal means by which IITA strengthens agricultural research in the 22 countries of its mandated area are training, information dissemination, germplasm exchange and other collaborative project activities which convey IITA technologies.

Four mechanisms have been designed for the strategies in the IITA Medium-Term Plan (1989-1993) to enhance usefulness of collaborative research and training activities and enable IITA to respond with greater sensitivity to perceived needs. They are:

- **Networking.** Collaborative networks link IITA with national and regional research institutions in Africa and elsewhere, to address common problems and issues.

- **Research liaison scientists.** The Medium-Term Plan provides for three research liaison scientists. One is working with the anglophone countries of West Africa, while another will work with all Central African countries. A third (to join IITA during 1990) will work with the francophone West African countries.

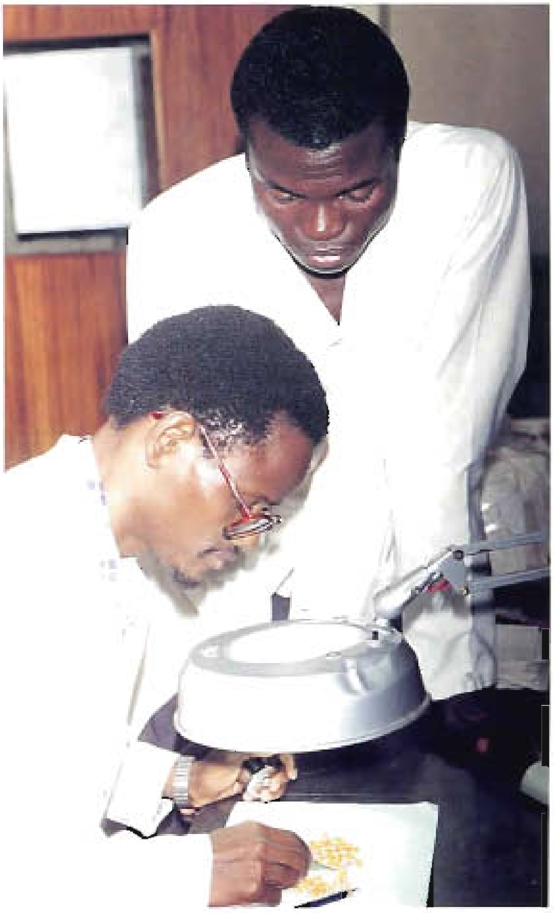
- **Resident scientist teams** in specific countries collaborate with national colleagues in adapting IITA technologies to meet crop research problems and needs.

- **Training.** The training program within international cooperation provides training opportunities to national scientists in the form of graduate research fellowships, short-term courses and short-term attachments to acquire specific skills in IITA research programs. Short-term fellowships are arranged for visiting scientists from national programs to do collaborative research for periods of up to 12 months, whereby they acquire new insights and skills at IITA which can be applied in solving specific problems in their home countries. Training achievements are described in the last part of this article.

The international cooperation program manages special projects which involve the national programs with IITA as the executing agency. During 1989, IITA operated 18 such projects in various sub-Saharan countries with 46 scientists, whose technical support was designed to strengthen national capacities to conduct adaptive research. Examples of on-going collaborative projects are described in the next section on achievements. Salient funding features are given in table 1 on the next page.

. . . and achievements

Networks. Through network activity, IITA has encouraged complementarity among research programs of various countries and their interaction



Dr. D. K. Kossou, a visiting collaborating scientist at IITA, is engaged in entomological research with the maize program.

Table 1. Bilateral and multilateral special projects, 1989

Project	Donor(s)	Total staff	Life budget US$ million	1989 budget US$ million
Institution-Building				
NCRE II/Cameroon (terminates December 1990)	USAID	19	14.31	3.35
RAV/Zaire (terminates September 1990)	USAID	11	8.12	1.96
Resident Scientist Teams				
Ghana Grains Development	CIDA	1	1.12	0.13
Ghana Smal holder	IFAD	1	0.8	0.07
Cameroon Root Crops (terminates June 1990)	France	2	0.7	0.07
Congo Kindamba	IFAD	-	0.4	0.07
SADCC Cowpea Project (to begin in 1990)	EEC	3	1.78	-
Networks				
SAFGRAD	USAID	2	4.08	1.00
ESARRN	USAID	1	1.94	0.42
	IDRC		0.76	0.06
AFNETA	CIDA/IDRC	2	3.17	0.73
	USAID		1.00	-
	DANIDA		0.07	0.57
	IFAD		1.20	-
Other Research Projects				
On-Farm/Adaptive Research (to begin in 1990)	EEC	-	2.79	-
Improved Agricultural Research Systems	FF	-	0.15	0.11
Soybean Uti ization	IDRC	-	0.16	0.05
Legume Viruses (to begin in 1990)	IDRC	-	0.46	-
Ut lization of Cassava Flour	AGCD	-	0.64	0.24
Dynamics of Soil Organic Matter	AGCD	-	0.16	0.16
Training Projects				
Human Resources Development	UNDP	-	0.78	0.34
Training of Women Agricultural Professionals (East/Southern Africa; to begin in 1990)	FF	-	0.28	0.17
Training of Women Agricultural Professionals (West/Central Africa; to begin in 1990)	FF	-	0.42	-
Totals		**42**	**45.30**	**9.51**

with other international agricultural research centers. Through networks, IITA backstops research efforts with improved germplasm and technical information. IITA has helped networks in identifying funding sources and providing technical support until the member institutions can sustain the effort on their own. Such networking projects include the second phase of SAFGRAD, ESARRN and AFNETA. These networks have elected steering committees which guide their coordinators in implementing activities.

AFNETA came into being during 1989 and held an inaugural conference and a training course in August on alley farming research technologies. The first two issues of its newsletter, *The Afnetan*, were published in that year. AFNETA has received collaborative research proposals from 28 institutions in 17 countries, which were funded and launched from early in 1990.

ESARRN activities during 1989 included germplasm exchange, workshops and scientific exchange visits among member institutions. In Malawi, introduced IITA cassava lines were hybridized with the best local selections, producing some 146,000 seeds through open pollination. Prolific local parents produced four-fifths of all seeds. Two seedling nurseries were established for cassava and one for sweet potato, and improved IITA cassava lines were imported in tissue culture form and multiplied for distribution in various projects. Three graduate students completed their M.Sc. degrees with ESARRN support. Altogether 24 technicians were trained in-country and at IITA.

The SAFGRAD maize network supported several of its member countries in testing of improved germplasm and crop management techniques. It sponsored various technical training and exchange visits, including a five-month course for technicians from three countries in trial management, varietal maintenance and related areas.

The SAFGRAD cowpea network received feedback on 42 of its 53 regional trials. National programs will repeat the trials during 1990 and promising lines will be taken to the next stages of multilocation trials and on-farm testing, before release to farmers. National scientists benefited from formal group training, exchange visits and interaction with IITA scientists in research planning. Some new cultivars have gained wide acceptance in West African countries after being developed in the network, including SUVITA-2 which was developed in Burkina Faso and is being widely cultivated in Seno province, Mali.

Research liaison scientists. The scheme was introduced during 1988 as an initiative intended to link identified needs in research and training in national institutions with the relevant IITA programs. The 22 national agricultural research systems in IITA's particular area of concern, West and Central Africa, are diverse in terms of research infrastructure, technical expertise and manpower, material resources, capacity to set and pursue research priorities that are in line with national development goals, and capacity to transfer research results to the farm through effective extension linkages. It is essential that IITA understand all these aspects of national systems. To that end the research

Acronyms cited in the text

AFNETA	Alley Farming Network for Tropical Africa
AGCD	Belgian Agency for Cooperation and Development
CIAT	Centro Internacional de Agricultura Tropical
CIDA	Canadian International Development Agency
CIP	Centro Internacional de la Papa
CIMMYT	Centro Internacional de Mejoramiento de Maiz y Trigo
CTA	Technical Centre for Agricultural and Rural Cooperation, Netherlands
DANIDA	Danish International Development Agency
EEC	European Economic Community
ESARRN	East and Southern Africa Roots and Tubers Research Network
FF	Ford Foundation
GCF	Gatsby Charitable Foundation
GTZ	German Agency for Technical Cooperation
IBSRAM	International Board for Soil Research and Management
ICRAF	International Council for Research in Agro-Forestry
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IDRC	International Development Research Centre, Canada
IFAD	International Fund for Agricultural Development
ILCA	International Livestock Center for Africa
INIBAP	International Network for Improvement of Bananas and Plantains
NCRE	National Cereals Research and Extension Project, Cameroon
RAV	Applied Agricultural Research and Outreach Project, Zaire
SADCC	Southern African Development Coordination Conference
SAFGRAD	Semi-Arid Food Grains Research and Development Project, Burkina Faso
UH	University of Hohenheim, Federal Republic of Germany
UNDP	United Nations Development Programme
USAID	U.S. Agency for International Development

"Farmers' Day" at IITA brings together scientists and trainees from the international cooperation program with Nigerian farmers, to gain a practical perspective on research concerns.

liaison scientist role has been conceived and information-gathering begun in a five-year action plan.

IITA research liaison scientists made introductory visits during 1989 and early in 1990 to research institutions in four francophone countries of Central Africa (Cameroon, Congo, Gabon, Zaire) and four anglophone countries of West Africa (Gambia, Ghana, Liberia, Sierra Leone) to discuss new initiatives in collaborative research in the IITA Medium-Term Plan.

In Gabon, IITA scientists participated in a joint assessment of collaborative maize and cassava trials. Plans were made for training course and study tours to IITA by two Gabonese researchers.

In Gambia, IITA scientists joined consultations of the government's task forces on rice, cropping systems and resource management; and contributed to preparations for Gambia's medium-term research plan. Seeds of elite IITA rice and cowpea varieties as well as farm tools (rolling injector planter, rice weeder) were made available for evaluation and adaptation.

A visit with IITA research and training programs was arranged for a Ghanaian researcher from the University of Science and Technology, Kumasi, for exchange of ideas and familiarization with current research on processing/eating qualities of improved cassava clones, soybean seed longevity and promiscuous nodulation, and evaluation of leguminous tree species, e.g. leucaena, for alley cropping.

An IITA scientist visited Liberia in connection with the setting up of a plant and soils laboratory at the Central Agricultural Research Institute, Suakoko. For Sierra Leone, IITA delivered half a ton of streak-resistant maize seed at the request of the Institute of Agricultural Research, Njala, and improved rice seed for on-farm assessment and multiplication.

Resident scientist teams. Teams of two or three IITA scientists work in specific country projects on adaptive research problems: principally, in the Cameroon National Root Crops Improvement Program, the Ghana Grains Development Project, Ghana Smallholder Rehabilitation and Development Program, Nigerian Soybean Utilization Program, SADCC Cowpea Research Project and, before it was completed, the Rwanda farming systems research project. The teams work with national institutions on food crop production problems for which IITA has developed technologies that require adaptive research to suit local conditions. First fielded in the region in 1984, these teams are preferably based in national programs at an early stage of development.

IITA's project with the Cameroonian National Root Crops Improvement Program, to disseminate new cultivars to farmers, completed its final activity in 1989 with the release of three sweet potato varieties and three cassava clones. A 1989 evaluation concluded that the program had succeeded in widely disseminating new sweet potato varieties in lowland and mid-altitude zones of Cameroon. Researchers and technicians received in-service training, and 360 extension agents attended training courses.

In the grain legume component of Ghana Grains Development Project, IITA germplasm was screened for selection of early-maturing, high-yielding, disease-resistant cowpea varieties which combine erect or semi-erect plant type, acceptable seed colour and cooking quality suitable for the maize-cowpea rotation system in Ghana. IITA and local germplasm was screened for the development of high-yielding, bruchid-resistant varieties. Exotic soybean varieties were screened for the selection of high-yielding, early-to-medium-maturing varieties which combine promiscuous nodulation, seed longevity, and shattering and disease resistance. Extension staff received in-country training.

In the Ghana Smallholder Rehabilitation and Development Program, highlights of 1989 included selection of five clones of cassava from IITA for trials in farmers' fields by the Crop Services/Extension Department. The clones selected were TMS 91934, TMS 30572, TMS 4(2)1425, TMS 50395 and TMS 30001. Eighty-five clones of "poundable" cassava were selected from seedlings for further evaluation. The Soronko variety of cowpea was found to intercrop well with the TMS 91934 cassava variety. Three lines of sweet potato—two from IITA and one local variety—were selected for high yields and cooking quality. They have been multiplied for distribution to farmers in the 1990 planting season.

The Soybean Utilization Project aims to develop and introduce improved soybean utilization technology for use in households and in small-scale processing enterprises in rural Nigeria. During 1989, a monitoring survey measured the impact of soybean production and utilization in Oyo State, revealing that the project's training sessions had reached an aggregate audience exceeding 11,000 people. Extruded soybean products were introduced for home use in selected areas and development of small-scale processing technology continued.

Preparations began in 1989 for the SADCC Cowpea Research Project, which will develop cowpea genotypes with suitable resistance and eating quality characteristics.

Institution-building. The prime examples are the NCRE project in Cameroon (see inset story) and the RAV project of Zaire. Such projects bring IITA scientists to work with national colleagues in strengthening specific aspects of their research programs.

The year 1989 marked 16 years of continuous association of IITA with Zaire, and the end of RAV's first phase. Initially the government had invited IITA to seek solutions to cassava pest problems and CIMMYT to undertake maize improvement, which let to the creation of two national programs for those crops, with USAID support. The cassava program's successes in turn led to creation of RAV in 1985 to oversee the cassava and maize programs and a third body for legumes. All three RAV programs have chalked up notable successes in development of new crop varieties, resource and crop management, human resources and links between research and extension services.

During 1989 RAV continued on-farm testing of promising disease-resistant and high-yielding cassava clones, and transferred streak virus and downy mildew resistance to two maize varieties. Two new varieties each of cowpea, soybean and maize were released. Research continued on methods for improving soil fertility and agronomic practices which contribute to increased yield potential.

Training achievements

To conduct agricultural research and development, all national systems need capable and committed professional staffs. When IITA began operating in 1967, the lack of scientists and professionals in African agriculture—especially Africans—was enormous and growing. Training in research for African agricultural professionals at all levels, therefore, was part of the Institute's original mandate; and training remains an essential aspect of IITA's mission today. No proposal to develop or transfer technology from IITA fails to consider the training requirements of the participating countries. In international cooperation's varied partnerships with national systems, training is the constant theme.

To realize the potentials in their own programs or to contribute effectively to regional projects, nearly all national agricultural research institutions in tropical Africa need to improve professional skills on a regular basis through training in various forms. The IITA training program seeks to strengthen their capacities in both research and training. Since 1971 IITA has organized training courses for more than 6,000 participants, most of whom have come from African countries.

The RAV project focuses research attention on cassava leaves, an important vegetable in some parts of Zaire.

IITA's Strategic Plan (1989-2000) set the following guidelines for development of its training program:

- Shifting emphasis at IITA from group to individual training.
- Decentralizing group training to national programs.
- Increasing the proportion of core IITA resources for training.
- Strengthening training materials.
- Increasing women's participation in training.

Individual training seeks to improve research abilities through doctoral, master's and non-degree levels of training tailored to specific needs in national programs. To promote the increase of graduate researchers in Africa, in 1988 IITA initiated the Graduate Research Fellowship Program, that eventually will support 30 graduate students in conducting their research with IITA scientists. Between April 1988 and December 1989, IITA accepted 15 graduate trainees out of 244 applications for the fellowship program, thus achieving the Medium-Term Plan target.

In 1989 IITA scientists supervised 48 Ph.D., 30 M.Sc., and 29 non-degree trainees. (See annex to this article for a summary table.) As part of IITA's special relationship with the University of Ibadan, 12 of the Ph.D. and M.Sc. trainees benefited from IITA research facilities while being registered with the University.

Group training. The aim in group training courses is, foremost, to expand research knowledge and skills.

Double Impact In Cameroon

For country and continent—a cooperative project in agricultural research in Cameroon, funded by the U.S.A. and drawing on IITA knowhow, has had a double impact, helping Cameroon to benefit from its own research and to become a producer of technologies which can benefit other African countries.

The National Cereals Research and Extension (NCRE) Project was conceived to build up Cameroonian capability in cereals research and in translating the results into practical technologies for the farmer. The project was based at the Institut de la Recherche Agronomique (IRA) at Yaounde, with financial support from the United States Agency for International Development (USAID). IITA fielded up to 19 scientists at a time during the first two project phases (1981-1990).

The IITA resident scientist team worked on the four staple crops of maize, rice, sorghum and millet with national staff at stations in Cameroon's six different agroclimatic zones. The team's brief was to help their Cameroonian colleagues to develop research programs, as well as to carry the research through on-farm trials and produce results useful to small-scale or subsistence farmers.

Parallel with the research agenda was a program to transmit research results to extension agencies for onward transmission to farmers, and to communicate farmers' problems to researchers as feedback to enhance the usefulness of future work. This operation was handled through a testing and liaison unit (TLU).

The first phase of the project (1981-1985) saw development of disease- and pest-resistant maize varieties and crop management techniques, with on-farm trials conducted by the TLU. Rice, sorghum and millet varieties were also selected and improved, the latter two with help from the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT). New high-yielding sorghum varieties were released to farmers. Apart from fielding the trials, the TLU trained extension workers and tested new farming techniques and technologies. Cameroonian researchers also began to network with their peers in other African institutes and international centers.

A second phase was launched in 1986 to continue the development of the IRA research programs for crops in all six agroclimatic zones, and to establish TLUs in all zones. The same goal was reaffirmed: the transmission of research results to the farm and feedback to researchers on their usefulness. The IITA team, in working with counterpart Cameroonian scientists, was to transfer knowledge and knowhow to them through training programs and working together.

Already by 1989, seven varieties of lowland maize and four of highland maize were being or about to be released, as were four rice varieties and five sorghum varieties. New agronomic techniques had been introduced with significant impact: use of minimum or no tillage in the North Province had begun to reduce erosion of fragile alfisols. Use of an insecticide as a seed treatment for maize and sorghum had improved seedling establishment and led to higher yields than with earlier seed treatments. TLUs had successfully worked back up the research pipeline to improve on-station experimentation by sensitizing researchers to farmers' problems. The TLUs had characterized the complex production systems in each zone, identifying constraints and opportunities for improvements.

By the end of 1991, it is expected that three Cameroonian researchers will have completed their doctorates and eight their master's degrees in relevant disciplines, while additional doctoral and master's degree candidates will be completing their studies. By 1989, one sorghum breeder and one agricultural economist had already returned to the project with M.Sc. degrees.

The project donor, USAID, has ranked Cameroon in the foremost group of African countries that can research and produce agricultural technologies for other African countries. IRA has become one of the strongest of its kind in the region. Cameroon has developed its research manpower and facilities to a stage of maturity that can demonstrate successful impact from IITA's work with a national research institution.

Because of these favorable factors for agricultural research, IITA has selected Cameroon for the location of the new humid forest station and has begun to set up research facilities for cassava and resource management at Mbalmayo, near Yaounde.

IITA has also decided to continue to provide support to IRA for a third project phase, from 1991 through 1994. The IITA team will continue to focus on cereals research, TLUs and human resources development, together with two new components: sustainable production systems and economic policy research. During this final phase, Cameroonian counterpart staff will gradually replace IITA scientists.

The second and closely related aim is to impart skills and foster attitudes that prepare the researcher-trainees to become, in turn, trainers who will pass their knowledge and skills on to others: research colleagues, extension specialists, farmers and other agricultural professionals.

During 1989, 304 technicians and scientists participated in 15 group training courses at IITA, which collectively amounted to 61 weeks of training. Some 110 persons participated in regional or in-country courses in Benin, Burkina Faso, Guinea Bissau, Kenya and Mozambique. Another 128 participated in individual training programs. (See table 2 for a summary of courses and trainees.) Two courses contributed to the development of new IITA-supported research networks: on alley farming and soil and plant analysis. With regard to the participation of women during 1989, 56 women took part in IITA courses (18 percent of all participants), while 9 women participated in regional or in-country courses (8 percent). Some 16 women made up 20 percent of graduate trainees at IITA/Ibadan and elsewhere during 1989.

Group training received new stimulus during 1989 for future development. A new group training coordinator arrived, and key plans began to be implemented: decentralization of group training activities to national programs, and a shift in emphasis from group to individual training.

Training materials. Decentralization and sharing of training responsibilities with national programs depend on well-trained researchers and easily accessible scientific and technical information. Training materials offer a means to make information available.

Training materials apply in a broad range of activity throughout the training process: assessing needs, specifying objectives, developing curricula and programs, instruction, evaluation and follow-up procedures. The contents should be easily adaptable for the purposes of national programs, and the formats should encourage reproduction and use.

In 1989, a reference manual on cassava in tropical Africa was prepared with UNICEF support and used initially in two training courses. The IITA food crops utilization and nutrition training manual was recast for use in the fourth training course on the subject.

A new training materials specialist arrived during 1989 and put the production of training materials on a new footing, concentrating on training curricula, research guides, production guides, slide collections, posters and charts, and evaluation instruments.

Women in training. Agricultural researchers generally underestimate the contribution of women, who produce by far the greater share of Africa's home-grown food supply. They are often unaware of the impact of new technologies on farm women's lives.

IITA is committed to improving the condition of African women farmers through promoting research results which reinforce or supplement their contribution. In IITA's research programs, multidisciplinary working groups that coordinate cropping systems research are responsible for making sure that new technologies fit the needs of women farmers. And whenever training opportunities are announced, the IITA training program encourages nomination of women participants.

In 1989 IITA developed and obtained funds for a project to train African women for leadership roles: 10 agricultural professionals from West Africa will receive grants to study for M.Sc. or Ph.D. degrees.

Besides the efforts to include women participants in training, IITA is aware that simply increasing numbers is not enough. Gender perspective and gender sensitivity must become part of training curricula. IITA is studying ways to program its training activities and materials which will promote its objectives for women in agricultural research.

Collaboration with international centers. For several years, IITA has worked with CIAT and CIP in a joint training project on human resource development for generation and transfer of root and tuber crop technologies, funded by UNDP. IITA also collaborates

IITA research fellow Mary Mgonjo from Tanzania expects to complete the requirements for her Ph.D. ot the Univeristy of Ibadan in 1990.

IITA's multidisciplinory research groups must ensure that new technologies fit the needs of women formers.

with ICRAF, ILCA, IBSRAM, INIBAP, ICRISAT, CTA, University of Arkansas and other institutions in course planning, development of training materials, course presentation and follow-up, including evaluation.

Future directions in training. IITA's training program aims to help national programs and research networks eventually to do for themselves all the field-level training that is needed to support their own research efforts. Decentralization is a strategy which promotes this aim of IITA's long-term planning. National programs and IITA together offer training that is increasingly organized, conducted and sustained by those programs.

IITA's approach to the "training of trainers" in national programs is evolving and varied according to the needs and opportunities in those programs. Training of researchers to train others is a central part of IITA's decentralization strategy. For full-time training officers in national programs, IITA arranges two-to-three-month attachments to enable them to work alongside IITA training staff to acquire on-the-job experience.

Wherever possible, IITA offers training in national training institutions and invites national scientists to join in training as coordinators, teachers and advisers. IITA in the first instance collaborates in training with those countries that have well-defined plans and goals for research and training, especially those countries with which IITA already has collaborative ties. Involvement in training activities reinforces collaborative ties between IITA and the recipient country.

Table 2. IITA group training courses in 1989

	Weeks	Trainees		Countries
		total	women	
IITA Ibadan				
Editing and publication	2	24	4	5
Village and institution-level cassava survey (Collaborative Study on Cassava in Africa)	2	20	3	7
Advanced soil and plant analysis	4	17	4	14
Root crops research and technology transfer	10	24	6	18
Sustainable food production systems	3	33	3	18
Food crops utilization and nutrition	5	32	22	10
Alley farming	2	34	2	18
Plantain research and technology transfer	3	13	2	8
On-farm experimentation	2	21	1	9
Cowpea and soybean research and technology transfer	8	19	3	10
Maize research and technology transfer	10	16	1	10
Total IITA Ibadan	51	253	51	-
IITA Cotonou				
Biological control	5	19	2	12
Biological control	5	32	3	15
Total IITA Cotonou	10	51	5	-
Regional/in-country				
Cassava production, processing and utilization (Guinea Bissau)	2	22	5	1
Maize and cowpea production (Burkina Faso)	2	23	0	1
Vegetative seed production (Kenya)	2	17	1	9
Root and tuber crop production, processing and utilization (Mozambique)	2	19	1	2
Rapid multiplication of root crops (Benin)	1	29	2	1
Total regional/in-country	9	110	9	-
Grand total	**70**	**414**	**65**	**-**

Annex to International Cooperation: Graduate Research Fellows and Scholars 1989

Research Fellows (Doctoral Degree Studies)

Program	Country	University	Sponsor	Thesis[1]
Biological Control Program				
Ms A. Akpokodje	Nigeria	University of Ibadan	IITA	-
Mr. S. Bruce-Oliver	Gambia	University of California, Berkeley	IITA	-
Mr. A. Chalabesa	Zambia	Wye College, London	IITA	-
Mr. A. R. Cujoe	Ghana	Wye College, London	IITA	-
Mr. G. Goergen	Germany, Fed. Rep.	University of Giessen	IITA	-
Mr. H. Rogg	Germany, Fed. Rep.	University of Giessen	GTZ	-
Grain Legume Improvement Program				
Mr. S. A. Adebitan	Nigeria	University of Ibadan	IITA	-
Mr. H. Adu-Dapaah	Ghana	University of Ibadan	USAID/IITA	Studies on phenotype stability and male sterility in cowpea.
Ms N. F. U. Agwaranze	Nigeria	University of Ibadan	IITA[2]	-
Mr. B. Asafo-Adjei	Ghana	University of Minnesota	CIDA	Genetics of soybean breeding.
Mr. I. D. Atokple	Ghana	Ahmadu Bello University	IITA[2]	-
Mr. S. Blade	Canada	McGill University	CIDA	Evaluation of improved cowpea lines under intercropping systems in various agroclimatic zones in Nigeria.
Ms K. K. Mogotsi	Botswana	University of Botswana	FF	-
Ms A. Noameshie	Togo	University of Ibadan	IITA	-
Mr. S. Oghiakhe	Nigeria	University of Lagos	Self/IITA	Host plant resistance studies on the legume pod borer, *Maruca testulalis* Geyer (Lepidoptera: Pyralidae).
Mr. T. Omobuwajo	Nigeria	Obafemi Awolowo University	IITA	-
Ms C. P. Paul	Sri Lanka	University of Ibadan	Italy	-
Mr. M. Touré	Mali	Université Laval Ste. Foy, Canada	IITA[2]	-
Maize Research Program				
Mr. Y. A. Akintunde	Nigeria	University of Ibadan	IITA[2]	-
Mr. M. Asanzi	Zaire	Ohio State University	USAID	-
Mr. O. J. Osanyintola	Nigeria	University of Ibadan	IITA	-
Resource and Crop Management Program				
Mr. P. T. Akonde	Republic of Benin	Universität Hohenheim	UH	-
Mr. A. I. Babalola	Nigeria	University of Ibadan	Self	-
Mr. M. Baten	Bangladesh	University of Ibadan	FF/Self/IITA	-
Ms R. Ernst	Germany, Fed. Rep.	Universität Hohenheim	UH	Maize-cassava cropping systems.
Mr. T. L. Gaiser	Germany, Fed. Rep.	Universität Hohenheim	UH	-
Mr. B. D. Kadiata	Zaire	Institut Facultaire des Sciences Agronomique	IITA[2]	-

[1] *Applies to graduate students who completed their research at IITA during 1989. No entry in this column if thesis not yet completed.*

[2] *Funded by the IITA Graduate Research Fellowship Program.*

Research Fellows (Doctoral Degree Studies) – *continued*

Program	Country	University	Sponsor	Thesis[1]
Resource and Crop Management Program – *continued*				
Ms S. Liya	United Kingdom	University of Ibadan	Self	-
Mr. H. J. Lutzeyer	Germany, Fed. Rep.	Universität Hohenheim	UH	Weed management.
Mr. A. G. Maul	Germany, Fed. Rep.	Universität Hohenheim	UH	Socioeconomic surveys in some villages in the Republic of Benin.
Mr. [illegible]. E. Njoku	Nigeria	University of Nigeria	Self	Demand elasticities for food in the minor food-producing areas of southern Nigeria.
Mr. M. A. Olagoke	Nigeria	University of Nigeria	AGCD	Relative efficiency of resource allocation in yam and rice production in south-east Nigeria.
Mr. O. Onafeko	Nigeria	University of Ibadan	IITA[2]	-
Mr. G. O. Oyediran	Nigeria	Obafemi Awolowo University	Self	Wetland soils of different agroecosystems: characterization and productivity evaluations.
Mr. B. A. Ruhigwa	Zaire	Institut Facultaire des Sciences Agronomiques	IITA/AGCD	-
Mr. D. E. Siaw	Ghana	University of Ibadan	Self/IITA	Alley cropping trial using *Leucaena leucocephala* and *Acioa barteni* mixtures.
Mr. M. A. K. Smith	Nigeria	University of Ibadan	Self	-
Mr. G. Tian	China	Agricultural University, Wageningen	IITA/ Netherlands	-
Mr. B. Ugwu	Nigeria	University of Nigeria	Self	Efficiency of resource use in food crop production in south-eastern Nigeria.
Ms A. Weber	Germany, Fed. Rep.	Universität Hohenheim	UH	-
Rice Research Program				
Mr. M. S. Mansaray	Sierra Leone	Njala University College	IITA[2]	-
Ms M. Mgonja	Tanzania	University of Ibadan	FF	-
Root, Tuber and Plantain Improvement Program				
Mr. Agueguia	Cameroon	University of Ibadan	UNDP/GCF	-
Mr. M. H. Makame	Tanzania	University of Ibadan	UNDP	-
Ms R. Ndibaza	Tanzania	University of Ibadan	UNDP	-
Mr. T. E. Njock	Cameroon	University of Ibadan	UNDP	-
Ms O. Salau	Nigeria	University of Ibadan	Self	-
Mr. N. W. Wanyera	Uganda	University of Ibadan	UNDP	-

Research Scholars (Master's Degree Studies)

Program	Country	University	Sponsor	Thesis[1]
Biological Control Program				
Mr. A. J-M. Anga	Côte d'Ivoire	University of Wales	IITA	-
Mr. A.M. Animashaun	Nigeria	Wye College, London	IITA	-
Mr. H. Braimah	Ghana	University of Reading	IITA	Biology of mealybugs and natural enemies.
Mr. K. Konan	Côte d'Ivoire	Simon Fraser University	IITA	-
Mr. P. Ndayiragije	Burundi	University of Ottawa	IITA	-
Mr. G. Oduor	Kenya	Imperial College	IITA	-
Mr. F. Senkondo	Tanzania	Wye College, London	IITA	-
Mr. A. J. Sumani	Zambia	University College, Cardiff	IITA	-
Mr. K. Tata Hangy	Zaire	University College, Cardiff	IITA	-
Mr. L. Traore	Guinea	Université de Montréal	IITA	-
Grain Legume Improvement Program				
Mr. J. Afun	Ghana	Wye College, London	CIDA	A comparative study of "calendar" and "guided" insecticide applications for control of cowpea pests.
Mr. L. A. Okosun	Nigeria	University of Ibadan	Self	Screening of cowpea lines for drought tolerance.
Ms N. Ssemakula	Uganda	University of Ibadan	FF	-
Resource and Crop Management Program				
Ms U. A. Anoka	Nigeria	University of Nigeria	Self	Effect of early season on *Imperata cylindrica*
Mr. M. O. Atayese	Nigeria	University of Ibadan	Self	-
Mr. O. O. Awotoye	Nigeria	University of Ibadan	Self	-
Ms J. Baie	Belgium	Université Laval	AGCD	Nitrogen mineralization potential of soils (alfisols and ultisols) collected under fallows of different ages and relationship with size of populations of nitrifying micro-organisms.
Mr. A. Dikko	Nigeria	Agricultural University, Norway	IITA[2]	-
Mr. L. R. A. Hermans	Belgium	Katholieke Universiteit, Leuven	AGCD	Dynamics in maize plot treated with fertilizer N and leaves of different woody species.
Mr. P. Idisi	Nigeria	Ahmadu Bello University	IITA	-
Mr. P. Karinge	Kenya	University of Nairobi	FF	Effect of alley cropping *Calliandra calothyrsus* and nitrogen rates on maize and cowpeas.

[1] *Applies to graduate students who completed their research at IITA during 1989. No entry in this column if thesis not yet completed.*

[2] *Funded by the IITA Graduate Research Fellowship Program.*

Research Scholars (Master's Degree Studies) – *continued*

Program	Country	University	Sponsor	Thesis[1]
Resource and Crop Management Program – *continued*				
Mr. T. Leyman	Belgium	Rijksuniversiteit Gent	AGCD	Effect of cassava-based cropping systems on soil physical and chemical properties of an alfisol in western Nigeria.
Rice Research Program				
Mr. R. Rodrigus	Belgium	Université Libre de Bruxelles	AGCD	-
Root, Tuber and Plantain Improvement Program				
Mr. C. E. Felix	Nigeria	University of Ibadan	UNDP	-
Mr. C. M. Githunguri	Kenya	University of Ibadan	IDRC	Cassava varietal response to drought stress.
Mr. M. Ntimpirangeza	Burundi	University of Nairobi	IDRC/ESARRN	-
Ms A. Peters	Belgium	Katholieke Universiteit, Leuven	AGCD	Screening plantain and banana germplasm for resistance to black Sigatoka disease using different techniques.
Mr. G. S. N. Phiri	Malawi	University of Ibadan	IDRC	-
Mr. R. N. Sauti	Malawi	University of Ibadan	USAID/ ESARRN	-
Mr. M. Walangululu	Zaire	Institut Facultaire des Sciences Agronomiques	UNDP	Mechanism of resistance of cassava to cassava green mite.

Information and Scientific Support Services

Information Services

The Information Services Program embarked on a campaign to promote public awareness in Nigeria of IITA's goals and accomplishments. At a meeting of the main Nigerian print and electronic media houses with IITA in November 1989, the Media Forum for Agriculture was established. The Forum was inaugurated in April 1990 and held a workshop on "Communication for sustainable agriculture" at which participated the representatives of the major newspapers, magazines, radio and television agencies, research institutes, farmers' organizations, the Central Bank of Nigeria, the Nigerian Agricultural and Cooperatives Bank and FAO of the United Nations.

The Director General, Dr. Laurence D. Stifel, gave a public lecture on the work of IITA at the Nigerian Institute of International Affairs in March 1989 and a presentation at the National Workshop on the Economic Recovery Program, which was organized by the Office of the President of the Federal Republic of Nigeria in February 1990. Both events were reported extensively in national newspapers, which published the texts of his presentations in part or whole.

Many journalists visited IITA and reported on the research here. Selections of IITA's press coverage during 1989 have been produced in two volumes entitled *IITA in the News*.

Library Services. The library offered training in the use of the online public access catalogue to 205 people, who included scientists from IITA and national agricultural research institutions. Training was also provided for staff of other libraries in Nigeria and the librarian of the Central Agricultural Research Institute (CARI) of Liberia.

Assistance to national research institutions continued in the form of literature searches, interlibrary loans, preparation and supply of bibliographies, donations of duplicate or redundant publications and provision of general information.

As a part of its selective dissemination of information, the library introduced a weekly current-awareness series to circulate among scientific staff the tables of contents of professional journals received at the library. About 150,000 page copies were circulated during 1989. For users outside the Institute, scientific information was provided in response to 312 requests by mail from 42 countries, which included 19 in Africa. A guide to the library and its services was published in English and French editions.

In-house database management was improved with implementation of the thesaurus module of BASIS. About 12,300 records were added to the library's database during 1989. Database error correction and retrospective data input of selected journal articles were increased. Eleven additional databases on compact disk (CD-ROM) were acquired.

Publications. The total editorial output for jobs completed during 1989 exceeded 5,000 printed pages.

A management review brought innovations to IITA publications. The content and style of *IITA Annual Report 1988/89* show modifications intended to enhance communication to the non-scientific as well as scientific readership. *Research Briefs* published its last issue during 1989. A new semiannual periodical for scientists which presents current information on research results was launched in 1990, entitled *IITA Research*.

IITA hosted the Fourth Conference and General Assembly of the African Association of Science Editors from 5 to 9 March 1990. Participants came from all regions of Africa as well as other parts of the world. The conference provided IITA editiorial staff with an opportunity to interact with African professional colleagues and to contribute towards strengthening of scientific editing capabilities in Africa.

Interpretation and Translation. Interpretation services were provided to 13 training courses and several meetings. Many thousands of pages of scientific and information documents were translated.

Scientific Support Services

Genetic Resources
Since the establishment of its crop improvement programs in 1970, IITA has devoted considerable resources to assembling and evaluating germplasm of cowpea (*Vigna unguiculata*), African rice species (*Oryza sativa, O. glaberrima*), yams (*Discorea* spp.), cassava (*Manihot esculenta*), maize (*Zea mays*), bananas and plantains (*Musa* spp.), soybean (*Glycine max*), sweet potato (*Ipomoea batatas*) and bambara groundnut (*Vigna subterranea*). IITA established its genetic resources unit in 1975 to collect, characterize, evaluate and preserve germplasm species of its mandated crops.

The germplasm collection, which includes the world collections of cowpea and African land races of rice, supports breeding and related research activities by IITA, national programs in tropical Africa and organizations with kindred objectives elsewhere. IITA's plant geneticists seek to promote the usefulness of this germplasm and to enlarge knowledge about its taxonomy, genetics, interspecific relationships and its potential contribution as a genetic resource for breeding programs.

Achievements. IITA plant explorers had, by early in 1990, conducted 58 exploration and collection missions in 31 African countries. The unit maintains a collection of 15,000 accessions of cowpea, 1,400 of wild *Vigna*, 12,000 of rice, 2,000 of bambara groundnut, 1,400 of soybean, 1,800 of yams, 1,200 of maize and some hundreds of samples each of other species. The IITA seed storage unit comprises two storerooms for an "active collection", with a combined capacity of 409 cubic meters that are kept at 5°C±1° and 30-35%RH; and a "base collection" seed store of 132 cubic meters conditioned at -20°C. In addition, 2,000 lines of cassava and wild *Manihot*, 1,000 clones of sweet potatoes and 300 clones of plantain and bananas are maintained by IITA's root, tuber and plantain improvement program.

Current germplasm research includes:
- Germplasm characterization and evaluation of cowpea, rice, yam and their related species.
- Surveys of *Vigna* and *Oryza* distribution in Africa.
- Interspecific hybridization between cowpea and wild *Vigna*, in order to study the genetic affinity between species and to identify potential bridging species which can help effect crosses in breeding for resistance against flowering pests.
- Agrobotanical variability of *Vigna* species within the *Catiang* group closely related to cowpea.
- Genetic inheritance studies of particular traits.
- Seed longevity in cowpea and bambara groundnut.
- Genetic diversity and differentiation of the African rice and land races of Asian rice collected in Africa.
- Seed viability and tuber quality of the yam germplasm collection.

Operational Strategies. Exploration and collection activities seek to fill gaps in the collections of African *Oryza*, *Vigna* and *Dioscorea*. Germplasm samples will be acquired from other parts of the world. Germplasm of other mandated crops will be collected within the region, particularly of cassava and maize.

A sound system of germplasm storage and periodic regeneration, combined with duplicate/triplicate storage in allied collections elsewhere for security against loss, has been developed. Duplicate germplasm accessions will be eliminated by morphological comparison and chemical techniques. A core collection of each species will be selected for full evaluation.

The unit continues to service demands for seed materials which average around 200 requests per year.

Characterization and evaluation are systematically conducted for cowpea, wild *Vigna*, rice and yam. Many accessions are grown out in experimental fields each year for these activities. The unit has already characterized and evaluated more than half of the existing collection of bambara groundnut. The collection of soybean has been characterized for six agronomic characters. A computer file is kept on each accession with information on descriptive and agrobotanical characteristics, and on resistance to selected diseases, pests and physiological stresses.

Improvements are planned for yam tuber treatment and storage facilities, in order to increase shelf life and reduce tuber loss.

Training courses are conducted for national scientists or technicians in germplasm exploration, collection and conservation, seed technology and gene bank management, among other related areas.

Collaborative linkages. Research projects have commenced with the Università degli Studi di Napoli, the Istituto del Germoplasma, Bari, and the Istituto Nazionale della Nutrizione, Rome. The areas of common interest are cytology of cowpea and wild *Vigna*; wide crosses between cowpea and wild *Vigna*; cell and protoplast culture of cowpea; variability of *Vigna* germplasm with respect to seed-protein electrophoretic band patterns, nutritional values and antinutritional factors; and chemical studies related to insect pest resistance. These activities will utilize biotechnology techniques in exploiting the gene pool of wild *Vigna* for cowpea improvement.

IITA plant geneticists often work closely with IBPGR, other international organizations and genebanks in collecting and supplying germplasm samples and disseminating germplasm information to researchers all over the world. They collaborate with IITA crop improvement scientists and virologists and with scientists from national programs to evaluate germplasm for resistance to insect pests, diseases and physiological stresses. The unit also helps to strengthen national programs in West and Central Africa in exploration, collection, conservation, evaluation and documentation.

Seed health and plant quarantine are shared concerns with virologists and others at IITA. A major seed health problem of legume crops is seed-borne viruses. In conjunction with the IITA seed health committee, accessions of *Vigna* and *Glycine* which may be virally contaminated are grown under screenhouse conditions to produce virus-free materials. The unit liaises with the Nigerian Plant Quarantine Service for both the import of plant materials and certification of materials for export.

A seed health unit is being set up to ensure proper transfer of germplasm materials in coordination with the national plant quarantine authorities.

Germplasm security. Duplicate germplasm storage ensures security of holdings. IRRI and IITA are comparing their respective holdings and intend to make complete set of duplicates of all African collections for storage at each center. In addition, IITA recently sent 2,000 accessions of rice germplasm to the national seed storage laboratory for duplicate storage and research purposes.

About one-third of IITA's cowpea collection has been duplicated at the U.S. national seed storage laboratory. Part of that collection is to be duplicated for the Istituto del Germoplasma, Bari.

During 1989 CIP and IITA produced a set of duplicates of all IITA's sweet potato germplasm for conservation and research purposes at CIP. Duplicate samples of bambara groundnut will be sent to Fal, Federal Republic of Germany for storage. Other duplicate storage arrangements are made for *Musa* specimens through the International Network for the Improvement of Bananas and Plantains (INIBAP) and at the Katolic Universitet, Leuven; and for soybean germplasm with the International Soybean Program (INTSOY), U.S.A. and Asian Vegetable Research and Development Center (AVRDC).

Virology

The virology unit conducts research on virus diseases occurring in IITA's mandated crops in Africa. The unit's activities are closely linked with the work of breeders, pathologists and entomologists in each of IITA's crop improvement programs.

Virology at IITA characteristically focuses on two different but complementary fields of interest. The first includes studies on the etiology and epidemiology of virus diseases as well as research which supports the development of new disease-resistant varieties. Quarantine aspects of crop improvement and international transfer of improved germplasm also fall within this field.

The second concerns virus purification, characterization and detection techniques. The unit maintains pure and characterized virus isolates that are used in testing breeding lines for resistance. When an unknown virus is found or a known virus has assumed an unfamiliar form, the IITA virologists try to identify and purify it, develop antisera, and describe the pathogen in terms of isolate characteristics for reference and comparison.

Recent, rapid developments in molecular biology have opened up highly effective means for detection of viruses. New biotechnological procedures permit detection with, for example, serological techniques which utilize monoclonal antibodies (MAB) and complementary DNA (cDNA) fragments. Because of its specific binding or hybridization properties, cDNA can be used in the development of extremely sensitive detection methods. IITA virologists have sought the help of advanced laboratories in applying such techniques with selected crops.

Agroecological Focus. Studies of the ecology, epidemiology and agroecological significance of virus diseases are framed within the agroecological zones of the specific crop-pest problem. Part of the work in cowpea virology, for example, will be conducted out of the new IITA research station at Kano, in the dry savanna of northern Nigeria.

Achievements. During 1989, the unit continued to test the resistance of elite cowpea and rice genotypes from the breeding programs to newly recognized viruses or virus strains. The unit also continued to test routinely all breeders' germplasm of cowpea and soybean for presence of seed-borne virus in order to ensure its phytosanitary safety.

Epidemiological studies as well as long-term evaluations of the ecology and geographical distribution have allowed the virologists to obtain a reliable picture of the economic importance of virus diseases in IITA's mandated crops.

Field surveys in Nigeria during 1989 unexpectedly turned up an instance of rice yellow mottle virus infection of *Oryza longistaminata*, near Numan, in the Benue River valley of Gongola State. This exciting discovery is the first such occurrence of that virus reported in a perennial wild rice variety in Nigeria; although it has been reported in this species from other West African countries. In order to obtain a better insight into pathogenic variation in the virus, collections of wild rice, as well as *O. sativa* germplasm tolerant of the virus, are being tested using the standard IITA isolate and the newly obtained isolate of the virus from *O. longistaminata*.

The results of such studies to date have shown that pathogenic properties of this new "wild reservoir" isolate of the virus do not differ significantly from those of the standard isolate that has been used at IITA in resistance screening since the virus was first found in Nigeria in 1978. Likewise, comparison of a wide range of isolates of cowpea aphid-borne mosaic virus and other viruses found in cowpea in Africa for pathogenic variation in a wide range of elite germplasm has shown that types of these viruses which occur in Nigeria are well covered, for resistance screening purposes, by the standard isolates of the viruses at IITA.

IITA virologists have made significant progress in characterizing viruses. Several newly discovered viruses and new strains of viruses occurring in IITA's mandated crops and related or associated weed species have been purified for the production of antisera, which are being used for diagnostic purposes and virus indexing at IITA. Such antisera have been provided to several national program scientists at their request.

Maize mottle virus was purified for MAB production required for large-scale, reliable diagnosis of similar or identical diseases in this crop in other parts of Africa. Maize mottle virus is the second most important virus of maize in Nigeria and possibly has a continent-wide distribution.

Collaborative research. IITA is acquiring experience and capability in MAB and cDNA techniques through cooperative research with scientists at the U.S. Department of Agriculture laboratory at Beltsville, Maryland. The objective is to produce MBAs and cDNA probes for the detection of viruses affecting root and tuber crops.

A project with the International Development Research Center, Canada, is assisting national programs in Africa in identifying viruses in their major food crops. National program scientists will be trained in the use of MABs, which are being produced by the Canadian Department of Agriculture at Vancouver. MABs will open a shortcut to crop virologists at IITA as well as national programs which do not have the equipment and other facilities to identify viruses with conventional methods. Once they have been trained in the use of MABs, they should be in a better position to conduct reliable virus identification specific to their own areas. After locally prevalent virus strains have been identified, IITA and national program breeders can adopt strategies to incorporate appropriate virus resistance in improved crop varieties.

Biometrics

The biometrics unit advises all IITA's scientists and postgraduate students on mathematical and statistical aspects of agricultural research. The unit assists scientists and trainees in designing surveys and experiments, analyzing and interpreting data, using statistical information in publications and presentations, and applying appropriate mathematical and statistical techniques in their work. The unit also designs and teaches the statistics components of most IITA training courses, and conducts occasional, more specialized courses in statistics and statistical computing.

During 1989 students and researchers from the universities of Ibadan, Ife and Benin and several other groups from Nigeria came to the unit for assistance. The IITA biometrician contributed to the on-farm research workshop in April and the training course which followed from it in September. Subsequently he presented the analytical methods component of that course at a workshop in Cameroon. Together with a visiting specialist, the biometrician analyzed sets of cowpea international variety trials from 1983 to date. These data were used with further assistance from the unit in a course on analysis of genotype x environment interactions. A visiting specialist from the Food and Agriculture Organization of the United Nations spent one month with the unit in training in experimental design.

Analytical Services

The analytical services laboratory assays soil, plant and water samples submitted by IITA researchers and their collaborators. The lab analyses soil and water samples for various physical and chemical properties. Plant samples are analyzed for primary and secondary nutrients and for micronutrients.

The laboratory contributed during 1989 to the development of IITA research stations. For the humid forest station being established at Mbalmayo, Cameroon, the lab designed a new soil and plant analysis laboratory; selected methods and procedures for soil, plant and water analysis; and prepared orders for equipment, chemicals and supplies. The lab also analyzed samples for site characterization. For the moist savanna station at Kano in northern Nigeria, the laboratory performed soil analyses for site characterization and water analysis for irrigation. Lab support for the stations at Onne and Cotonou included analysis of soil, plant and water samples from research projects, analysis of drinking water and supply of deionized water for their laboratories.

The unit also analyzed soil and plant samples from on-farm trials and from national research centers within and outside Nigeria. Laboratories from Liberia and Sierra Leone were assisted with procurement of spares and supplies or with assessment and advice for improvements. On-the-job and formal training of laboratory staff from developing countries continued as regular activities of the unit.

The decentralization of IITA research activity from headquarters to different agroecological zones affects the laboratory in various ways. Samples received from each zone have distinct properties and require development of new analytical methods and procedures. Because of the distances involved from sample origin to IITA, problems can arise concerning contamination during shipment and time lapse between sample collection and its analysis.

Networking. The first advanced training workshop on soil and plant analysis for laboratory directors and supervisors from tropical regions was organized in 1989 and repeated early in 1990.

A proposal to establish a soil and plant analytical laboratories network for Africa (SPALNA) was developed during the two workshops. Formal inauguration of the network is scheduled early in 1991. The goal of the network is to improve soil and plant analytical services to support research at national programs through collaboration among laboratories in Africa. The network will concentrate on such priority areas as maintenance of laboratory equipment, training, infrastructure, communication of new developments in analytical methods, quality control of analytical data, standardization of methods and improvements in supply of equipment and materials.

In future, the range of analytical services at IITA will be extended significantly with the introduction of a high-pressure liquid chromatograph. To process the increasing number of soil, plant and water samples from IITA researchers and collaborators, further automation of the analysis and of data processing will be required. Development of new methods of soil and plant analysis will also continue.

Farm Management

The farm management unit is responsible for the management, maintenance and development of experimental farms at IITA's headquarters and at four research stations in Nigeria and Cameroon. In addition, the unit's mobile team supports research testing in the different agroecological zones of Nigeria.

The new moist savanna research station at Minjibir near Kano, northern Nigeria, is being developed in collaboration with the Institute for Agricultural Research of Ahmadu Bello University, Zaria. The Kano station covers 105 hectares of which 30 hectares are assigned for IITA use. Access roads, soil conservation installations and rudimentary irrigation facilities have already been provided. During 1989 and early in 1990 a small building complex was erected which houses field laboratories, crop threshing and drying areas, a farm workshop, implement storage sheds and field offices. Fencing of the experimental fields is well advanced and land development to improve soil uniformity is under way.

The new high rainfall station at Mbalmayo, Cameroon is being established on a 1,000-hectare site in a forest reserve, involving much basic land development work. Boundary demarcation, road development and land clearing (by hand, in order to minimize soil disturbance) commenced during 1989.

The farm management staff assists resource-management scientists in studies of soil-conserving tillage methods. For the purposes of these studies, most trials on IITA farms are planted with no-till materials that reduce soil erosion and degradation. The unit also multiplies improved crop varieties developed by IITA scientists and their collaborators, distributing up to 100 tons of seed annually to government seed services, seed companies, and farmers, in Nigeria and other African countries. At Ibadan, the unit maintains a demonstration area, where IITA crop varieties and farming technologies are shown to more than 2,000 visitors each year.

On a collaborative basis, the unit assisted other international agricultural research centers during 1989. Kano-based staff of the International Crop Research Institute for the Semi-Arid Tropics (ICRISAT) received support in planting trials on 22 hectares. Dry-season irrigated sorghum isolation sites were also provided for ICRISAT at the IITA headquarters farm at Ibadan. The unit also worked with Ibadan-based scientists of the International Livestock Center for Africa (ILCA) to determine optimal methods of shrub establishment in pastures for alley cropping.

West African training course. Early in 1990 the unit conducted the first research farm management group training course to be held at IITA. Seventeen research farm managers from five countries of West Africa reviewed the following topics during the three-week course: surveying for soil conservation, maintenance and calibration of field machinery, and farm workshop planning and management. Joint organized by IITA, ICRISAT and the University of Arkansas, the course will be repeated in 1991 and 1992 as a contribution toward improved experimental farm support for national research programs in the region.

Annexes

Financial Statements 1989

Extracts from Financial Statements for the Year Ended 31 December 1989

The full Financial Report and the Report of the Auditors Arthur Andersen and Company are available from IITA on request.

IITA

STATEMENT OF FINANCIAL POSITION

31 DECEMBER 1989

	Expressed in US $ Thousands	
ASSETS	1989	1988
Cash and Short-Term Deposits	6,936	5,293
Accounts Receivable:		
Donors	8,058	8,490
Others	503	563
Inventories	3,627	4,461
Other Assets	178	238
Property, Plant and Equipment	55,768	51,677
	75,070	70,722

LIABILITIES AND FUND BALANCES		
LIABILITIES		
Accounts Payable and Other Liabilities	8,094	6,998
Accrued Salaries and Benefits	3,053	3,641
Payments in Advance – Donors	3,465	3,116
	14,612	13,755
FUND BALANCES		
Capital	55,768	51,677
Capital Development	976	1,576
Operating	3,714	3,714
	60,458	56,967
	75,070	70,722

IITA
STATEMENT OF ACTIVITY
FOR THE YEAR ENDED 31 DECEMBER 1989

	Expressed in US $ Thousands	
REVENUE	1989	1988
Grants	31,218	33,577
Other Income	619	616
	31,837	34,193

EXPENSES		
Research Programs	18,342	17,398
Conferences and Training	1,883	2,083
Information Services	1,432	1,441
General Administration	3,522	3,979
General Operations	2,886	2,764
Property, Plant and Equipment	3,634	4,453
Exchange (Gains) / Losses	(263)	(547)
Total Expenses	31,436	31,571
Allocation to Capital Development Fund	401	1,349
Allocation to Operating Fund	-	1,273
	31,837	34,193

IITA
STATEMENT OF CHANGES IN FINANCIAL POSITION
FOR THE YEAR ENDED 31 DECEMBER 1989

	Expressed in US $ Thousands	
SOURCES OF FUNDS	1989	1988
Excess of Revenue over Non-Capita Expenses	4,035	7,075
Decrease in Accounts Receivable – Donors	432	-
Decrease in Accounts Receivable – Other	60	-
Decrease in Inventories	834	143
Decrease in Other Assets	59	24
Increase in Accounts Payable and Other Liabilities	1,096	2,036
Increase in Payments in Advance – Donors	349	-
	6,865	9,278

APPLICATION OF FUNDS		
Purchase of Property, Plant and Equipment	4,634	6,237
Increase in Accounts Receivable – Donors	-	4,234
Increase in Accounts Receivable – Other	-	247
Decrease in Accrued Salaries and Benefits	588	243
Decrease in Payment in Advance – Donors	-	231
	5,222	11,192
INCREASE/(DECREASE) IN FUNDS	1,643	(1,914)
CASH, BEGINNING OF YEAR	5,293	7,207
CASH, END OF YEAR	6,936	5,293

DONORS 1989

Donors	Core Funding	Special Project Funding
	Expressed in US $ Thousands	
African Development Bank	225	-
Australia	94	-
Austria	90	-
Belgium	510	264
Canada	1,637	202
China	10	-
Commission of the European Communities in Nigeria	-	9
Denmark	106	70
Finland	237	-
Food and Agriculture Organization	-	260
Ford Foundation	100	74
France	273	-
Gatsby Charitable Foundation	-	262
Germany, Federal Republic of	1,379	40
India	24	-
International Development Research Center	-	487
International Fund for Agricultural Development	-	650
Italy	641	885
Japan	2,280	-
Netherlands	654	571
Nigeria	24	15
Norway	588	-
Rockefeller Foundation	503	-
Sweden	194	121
Switzerland	933	46
United Kingdom	743	-
United Nations Development Program	147	-
United Nations University	-	41
United States Agency for International Development	5,435	5,550
University of Hohenheim	-	136
World Bank	4,690	11
Closed and Miscellaneous Projects	-	7
Total	21,517	9,701

The CGIAR

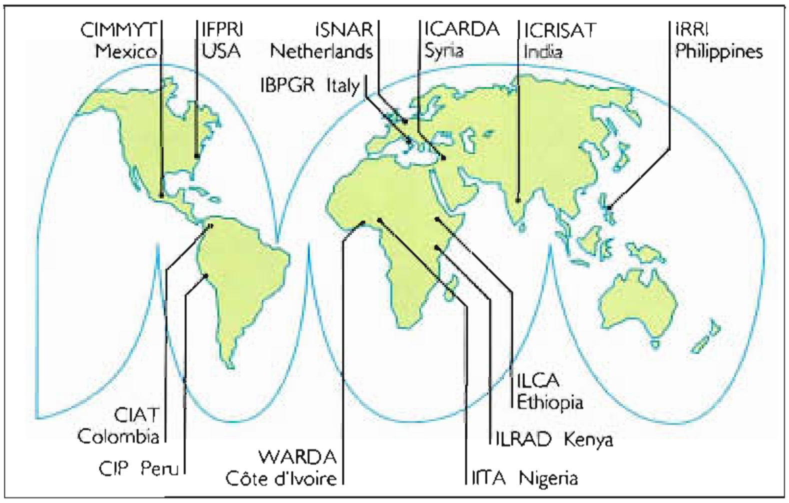
The Consultative Group on International Agricultural Research (CGIAR) is an informal association of countries, international organizations and private institutions, formed in 1971 to provide sustained support for a well-defined and closely monitored program of international research on food commodities of vital importance to the developing countries of the world.

Cosponsored by the World Bank, the Food and Agriculture Organization of the United Nations (FAO) and the United Nations Development Programme (UNDP), the CGIAR operates without a formal charter, relying on a consensus deriving from a sense of common purpose. The CGIAR started with a nucleus of four existing international agricultural research centers, including IITA. The number of centers has increased to 13, supported by 39 donor members and other contributors, who provided about US$260 million in funding during 1988.

Each CGIAR-affiliated center is independent and autonomous, with its own structure, mandate and objectives, and is overseen by its own board of trustees. Some centers focus on one or two commodities for which they have global mandates, while others have regional or ecological mandates for one or more commodities. Still others perform specialized functions in the fields of food policy research, genetic resources conservation, and the strengthening of national agricultural research in developing countries.

The CGIAR is serviced by an executive secretariat, which is provided by the World Bank and located in Washington. A Technical Advisory Committee (TAC), comprising a chairman and 13 scientists, is drawn equally from developed and developing countries. The TAC makes recommendations on research programs and priorities, and monitors performance through annual program and budget reviews and periodic external reviews by independent scientists invited to serve on specially constituted panels. The TAC is supported by a secretariat provided by the three cosponsors of CGIAR and located at FAO headquarters in Rome.

The CGIAR meets twice a year: once in Washington during October/November and once elsewhere during May. The meetings hear and discuss recommendations about over-all strategy, budgetary needs and management issues. Reports from individual centers, as well as independent external evaluations, are presented periodically at those meetings.



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

Principal Staff

Management and Support Services

Executive Management

L. D. Stifel, Ph.D., director general

S. A. Adetunji, Ph.D., special assistant to the director general

J. Cramer, B.A., executive assistant to the director general

J. H. Davies, B.Sc., director, office of the director general

J. P. Eckebil, Ph.D., deputy director general, international cooperation

K. S. Fischer, Ph.D., deputy director general, research

F. McDonald, M.S., assistant to the deputy director general, research

R. Oyekanmi, A.C.A., internal auditor *

W. P. Powell, B.Sc., deputy director general, management

W. M. Steele, Ph.D., special assistant to the director general *

Administrative and Auxiliary Services

K. A. Aderogba, F.C.I.S., principal administrative officer *

C. A. Enahoro, manager, Ikeja guest house

A. R. Middleton, B.Sc., manager, international house

R. I. Olorode, security manager

D. J. Sewell, manager, aircraft operations

Budget and Finance

D. A. Governey, F.C.A., director, budget and finance

B. A. Adeola, F.C.I.S., accountant

O. E. Adepoju, A.C.A., analyst, accounting procedures

G. A. Agbarin, G.D.C.S., technical analyst *

O. A. Ajayi, M.B.A., senior technical analyst *

C. A. Babalola, A.C.A., analyst, accounting procedures

P. O. Balogun, A.C.A., finance manager

J. Bolarinwa, M.B.A., payroll accountant

P. O. Etuk, M.B.A., budget and planning coordinator

E. D. Greene, M.Sc., materials manager

G. R. McIntosh, C.M.A., procedures manager, financial information systems

F. O. Ogunyemi, F.C.A.A., accountant *

S. J. Udoh, A.M.N.I.M., chief accountant

D. Wheeler, C.P.A., project manager, financial information systems

Computer Services

L. J. McDonald, Ll.B., computer manager

S. Adalumo, M.Sc., computer electronics and operations officer *

A. A. Akinbola, B.Sc., computer programmer

N. N. Eguzozie, B.Sc., computer programmer

T. D. Oluyemi, M.Sc., computer programmer

Human Resources

J. Thackway, M.A., director, human resources

T. A. Akintewe, M.D., senior medical officer .

J. O. Badaki, M.B.A., employee relations manager

O. A. Cole, M.D., medical officer

J. B. Elegbe, M.Sc., manpower development manager

Information Services

S. M. A. Lawani, Ph.D., director

J. A. Adedigba, M.A., principal librarian

A. O. Adekunle, M.Sc., editor

O. R. Adeniran, M.Sc., principal librarian

A. R. Astill, M.A., editor *

K. Atkinson, M.Sc., editor and head, publications

S. Auerhan, Lic., interpreter/translator

B. Auvard, B.A., interpreter/translator

A. A. Azubuike, M.Sc., principal librarian

S. Bailey, Lic., interpreter/translator

O. Hounvou, D.A.S., interpreter/translator

E. Molinero, Lic., head, interpretation/translation

C. Moudachirou, Lic., interpreter/translator *

E. Nwulu, M.Sc., audio-visual specialist

J. O. Ojurongbe, B.Sc., production manager

L. Ouédraogo, Lic., interpreter/translator *

J. O. Oyekan, B.Sc., head, public affairs

D. R. M. Raj, Ph.D., senior science writer and editor

E. Tordeur, Lic., translator *

F. N. Ubogu, M.Sc., principal librarian

Physical Plant Services

J. G. H. Craig, director

E. O. A. Akintokun, research vehicle services officer

A. Amrani, heavy equipment services officer *

A. K. Bhatnagar, B.Sc., assistant director

A. C. Butler, building and site services officer

P. G. Gualinetti, construction site engineering services officer

J. Kane, electrical services officer *

E. Ojinere, heavy equipment/fabrication services engineer

A. Oyedeji, heavy equipment services officer

S. Quader, electronic services officer

** Left during the year (1 April 1989 - 31 March 1990)*

Research and Support Services

Biological Control Program

H. R. Herren, Ph.D., director

D. T. Akibo-Betts, Ph.D., entomologist and East/Southern Africa regional coordinator

W. N. O. Hammond, Ph.D., entomologist and West/Central Africa regional coordinator

P. Neuenschwander, Ph.D., entomologist and research coordinator

F. Schulthess, Ph.D., ecologist

T. Shanower, Ph.D., entomologist

A. Wodageneh, Ph.D., training officer, FAO

J. S. Yaninek, Ph.D., acarologist

J. B. Akinwumi, M.Sc., engineer

T. M. Haug, M.Sc., mass rearing specialist

B. Mégevand, M.Sc., mite rearing specialist

Associate experts

C. Boavida, M.Sc., ecologist

M. Tamo, M.Sc., ecologist

Grain Legume Improvement Program

S. R. Singh, Ph.D., director

K. F. Cardwell, Ph.D., plant pathologist

P. Q. Crawford, Ph.D., crop physiologist

K. E. Dashiell, Ph.D., breeder

L. E. N. Jackai, Ph.D., entomologist

D. M. Naik, Ph.D., agronomist/breeder, Zimbabwe

O. Nakayama, Ph.D., food technologist

B. R. Ntare, Ph.D., breeder and liaison scientist to ICRISAT, Niger

B. B. Singh, Ph.D., breeder

I. Watanabe, Ph.D., plant physiologist

H. O. Ogundipe, M.Sc., food technologist

Postdoctoral fellows

C. N. Akem, Ph.D., pathologist/breeder

G. O. Myers, Ph.D., breeder

Maize Research Program

I. W. Buddenhagen, Ph.D., director *

M. Winslow, Ph.D., director

N. A. Bosque-Perez, Ph.D., entomologist

S. K. Kim, Ph.D., breeder

J. H. Mareck, Ph.D., breeder

T. Mesfin, Ph.D., vector entomologist

M. Rodriguez, Ph.D., agronomist *

G. K. Weber, Ph.D., national program coordinator

Postdoctoral fellows

A. E. Awad, Ph.D., striga biologist

J. G. Kling, Ph.D., breeder

O. M. Olanya, Ph.D., pathologist

Visiting scientists

B. Badu-Apraku, Ph.D., breeder

D. K. Kossou, Ph.D., entomologist

Resource and Crop Management Program

D. S. C. Spencer, Ph.D., director

I. O. Akobundu, Ph.D., weed scientist

A. N. Atta-Krah, Ph.D., coordinator, alley farming network

K. Dvorak, Ph.D., agricultural economist

H. C. Ezumah, Ph.D., agronomist, cassava-based working group

B. S. Ghuman, Ph.D., soil scientist *

M. P. Gichuru, Ph.D., agronomist (soil fertility)

G. Gillman, Ph.D., soil chemist

N. R. Hulugalle, Ph.D., soil physicist

A. E. Ikpi, Ph.D., economist

A-M. N. Izac, Ph.D., agricultural economist

S. S. Jagtap, Ph.D., agroclimatologist

B. T. Kang, Ph.D., soil scientist/agronomist

T. L. Lawson, Ph.D., agroclimatologist *

K. Mulongoy, Ph.D., soil microbiologist

H. J. W. Mutsaers, Ph.D., agronomist, maize-based systems working group

M. C. Palada, Ph.D., agronomist , rice-based systems working group *

N. Sanginga, Ph.D., assistant coordinator, alley farming network

J. Smith, Ph.D., economist, maize-based systems working group

M. Swift, Ph.D., leader, resource management research

Collaborative Study of Cassava in Africa

F. I. Nweke, Ph.D., agricultural economist, team leader

G. R. Mullins, Ph.D., East/Southern Africa regional coordinator

Y. C. Prudencio, Ph.D., regional coordinator

Postdoctoral fellows

R. J. Carsky, Ph.D., agronomist

S. Ehui, Ph.D., agricultural economist *

G. Fairchild, Ph.D., soil microbiologist

A. C. Goldman, Ph.D., economic geographer *

R. A. Polson, Ph.D., agricultural economist

E. Tucker, Ph.D., weed scientist

Visiting scientists

P. O. Adetiloye, Ph.D., agronomist *

S. Hauser, Ph.D., agronomist

R. Markham, Ph.D., entomologist

Associate experts

J. Foppes, Ir., agricultural economist, Onne station

M. C. Van der Meersch, Ir., microbiologist

Rice Research Program

M. Winslow, Ph.D., program leader and breeder
K. Alluri, Ph.D., coordinator, INGER-Africa/IRRI liaison scientist
T. M. Masajo, Ph.D., breeder

Postdoctoral fellow

R. C. Joshi, Ph.D., entomologist

Root, Tuber and Plantain Improvement Program

S. K. Hahn, Ph.D., director
A. M. Almazan, Ph.D., biochemist/food technologist *
R. Asiedu, Ph.D., breeder
Y. W. Jeon, Ph.D., postharvest technologist
S. Y. C. Ng, M.Sc., tissue culture specialist
D. S. O. Osiru, Ph.D., crop physiologist
J. A. Otoo, Ph.D., agronomist/breeder
M. C. M. Porto, Ph.D., CIAT-IITA physiologist/breeder
G. D. Sery, Ph.D., regional coordinator, INIBAP, Onne station
R. L. A. Swennen, Ph.D., agronomist/breeder, officer-in-charge, Onne

Postdoctoral fellows

M. Bokanga, Ph.D., biochemist
A. G. O. Dixon, Ph.D., breeder
G. Eggleston, Ph.D., biochemist

Visiting scientists

K. V. Bai, Ph.D., cytogeneticist
T. Ikotun, Ph.D., pathologist
H. Kanno, Ph.D., entomologist, JICA
I. G. Mok, Ph.D., breeder, CIP *

Associate Expert

D. R. Vuylsteke, Ir., agronomist, INIBAP, Onne station *

Analytical Services Laboratory

J. L. Pleysier, Ph.D., head

Biometrics

P. Walker, M.A., biometrician

Farm Management

D. C. Couper, M.Sc., farm manager
P. D. Austin, B.Sc., farm manager, Onne station
S. L. Claassen, M.Sc., assistant farm manager
P. V. Hartley, B.Sc., farm manager/engineer

Genetic Resources Unit

N. Q. Ng, Ph.D., head and plant geneticist
S. Padulosi, Dott., plant explorer

Virology Unit

H. W. Rossel, Ir., head and virologist
G. Thottappilly, Ph.D., virologist

International Cooperation

H. Gasser, Ph.D., director, training program
E. Arubayi, M.B.A., coordinator, monitoring and evaluation *
E. F. Deganus, B.Sc., project development coordinator
J. L. Gulley, Ph.D., group training coordinator
O. M. Ogunyinka, M.Sc., coordinator, monitoring and evaluation
J. C. Sentz, Ph.D., USAID liaison scientist
J. B. Suh, Ph.D., research liaison scientist
A. P. Uriyo, Ph.D., project development coordinator
R. Zachmann, Ph.D., training materials specialist

CIDA/CIMMYT/IITA Ghana Grains Development Project, Ghana

A. M. Hossain, Ph.D., breeder

Gatsby Charitable Foundation/IITA/National Root Crops Improvement Program, Cameroon

J. B. Abaka-Whyte, Ph.D., breeder and project leader
M. O. Akoroda, Ph.D., agronomist/breeder

IFAD/IITA Ghana Smallholder Rehabilitation and Development Program

O. O. Okoli, Ph.D., breeder and root crops coordinator

Semi-Arid Food Grains Research and Development (SAFGRAD) Project, Burkina Faso

J. M. Fajemisin, Ph.D., pathologist/breeder, project leader and maize network coordinator
N. Muleba, Ph.D., agronomist and cowpea network coordinator

USAID/IDRC/IITA East and Southern African Root Crops Research Network (ESARRN), Malawi

M. N. Alvarez, Ph.D., breeder and network coordinator

USAID/IITA/National Cereals Research and Extension (NCRE) Project, Cameroon

E. A. Atayi, Ph.D., chief of party and agricultural economist
S. W. Almy, Ph.D., social economist
D. C. Baker, Ph.D., agricultural economist
V. Balasubramaniam, Ph.D., agronomist
O. P. Dangi, Ph.D., breeder
L. Everett, Ph.D., breeder
M. P. Jones, Ph.D., breeder
M. Kamuanga, Ph.D., agricultural economist
J. Kikafunda-Twine, Ph.D., agronomist
D. McHugh, M.Sc., extension agronomist
J. A. Poku, Ph.D., extension agronomist
A. C. Roy, Ph.D., agronomist
J. T. Russell, Ph.D., extension agronomist
L. Singh, Ph.D., breeder
T. Stilwell, Ph.D., deputy chief of party and soil chemist
H. Talleyrand, Ph.D., agronomist
T. Woldetatios, Ph.D., extension agronomist *

* *Left during the year (1 April 1989 - 31 March 1990)*

Consultants

USAID/IITA Applied Agricultural Research (RAV) Project, Zaire

F. E. Brockman, Ph.D., chief of party and agronomist
M. S. Alam, Ph.D., entomologist
C. D. S. Bartlett, Ph.D., agricultural economist
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A. D. Florini, Ph.D., regional outreach specialist
K. M. Johnson, Ph.D., breeder
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G. F. Montalban, plant superintendent
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M. Seye, M.A., administrative officer
D. A. Shannon, Ph.D., agronomist
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Technology Transfer Unit

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S. O. Adeyeye, cassava breeding research
S. A. Aman, training
Guy Baird, research evaluation
R. A. Boxall, grain storage research
A. H. Bunting, research evaluation
Russell Cramer, editing
Direk Ditwiler, cassava research
Clifford S. Gold, biological control
L. S. Halos, postharvest technology
Haldore Hanson, writing
Joseph A. Kwarteng, training materials
D. S. Mikkelsen, research evaluation
Alan W. Moore, writing/editing
Sagary Nokoe, research evaluation
B. C. Nzotta, editing
Chris Parker, striga biology
Henry Romney, public relations
P. A. Shah, biological control
Eric M. Sicely, biological control
Eric Tollens, economics
Anthony Wolff, writing
A. Youdeowei, editing

Collaborative Projects on Food and Technology

F. Adesanye, food utilization
J. O. Akingbala, food technology
Tola Atinmo, food utilization
O. C. Aworh, food technology
J. Burdon, food utilization
J. Delcour, food technology
L. Denton, food utilization
Janet Kwatia, food utilization
K. G. Moore, food utilization
P. O. Ngoddy, food technology
G. B. Oguntimein, food utilization
S. L. Oke, food utilization
J. E. Okeke, food technology
O. Olatunji, food technology
Sidi Osho, food utilization
A. S. O. Oyakhilome, food utilization
D. Taylor, food utilization
A. C. Uwaegbute, food utilization
Carol Williams, food utilization

Publications by IITA Staff 1989

Published Journal Articles and Monographs

Alam, M.S. 1989. Whitefly (Hemiptera: Aleyrodidae) – a potential pest of rice in West Africa. *International Rice Research Newsletter* 14: 3.

Alam, M.S. and J.A. Lowe 1989. Incidence of two grain suckers in irrigated and upland rice. *International Rice Research Newsletter* 14: 3.

Balasubramanian, V. and A. Egli. 1989. Un aperçu sur les systèmes de production au Bugesera et Gisaka-Migongo (BGM). *Bull. Agric. Rwanda* 2: 86-98.

Boussienguet, J. and P. Neuenschwander. 1989. Le complexe entomophage de la cochenille du manioc en Afrique. 3. Clé et annotée pour la détermination des hymenoptères parasitoides associés à ce ravageur. *Rev. Zool. Afr.* 103: 395-403.

Brewbaker, L. and S.K. Kim. 1989. The MIR (maize inbred resistance) trials: performance of tropical-adapted maize inbreds. Research Series 062. University of Hawaii, College of Tropical Agriculture and Human Resources.

Chen, Y.S., B.T. Kang and F.E. Caveness. 1989. Alley cropping vegetable crops with leucaena in southern Nigeria. *Hort. Sci.* 24: 839-840.

Cobbina, J., A.N. Atta-Krah and B.T. Kang. 1989. Leguminous browse supplementation effect on the agronomic value of sheep and goat manure. *Biol. Agric. Hort.* 6: 115-121.

Cobbina, J., B.T. Kang and A.N. Atta-Krah. 1989. Effect of soil fertility on early growth of leucaena and gliricidia in alley farms. *Agroforestry Systems* 8: 157-164.

Efron, Y., S.K. Kim, J.M. Fajemisin, J.H. Mareck, C.Y. Tang, Z.T. Dabrowski, H.W. Rossel, G. Thottappilly and I.W. Buddenhagen. 1989. Breeding for resistance to maize streak virus: a multidisciplinary team approach. *Plant Breeding* 103: 1-36.

Ehui, S.K. and T.W. Hertel. 1989. Computing the socially optimal forest stock for the Ivory Coast. *In:* B. Greenshields and M. Bellamy (eds.). Government intervention in agriculture. Aldershot, Darmouth Publishing Co. Ltd., U.K. 337p.

Ehui, S.K. and T.W. Hertel. 1989. Deforestation and agricultural productivity in the Côte d'Ivoire. *American Journal of Agricultural Economics* 71(3): 703-711.

Ehui, S.K., T.W. Hertel and P.V. Preckel. 1990. Forest resource depletion, soil dynamics, and agricultural productivity in the tropics. *J. Environ. Econ.* 18:136-154.

Gichuru, M.P. and B.T. Kang. 1989. *Calliandra calothyrsus* (Meissn) in alley cropping system with sequentially cropped maize and cowpea in southwestern Nigeria. *Agroforestry Systems* 9: 191-203.

Hahn, S.K., J.C.G. Isoba and T. Ikotun. 1989. Resistance breeding in root and tuber crops at the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria. *Crop Protection* 8: 147-168.

Ikeorgu, J.E.G., H.C. Ezumah and T.A.T. Wahua. 1989. Productivity of species in cassava/maize/okra/egusi melon complex mixtures in Nigeria. *Field Crops Research* 21: 1-7.

Ikeorgu, J.E.G., T.A.T. Wahua and H.C. Ezumah. 1989. Effects of melon (*Citrullus lanatus* Thunb.) and okra (*Abelmoschus esculentus* [L.] Moench) on the soil moisture and leaf water status of intercropped cassava maize in Nigeria. *Trop. Agric. (Trinidad)* 66(1): 78-82.

Jackai, L.E.N. 1989. A laboratory procedure for rearing the cowpea coreid, *Clavigralla tomentosicollis* Stål., using dry cowpea seeds. *Bull. ent. Res.* 79: 275-281.

Jackai, L.E.N. and S. Oghiakhe. 1989. Pod wall trichomes and resistance of two wild cowpea, *Vigna vexillata*, accessions to *Maruca testulalis* (Geyer) (Lepidoptera: Pyralidae) and *Clavigralla tomentosicollis* Stål. (Hemiptera: Coreidae). *Bull. ent. Res.* 79: 595-605.

Kang, B.T. 1989. Nutrient management for sustained crop production in the humid and subhumid tropics. *In:* J. van der Heide (ed.). Nutrient management for food crop production in tropical farming systems. Institute of Soil Fertility (IB), Haren, Netherlands. 3-28.

Kang, B.T. and L. Reynolds (eds.). 1989. Alley farming in the humid and subhumid tropics. Proceedings. IDRC, Ottawa.

Kang, B.T., L. Reynolds and A.N. Atta-Krah. 1989. Alley farming. *Advances in Agronomy* 43: 315-359.

Kang, B.T., A.C.B.M. van der Kruijs and D.C. Couper. 1989. Alley cropping for food crop production in the humid and subhumid tropics. *In:* B.T. Kang and L. Reynolds (eds.). Alley farming in the humid and subhumid tropics. IDRC, Ottawa. 16-26.

Löhr, B., B. Santos and A.M. Varela. 1989. Larval development and morphometry of *Epidinocarsis lopezi* (De Santis) (Hym., Encyrtidae), parasitoid of the cassava mealybug, *Phenacoccus manihoti* Mat.-Ferr. (Hom., Pseudococcidae). *Z. ang. Ent.* 107: 334-343.

Löhr, B., A.M. Varela and B. Santos. 1989. Life-table studies of *Epidinocarsis lopezi* (De Santis) (Hym., Encyrtidae), a parasitoid of the cassava mealybug, *Phenacoccus manihoti* Mat.-Ferr. (Hom., Pseudococcidae). *Z. ang. Ent.* 107: 425-434.

Mareck, J.H., N.A. Bosque-Perez and M.S. Alam. 1989. Screening and breeding for resistance to African maize borers. *Annual Plant Resistance to Insects Newsletter* 15: 58-59.

Moraes, G.J. de, J.A. McMurtry and J.S. Yaninek, 1989. Some phytoseiid mites (Acari: Phytoseiidae) from tropical Africa with descriptions of one new species. *Internat. J. Acarology* 15: 95-102.

Moraes, G.J. de, H. van den Berg and J.S. Yaninek. 1989. Phytoseiid mites (Acari: Phytoseiidae) of Kenya, with descriptions of eight species. *Internat. J. Acarology* 15: 79-93.

Mulongoy, K. and A. Bedoret. 1989. Properties of wormcasts and surface soils under various plant covers in the humid tropics. *Soil Biol. Biochem.* 21(2): 197-203.

Mutsaers, H.J.W. 1989. A dynamic equation for plant interaction and application to yield-density-time relations. *Annals of Botany* 64: 521-531.

Mutsaers, H.J.W. 1989. On-farm research: de tropenboer herontdekt. *Landbouwkundig Tijdschrift* 101(6/7): 21.

Nangju, D. and B.T. Kang. 1989. Cowpea. *In:* D.L. Plucknett and H.B. Sprague (eds.). Detecting mineral deficiencies in tropical and temperate crops. Boulder, Westview Press. 145-153.

Neuenschwander, P., W.N.O. Hammond, A.R. Gutierrez, A.R. Cudjoe, R. Adjakloe, J.U. Baumgärtner and U. Regev. 1989. Impact assessment of the biological control of the cassava mealybug, *Phenacoccus manihoti* Matile-Ferrero (Hemiptera: Pseudococcidae), by the introduced parasitoid *Epidinocarsis lopezi* (De Santis) (Hymenoptera: Encyrtidae). *Bull. ent. Res.* 79: 579-594.

Neuenschwander, P., T. Haug, O. Ajounu, H. Davis, B. Akinwumi and E. Madojemu. 1989. Quality requirements in natural enemies used for inoculative release: practical experience from a successful biological control program. *Journal of Applied Entomology* 108: 409-420.

Ntare, B.R. 1989. Evaluation of cowpea cultivars for intercropping with pearl millet in the Sahelian zone of West Africa. *Field Crops Research* 20: 31-40.

Sanginga, N., S.K.A. Danso and G.D. Bowen. 1989. Nodulation and growth response of *Allocasuarina* and *Casuarina* species to phosphorus fertilization. *Plant and Soil* 118: 125-132.

Sanginga, N., K. Mulongoy and A. Ayanaba. 1989. Effectivity of indigenous rhizobia for nodulation and early nitrogen fixation with *Leucaena leucocephala* grown in Nigerian soils. *Soil Biol. Biochem.* 21(2): 231-235.

Sanginga, N., K. Mulongoy and A. Ayanaba. 1989. Nitrogen fixation of field-inoculated *Leucaena leucocephala* (Lam.) de Wit estimated by the ^{15}N and the difference methods. *Plant and Soil* 117: 269-274.

Sanginga, N. and C. van Hove. 1989. Amino acid composition of azolla as affected by strains and population density. *Plant and Soil* 117: 263-267.

Schulthess, F., J.U. Baumgärtner and H.R. Herren. 1989. Sampling *Phenacoccus manihoti* in cassava fields in Nigeria. *Tropical Pest Management* 35: 193-200.

Smith, J., G. Umali, M.W. Rosegrant and A.M. Mandac. 1989. Risk and nitrogen use on rainfed rice: Bicol, Philippines. *Fertilizer Research* 21: 113-123.

Swennen, R. and E. De Langhe. 1989. Threats to the highland banana in eastern Africa. International Network for the Improvement of Bananas and Plantains (INIBAP). *Musarama* 2(1): 2-4.

Thottappilly, G. and H.W. Rossel. 1988. Occurence of cowpea mottle virus and other viruses (cowpea yellow mosaic virus, southern bean mosaic virus) in cowpea. *FAO Plant Protection Bull.* 36(4): 184-185.

van Alphen, J.J.M., P. Neuenschwander, M.J. van Dijken, W.N.O. Hammond and H.R. Herren. 1989. Insect invasions: the case of the cassava mealybug and its natural enemies evaluated. *The Entomologist* 108: 38-55.

van der Kruijs, A.C.B.M., J. van der Heide and B.T. Kang. 1989. Observations on decomposition rates of leaves of several shrub and tree species applied as mulch under humid tropical conditions. *In:* J. van der Heide (ed.). Nutrient management for food crop production in tropical farming systems. Institute of Soil Fertility (IB), Haren, Netherlands. 361-366.

Vuylsteke, V.R. 1989. Shoot-tip culture for the propagation, conservation and exchange of *Musa* germplasm. Practical Manuals for Handling Crop Germplasm in Vitro: 2. International Board for Plant Genetic Resources (IBPGR), Rome, Italy.

Winslow, M.D., M. Yamauchi, K. Alluri and T.M. Masajo. 1989. Reducing iron toxicity in rice with resistant genotype and ridge planting. *Agronomy Journal* 81: 458-460.

Yaninek, J.S., A.P. Gutierrez and H.R. Herren. 1989. Dynamics of *Mononychellus tanajoa* (Acari: Tetranychidae) in Africa: experimental evidence of the effects of temperature and host plant on population growth rates. *Environ. Entomol.* 18: 633-640.

Yaninek, J.S., H.R. Herren and A.P. Gutierrez. 1989. Dynamics of *Mononychellus tanajoa* (Acari: Tetranychidae) in Africa: seasonal factors affecting phenology and abundance. *Environ. Entomol.* 18: 625-632.

Published Conference Papers

Adetiloye, P.O., A.A. Adekunle and H.C. Ezumah. 1989. Cassava intercropping with maize, cowpea and plantain at different intercrop populations and mixture complexities in a humid tropical environment. *Agron. Abstr. 1989 Annual Meetings* (15-20 Oct): 49.

Adetiloye, P.O. and H.C. Ezumah. 1989. Performance and production of plantain and cassava intercropping systems. *In:* IITA. Cassava-based cropping systems research II. 13-23.

Asadu, C.L.A., H.C. Ezumah, F.O. Akammigbo and F.I. Nweke. 1989. Relative changes in the nutrient composition of six cultivars of white yam grown in three ecozones of southeastern Nigeria. *In:* IITA. Cassava-based cropping systems research II. 126-137.

Balasubramanian, V., L. Sekayange and J.C. Rubyago. 1989. Effect of pigeonpea varieties and plant arrangements on the productivity of pigeonpea + maize/beans association. *Agron. Abstr. 1989 Annual Meetings* (15-20 Oct): 50.

Bosque-Perez, N.A. and Z.T. Dabrowski. 1989. Mass rearing of the maize stem borers *Sesamia calamistis* and *Eldana saccharina* at IITA. *In:* Centro Internacional de Mejoramiento de Maiz y Trigo (CIMMYT). Toward insect-resistant maize for the third world. Proceedings. Mexico D.F.

Bosque-Perez, N.A., J.H. Mareck, Z.T. Dabrowski, L. Everett, S.K. Kim and Y. Efron. 1989. Screening and breeding maize for resistance to *Sesamia calamistis* and *Eldana saccharina*. *In:* CIMMYT. Toward insect-resistant maize for the third world. Proceedings. Mexico D.F.

Efron, Y., S.K. Kim, V. Parkinson and N.A. Bosque-Perez. 1989. IITA's strategies to develop striga-resistant maize germplasm. *In:* T.O. Robson and H.R. Broad (eds.). Striga—Improved management in Africa. Proceedings. FAO, Rome. 141-153.

Ezumah, H.C. and N.C. Hulugalle. 1989. Studies on cassava-based rotation systems in a tropical alfisol. *Agron. Abstr. 1989 Annual Meetings* (15-20 Oct): 53.

Haug, T. and B. Mégevand. 1989. Development of technologies in support of contemporary biological control. *In:* J.S. Yaninek and H.R. Herren (eds.). Biological control: a sustainable solution to crop pest problems in Africa. 141-146.

Herren, H.R. 1989. The Biological Control Program of IITA: from concept to reality. *In:* J.S. Yaninek and H.R. Herren (eds.). Biological control: a sustainable solution to crop pest problems in Africa. 18-30.

Ikeorgu, J.E.G., R.P. Unamma and H.C. Ezumah. 1989. Effect of fertilizer and time of introduction of cassava or maize on productivity of yam and cassava-based intercrops in a humid ultisol. *In:* IITA. Cassava-based cropping systems research II. 36-41.

Jackai, L.E.N. and S.R. Singh. 1989. Etude sur les techniques de criblage pour la résistance de la plante-hôte aux insectes nuisibles du niébé. *In:* Y. Demarly (ed.). Les leguminenses à graines. Actes du Séminaire organisé par la FIS. Madagascar, 22-27 Feb 1988. Stockholm, Fondation internationale pour la science. 23-50.

Kang, B.T. and O. Onafeko. 1989. Spatial chemical soil variability in alley cropped plots. *Agron. Abstr. 1989 Annual Meetings* (15-20 Oct): 55.

Karunwi, A. and H.C. Ezumah. 1989. Economics of indigenous cassava processing techniques in a humid forest ecology of Nigeria. *In:* IITA. Cassava-based cropping systems research II. 181-193.

Klay, A. and G.J. de Moraes. 1989. Problems and issues in managing and rearing natural enemies. *In:* J. S. Yaninek and H. R. Herren (eds.). Biological control: a sustainable solution to crop pest problems in Africa. 127-132.

Lawani, S.M. 1989. Constraints to the exchange of information and documentation on banana and plantain in West Africa. *In:* P. Thompson and C. P. Montpellier (eds.). Information and documentation for banana and plantain. Proceedings. International Network for the Improvement of Banana and Plantain (INIBAP) workshop. 2-5 Jun 1987. La Grande Motte, France. 257-265.

Markham, R.H. and E.M. Sicely. 1989. Appropriate support for national programs: training, research, administration and funding. *In:* J. S. Yaninek and H.R. Herren (eds.). Biological control: a sustainable solution to crop pest problems in Africa. 156-165.

Naik, D.M. 1989. Research on grain legumes in SADCC countries. *In:* G. Mudimu and R.H. Benton (eds.). Household and national food security in southern Africa. Proceedings of a conference, 31 Oct - 3 Nov 1988. University of Zimbabwe/Michigan State University Food Security Research Project, Harare.

Neuenschwander, P. and A.P. Gutierrez. 1989. Evaluating the impact of biological control measures in Africa. *In:* J.S. Yaninek and H.R. Herren (eds.). Biological control: a sustainable solution to crop pest problems. 147-155.

Ntare, B.R., L.K. Fussell and P.G. Serafini. 1989. Recent developments in millet/cowpea cropping systems for low rainfall areas of Sudano-Sahelian zone of West Africa. *In:* Proceedings of a workshop on soil, water and crop management systems for rainfed agriculture in the Sudano-Sahelian zone of West Africa. 11-15 Jan 1987.

Oyedokun, J.B., T.A. Akinlosotu, M.O. Omidiji and H.C. Ezumah. 1989. Introduction of cassava through maize in a humid environment. *In:* IITA. Cassava-based cropping systems research II. 24-35.

Rossel, H.W., G. Thottappilly, J.M.W. van Lent and H. Huttinga. 1989. The etiology of cassava mosaic disease in Nigeria. Proceedings of an international conference on African cassava mosaic disease and its control. 4 - 8 May 1987. ORSTOM, Côte d'Ivoire. 43-56.

Seshu, D.V., K. Alluri, F. Ceuvas-Perez, S.W. Ahn, M. Akbar, K.G. Pillai and M.J. Rosero. 1989. Report of activities and accomplishments of the International Rice Testing Program 1985-89. International Rice Research Institute (IRRI). 68p.

Shannon, D.A., K.N. Kabaluapa and M.C. Ngoyi. 1989. Alley cropping: a promising technology for the savanna of Zaire. *Agron. Abstr. 1989 Annual Meetings* (15-20 Oct): 59.

Shannon, D.A, M. Kubengu and M.C. Ngoyi. 1989. Evaluating maize varieties in on-farm trials in south central Zaire. *Agron. Abstr. 1989 Annual Meetings* (15-20 Oct): 59.

Thottappilly, G. and H.W. Rossel. 1988. Virus diseases of sweet potato in Nigeria. Report of the UNDP/CIAT/CIP/IITA Workshop on Sweet Potato Improvement in Africa. 28 Sept - 2 Oct 1987. Nairobi, Kenya. 53-64.

Unamma, R.P.A., A. Udealor, T.O. Ezulike, G.C. Orkwar, L.S.O. Ene, J.E.G. Ikeorgu and H.C. Ezumah. 1989. Evaluation of the productivity of cassava-yam-maize intercrop in the rainforest zone of Nigeria. *In:* IITA. Cassava-based cropping systems research II. 47-56.

Vogel, W.O. and H.J.W. Mutsaers. 1989. Economic returns of alley farming. *In:* B.T. Kang and L. Reynolds (eds.). Alley farming in the humid and subhumid tropics. Proceedings. IDRC, Ottawa. 197-207.

Waage, J.K. and F. Schulthess. 1989. Relevant research activities in support of sustainable pest management. *In:* J.S. Yaninek and H.R. Herren (eds.). Biological control: a sustainable solution to crop pest problems in Africa. 133-140.

Wilson, G.F. and R. Swennen. 1989. Alley cropping: potential for plantain and banana production. *In:* B.T. Kang and L. Reynolds (eds.). Alley farming in the humid and subhumid tropics. Proceedings. IDRC, Ottawa. 31-41.

Wodageneh, A. 1989. Constraints confronting national biological control programs. *In:* J.S. Yaninek and H.R. Herren (eds.). Biological control: a sustainable solution to crop pest problems in Africa. 166-172.

Yaninek, J.S. and M.J.W. Cock. 1989. Identifying pest problems in relation to implementing biological control in Africa. *In:* J.S. Yaninek and H.R. Herren (eds.). Biological control: a sustainable solution to crop pest problems in Africa. 116-126.

IITA Series

Balasubramanian, V. 1989. Alley shrubs in a high-altitude, semi-arid environment. *IITA Research Briefs* 9(1): 3.

Hahn, N.D. (ed.). 1989. In praise of cassava. Proceedings of the interregional expert group meeting on the exchange of technologies for casssava processing equipment and food products. 13-19 Apr 1988. IITA, Ibadan. Copublished with UNICEF. 241p.

Hahn, S.K. and R.L. Théberge. 1989. Root and tuber crops: food security in Central Africa. Third Central Africa regional workshop on root and tuber crops: proceedings. 116p.

Lawani, S.M. 1989. The cowpea, biotechnology and natural pest control. *IITA Research Briefs* 9(2): 1, 6.

Mutsaers, H.J.W. 1989. Nigeria adopts improved cassava varieties bred at IITA. *IITA Research Briefs* 9(1).

Neuenschwander, P. 1989. Biological control of mango mealybug. *IITA Research Briefs* 9(3): 5-6.

Nweke, F.I. 1988. Collaborative study of cassava in Africa: project description. COSCA Working Paper I. IITA.

Nweke, F.I., H.C. Ezumah and D.S.C. Spencer. 1988. Cropping systems and agronomic performance of improved cassava (Manihot esculenta Crantz), in a humid forest ecosystem. RCMP Research Monograph 2.

Singh, S.R., L.E.N. Jackai, B.B. Singh, B.N. Ntare, H.W. Rossel, G. Thottappilly, N.Q. Ng, M.A. Hossain, K. Cardwell, S. Padulosi and G. Myers. 1989. Cowpea research at IITA. GLIP Research Monograph 1. 23p.

Stifel, L.D. 1990. IITA research for sustainable agriculture in Africa. 28p.

Stifel, L.D. 1990. Toward recovery in national food production. 19p.

Stifel, L.D. 1989. Transforming Nigerian agriculture: the role of research. 28p.

Swennen, R., D. Vuylsteke and S.K. Hahn. 1989. Combatting the black Sigatoka threat to plantains. *IITA Research Briefs* 9(2): 2-4.

Vuylsteke, D. and R. Swennen. 1989. Plantain/banana tissue-culture laboratory established in Nigeria. *IITA Research Briefs* 9(2): 3.

Weber, G.K. and A.O. Akalumbe. 1989. Macroeconomic data related to production, consumption and nutrition. Maize Database for Sub-Saharan Africa: 1.

Yaninek, J.S., G.J. de Moraes and H.R. Markham. 1989. Handbook on the cassava green mite *Mononychellus tanajoa* in Africa: a guide to its biology and procedures for implementing classical biological control. 140p.

Yaninek, J.S. and H.R. Herren (eds.). 1989. Biological control: a sustainable solution to crop pest problems in Africa. Proceedings. 224p.

IITA Publications 1989

Afnetan. Newsletter of the Alley Farming Network for Tropical Africa. Vol. 1. nos. 1, 2. (Bilingual: English and French.)

Biological control: a sustainable solution to crop pest problems in Africa. Edited by J. S. Yaninek, G. J. de Moraes and R. H. Markham. Proceedings. ISBN 978-131-039-1. 224p.

Bulletin du réseau des plantes à tubercules tropicales. Vol. 4, n° 1-4.

Bulletin du réseau des systèmes de production en Afrique de l'Ouest. N° 4.

Cameroon National Root Crops Improvement Program annual report 1988.

Cassava-based cropping systems research II: contributions from the second annual meeting of the collaborative group in cassava-based cropping systems research.

Cassava in tropical Africa: a reference manual. ISBN 978-131-041-3. 184p.

CGIAR Task Force on Sub-Saharan Africa: strengthening maize and cassava research in eleven countries of coastal West and Central Africa: plan of action/request to donors.

Collaborative Study of Cassava in Africa: project description. F. I. Nweke. COSCA Working Paper 1.

Cowpea research at IITA. S. R. Singh et al. GLIP Research Monograph 1. 23p.

Cropping systems and agronomic performance of improved cassava (*Manihot esculenta* Cranz) in a humid forest ecosystem. F. I. Nweke, H. C. Ezumah and D. S. C. Spencer. RCMP Research Monograph 2. 48p.

Echo de l'Iita. Vol. 9, n° 1, 2.

ESARRN Newsletter. Eastern and Southern Africa Root Crops Research Network.

Food crops utilization and nutrition training manual. ISBN 978-131-040-5. 250p.

Genetic Resources Unit annual report 1987.

Grain Legumes Improvement Program annual report 1987.

Groupe d'intervention du Gcrai pour l'Afrique subsaharienne: le renforcement de la recherche sur le maïs et le manioc dans onze pays côtiers de l'Afrique occidentale et centrale: plan d'action/requête aux donateurs.

Guide des adventices d'Afrique de l'Ouest. I. O. Akobundu and C. W. Agyakwa. ISBN 978-131-031-7. 522p.

Handbook on the cassava green mite *Mononychellus tanajoa* in Africa: a guide to its biology and procedures for implementing classical biological control. Edited by J. S. Yaninek, G. J. de Moraes and R. H. Markham. ISBN 978-131-037-5. 140p.

IITA Medium-Term Plan 1989-1983. (Corrected edition). ISBN 978-131-042-1. 97p.

IITA Research Briefs. Vol. 9, nos. 1-4.

In praise of cassava. Proceedings of the interregional expert group meeting on the exchange of technologies for cassava processing equipment and food products. April 1988. Edited by Natale D. Hahn. Copublished with UNICEF. ISBN: 978-131-034-0 (IITA)/ 978 30600 17 (UNICEF). 241p.

International Cooperation and Training Program annual report 1987.

IRTP-Africa reports from the nurseries 1986 and 1987.

Media Forum for Agriculture: preliminary meeting.

Meeting of the directors of Nigerian agricultural research institutes with IITA. IITA Meeting Reports Series 1988/5.

Plan à moyen terme de l'Iita. (Corrigé). ISBN 978-131-029-4. 101p.

Resource and Crop Management Program annual report 1987.

Rice Research Program annual report 1987.

Root and tuber crops: food security in Central Africa. Third Central Africa regional workshop on root and tuber crops: proceedings. Edited by S. K. Hahn and R. L. Théberge. ISBN 978-131-054-5. 116p.

Root crops and low-input agriculture. Third eastern and southern Africa regional workshop on root and tuber crops: proceedings.

Root, Tuber and Plantain Improvement Program annual report 1987.

Screening techniques for host plant resistance to insect pests of cowpea. (Reprint.) L. E. N. Jackai and S. R. Singh. 23p.

Semi-Arid Food Grains Research and Development (SAFGRAD) Project annual report 1987.

Soybeans for good health: how to grow and use soybeans in Nigeria. 22p.

Summary report of an IRTP-Africa rice monitoring tour to Kenya and Madagascar and workshop in Nairobi, Kenya. 10-23 March 1989.

Sustainable crop and livestock production for Rwanda.

Transforming Nigerian agriculture: the role of research. Laurence D. Stifel. 28p.

Tropical Root Crops Network Newsletter. Vol. 4, nos. 1-4.

West African Farming Systems Research Bulletin. No. 5.

INTERNATIONAL INSTITUTE OF TROPICAL AGRICULTURE

Maize *Plantain*

Soybean *Cowpea*

Yam *Cassava*

ANNUAL REPORT 1989/90

IITA Annual Report 1989/90
ISSN 0331-4340

Editing
Kim Atkinson

Design and production
Chapman Bounford & Associates, U K

Printing
Technographic, U K

Additional text
p20-26 (articles), p43-48 (inset stories) Anthony Wolff

Illustrations/Photographs
cover S Padulosi/IITA; p4 B Fadare/IITA; p5 from World Bank IBRD 20126, after H R J Davies; p12 M Usman/IITA; p14 B Fadare/IITA; p20 J Gaumy/Magnum; p22 Abbas/Magnum; p24 A Wolff/IITA; p25 A Wolff/IITA; p26 A Wolff/IITA; p28 E Nwulu/IITA; p32 H Chazine/FAO; p34 E Nwulu/IITA; p37 E Nwulu/IITA; p38 J Gaumy/Magnum; p40 E Nwulu/IITA; p42 from W R Coffman/Cornell University, using FAO data; p44 N Q Ng, R Asiedu, A Ala/IITA; p45 A Wolff/IITA; p46 J Allan Cash Ltd; p47 B Fadare/IITA; p48 (left) B Fadare, (right) R Swennen/IITA; p53 H Rossel/IITA; p55 H Rossel/IITA; p56 B Fadare/IITA; p60 E Nwulu/IITA; p61 M Usman/IITA; p62 B Fadare/IITA; p64 B Fadare/IITA; p67 M Winslow/IITA; p70 B Fadare/IITA; p71 B Fadare/IITA; p73 B Fadare/IITA; p74 B Fadare/IITA; p75 M Usman/IITA; p77 R Zachmann/IITA; p79 B Fadare/IITA; p81 (top) E Nwulu/IITA, (bottom) J van Acker/FAO

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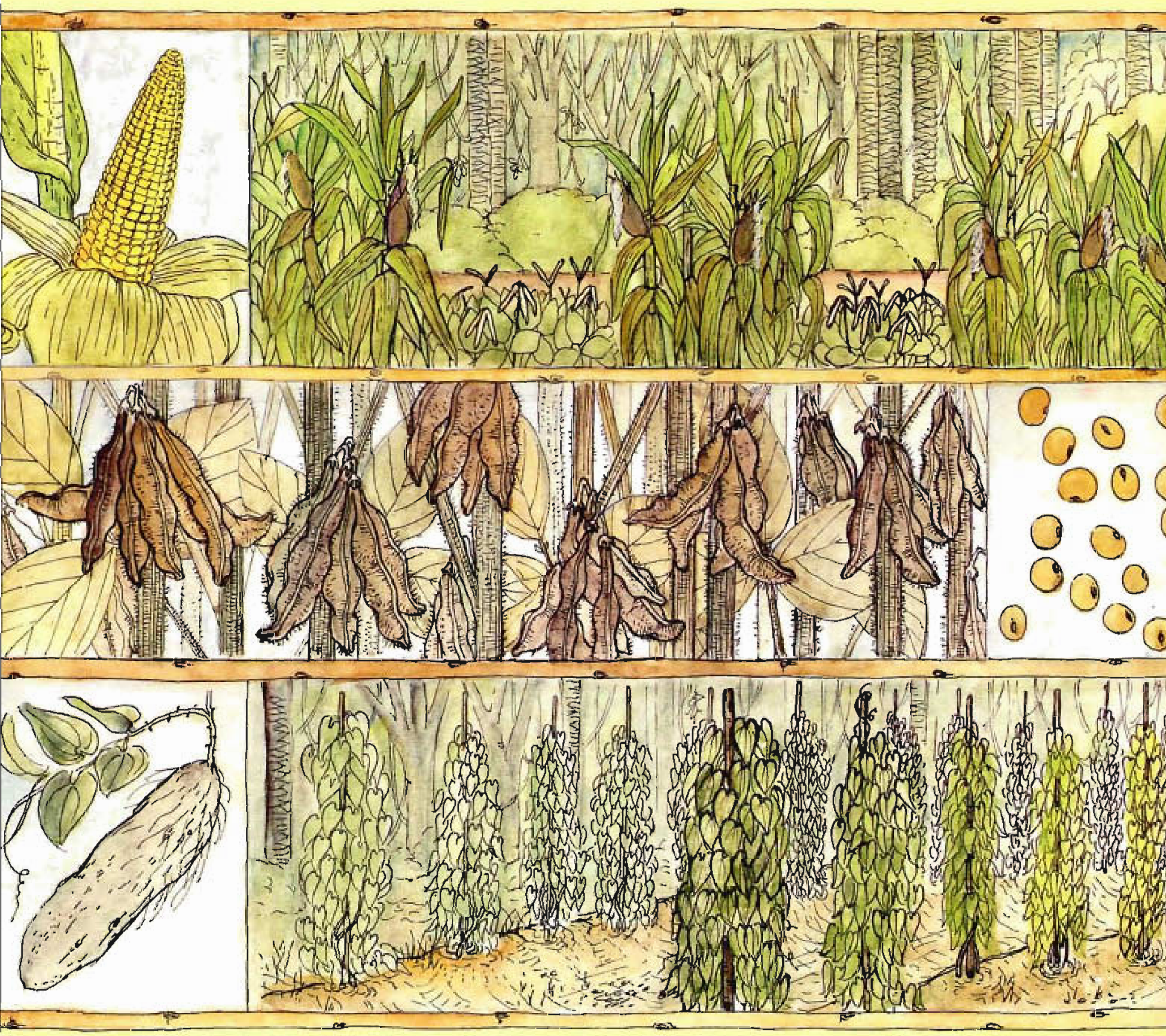

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ISSN 0331-4340