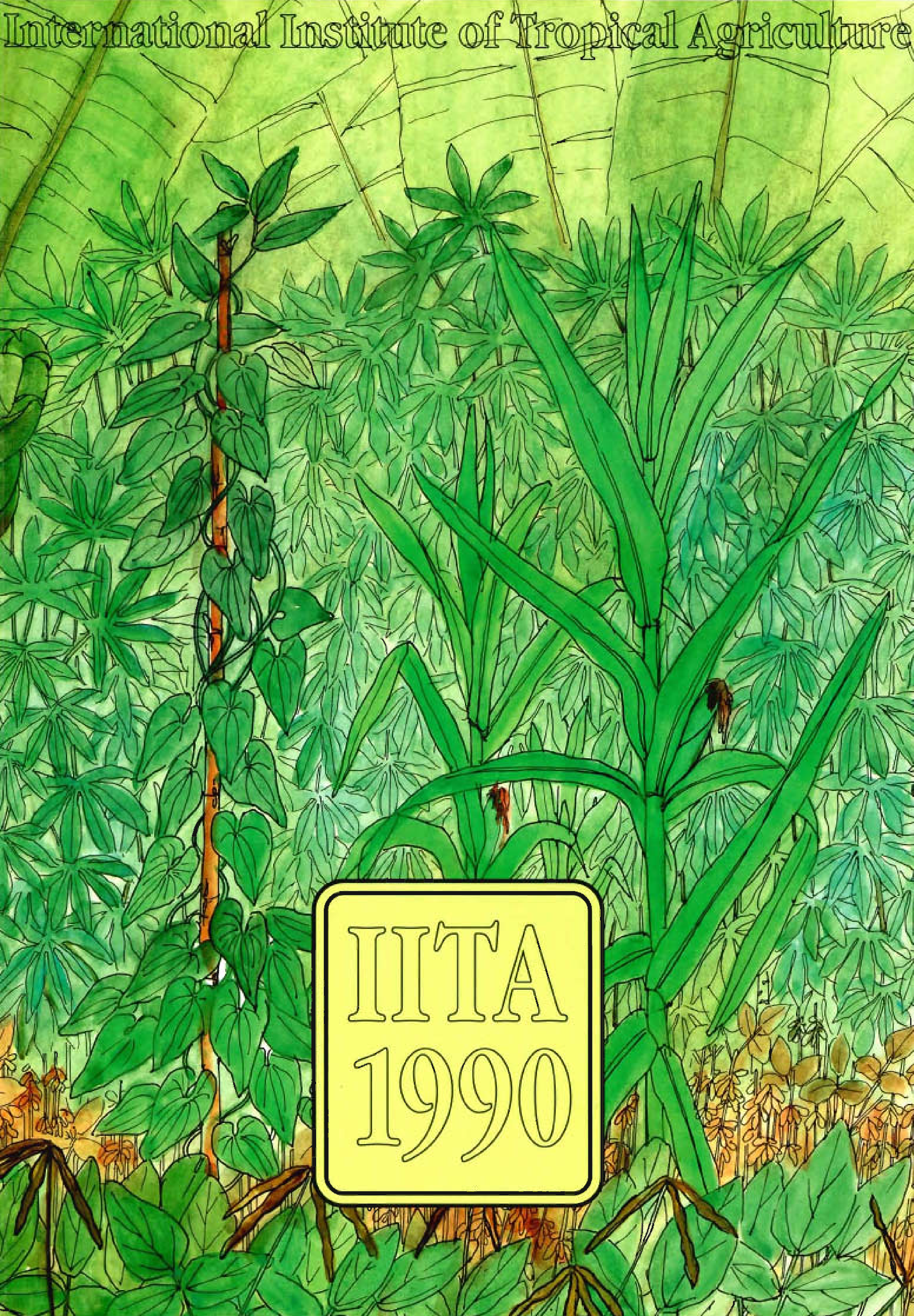
International Institute of Tropical Agriculture



IITA 1990

contents

Annual report of the International Institute of Tropical Agriculture 1990

IITA
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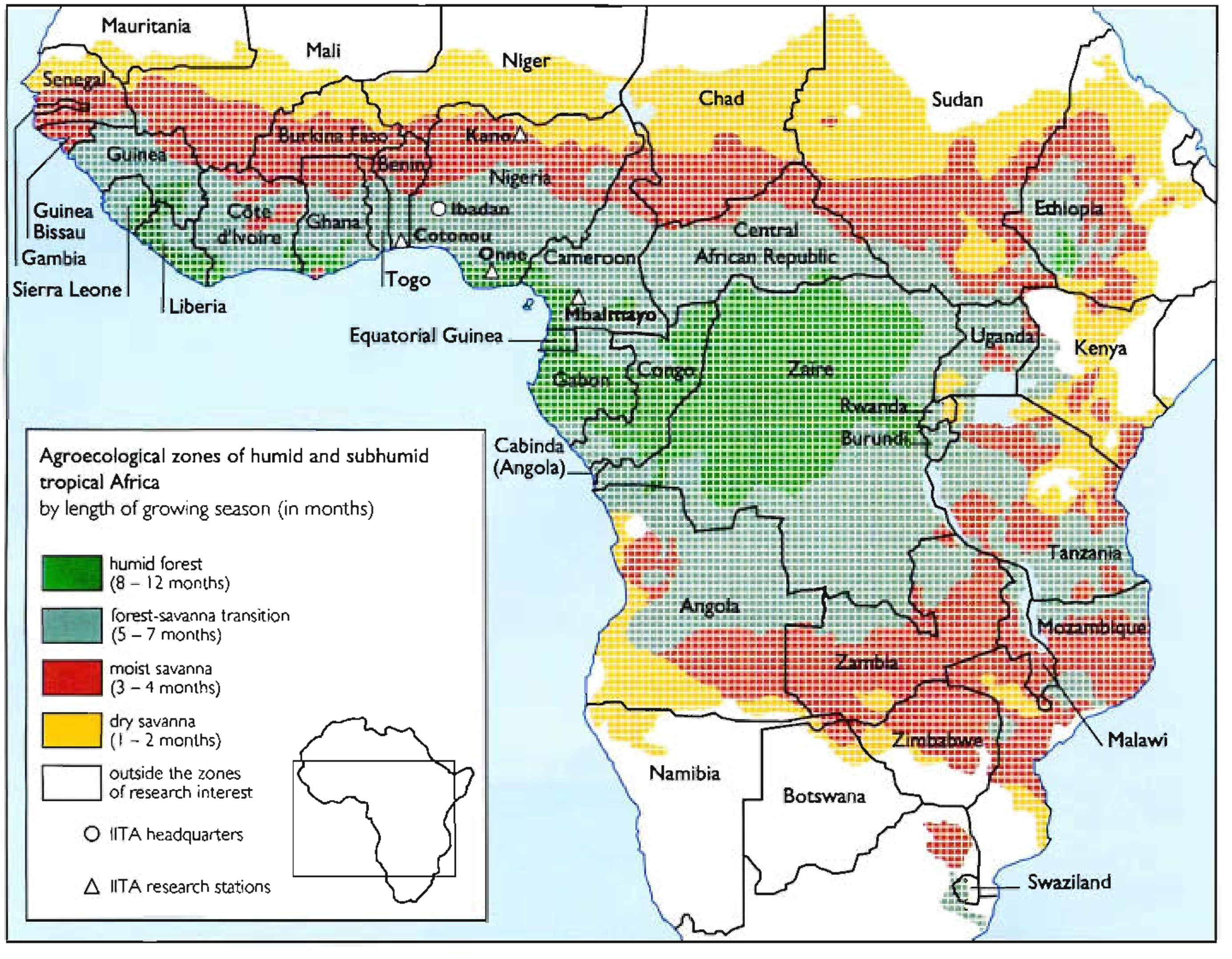
Mauritania
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Togo
Liberia
Mbalmayo
Equatorial Guinea
Uganda
Kenya
Gabon
Congo
Zaire
Rwanda
Burundi
Cabinda
(Angola)
Agroecological zones of humid and subhumid tropical Africa
by length of growing season (in months)
humid forest
(8 – 12 months)
forest-savanna transition
(5 – 7 months)
moist savanna
(3 – 4 months)
dry savanna
(1 – 2 months)
outside the zones
of research interest
IITA headquarters
IITA research stations
Tanzania
Angola
Mozambique
Zambia
Zimbabwe
Malawi
Namibia
Botswana
Swaziland

Foreword

The Board of Trustees and the staff of IITA have pleasure in presenting to you the annual report for 1990.

Nicholas E. Mumba

Lukas Brader

Our report gives an overview of the progress we have made in research and other program activities during 1990, highlighting significant results in each program. Improved crop varieties well suited for the various stress conditions of tropical Africa have been developed, while we continue to provide national systems and farmers with sustainable plant protection technologies. Research on sustainable production systems in fragile tropical environments which involve alley farming techniques continues to produce encouraging results, as is clearly demonstrated in tests and adoption of alley farming under farmers' conditions.

Research and training activities have continued to be implemented according to the objectives and proposals laid down in our medium-term plan for the period 1989–1993. Funding limitations, however, forced us during 1990 to limit the number of senior staff-years in research to 55, vis-a-vis the 66 envisaged in the medium-term plan. Notwithstanding the prospects for continuing restriction in funding for the foreseeable future, we will endeavor to increase our research capacity through internal shifts and by attracting special projects.

The year 1990 was marked by a number of events that will have a direct bearing on IITA activities in the short and long term. They include:

• The submission of the reports of the external review panels to the CGIAR mid-term meeting. While a number of suggestions were made for further improvements in research activities and in the program structure, the reviews and the comments by various donors were positive and an encouragement for the way the staff of IITA is carrying out its responsibilities.

• The opening of the savanna station at Kano in northern Nigeria, the establishment of the humid forest station at Mbalmayo in southern Cameroon, and the opening of a biotechnology laboratory at our headquarters at Ibadan.

• The endorsement by the CGIAR of a region-wide, agroecologically oriented ("ecoregional") approach to agricultural research and the reconfirmation of the need for closer cooperation with national agricultural research systems, as well as the admission of a number of new international centers to the system.

• IITA was again fortunate to receive, this time jointly with CIAT, the King Baudouin award for excellence in agricultural research. The award recognizes our contributions to the biological control of the cassava mealybug.

• The election of Nicholas E. Mumba in July 1990 as chairman of the Board of Trustees for a two-year period, replacing Luis B. Crouch who had resigned for reasons of health.

• The appointment of Lukas Brader as Director General for a five-year term from 1 December 1990.

The trustees and staff of IITA feel confident in shouldering our research and training agenda in addressing the needs in the humid and subhumid regions of sub-Saharan Africa. Our agenda, moreover, increasingly involves close cooperation with our agricultural research partners in the countries concerned. We trust that the donors of the CGIAR will continue to respond with confidence in us and continue their support, which helps to bring us closer to the goal of eliminating hunger and improving the well-being of the peoples of tropical Africa.

Nicholas E. Mumba
Chairperson, Board of Trustees

Lukas Brader
Director General

Research Highlights

A new maize modernizes savanna farming

A new maize has broken the subsistence mold of agriculture in northern Nigeria, enabling farmers to begin modernizing their age-old practices with intensified farming.

The main elements for intensification were in place by the end of the 1970s: nationwide road links and an agricultural extension system. Maize became the crop which activated the process during the 1980s—the extension services were there to promote its cultivation, and the harvests could be transported from northern fields to southern markets. With an improved maize variety in that setting, well adapted to that environment, farmers at last had a crop technology which could earn them enough cash to buy the fertilizer and hire the field hands essential for intensified farming.

With the process in motion, agricultural scientists have begun exploring ways to help strengthen or enhance it. The prime concern is how to sustain intensification—how to enable farmers to continue gaining high enough profits from highly productive crops to buy the required inputs for the next season's cycle. The issue, moreover, is not simple economics, but an understanding of the right mixtures of crops and rotations in order to maintain productivity over the long term. The sustainability of the intensified system involves stabilization of the increases in farmers' harvests and their well-being, which is the goal of all development efforts.

Beginnings

In most of West and Central Africa, population density has increased rapidly during the past 20 years. The increasing pressure on the land has caused most farmers to shorten their customary fallow periods. The result has been decline in crop yields, since no other measures to sustain farm productivity have compensated for the reduced fallows, and since the availability of farm labor had, at least through the mid-1980s, not increased along with the increasing regional population.

Agricultural productivity has improved markedly in the moist savanna zone (or, Guinea savanna) of northern Nigeria. Recent surveys there by IITA and the Institute for Agricultural Research (IAR) of Ahmadu Bello University have shown increases in use of improved maize, fertilizer, and improved management practices, such as animal traction and effective weeding, as fallow periods have become abbreviated. Farmers have asserted that they are better off than before, attributing their well-being to greater profitability of farming.

Several elements combined to prime the agricultural "take-off" in northern Nigeria. A good road network, linking the northern and southern parts of the country, was built with revenues from oil production during the 1970s. During the same period an extension program was organized as part of the World Bank-assisted agricultural development projects, initially in the north at three centers. With an extension system in place to introduce new technologies and supply fertilizer to farmers, and with roads to serve these inputs and delivery of the produce to markets in the populous south, all that remained to trigger the dynamic was the right crop technology.

The traditional cash crops of the north were groundnuts and cotton. Neither was profitable enough to attract farmers' interest in expanding production. But by late in the 1970s, IITA had developed a high-yielding maize

Maize harvests bring a cash economy to savanna farmers.

variety, TZB, by building on two composite breeding lines of Nigeria's Federal Department of Agricultural Research. In experimental trials the new variety yielded consistently one-and-a-half to two times as much as local varieties. Also, it was resistant to the fungal diseases of rust, blight, and ear rot. and highly adapted to growing conditions in the savanna.

The agricultural development projects introduced TZB to northern farmers and demonstrated how to obtain high yields using fertilizer. When the farmers found that the maize gave them a far more profitable return than other cash crops, they began to expand production rapidly.

During the next decade, the spread of maize in the moist savanna was phenomenal. According to IAR and IITA research, maize had been grown in that zone as a backyard crop in the 1970s. By 1989, maize had become a major food crop in virtually all villages, and a major cash crop in more than two-thirds of them. Most of this maize was the high-yielding TZB—in over half of the villages surveyed by IAR and IITA, almost no local maize varieties were being cultivated. Improved maize had overtaken and changed the role of its predecessor.

Sorghum, traditionally the favorite food crop, is still planted over a greater area than maize. However, since TZB outyields local varieties of sorghum and millet, the other staple cereal in the region, TZB can reduce the land requirement for feeding farmers' families. Many farmers have found that, by growing TZB for household consumption, they can free additional land for cash crops. With the surplus over food needs being marketed, farmers have increased their cash income which they can use to reinvest in cash crop production.

The characteristics which enabled TZB to make farming so commercially viable are its high yields and attractive appearance. Experiments on farmers' fields show that TZB, with moderate levels of fertilizer, yields 21–115% more than local maize. Its grain quality, with a pearly white color and resistance to the disfiguring ear rot, make it compatible with local food preferences. For the new maize to have played such a role at all, IITA and IAR scientists believe, it had to be able to show a substantial advantage over existing options—a minor improvement would have been unlikely to succeed on the scale that TZB has.

Sustaining the phenomenon

How long-lived will the phenomenon be? Can intensification with TZB be replicated in savanna areas of other countries?

Whether intensification can be replicated is an easier question to answer than how long-lived it will be. The first requirement for intensification is a set of favorable economic preconditions—transportation links, technical advice, fertilizer—as well as a favorable growing environment. The second requirement is the right crop technology—a crop variety well-adapted to the environment with an all-around performance good enough to attract farmer commitment to providing the inputs. Inextricably linked with these two sets of requirements is a third: suitable quality of the crop, which determines its marketability. Demand for the product must provide a satisfactory return to the farmer-investor.

Replication to some extent already seems to have occurred, and Nigeria's neighbors appear to be emulating her savanna success, although confirmatory data have yet to be collected. TZB and derivative varieties are reported to have been expanding in the Cameroonian savanna, under strong demand from breweries, benefiting from an extension network and fertilizer supply line that had been set up for cotton. Westwards, in Benin, Ghana, and Côte d'Ivoire, production of TZB and its derivatives also appears to have been expanding.

Initial IITA investigations have, however, revealed that there may be a problem with the technology: TZB may need to be adapted to the lighter soils that exist in moist savanna areas west of Nigeria, if it is to perform as well as it did in Nigeria. And specifically in Benin, there may also be a need to breed for a softer, more floury grain texture to suit consumer preferences.

In assessing how far the phenomenon might develop in Nigeria or how long it could last, there are again the market factors and the status of favorable preconditions to be considered. First of all, market demand for maize as a food, and as a basic ingredient in brewery products and animal feeds, continues to absorb production increases. The livestock and poultry industries, for example, prefer maize as a feedstock because it produces more weight gain per unit weight of feed than do most other sources of carbohydrates.

The question of sustaining intensification, moreover, spotlights two distinct and critical issues: economic sustainability, in terms of the profitability of maize production; and environmental sustainability, in keeping up soil fertility and keeping down pests and diseases.

The foremost economic problem looms with fertilizer, a mainstay of intensification. The Nigerian government has hitherto subsidized fertilizer prices in order to encourage agricultural development, but is now committed to the removal of that subsidy for economic reasons. Fertilizer prices are expected to double or triple when that occurs.

IITA scientists believe that high fertilizer prices will induce a reduction in maize hectarages and an increase in the areas planted to sorghum (for food needs) and the cash crops of groundnuts or cotton. Since those crops are less productive than TZB, the returns to farming will diminish. Farmers will be able to afford fewer of the inputs required for intensified farming.

Environmental sustainability becomes a problem when cereals dominate the cropping regime, as sorghum and maize do in the moist savanna. Cereal dominance drains the soil of nutrients, because cereals demand a high level of soil fertility to be productive. And cereal dominance leads to a build-up of specific pests—insects, fungal diseases, nematodes, the parasitic weed striga, among others—because a similar pest and disease complex preys on all cereals. An ominous threat lies in the proximity of sorghum, historically striga's main host, with maize, also highly susceptible. The combination appears to be hastening the spread of the pest. (See striga inset on page 46.)

Achieving sustainability

To counter the effects of anticipated fertilizer price increases, IITA is examining ways to improve the efficiency of the maize plant's use of nitrogen.

Several research institutes in Benin, Cameroon, Côte d'Ivoire, Ghana, Nigeria, and Zaire have joined forces with IITA in a collaborative group on maize-based

The right combination of factors on northern Nigeria's moist savanna has permitted maize to flourish like no other cash crop.

systems research (COMBS), to explore ways to help promote sustainability by expanding the role of nitrogen-fixing legumes in the cropping system. Legumes restore soil fertility with nitrogen from their residues or direct deposits.

Nitrogen-fixing legumes also hold promise in helping to "balance" the total crop system. Since legumes attract different pests and diseases, they can prevent the build-up of cereal pests and diseases.

IITA is examining the possibilities of forage legume rotations with the Nigerian Animal Production Research Institute (NAPRI), as livestock is a crucial component of savanna farming. IITA and IAR are investigating why traditional legumes, such as cowpea, are not more widely grown, and whether there are problems which crop scientists could tackle. They are also adapting soybean for cultivation in the moist savanna, and improving ways to utilize it in order to stimulate new demand.

Agroforestry, incorporating leguminous shrubs, has tested well in many combinations with maize over the past decade in forest-fringe areas, and is being adapted to the moist savanna in ongoing trials in many countries. (See "Alleys across Africa" inset on page 26.)

The present prospects for maize are still bright, as research on both striga and legumes has demonstrated progress. Growing urban populations hold a promising market for maize products. Industrial demand for maize is already evident in livestock feeds and brewery products. High-yielding maize, which has given farmers in northern Nigeria an opportunity to produce commercial-scale harvests, is a crop with the potential to feed further regional development.

Legumes which provide fodder can play a key role in the savanna, in countering the effects of cereal dominance.

The research horizon for cassava as a cash crop

Africa's cassava belt stretches across the continent from the west coast, between Senegal and Angola, to the east coast, between Somalia and Mozambique—the green core of the African tropics. Cassava is the single most important crop for the farmers of that vast region, and for the more than 200 million people, farm families and citydwellers, who depend on it for their daily energy.

For many farmers, cassava has become more than a staple food. Sold fresh, or processed in a storable form, it is a source of income as well. Improved varieties of cassava have enlarged this role of the crop in Nigeria, and show signs of spreading in other countries. New information on the cash-crop role of cassava has come from the first large-scale study of cassava in Africa, undertaken by IITA in a joint effort with other institutes, donors, and governments.

Improvements in the crop and in its cultivation are required for more than the greater well-being they may bestow on farm families, according to the landmark study. Urban populations and their food needs are increasing, and farmers are straining soil resources ever more to support their own and the market demand. If the environmental and economic consequences are not to get out of hand, crop scientists and national policymakers must see to it that farmers have suitable technologies, both improved cassava varieties and cultivation practices, that will enable them to keep pace with the growing needs and to sustain the expanded production without exhausting the soil.

The need for a clear view of the impact of improved cassava varieties and of economic pressures on production led IITA to organize a study together with others, on cassava farming and food systems in Africa. Called the collaborative study of cassava in Africa (COSCA), it covers the production, processing, marketing, and consumption of cassava and other important crops associated with cassava-based systems. The aim of COSCA is to collect information that will enable agricultural researchers to produce technologies which, in turn, farmers need to use to achieve national food production goals.

Collaborating in the study with IITA are Centro Internacional de Agricultura Tropical (CIAT), the Natural Resources Institute of the Overseas Development Administration, UK, and the Rockefeller Foundation, as well as national teams in the participating countries: Côte d'Ivoire, Ghana, Nigeria, Zaire, Uganda, and Tanzania. Those countries were chosen because they embrace the range of important conditions—climate, population density, and market access—which shape cassava systems, and because they could provide scientists to help execute the study. Moreover, they collectively produce 70% of Africa's cassava harvest each year. The study sample comprises 250 representative villages.

Significance

The significance of cassava for the economic development of African countries cannot be overestimated. Cassava root flesh is eaten as a starchy staple dish, to which is added soups or sauces of other foods for variety. Cassava leaves are also eaten as a vegetable in many places. Cassava crops are a reliable food source for most of the year. In some places they are harvested continuously throughout the year, tiding farmers over the "hungry season" after other crops have been planted but are not yet mature. Famine rarely occurs where cassava is widely grown, because cassava can produce a harvest even under erratic rainfall or drought and in poor soils. Its high productivity per unit of land and labor have rewarded scientific efforts to improve yields and increase production, and hold promise of further gains in helping to meet national economic goals.

Cassava goes to market in a big way, in rapidly developing areas where farmers have improved varieties.

Market needs for increased production are driving farmers' selection of cassova varieties to grow.

Some key areas for future crop improvement research are already suggested in findings from the analysis of COSCA's first phase of data collection, on production in 1988/89. Other components of phase I are still being analyzed, and include a broad characterization of cassava processing, distribution, and consumption. Phases II and III, to extend through 1992, focus on crop yields, farm size, resource management, farmer decision-making, postharvest processing, quality factors, and socioeconomic factors, including health.

Breeding objectives will be formulated on farmer preferences in selecting cassava varieties for their own cultivation which have emerged from the COSCA findings. Farmers who live in areas with good access to markets, or who live in areas of high population density, look primarily for high yields, early crop maturity, and effective resistance to diseases and insect pests. These needs reflect a growing market orientation of farmers and economic pressures to increase production. Varieties that can store long underground, or "sweet" varieties that produce low levels of cyanide, do not appear to be critical needs.

By implication, processing quality in cassava should be an important related breeding issue. At present, however, a wide range exists in processed forms of cassava, each with its particular taste or texture which appeals to specific consumer groups. Perhaps the influences of urbanization will eventually narrow this range down to a manageable number of quality variations, when research will be able to address issues in quality preferences. In the short term, therefore, improvement in processing technologies will have to satisfy market demand for processing improvements.

Trends

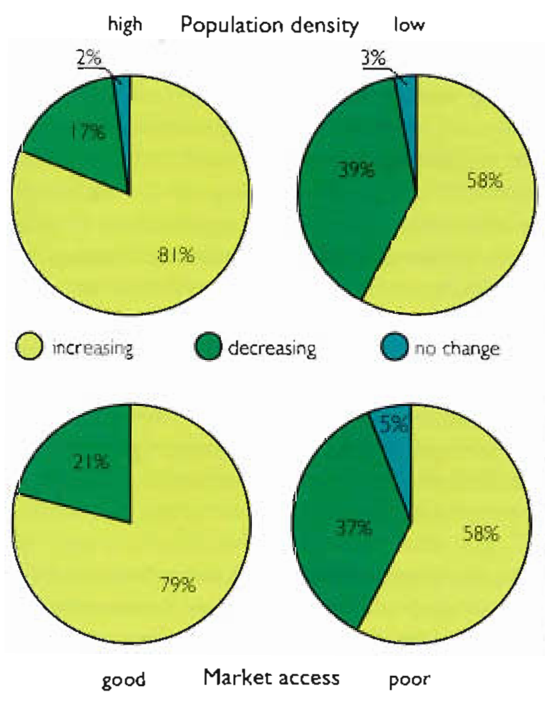
Farmers affirmed that cassava production had increased during the past 20 years, in 70% of the 250 villages which COSCA surveyed. They believed that the increases had been stimulated by a favorable market, incidence of food scarcity or famine, population growth, declining soil fertility, and drought. In their eyes, then, the key determinants appear to have been climate, demographic pressure and improved market access.

Cassava production appears to be increasing relatively more in villages in the humid tropics, as opposed to the drier climatic zones of the savanna or the mid-altitudes. Within the humid zones, production is increasing at a greater rate in villages where population density is relatively high and where market access is relatively good. (See figure 1, opposite.) Where production is increasing, it is replacing mainly other cultivated crops, as opposed to tree crops or fallow crops. Where cassava is replacing other cultivated crops, fallow periods are declining, which is leading to decline in soil fertility.

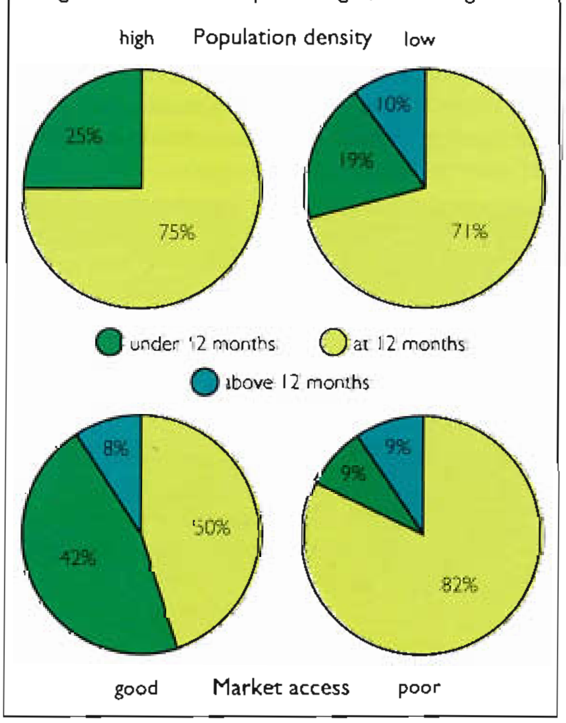
Cassava is widely produced with purchased inputs, such as hired labor, improved planting materials, fertilizers, and mechanized land preparation. Those observations hold more in areas of high rather than low population density, and in areas of good rather than poor market access. In Nigeria, where state agricultural development projects have multiplied and provided improved cassava varieties to farmers, the study reports the presence of such varieties in nearly 90% of 64 villages visited, and their cultivation by many farmers in nearly 60% of those villages. Improved varieties outyielded local varieties by margins ranging 75–300% in specific villages where yields were evaluated. In the five other survey countries apart from Nigeria, however, no such developments were observed, because investment in research, multiplication, and distribution of planting materials had not been made.

The study cites a significant degree of turnover in the

1. Production trends in sampled villages, according to:



2. Age of harvest in sampled villages, according to:



cassava varieties which farmers grow, as they replace existing varieties with new ones that possess desired attributes such as disease resistance, high yields, or early maturity. The proportion of low-cyanide or sweet varieties being cultivated is declining, although over 70% of all varieties grown still are sweet varieties. High-cyanide varieties are judged by farmers to be superior in pest resistance, yield, and underground storage, although not in early maturity.

In areas of high population density, all farmers reported that they harvest their cassava at or before 12 months after planting (see figure 2), whereas 10% of the farmers in low-density areas harvest their crop after 12 months. Similarly, nearly 45% of farmers in areas with good market access reported that they harvest their cassava at less than 12 months after planting, whereas less than 10% of those in areas of poor market access do so.

Dynamics

For the first time on such a large scale, COSCA has substantiated the importance of cassava for farmers as a cash crop. Farmers have begun to respond to the market dynamics with an approach to intensified cassava farming. Cassava, once characterized as the "poor man's crop", is being thrust into an enlarged role in providing a low-cost food source for growing urban populations.

As economic pressures shorten the fallow periods and accelerate soil degradation processes, cassava farmers need to be able to increase their production in a sustainable way. Research should develop the varietal improvements indicated in the study, as well as the resource and crop management technologies that can ensure sustainability of an intensified farming system.

This package can double the income from the harvest

Processing technology can determine how much cassava farmers will benefit from their labor. Well-designed equipment in a well-organized system can significantly improve farm families' income from their cassava harvest, even double it, as IITA has found with two new projects during 1990.

Research and development of postharvest technology is a broad subject area covering all operations in processing, storage, and utilization of a food crop. In cassava processing, the first challenge is to solve the mechanical problems of excessive product losses and labor input, and of poor product quality. With such basic improvements, the returns to cassava farmers in the form of productivity and income can also begin to improve.

In Africa, cassava is processed largely by women, so research gains hold a special significance for the well-being of farm women and their families.

New directions

IITA has analyzed existing cassava processing systems, in order to define the problems and the directions for technology development. Postharvest losses as a whole can exceed 40% of the harvested crop, half of which is attributable to processing. The contributing factors are field conditions, characteristics of the crop variety, and lack of efficient tools or knowledge of efficient methods, as well as workers' attitudes.

Moniya farmers use an IITA-improved grater in processing fresh cassava for making gari.

Processing alone requires more time than harvesting and handling operations. The labor input is estimated at 82 person-days for a harvest of 10 tons per hectare. More than 80% of that time requirement is contributed by women and children.

The IITA postharvest research unit has, since 1988, developed an equipment package for the main stages in cassava processing. The package includes a peeling knife, machines for grating, dewatering, chipping, drying, grinding, and sifting cassava, and a stove with fryer. Each of them takes the cassava one step further toward a particular food preparation. All of them are being tested in pilot locations in Nigeria. Designs are modified during field tests, to adapt the equipment to the work setting. The unit is developing the package together with end users in each community, which helps enhance the utility of the various machines.

Selection of the pilot test locations has been based on local needs or problems, which are first assessed in a comprehensive survey. Interviewers are locally recruited and trained. They keep records of available equipment, system capacities, and operational requirements, among other data. Family information and community profiles are recorded, including income sources, crops and areas planted, production potential, expenditures, and activities other than farming. Such basic information is later used in assessing the impact of technology utilization, or the quality of life before and after the technology is introduced.

Moniya. A group of 18 women at Moniya, near IITA on the northern edge of Ibadan, have called themselves the "Stop Hunger" group and decided to set up a community center for processing cassava. Their aim was to improve the quality of the food they and their families consume, and to reduce the time they must spend in processing activity. The equipment package for Moniya, where cassava had been processed by pooled family effort, contained a grater, chipping machine, dewatering device, sifters, stove/fryer, and grinder. Subsequently other equipment, such as new peeling tools and a baking oven, was installed there for testing.

The Moniya group began operating the center essentially as a food exchange scheme, taking on some contract processing as well. Farmers gave their fresh cassava tubers to the center in exchange for processed cassava. During the latter part of 1990, operations had improved so much that the center began processing cassava on a commercial basis. By the end of the year, commercial processing had exceeded the volume of exchange and contract processing combined.

After six months of operation, the center had reduced losses under the family processing system by 50%, while the labor requirement had been reduced by 70%. These savings result from a combination of the arrangement of the facilities, training, attitudinal changes, as well as the new technology package. The new system has improved product quality, and leaves the women with more free time to devote to other activities.

Aba Lawyer. This rural village in Oyo state, with 26 households, is the site of another community processing center, which farmers set up to increase their income through improvements in their customary processing activities. Farmers here grow a variety of food crops besides cassava, but depend on processing their cassava into "gari" meal for their cash income. The technology package for the village contained grater, chipping machine, grinder, farm cart, stove/fryer, sifters and dryer.

Six months after the new system and equipment had been introduced, processing labor inputs had been reduced by 72%, and fuel consumption by 30%. Processing losses had declined by 55%. The consequent increase in productivity has tripled production volumes, and family incomes have doubled.

Product quality has also improved, which has attracted higher prices. Aba Lawyer farmers no longer need to travel to distant markets in order to sell their produce—bulk buyers now go to the village for its high-quality gari, and pay the same price as the farmers would receive for it in town, effectively paying them a premium for quality.

The quality of life has improved dramatically for the community. The village environment is clean and looks prosperous, income-generating activities are expanding, the villagers are beginning to participate more actively in community functions. They have set up their own day-care facility for young children, who are starting to learn the alphabet at an early age. Few now need to leave Aba Lawyer in search of better opportunities.

Left: *At Moniya, frying the grated and dried cassava on an IITA-designed stove saves fuel and time in making gari.*

Right: *Built-in sieves separate large from small particles of cassava flour in this IITA-designed grinder at Aba Lawyer.*

Making a home for the soybean in Africa

From the beginning of soybean research at IITA, early in the 1970s, breeders have seen soybean as an ideal crop for tropical Africa. As a legume, it converts nitrogen from the air into a form that it can use, and thus has no need of applied fertilizer. It also provides a nitrogen source for the next crop, if its leaves and roots are plowed into the soil after the grains are harvested. As a food crop, it provides an inexpensive source of protein and fats to improve the quality of traditional diets. Soybean cake, a byproduct of oil production, also makes a high-protein animal feed. But the main impetus behind IITA's soybean research has been the need to add protein in African diets using a vegetable legume, because animal sources of protein cannot easily be increased in the present setting.

During the mid-1970s, breeders overcame plant characteristics that had blocked earlier attempts at adapting American-bred varieties to the tropics. Soybean plants, like most legumes, use nitrogen from the air for nourishment in a process called nitrogen fixation. The roots of legumes are invaded by bacteria which capture atmospheric nitrogen and convert it to a form which is useful for the nutrition of the host plant. Unlike other legumes indigenous to Africa, such as the cowpea, the roots of American-bred soybeans were not congenial hosts to African bacteria and did not form nodules where bacteria could reside. During the 1970s and 1980s, however, IITA scientists bred high-yielding soybeans that accepted the bacteria found in African soils and improved nodulation.

Besides the problem of poor nodulation, seeds of American soybeans quickly lost their ability to germinate in the warm, moist environment of tropical farms. In storage from harvest of one year to planting the next, very few seeds would retain their ability to germinate and grow. IITA breeders improved the soybean's "storability" under African ambient conditions. The two biggest obstacles to soybean production in tropical Africa were thus largely removed.

Other characteristics needed improvement—the tendency of pods to shatter and disperse the beans before they could be harvested; the tendency of the stems of improved varieties to buckle under the weight of high pod yields; and vulnerability to a few tropical insect pests and diseases.

Apart from those basic problems, researchers needed to tackle the particular problems of adapting soybeans for cultivation in different environments and different agroecological zones. For example, in the dry and moist savannas where soybeans grow best, the rainfall each year spans a period of some 90 to 180 days. Improved soy varieties for the savannas should therefore be able to mature within that period, leaving a margin for planting considerations. They should also be able to fit into existing crop rotation systems and intercropping systems which combine legumes with cereals such as sorghum, millet, and maize.

Most importantly, however, scientific attention had to turn to new objectives concerning the processing and utilization of soybeans by African consumers. Farmers would have little incentive to grow the crop if they could neither use it themselves nor sell it to others.

Utilization research

For thousands of years, East Asian farm families have grown and eaten soybeans. Not until the twentieth century, however, was the crop adapted to other environments by scientists in the United States, Canada, China, Brazil, and Australia. Their research has enabled soybeans to be grown not only in temperate countries but also in the subtropical-to-subtemperate zones of southern Brazil, central and northern India and Queensland, Australia. Availability of home-level as well as industrial processing methods and export markets has fed demand for soybeans, and hence production of the crop, in those countries.

Most of the available processing techniques, however, are not appropriate for tropical Africa. Asian homes make soybean foods using techniques and equipment not found in African households. Most of the industrial processing techniques developed in Europe and the Americas require large capital investments. Relatively few researchers have investigated soybean processing or utilization methods from the African perspective.

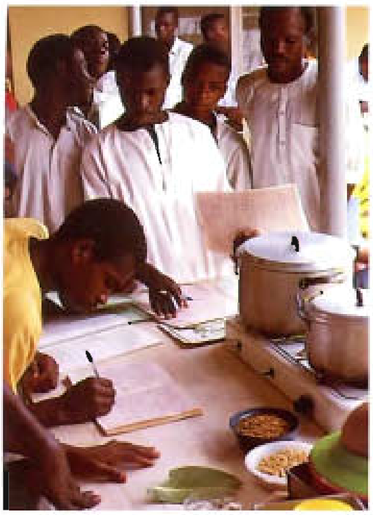
Having succeeded in adapting the crop to tropical conditions, IITA sought to create technologies for processing soybeans, enlisting the support of the International Soybean Program (INTSOY, at the University of Illinois, USA), the Nigerian government and other donors. In 1985, IITA acquired a screw press for oil extraction and a dry extruder for making soy flour. A food technologist joined the staff. In October 1985, IITA held the tropical soybean workshop, which concluded that the main obstacle preventing rapid expansion of soybean production in Africa was that consumers lack the means of processing and using them at household or village level.

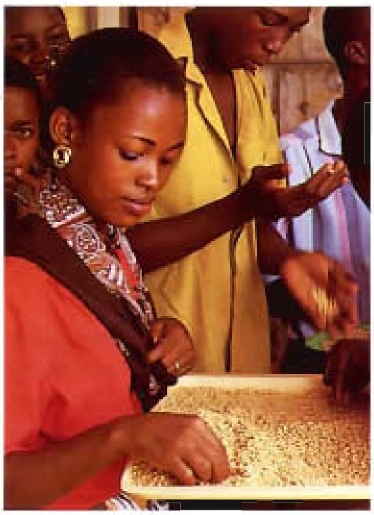
The research first focused on equipment and processing methods geared to household and small-scale business enterprises. Together with the Institute of Agricultural Research and Training (IAR&T) at nearby Moor Plantation in Ibadan, IITA launched a project with funds from the International Development Research Centre (IDRC) of Canada and a food technologist sent by the Japan International Cooperation Agency (JICA). The goal is to develop new recipes which enhance the nutrition and taste of traditional dishes, make use of implements already in the typical Nigerian home, but do not increase the time or cost of preparing traditional foods.

Among the project's successes in adding soybeans to basic dishes is soy flour, or paste, in the various vegetable sauces which accompany a starchy staple (such as pounded yam or cassava). New methods of processing soy milk have eliminated the hand-burning hazards and reduced time-consuming labor, and have been successfully introduced. "Soy gari" (cassava meal with added soy flour that has a 10% protein content as against less than 1% protein of traditional Nigerian gari) has been developed and introduced. "Soyamusa", a new extruded, inexpensive baby food of plantain and soy, has been tested with the help of the National Horticultural Research Institute (NIHORT; also in Ibadan). Several recipes utilizing soy milk residue have been developed. The project also evaluated the performance of screw presses for oil extraction made in Africa.

Nigerian impacts

In 1984 soybean was virtually unknown, being neither grown nor used, in Nigeria's Oyo state where IITA's





Students learn about soybean processing on a visit to the National Cereals Research Institute, which spearheads soybean research in Nigerio.

campus headquarters is located. As a result of the IDRC-funded project, IITA and IAR&T have introduced the soybean in four local government areas of Oyo. A recent survey has revealed that about one-third of all farmers in those areas are growing soybeans. Among soybean growers, the average area planted to soybean is nearly one-quarter of a hectare. Over half of the growers cook and eat soybean in their home. Those who eat soybean consume an average of 1.4 kilograms of soybean per week per family. These figures reflect a very rapid rate of adoption of soybeans as a crop and a food.

From surveys conducted in Nigeria's Benue state, where traditional soybean varieties have been cultivated by the Tiv tribe, farmers show a strong preference for seed of the improved varieties over the traditional variety, and the number of farmers planting improved seed is increasing. The surveys, conducted by a volunteer of the Canadian University Service Overseas (CUSO), have also revealed that almost nine in ten villages in eastern Benue have increased their soybean production over the past five years, and more than half of them consider the crop to be a major cash earner.

IITA has also helped other African countries to produce improved soybean varieties. Zaire and Ghana have released IITA varieties for farmers to begin planting. The genetic backgrounds of soybean varieties have been improved. Soybean yields of up to 2.5 tons per hectare have become possible with improved IITA varieties that have been tested in many African countries. More than 25 African countries are involved in annual trials to test IITA soybean varieties for suitability for local conditions.

For soybeans to realize their full potential as a protein source in African diets, research must continue into new products and adaptive uses in traditional diets. The path for such research has been marked by the IITA and IAR&T collaboration. With development of new projects in other countries in future, the promise of soybeans seems likely to be fulfilled.

A cornucopia to come – rice research and future prospects

The IITA rice research program closed at the end of 1990, and all rice genetic improvement was transferred to IITA's sister institute, the West Africa Rice Development Association (WARDA). Some of IITA's achievements of 20 years of rice improvement are summarized in these pages.

Market trends show a growing taste for rice in most African countries, and are creating pressure for farmers to cater to this need. The reasons are deeper than just a menu choice—they reflect changes in traditional ways of life as societies urbanize and industrialize, and diets follow suit.

Rice is a crop that, after harvesting, is processed less laboriously than most crops; stores longer and more conveniently, especially in a crowded living space; lends itself to easier, more versatile meal preparation; and appeals to a new appetite for quality. Rice also holds, for farmers, the economic virtue of yielding more profit as cultivation is intensified—once they make the initial investment in developing the paddies and water control, they can intensify production and gain more in yields from the added inputs than they could with other crops.

Scientists should guide farmers' steps in breaking new ground for rice in Africa, for the market is pointing to a new direction for agriculture to take.

Ancient history, new hope

Rice is an ancient crop in Africa. But over its 3,500-year history here it has made little headway in exploiting lands suitable for its cultivation or feeding the numbers of people it could. Cultivation technologies did not become efficient enough over time to reduce the cost of production or to encourage demand to grow, so rice was long regarded as a rich man's cereal.

Rice cultivation in Africa has to date spread only over some 5 million hectares. But, paradoxically, at least 200 million hectares of wetlands exist—good rice-growing environments—which are not being planted to other crops. They could become a cornucopia for Africa, provided farmers have the right varieties and the knowhow to produce rice there.

With a limited market because of its cost, African rice production grew slowly and could not match the competition from cheap imports, which became available during the 1970s and 1980s as a result of consumer demand. African purchases of rice came to absorb one-quarter of all rice in international trade, draining substantial amounts of foreign exchange from the continent. The supply of cheap rice in the home markets limited the returns to farmers on local food crops, thus deepening poverty in the producing areas. Governments were compelled to take practical steps to make the local rice farmers' labor more productive and their rice more competitive with imports.

Beginning in the 1970s African governments began to address the obstacles to expanding rice production. International organizations have backstopped their efforts in different ways. Large-scale development projects were among the first attempts to stem imports, but met start-up problems. Nevertheless, once managerial measures have overcome the problems, such projects should lay the ground work for long-term development of the production potential.

Research approaches have set several countries on the track to a durable solution. Rice research in Africa has generally aimed at improving efficiency under

Improved upland rice has spread across Nigeria's forest and moist savanna belts, earning price premiums for quality and early maturity before the lowland crop reaches the market.

Prime rice-growing wetlands exist among Africa's inland valleys, but farmers need to have the right technologies to exploit their potential.

intensified cultivation, with fertilizer and good weed control. The objective is to produce rice varieties with ample yields which can resist or tolerate the specific diseases, insect pests, and environmental stresses present in each area.

Rice research in Africa within the CGIAR system has been conducted by three organizations: over the past 20 years from both IITA and the West Africa Rice Development Association (WARDA); and for the past 30 years from the International Rice Research Institute (IRRI). WARDA's capability has been strengthened, so IITA has since 1987 been gradually transferring its rice research activity to its sister institute. The goal of completing the handover by 1990 has been accomplished. IITA will continue, however, to collaborate with WARDA and IRRI in development of improved technology packages for rice-based cropping systems. IITA's experience in the region is summarized in the rest of this article.

Two decades

To harness the regional potential, IITA began research in 1970 into varieties for efficient production in the different growing environments of West and Central Africa. IITA breeders sought to develop insect- and disease-resistant varieties that, together with improvements in farming methods, would yield more generous harvests than possible with traditional varieties and methods. The farming ecologies they targeted were the rainfed uplands, inland valleys (which are seasonally flooded), and the irrigated paddies.

Uplands. In its first experiments in breeding upland rice during the mid-1970s, IITA found that Asian genetic types adapted poorly to the acid, nutrient-poor African soils and succumbed to diseases. So IITA's program for upland rice began building on a base of traditional African genetic material, together with some valuable materials from similar areas in Brazil and from the Institut de recherches agronomiques tropicales (IRAT) of France. Breeders improved the yield potential and shortened the plant, while producing longer grains with a higher market value—at the same time preserving the excellent stress and disease resistance of the source material.

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 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 has also been released in Sierra Leone. The short-growth cycle of ITA 150 and ITA 257 gives quick returns on investment for farmers and improves total income, because the two varieties are ready for harvest when prices are at their annual peak in July/August, well before the lowland crop reaches the market. Their excellent eating quality also earns price premiums.

Inland valleys. In a revision of research strategy, upland work was scaled down after 1987 so that resources could be concentrated on the rich potential of the inland valleys. Such valleys are scattered across the region, from the coastal forests northward as far as the dry savannas, usually watered by streams which rise and fall with the rainy seasons. They are relatively fertile and ideally suited for rice, but to date have remained under-utilized because of the environmental hurdles they pose for farmers: water control problems, rough soil tillage, uneven establishment of the crop after planting, difficult weeding in soggy soils. Traditional farmers find it hard to modify their bush-fallow/slash-and-burn farming regime to these wetlands. The threat of water-borne diseases has also discouraged exploitation, in the absence of public health measures.

IITA began its breeding program for the inland valleys early in the 1980s. The aim was a plant type that could compete with weeds, tolerate physical stresses, resist iron toxicity and diseases such as blast fungus and yellow mottle virus, and show a high yield.

Farmer management of the crop is crucial in getting the best yield. In some swampy iron-toxic areas, farmers grow their rice on ridges which permits air to reach the roots, and oxidize the ambient iron into a form harmless to the plant. IITA scientists have investigated this practice and have shown that it helps increase yields threefold—or even more, with resistant IITA varieties. In this case as in others, IITA has adapted its technologies, or research products, to local farming systems as well as national or regional needs.

Excellent varieties for inland valley cultivation are reaching final testing stages in national research programs. They are poised to make a significant impact over the next decade and also enable WARDA to begin its work in the area with superb elite materials.

Irrigated. Work on irrigated varieties began early in the 1970s, and succeeded remarkably during the following decade. The Nigerian government has released five varieties for use in large-scale irrigation projects. Two of them are spreading in Cameroon, one is commercially grown in Ghana, while a third is important in Benin—mostly in large-scale projects.

IITA breeders developed irrigated varieties from a base of high-yielding semi-dwarf types from IRRI, adding genes for resistance to African pests and stresses from local varieties. A landmark in irrigated rice development is the 1977 release of "Suakoko 8" in Liberia. The first African improved variety to succeed in resisting iron toxicity from the soil, it was developed by IITA and the Central Agricultural Research Institute of Liberia, utilizing an Asian traditional variety as the genetic source of resistance.

Fruits of collaboration

Many scientists in African country programs have earned their qualifications at universities and in the field with IITA sponsorship or project involvement. IITA has developed its research and training around the needs of rice-producing countries, and designed projects with their scientists, to ensure good feedback as well as to build up their manpower—from technicians to fully fledged PhDs.

Of all IITA's country relationships in rice, that with Sierra Leone stands out. Rice is Sierra Leone's most important staple, yet the country can produce only half of what it needs. In 1974 a pathologist and agronomist joined national program scientists at Rokupr to strengthen the country's research capability and increase its rice production, in a six-year project funded by the Food and Agriculture Organization of the United Nations (FAO).

Sierra Leone and IITA have benefitted in many lasting ways. Eight Sierra Leonian scientists completed master's degree programs. Twenty technical staff received training at IITA. Eight varieties were released during the period, most of which are still being used by farmers. Two of them were lines developed by IITA breeders.

IITA's special relationship with Sierra Leone did not end with the project. From 1981 to 1989, 17 more varieties were released. Currently a Sierra Leonian breeder is finishing a doctoral fellowship at IITA, studying the genetics of resistance to rice yellow mottle virus.

New directions. In working with IITA in rice research for western and central Africa, IITA will lend its germplasm collection, laboratory and field facilities for continued experimentation. Crop management research at IITA will continue to study ways to improve land use in inland valleys, the prime areas for future rice development.

As countries in eastern and southern Africa call for assistance in developing their rice programs, IITA can extend its facilities for research support to those farther regions. Together with IRRI, IITA has offered its technical support to the members of the International Network for the Genetic Evaluation of Rice (INGER-Africa).

At the end of the research pipeline, farmers are expected to turn research products into the harvests of tomorrow. The challenge to scientists lies as well in improving the farming environment, in helping farmers to move into a new horizon where they can make a profitable enterprise of it.

IITA Today

IITA and the CGIAR

IITA was established in 1967 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 the land for the headquarters and experimental farm at Ibadan, while the Ford and Rockefeller foundations provided the initial planning and financial support.

IITA has four objectives:

1. To improve agricultural production systems for the African humid and subhumid tropics which can be sustained without degradation of the environment.

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

3. To develop national agricultural research capabilities including human resources on a basis of shared responsibility with IITA, by means of training, information, and other outreach activities.

4. To improve food quality and availability, including food storage, processing, and marketing.

IITA conducts research and training activities at its headquarters and stations in West and Central Africa, and in conjunction with regional and national programs in many parts of sub-Saharan 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.

IITA maintains vital links with national agricultural research programs, through various forms of cooperative research and training arrangements. By developing new technologies with IITA, adapting them to local conditions, and taking them to farmers, national programs can translate research into increased food production.

IITA programs comprise:

- **Resource and crop management**
  (emphasizing soil resources and farming systems with cassava, maize, and rice)

- **Root, tuber and plantain improvement**
  (focusing on cassava, yam and plantain)

- **Grain legume improvement**
  (focusing on cowpea and soybean)

- **Maize research**

- **Biological control**
  (emphasizing environmentally sound plant protection)

- **Research support**
  Genetic resources
  Biotechnology
  Virology
  Biometrics
  Analytical services
  Research farms

- **International cooperation and training**
  (emphasizing self-development of national agricultural research systems)

- **Information services**
  Public affairs
  Library
  Publications

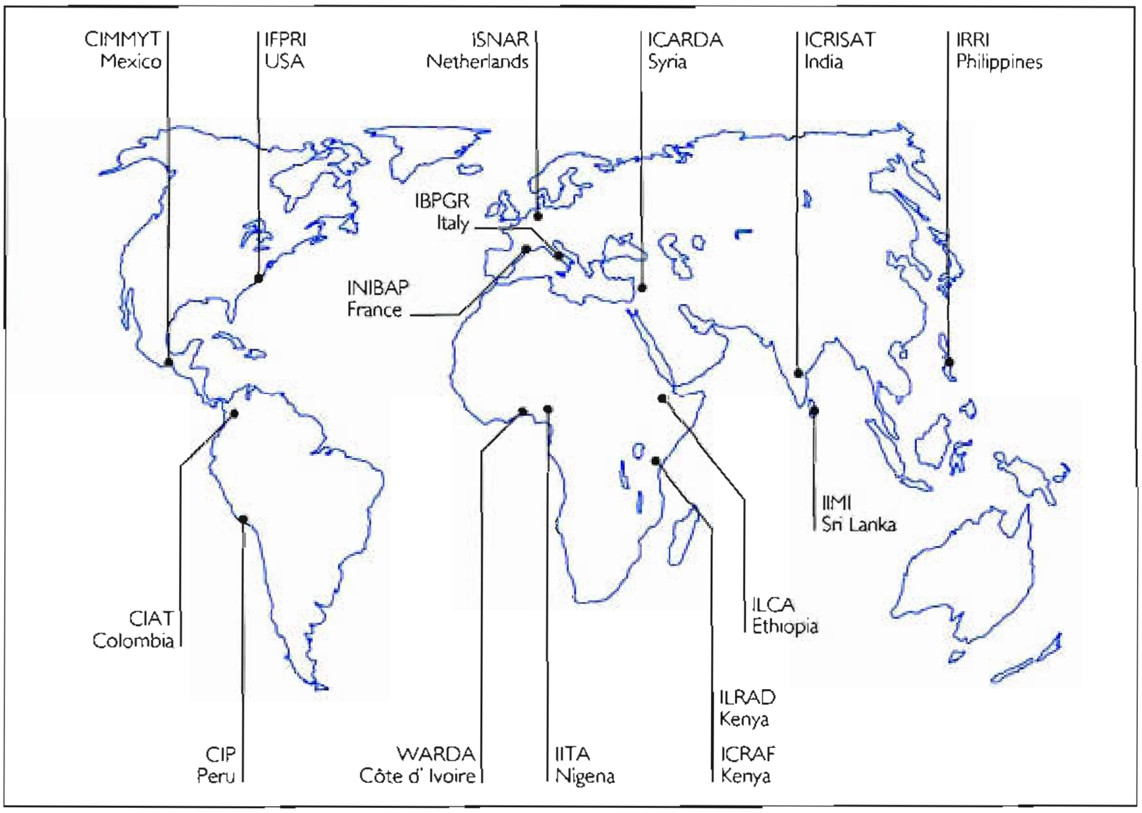
IITA is a nonprofit, international agricultural research and training institute supported primarily by the CGIAR. IITA employs about 180 scientists and professional staff members from over 40 countries and about 1,400 support staff, mostly from Nigeria. Most of the staff are located at headquarters, where 300 hectares of the 1,000-hectare campus have been developed for experimental fields. An 80-hectare research station lies in the high-rainfall 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 for Agricultural Research. A station at coastal Cotonou, Republic of Benin, houses the biological control program. A 1,000-hectare, humid forest station began operating in 1990 at Mbalmayo, Cameroon, in collaboration with Institut de la recherche agronomique (IRA). Several collaborative projects were under way in sub-Saharan African countries during 1990.

Founded in 1971, the CGIAR is an informal association of about 40 public and private sector donors, which include government agencies, international organizations, and private foundations. During 1990 they provided about US$ 235 million in core funding. The CGIAR supports 16 international research centers, whose collective goal is to improve the quantity and quality of food production in developing countries.

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 derived from a sense of common purpose.

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 such fields as food policy, genetic resources, agroforestry, irrigation management, 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 18 scientists, is drawn equally from developed and developing countries. 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. 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 in October or November, and once elsewhere in May. The meetings review program activities undertaken by the centers, discuss agricultural research needs, and adopt strategies to address the needs, as well as review proposals on funding and management issues.

Resource and crop management

Agriculture in Africa poses unique problems for research and development. In all but a few parts of the continent, agricultural production is not growing as fast as the population is, while soil resources are being depleted, threatening future production. This syndrome has defied quick solution, despite decades of development activity and some billions of dollars worth of external assistance.

The difficulty in getting a grip on the problems stems from an incomplete understanding of farming practices in Africa. The typical farmer combats problems of infertile soils, pests and the weather by planting mixtures of up to 20 crops, which mature at different times, balancing the possibilities of failure in some with success in others. Moreover, shifting cultivation practices used to provide the farmer with low but stable crop yields. But that traditional system can no longer sustain such yields under growing population pressure and shortened fallow periods.

The challenge lies first in gaining an understanding of the farming environment, its physical and socio-economic dimensions, and of the production systems for different crops. With such an understanding can be built the means of enabling farmers to produce enough food for a growing population, while conserving the natural resource base so that future production will not be curtailed.

Mixed cropping of cassava, cocoyam, and maize helps this farmer combat pests and poor weather possibilities.

To meet this challenge, IITA's resource and crop management program conducts research on both fronts: resource sustainability and farm productivity. IITA research has shown that the time frame for realization of results, in the form of practical technologies, may be a few years—in the selection of a cover crop to suppress weeds, for example, or a hedgerow species in alley farming—or more than a decade, as in the development of the alley farming concept itself. The ultimate concern is to improve smallholder farming systems in the three main agroecological zones of tropical Africa (see map on page 2): the humid forest, the moist savanna, and the inland valleys.

The two streams of the program's research activity are complementary: (1) resource management and (2) crop management.

(1) Resource management research studies the resource base, which consists mainly of soil and soil fauna, water, sunlight, labor and mechanical energy inputs, and agrochemicals. Research findings help in developing new technologies—such as farming practices aimed at soil conservation, weed control, and no-tillage crop production.

The major research products are prototype technologies which are increasingly being tested by national agricultural research systems in Africa for use by farmers. They include:

- **Alley farming.** A means of sustaining soil fertility and an alternative to shifting cultivation, 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.
- **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 reduce 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 methods.** Studies at IITA and elsewhere have shown the advantages of minimum or no-tillage farming.
• **Fertilizer and soil additives.** Fertilizer regimes have been developed which can 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.

(2) **Crop management research** combines the products of resource management and of crop improvement, conducted by other IITA programs, into sustainable cropping systems which have greater productivity yet are compatible with the smallholder's resources and objectives. This synthesis of crop management is, in essence, the product of the concerted efforts of all IITA programs.

Multidisciplinary teams of scientists examine the factors which inhibit or could promote production in the key cropping systems in each of the three main agroecological zones. The three research groups cover:
• Humid forest systems (for cropping systems based on cassava).
• Savanna systems (for maize-based cropping).
• Inland valley systems (for rice-based cropping).

Technologies which will enhance farmers' crop management practices in a sustainable way have been identified over the past six years. They include:
• Cassava varieties with durable disease resistance, well adapted to the cassava/maize system.
• Soybeans adapted for growing as a second-season crop, in association with cassava.
• Maize varieties with durable disease resistance.

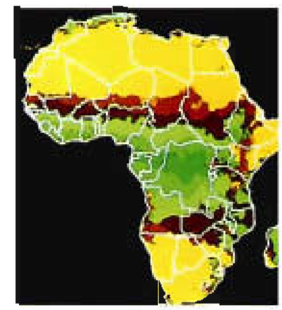
Feedback on farm-level problems from the systems research groups is helping to set the right emphasis in the research agenda of resource management researchers and breeders. Examples include problems in establishing leguminous trees in alley cropping systems; the relative contribution of trees and herbaceous legumes in improved fallow management systems; weed control problems in no-tillage, cassava-based systems in which herbicides are not used.

The results of the past year's research are outlined in these pages, together with their significance for IITA goals in general.

Resource management research

Maps and models. In 1990 IITA began cooperative working arrangements in agroclimatology, modelling, and a geographic information system with national and international institutes. A database of daily rainfall data for nine tropical African countries was established. Software for data analysis and quality control was developed which enabled IITA to share the data.

IITA's agroclimatologist developed a resource information system (RIS) which can generate maps showing specified environmental and socioeconomic conditions. The RIS database carries information which characterizes the African continent in 10-mile-square areal units. The information is important in analysis, planning, and sample survey work.



Computerized generation of maps is based on data for areal units 10 miles square.

Soil management

Effective technologies for soil improvement are the result of well-considered research. Since the technologies are designed for smallholder farmers to use, they must involve little or no additional expense by users. Such research requires a long lead time for results to crystallize into clearcut applications.

Soil erosion studies continued in Nigeria (on non-acidic soil types) and Cameroon (on acidic soils) under tillage, no tillage, and bare fallows, with support from the official German aid agency GTZ. Generally, soil loss has been much greater from the acidic than from the non-acidic soils, under all treatments. Acidic soils are more easily eroded and are lower in nutrients than non-acidic soils. Moreover, the subsoil under acidic soils is not as rich in basic minerals as the subsoil under non-acidic types. Acidic soils are typical of the humid forest, while the soils of the forest-savanna transition and savanna zones are non-acidic.

Experiments began during 1990 to characterize the acidic soil at IITA's new humid forest station at Mbalmayo, central Cameroon, near the capital city of Yaoundé. Soil physical properties, such as bulk density, temperature, and water infiltration rate, were measured under different crop management practices.

Changes in the main constituents and physical properties of soils were investigated in Nigeria, as they occurred following land clearing, cropping, and fallowing. The causes of these changes will also shape new soil and vegetation management practices which will improve soil fertility.

Sustaining fertility. IITA research on improving acid soils has followed two different but complementary approaches. Soil amendment is one, utilizing lime, fertilizers, and similar materials to combat acidity and aluminum toxicity in the soil. Even low applications of lime can reduce toxicity, permitting crop yields to increase.

A second approach to soil enrichment—using prunings from shrubs or trees—can be taken independently or together with amendments. An alternative to amendments is required because lime or fertilizer is frequently not available to farmers.

Alley cropping or farming is an agroforestry system which takes this second approach, sustaining soil fertility while reducing the need for fallow periods. Selected shrubs or tree species (usually nitrogen-fixing legumes) are planted in rows with food crops in the "alleys" between the hedgerows. Soil nutrition is improved with nitrogen and other nutrients from prunings of the hedgerow trees which are left on the ground to decompose. Other contributions of alley cropping to the soil include moisture conservation, weed suppression, and erosion control. "Alley cropping" becomes "alley farming" when the hedgerow prunings are grown to feed livestock and the woody stems are used as firewood or stakes for climbing crops. Altogether, the alley farm mimics the restorative processes of bush fallows concurrently with crop production. (See "Alleys across Africa", opposite.)

Alley cropping has evolved from IITA research since the 1970s, primarily for renewal of the non-acidic soils of the forest-savanna transition zone, but more recently for similar soils elsewhere and forest-zone acidic soils as well. Currently, long-term trials are investigating:
• what tree species are best for particular conditions or locations (such as acidic or non-acidic soils, or in combination with various food crops or cover crops),

Alleys across Africa

The promise of alley farming is being put to the test in a pioneering research scheme which links 21 countries across tropical Africa. Coordinated by the Alley Farming Network for Tropical Africa (AFNETA), 52 of the planned total of 95 experiments were in the ground by the end of 1990. The accompanying table summarizes all the projects by type of research and target agroecological zone in each country: humid forest, forest-fringe-to-moist-savanna (subhumid), dry savanna (semi-arid), and mid-altitudes (highlands, 800–1,500 meters above sea level).

AFNETA itself was established in 1986 with technical guidance from IITA, the International Council for Research in Agro-Forestry (ICRAF), and the International Livestock Center for Africa (ILCA). Project funding is being provided by the Canadian International Development Agency (CIDA), the International Development Research Centre (IDRC), and the International Fund for Agricultural Development (IFAD). In 1990 AFNETA membership grew to 47 institutions in 25 countries. AFNETA fosters research and development of alley farming technologies utilizing members' pooled efforts and experience. The aim is to build a foundation of research for prototype alley farming systems as a key means to sustain agricultural production in Africa for the foreseeable future.

The collaborative projects cover the primary areas of research issues in a progressive sequence:

1. Screening for selection of multipurpose shrub and tree species.
The hedgerows must suit a variety of purposes in the different zones: providing organic matter for soil renewal, forage for livestock, poles for climbing crops and other uses, and firewood. Multipurpose tree screening trials began at 28 sites over all agroecological zones in 14 countries. Each trial involves 10–15 local or exotic species which are assessed under continuous growth and alley farming management.

2. Alley farming management.
Once suitable hedgerow species have been identified, studies of system management and productivity can evaluate effects of hedgerow management in terms of different spacing and time factors, tree responses to fertilizer use, management of hedgerow prunings and their contributions to soil fertility, comparisons among various alley cropping systems, and integration of tree cropping and fallowing systems with alley farming. The management trials commenced at 43 sites over all zones in 17 countries.

3. Livestock integration.

Trials focusing on livestock benefits are concerned with two aspects. The first is production of forage by the hedgerows and pasture crops in the "alleys". The second is the fodder value from forage, in terms of digestibility, protein content, other characteristics, and the consequential gains in livestock productivity. Livestock integration projects were fielded at six sites over three of the agroecological categories (all excepting the dry savanna) in three countries. In addition, some factors relating to livestock issues are being tested in the species screening and management trials—for example, the fodder value of certain species, and fallows management for producing fodder.

4. On-farm research and socioeconomic assessment.

Finally, research and development must be conducted on-farm for fine-tuning the technologies, assessing efficiency and productivity under farmers' management, and determining farmers' interest, acceptability, and potential adoptibility of technologies. Some 18 projects over the range of zones in 9 countries have started, or plan to start, by 1992. With increasing experience, more countries will take up this kind of research, following the general thrust of network activity.

The four types of projects are designed to provide comparable data sets for agroecological conditions across tropical Africa. Each collaborating scientist in the 35 participating national institutes is collecting data on a minimum set of variables at each site, which include site conditions, hedgerow characteristics, pest damage, and crop yields, among others. During the fourth year of operations, AFNETA will assess the results to date at an international conference on alley farming.

AFNETA collaborative projects with national research programs, 1989-1993

Type of research project	Agroecological zones							
	Humid		Subhumid		Semi-arid		Highlands	
Tree species selection	Ghana	1	Benin	2	Benin	1	Malawi	1
	Guinea	1	Côte d'Ivoire	1	Burkina Faso	2	Uganda	1
	Liberia	1	Ethiopia	1	Côte d'Ivoire	1		
			Ghana	1	Ethiopia	2		
			Guinea	1	Ghana	1		
			Senegal	1	Mali	2		
			Togo	2	Senegal	1		
			Zaire	1	Togo	1		
					Zambia	2		
Farm management	Cameroon	3	Benin	1	Burkina Faso	3	Kenya	1
	Ghana	1	Côte d'Ivoire	1	Côte d'Ivoire	1	Malawi	1
	Guinea	1	Ethiopia	1	Ethiopia	1	Uganda	2
	Liberia	1	Guinea	1	Ghana	1		
	Nigeria	4	Malawi	2	Kenya	1		
	Sierra Leone	1	Nigeria	2	Mali	2		
			Sierra Leone	1	Togo	1		
			Tanzania	3	Zambia	2		
			Togo	2				
			Zaire	2				
Livestock integration	Cameroon	2	Benin	3	—		Rwanda	1
On-farm and socioeconomic research	Cameroon	1	Côte d'Ivoire	1	Burkina Faso	1	Kenya	1
	Côte d'Ivoire	1	Nigeria	4	Côte d'Ivoire	1	Rwanda	1
	Nigeria	3	Sierra Leone	1				
			Tanzania	1				
			Zaire	2				

• what management practices are most efficient for different objectives, and
• how alley farming affects soil fertility and crop productivity.

For example, results of 1990 trials on both acidic and non-acidic soils suggest that some hedgerow trees compete with the crops for soil nutrients, because they have lateral roots which spread near the soil surface. The solution is to select hedgerow species with deeper rooting patterns. In other trials over a nine-year period, maize crops without fertilizer yielded as much as non-alley-cropped maize which received 45 kilograms of nitrogen fertilizer each year. Four hedgerow species were involved: *Acioa*, *Alchornea*, *Gliricidia*, and *Leucaena*. All but *Acioa* recycled significant amounts of the minerals copper, iron, manganese, and zinc back to the soil with prunings which, in the long term, should boost yields further.

Weeds. Often the biggest demand on farmers' labor is weed control, usually a manual task. Weed scientists are investigating cultural and chemical means to reduce the labor requirement in weeding.

Cultural practices, such as planting of a fast-growing cover crop or hedgerow trees, as in alley farming, offer the more efficient solution in the long run. Cover crops can serve as a live mulch: a protective layer of vegetation which can control weeds, reduce evaporation, prevent erosion, lower daytime soil temperatures, and enrich the soil with organic matter.

A leguminous cover crop offers the additional advantage of providing a source of nitrogen for the next crop, if it is plowed back into the soil at the end of the growing season.

The legume *Pseudovigna argentea*, less of a climber than other herbaceous legumes, was assessed as a live-mulch cover crop with maize. In 1990 trials it controlled weeds adequately. *Crotolaria verrucosa* suppressed weeds in trials grown with other crops. Maize grown in 1990 trials in the same plots subsequent to the *Crotolaria* crop, which had been plowed under, required less weeding and less nitrogen fertilizer than maize in plots without previous *Crotolaria* cultivation.

The economics of resource management

A series of studies, beginning with southeastern Nigeria in 1990, is documenting the complexity of farmers' resource problems and their responses to them. With the knowledge gained from these studies, which will cover farming systems in West and Central Africa, IITA scientists should be able to design technologies or interventions appropriate to the problem situation. A study in Cameroon will begin in 1991.

The Nigerian phase has shown that economic pressures, other than changes in population density, result in diminishing returns to farming, chiefly through degradation of the soil. Rising demand for food crops from urban areas, the rising cost of farm labor, and immigration of new farmers are other sources of pressure which stimulate such reactions as shortened fallows, increased fertilizer use, the closing of common use privileges of forest lands, and changes in land tenure and tree tenure arrangements. For example, farmers in areas where the population density is thinning may rotate their land under long-term fallows because farming activity is reduced. Alternatively they may overuse some farmland, permitting only short fallows, because there is not enough labor to bring heavily overgrown land back under cultivation. In such a situation, new technologies with a high labor demand will not be acceptable.

Meanwhile, IITA resource economists in 1990 evaluated the relative economic benefits from soil erosion control, in southwestern Nigeria, using three systems: alley cropping with *Leucaena* (in 2-meter and 4-meter widths between hedgerows), no tillage, and bush fallow (with 3-year and 9-year fallows). The study gauged the theoretical "profitability" of those alternatives using a capital budgeting approach with a 10% interest charge, and taking into account the long-run and short-run impacts of soil erosion on agricultural productivity. Where population density is low and access to forestlands "costless", the 9-year bush fallow system is most profitable, followed by 4-meter-wide alleys, no tillage, 2-meter-wide alleys, and the 3-year fallows. Where land values are rising and fallows become an economic "luxury" because of lost production opportunities, the 4-meter alley cropping system is most profitable, followed by no-till, 2-meter-wide alleys, and finally the 9-year and 3-year bush fallows.

Crop management research

Humid forest systems

In Nigeria, maize grown during the second rainy season (August–October) is a minor crop, usually planted with cassava and bringing low yields (up to 500 kilograms per hectare). Farmers consider whatever they can harvest to be a bonus in addition to the more secure cassava. On-farm trials in 1990 showed that the elimination of stem borer as a threat to maize could bring about an eightfold increase in yields. (See "Food for thought from second-season maize" inset in this article.) But the cost of production per unit of maize produced appears to be reduced only by up to one-quarter, which may not make the proposition attractive enough for most farmers. Final conclusions await the results of a model which incorporates farmers' decision-making and the production increase that could be induced by a lower unit cost.

Results from the collaborative study of cassava in Africa (COSCA) in six countries, which produce two-thirds of Africa's cassava, became available in 1990. (See Research Highlights article "The research horizon for cassava as a cash crop".) COSCA provides benchmark information on factors influencing the spread of new cassava varieties, farmers' cultivation and processing practices, and research needs.

Other 1990 studies yielded information about the kinds of farmers that adopt IITA-improved cassava, in southwestern Nigeria. Younger farmers who produce marketable surpluses on holdings bigger than 0.6 hectares were more likely to adopt the improved cassava than subsistence farmers. Activities of extension agents among subsistence producers had a significant effect on their adoption of the improved variety. Migrant farmers were early adopters.

Savanna systems

IITA's savanna systems research group is studying the intensification process of maize cultivation in the moist savanna and its problems. (See Research Highlights article "A new maize modernizes savanna farming".) The group is characterizing the various maize-growing environments, and studying the impact of and the means to control the parasitic weed striga.

Characterization takes a twofold approach: the maize genetic types and the various environments in which they are cultivated. Biophysical and socioeconomic data are compiled in a geographic information system. Different maize varieties, each with its own mix of characteristics, are matched to the environments in which they yield best.

The aim is to develop a model to explain the different genotype/environment (G x E) interactions of maize cropping in the humid forest and moist savanna zones, which could help streamline the testing process in the breeding of improved maize. In 1990, savanna group scientists, together with colleagues from the maize improvement program, began to test a maize growth model, incorporating six IITA-improved varieties.

The striga ("witchweed") problem is the shared concern of the savanna group and scientists from the Institute for Agricultural Research at Ahmadu Bello University, in northern Nigeria. They began intensive monitoring for striga in the fields of 63 farmers in five villages, in a study of the parasitic weed's impact on the evolving maize production system.

The first joint analysis reveals that "witchweed" infestation builds up increasingly in fields planted with its original host, sorghum, the longer that sorghum is planted there. The same holds true for maize, indicating that striga is adapting itself to living off maize. The popular system of sorghum and maize intercropping

Field teams survey cassava farmers in Akufo, in Nigeria's Oyo state, in conducting the Africa-wide study of trends in cassava production and consumption.

is therefore highly conducive to striga's spread. The risk of striga infestation increases with lateness in planting date, so early planting can help maize to escape striga attack. Farmers' cultivation practices can help in allaying the threats. In planting cowpeas or cotton in combination with maize, farmers usually do much weeding which destroys emerging striga and reduces its buildup. (See striga inset on page 46.)

Inland valley systems

Inland valleys are the relatively shallow and narrow valleys along the upper reaches of streams and rivers. In length they can extend up to 25 kilometers, in width from 10 meters in the uppermost stretches to about 800 meters in downstream tracts. Often swampy, inland valleys mark the convergence of drainage of the runoff and seepage from adjacent uplands. In addition, the water table in the lower parts of valleys or valley bottoms is near or above the soil surface during the wet season.

Inland valleys are found throughout Africa, covering between 10 and 20 million hectares in the moist and dry savanna zones of West Africa, and about 130 million hectares in all of tropical Africa.

Water availability makes an environment favorable for rice-growing in the inland valley swamps during the rainy season, and for cultivation of other crops during the dry season. The great interest in the swamps stems from their potential for sustainable production of rice, as the wetland rice systems of Asia have shown over many centuries. Their potential in general for increasing food crop production is important for a region where

Food for thought from second-season cropping

What should you plant during the second rainy season each year? If you are a farmer in southwestern Nigeria, you look for a crop to sow in July or August and harvest in November to earn you some cash, since you have already taken care of most food needs during the first rainy season, March–July.

IITA scientists interested in crop management in this region during the second season tried out some of the options, with farmers' cooperation, for three years from 1986 in the villages of Ayepe and Alabata, Oyo state. Three food crops appeared to make the best bet: maize, cowpea, and soybean. For farmers, they could add to cash income as well as family nutrition. For the research team, they would afford insights into farmer management of crop varieties that had been bred to suit the needs of this forest-fringe region.

Maize was already being grown as a second-season crop, but only by one in ten farmers. So few were interested in maize because of the uncertainty of rainfall and the certainty of pests, mainly two species of stem borer insects; and, to some extent, maize streak virus. Their scepticism was warranted—more than half of second-season maize-growers reaped no harvest in 1988. Farmers' concern about rainfall has been consistent with recent records, which show that maize of a medium maturity period (about 110 days) fails for lack of rain every four or five years.

Cowpea was another second-season crop with a checkered career, because serious pest problems have permitted only very low yields. Spraying had become an essential part of successful cowpea growing. The challenge for farmers was the regimen of spraying, apart from the costs involved.

Soybean was new to both villages, although it had been vigorously promoted in the region by the government as a nutritious crop for family consumption and sale to new markets. The research team introduced it in the two communities differently: in Alabata as a crop to be marketed, in Ayepe as a household food ingredient to improve protein consumption. Farmers in both places agreed to try it out.

The scientific harvest

After several years the IITA team reaped conclusions on the second-season potential of the three crops under farmer management, and insights for breeders on future research.

Research directions

Resource management

- Description, measurement, classification, and mapping work on the biological, physical, chemical, and socioeconomic characteristics of the IITA mandate area.
- Quantification of fundamental relationships among factors contributing to the sustainability of food production systems. Process studies (for example, biological regulation of nutrient cycling, physical factors affecting soil fertility, factors regulating interplant competition) to continue on non-acidic and acidic soils, including the low-phosphate acid soils at the new humid forest station at Mbalmayo, Cameroon.
- Development of indices for measuring the sustainability of small-scale cropping.
- Development of multipurpose agroforestry systems which combine improved soil and weed management.
- Development of economically viable and sustainable fallow management systems incorporating herbaceous legumes.
- Assessment of agricultural sustainability under traditional and improved resource management methods.
- On-farm testing and validation of new technologies, emphasizing alley farming under different socioeconomic conditions.
- Development of systems simulation models, emphasizing intercropping, nutrient cycling in alley farming systems, and economics/ecology of inland valleys.

Humid forest systems

- Investigation of resource use and productivity problems in cassava-based intercropping systems.
- Investigation of the adoption and impact of improved cassava varieties.
- Collaboration with national institutes, to improve cassava intercropping in alley farming systems.

Savanna systems

- Characterization and classification of maize-based farming systems in the moist savanna.
- Investigation of the effects of intensified maize farming on striga infestation.
- Development and testing of cultural methods for control of striga and improvement of soil fertility.

Inland valley systems

- Characterization and classification of inland valleys in West and Central Africa.
- Development of models of environmental and socioeconomic processes in inland valley agroecological systems.
- Design of technologies or interventions to improve land use and management practices.

Maize clearly would never be profitable while the stem borer problem persisted. Hence, maize trials were conducted under protection of a pesticide, to measure the yield potential in the case that resistant varieties become available. To beat the unpredictable beginning of the rainy season, planting had to start late, so an early-maturing variety ensured crop maturity by late in October. At harvesttime, farmers realized almost as much—about four-fifths—from the second season's crop as they had from their first, with the benefit of protection against stem borers. IITA maize breeders are reckoning these results in their calculations of the possible gains from breeding for stem borer resistance and other goals.

Cowpea crops were protected by three or four insecticide sprayings, an operation which posed no hurdle for the farmers. Their highest yield was about 1,500 kilograms of grain per hectare; their lowest, one-tenth of that. Even with an average yield of around 700 kilograms farmers could realize a return on their investment, because of the high market prices for cowpea during the study years. Spraying materials were no problem because the research team supplied all the items, against cash payment. But the value from this experience for the team remains to be gleaned—whether farmers will in future take the trouble to purchase their own supplies from the nearby town.

Soybean needed no sprays or fertilizers, and the yields were as good as with cowpea. But the market experience was not similar—in Alabata, no active market for the soybeans materialized, and the farmers' expectations could not be realized. Hence, Alabata farmers professed themselves disappointed with the crop and uninterested in further cultivation. In Ayepe, however, soybean harvests were consumed by the grower and the crop may have retained a small niche. To the IITA team, soybean clearly commands interest as a food crop for growers' consumption, with some possibility of commercialization. But until market channels are developed, and until grain quality and home processing are improved for traditional types of use, soybean is unlikely to occupy much of a place in this regional setting.

The cassava factor. In both villages, cassava usually accompanied maize grown during the second rainy season. Cassava seemed to be the insurance crop, while the maize if successful would provide a bonus.

Farmers often grow cowpea with cassava, and will likely grow soybean again and combine it with cassava as well. Experience has taught them the value of insuring their investment, while their entrepreneurial spirit still leads them to risk a new crop for new gains.

the amount harvested each year has to feed a proportionately greater number of people than the year before. Inland valleys afford a chance to supplement the harvests of the main producing areas, and to help satisfy the growing demand for rice among African consumers. (See Research Highlights article "A cornucopia to come".)

IITA's research group for the inland valleys, made up of scientists from several disciplines to ensure a broad and deep consideration of the problematique, drew up the following research strategy in 1990 for the coming five or six years.

• Measurement of land area occupied by inland valleys in West and Central Africa, and the proportion already being cultivated.
• Identification of the reasons why inland valleys are little used for cropping, the changes in land use in them over time, and what triggers changes in land use.
• Classification of the different types of inland valleys in the region and selection of representative experimental sites.
• Identification and assessment of problems with different forms of land use in the valleys, in terms of the sustainability of production and farmers' well-being.
• Development of computer-based models of the environmental and socioeconomic processes in the agroecological systems of inland valleys.
• Design of technologies or interventions to improve land use and management practices for inland valleys, and testing and modification of the technologies at the experimental sites.

The group began to tackle the first three objectives during 1990, with a time frame of about three years for completion of the expected results. The main problems with increasing crop production in inland valleys emerged from a detailed review of the literature in 1990. Weed competition with crops was the greatest problem, followed by low soil fertility, and variable water availability. Availability of suitable types of rice for those ecosystems was not a major problem.

Root, tuber, and plantain improvement

The starchy staples of cassava, yam and plantain supply food energy for most of tropical Africa's 400 million people each day. Cassava, a tuber-like root crop, provides for half the energy needs of over 200 million people. Yam is consumed by some 150 million people within this region—although production costs have put yam beyond the reach of the poorest. Plantain is a mainstay food for about 70 million people.

The IITA root, tuber, and plantain improvement program breeds improved varieties of cassava, yam, and plantain, focusing on problems of

- pest resistance
- adaptation to specific environmental conditions
- processing and eating quality.

The program works closely with national programs throughout tropical Africa, and with many research groups from other parts of the world, in fulfilling those aims and in developing processing systems for community industries and households. (See Research Highlights article on postharvest processing, page 12.)

Cassava

Cassava (*Manihot esculenta*) is native to South America and was domesticated at least 10,000 years ago. In the sixteenth century AD the Portuguese first brought cassava to Africa, where it flourished in the humid, forested lowlands.

Among the staple root and cereal crops, cassava tolerates drought best, is the most productive in poor soils and requires the least labor in cultivation. But the labor requirement in processing after harvest is very high, equalling the labor put into crop production.

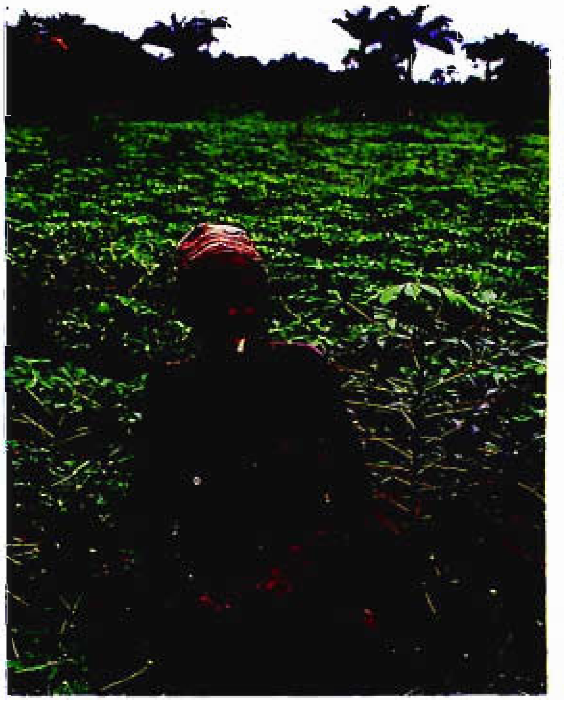
Because of its low cost and convenience in food preparation after processing, cassava will remain the biggest single source of calories for the foreseeable future, especially for the poor. Cassava is expected to play an ever greater role in feeding the expanding cities as African economies develop.

Tailoring breeds to suit needs. IITA began breeding high-yielding varieties in the 1970s, starting out with a few local varieties, some Latin American introductions and one line resistant to cassava mosaic virus disease that had been developed in East Africa. More genetic materials for this research came from African sources as well as Latin America, the home of cassava. Over the past 20 years IITA cassava specialists, working in multidisciplinary teams with colleagues in national programs, have developed high-yielding, pest-resistant varieties with good processing and eating qualities.

In 1987 IITA gave to its sister institute in Latin America, Centro Internacional de Agricultura Tropical (CIAT), its best 21 lines. CIAT crossed some of those lines with Latin American and Asian lines to improve them with other traits. In 1990, CIAT returned over 87,000 hybrid seeds to IITA's collection of cassava germplasm, or genetic material for breeding purposes. Evaluation of breeding lines produced from those seeds has since begun.

Cassava, unlike yam and plantain, can be grown in a range of environments in the tropical and adjacent subtropical zones of Africa (see map on page 2):

- humid forest and forest-savanna transition (high rainfall)
- coastal areas (high rainfall, sandy soils)
- moist savanna (moderately humid to semi-arid)
- mid-altitudes (800–1,500 meters above sea level; moderately humid to semi-arid).



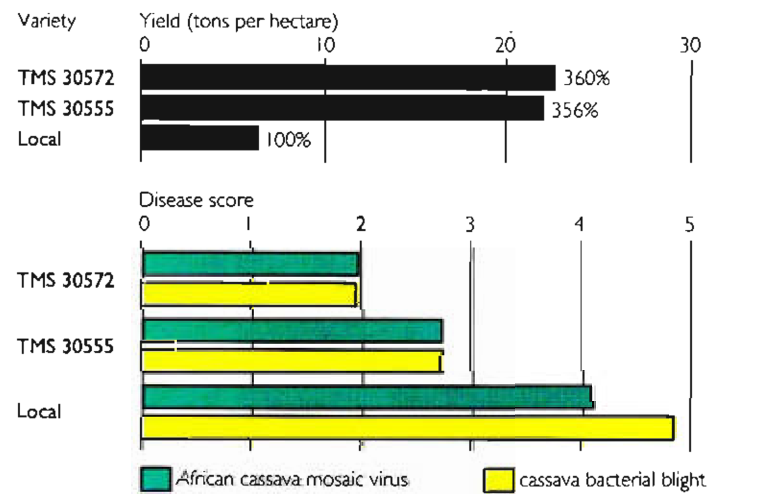
Africa's most widely grown staple food, cassava is being adapted to suit diverse farming and food systems.

IITA's goal for cassava has been to adapt the crop to conditions in these agroecological zones and to the farming and food systems there. Breeding schemes for these zones are dedicated to improving resistance to pests (particularly the cassava green mite and cassava mealybug), increasing the yield, enhancing cooking quality and nutritional value (through more carotene), and reducing the potential for cyanide in the flesh. (See "Mites meet a hairline defeat" and "Cyanide in cassava" insets in these pages.) IITA's improved cassava is resistant to the two major diseases of African cassava, mosaic virus and cassava bacterial blight.

Five improved lines of cassava germplasm, being tested in several zones in Nigeria, were evaluated during 1990. The new lines, with pest resistance and preferred consumer qualities, showed high and stable yields over the three-year trials. International testing, in collaboration with six West African countries, entered its second year of operations, of identifying IITA lines suited to the particular agroecological conditions in each country.

Two improved lines produced more than three times the harvests of local varieties, in a 1990 survey of farmers' fields in five states of eastern Nigeria. (See accompanying diagram.) Such high yields are due in large part to resistance to the major cassava diseases, as attested by comparative disease scores.

Comparative performances of IITA-improved cassava and local varieties in farmers' fields in eastern Nigeria, 1990



Cyanide in cassava —

Cyanide poisoning from cassava is rare, although hundreds of millions of people depend on cassava as a staple food. New findings about cyanide in cassava and the detoxification process are helping to explain why poisoning is so rare. They also suggest new breeding strategies to improve cassava, determined by the different ways in which cassava is prepared for eating.

The cassava plant does not accumulate cyanide in its tissues. Cyanide in cassava is a breakdown product of a reaction which takes place in the course of preparing the leaves or roots for eating. (See the accompanying diagram.) The plant accumulates two compounds known as linamarin and lotaustralin, in the proportion of 10 to 1. They are synthesized in the leaves and stored in the cytoplasm of the plant's cells, in different concentrations in different parts of the plant. For example, the peel or cortex of the cassava root retains much more linamarin/lotaustralin than does the edible portion of the root, the pith.

Cyanide is produced when linamarin and lotaustralin are hydrolyzed by the enzyme called linamarase. Normally linamarin/lotaustralin do not come into contact with linamarase in the living plant, because they reside inside vacuoles within the cell's cytoplasm, while linamarase is localized in the cell walls of the plant. However, when the plant is damaged by bruising, grating, or biting, for example, the integrity of the cells is lost and the content of the vacuoles comes into contact with the cell wall components, including linamarase. The enzyme will hydrolyze the two compounds, producing acetone cyanohydrin which is, at a pH above 5.0, converted to acetone and hydrogen cyanide.

Cassava varieties can be classified as "high-cyanide" or "low-cyanide". High-cyanide varieties seem to accumulate more linamarin and lotaustralin in the edible pith than in the peel or root bark. The opposite seems to be true with low-cyanide varieties, which store a greater proportion of the two compounds in the peel. In any case, the concentration of linamarin/lotaustralin varies considerably within each part of every plant.

Fit to eat

When the roots are grated or "chipped" in the first steps of preparing cassava to eat, most of the linamarin and lotaustralin is converted to free cyanide—the smaller the chips, the greater the conversion. Being volatile, the cyanide will evaporate, especially when

it's not there, it just happens

heated. (The boiling point of hydrogen cyanide is 25.7°c.) The same process occurs when cassava leaves are pounded and then boiled.

However, fermentation of the grated cassava, an intermediate stage before frying in the preparation of West African gari, itself contributes little to detoxification. The difference between residual cyanide contained in non-fermented gari, and gari fermented for four days, is not significant.

Detoxification of cassava prepared whole or in large pieces follows different pathways.

In the making of the Nigerian lafun or Central African kwanga, peeled or unpeeled pieces of cassava are first left to ferment in water for several days. During this period almost all of the linamarin and lotaustralin is eliminated from the fermenting cassava through leaching, or converted by enzyme activity to cyanide, which evaporates. Heating of the fermented dish removes the remaining cyanide.

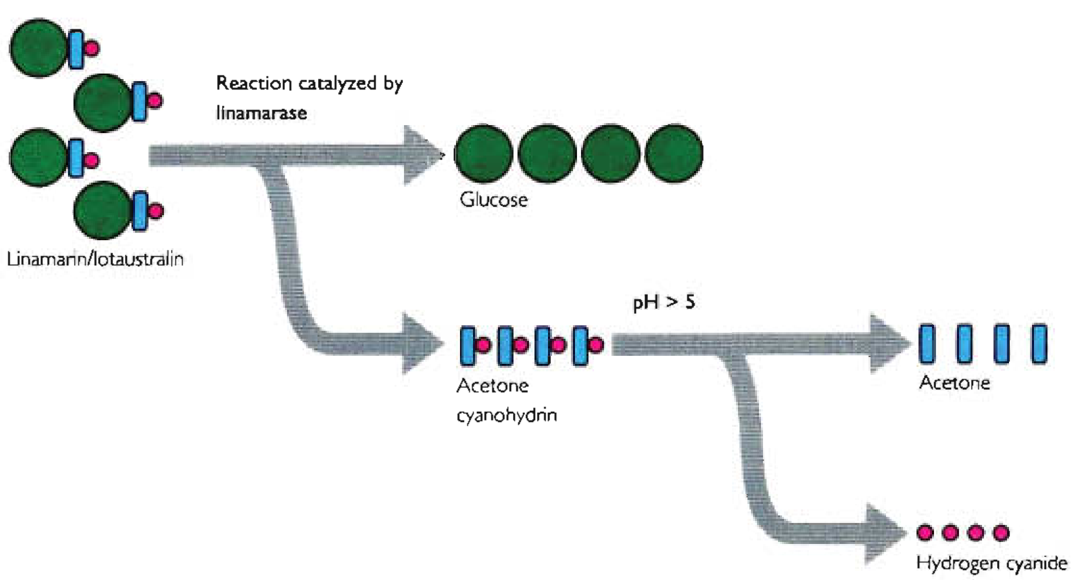
In the preparation of fresh cassava roots to be eaten without fermentation, such as in Ghanaian ampesi, the pieces are simply boiled for 10 to 30 minutes. As soon as the temperature reaches 70°c, the linamarase is inactivated. Cyanide thus has no chance to form. In boiling, about half of the linamarin and lotaustralin is leached into the water. The smaller the size of cassava pieces put to boil, the greater the leaching of linamarin/lotaustralin.

Paths to improvement

Large differences in linamarase activity do exist among cassava varieties. Breeders can take advantage of the high-activity trait by breeding it into new varieties for processing. Cassava varieties will thereby acquire this capacity to expedite the degradation of linamarin/lotaustralin to cyanide and, eventually, its elimination.

IITA breeders used to aim at producing "low-cyanide" varieties by selecting for low levels of linamarin/lotaustralin in the roots. Henceforth, they will in addition test varieties for the presence of the enzymes responsible for synthesizing those two compounds in the first place. Low-cyanide varieties in the future will be bred for a minimal potential for cyanide production, for low linamarin levels and high enzymatic activity to break down what linamarin there is.

Cyanide in cassava – a breakdown product of two chemical compounds stored in cassava plant cells



Mites meet a hairline defeat

It is invisible to the naked eye, yet the green spider mite counts as one of cassava's greatest enemies.

The cassava green mite (*Mononychellus tanajoa*), a dry season pest, feeds on the fluids of individual cells on the undersides of young cassava leaves and the tips of new shoots. The plants rarely die, but suffer severe defoliation and stunted growth which also stunts the cassava roots, halving their normal yield.

Native to South America, the mite was first sighted in Africa nearly 20 years ago, on the outskirts of Kampala, Uganda. It was thought to have been a stowaway on some cassava cuttings imported from Colombia. Eight years later it had migrated up and down the eastern African region and penetrated Nigeria to the west. By 1985 it had reached Guinea—some 5,000 kilometers west of where it ostensibly started. Today it is found in almost all the 39 countries of tropical Africa's "cassava belt".

When the mite began to infest West Africa early in the 1980s, IITA sought to control it through two approaches: breeding varieties which could resist the pest's attack, and biological control utilizing the mite's natural enemies.

A resistance capability bred into the plant appeals from several angles: economical for farmers, non-contaminating and therefore kind to the consumer and the environment, yet compatible with other control methods, biological or chemical.

And what qualities can be conjured up to fit such an unlikely assignment? After 10 years of research, the list is short but potent. On top is, logically enough, "hairiness"—resistance to the cassava green mite is linked with pubescence or density of hair-like trichomes, on the leaf's upper and lower surfaces, the basal section of the leaf stem, and the growing tip of the plant. Breeders have found that the greater the hairiness, the less the damage inflicted by mites; and vice versa. Trichomes appear to pose a mechanical barrier to the mites' feeding. Confirmation of these findings has come from 1990 field and laboratory studies of improved, high-yielding IITA cassava with and without resistance characteristics.

Other qualities on the list are less easily described, but show up tangibly in statistical assessments. They are: tolerance of the plant to infestation; antibiosis, or a metabolic product of the plant which can repel mites; and non-preference for the particular cassava variety by mites. The recent findings have also confirmed the measurable effectiveness of these characteristics in discouraging mite attacks.

IITA-improved cassava, which is high-yielding and resistant to various diseases and pests including the cassava green mite, has been given to cassava programs in 10 countries in sub-Saharan Africa for testing under their own environmental conditions. IITA plans further study of mite resistance in cassava, as a facet of a broader pest management which involves biological and other forms of control, in the main ecological zones of the African tropics.

By 1990, seven African countries had tested and released to their farmers cassava varieties derived from IITA materials: Cameroon, Gabon, Liberia, Nigeria, Rwanda, Sierra Leone, and Zaire. The spread of improved varieties has been documented in a few countries by the collaborative study of cassava in Africa. (See Research Highlights article "The research horizon for cassava as a cash crop".)

Enriched endowment. In crossing cultivated varieties with wild *Manihot* species, IITA breeders have discovered spontaneous cassava "polyploids"—plants with one-and-a-half or two times the normal complement of 36 chromosomes. These natural polyploids show enormous vigor and variation in plant architecture. They offer hope for further increases in yields, broader environmental adaptation, and new breeding possibilities, which include transfer of useful genes from wild *Manihot* to cultivated species. In 1990 the first polyploids were tested in three zones—the humid forest, moist savanna, and mid-altitude zones.

In the past decade IITA has developed laboratory techniques which reduce time consumed in the research process. Disease-free cassava plantlets are being produced in test tubes by culturing bits of plant tissue. They can be easily shipped, after testing for absence of viruses, to fellow workers in other countries.

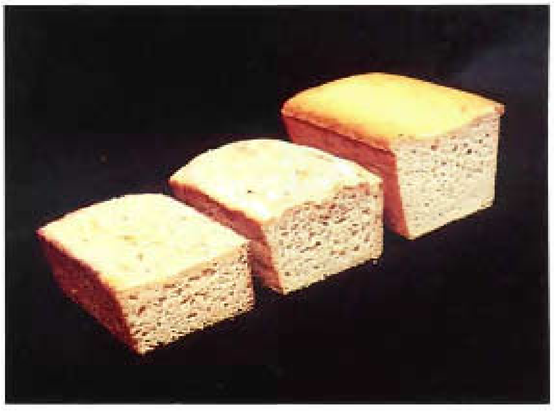
Procedures for culturing mature embryos from interspecific crosses are being adapted for the rescue of very young embryos which might otherwise be lost.

Embryos have been generated from young leaf tissues of several IITA cassava varieties in a liquid culture medium. Tissue culturists are exploring different ways to develop plantlets from these somatic embryos.

Bread without wheat. IITA food technologists have produced bread with a flour mixture of cassava (80%) and soybean (20%), together with other materials produced in African countries. Low-cost (using cassava instead of imported wheat) and nutritious (using eggwhite and soybeans), such a bread should answer a growing demand. To the flour is added margarine, to produce a spongy texture and trap air which prevents the bread from collapsing after it has risen. The research is funded by the Belgian government.

Research for bread-making also involves breeders, who select improved cassava varieties with particular flour-making properties. IITA's partners in flour studies include Katholieke Universiteit Leuven, Belgium, with Belgian government support.

A green vegetable, too. Cassava leaves are also eaten, in sauces which supplement the staple dish, providing nutrients in the form of protein, vitamins, and minerals. In preparing cassava leaves for eating, in a 1990 study, the first, traditional step of pounding the leaves was confirmed to be crucial in eliminating cyanide.



The loaf on the right was made with cassava flour, eggwhite, and margarine (locally made in African countries), and has a light texture with a fine crumb structure. The middle loaf was made with cassava flour and xanthan gum, an imported additive which is less successful and economically not the best solution. The lefthand loaf is an experimental control with no additives.

Cassava germplasm was screened for linamarase activity, which is key to the cyanide elimination process. Large differences in linamarase were found among varieties, a useful distinction in breeding of new varieties for safe processing of both leaves and roots.

Plantain

West and Central Africa produce about 60 percent of the world's plantains (*Musa* species). Because of its long history of widespread *Musa* cultivation, the region has been host to the evolution of at least 116 different varieties so far identified.

Plantain fits well into the agroecological conditions of the humid forest zone. And as a backyard crop which receives kitchen and garden wastes for its fertilizer needs, it can provide a year-round source of food.

Long thought to be disease-free because of an abiding resistance to the main banana diseases, plantain has proved to be highly susceptible to the fungal disease of black sigatoka. About 15 years ago, black sigatoka was accidentally introduced into Africa and has spread with such virulence that it appears to threaten all existing plantain varieties. None of the 116 varieties in IITA's germplasm collection has shown resistance to or tolerance of the disease.

Cassava leaves are a popular vegetable in Zaire.

IITA launched the first breeding program for African plantain in 1987, with the primary aim of producing resistance to black sigatoka. The genetic improvement work at IITA's high-rainfall station in Onne, southeastern Nigeria, has succeeded beyond all expectations. During the three years since breeding commenced, 200 hybrids between plantain and wild banana have been established. Among them, 24 hybrids of 8 different families show exceptional promise, with a combination of good bunch qualities and resistance to black sigatoka.

Seven plantain hybrids and a cooking banana hybrid, all resistant to sigatoka, began trials in 1990 to assess performance, fruit quality and consumer acceptance in comparison with those of regular plantain.

Indefinite preservation of germplasm is vital to the success of all breeding plans. During 1990 IITA's plant tissue culturists succeeded in doubling the life of plantain cultures in test tubes, to one year or more.

Research at Onne has turned up five cooking bananas, a distinctly different sister group to plantains, which showed black sigatoka resistance or tolerance. During 1990 IITA produced 5,000 plants of the resistant cooking bananas and distributed them in Nigeria to family farmers and to agricultural institutions for further multiplication and distribution. This exercise is testing whether consumers will accept the taste and cooking qualities of these bananas, as an alternative to plantains.

Laboratory tests for cooking quality in 1990 showed that cooking bananas and plantain hybrids have not yet attained the standards of regular plantain which are generally preferred. Cooking bananas become very soft and sweet on ripening, whereas ripe plantains remain relatively firm and half as sweet. Plantain hybrids come halfway toward the preferred quality; their medium firmness and sweetness provide an acceptable fried product, but an unacceptable boiled product.

Yam

A crop synonymous with a full belly and general well-being, yam (*Dioscorea* species) requires much labor to cultivate. Cultivation is expanding northward into the forest-savanna transition zone, as land in yam's native forests becomes scarcer under increased cropping. The promise of significant returns to research, as well as the importance of yam in the diet and in the social culture itself, more than justify IITA's continued effort. (See "Tomorrow's role for yam ancestors" inset in this section.)

The goals of yam breeding are to:

Yam is a preferred but expensive staple, which needs improvement research in order to make it more economical to grow, handle, and process.

Research directions

Cassava

• Breeding of cassava genotypes for agroecological zones: the humid forests, coastal zone, moist savanna, and mid-altitudes zone.

• Evaluation and improvement of exotic breeding materials from specific agro-ecological conditions in Africa and Latin America.

Cassava, plantain

• Investigation of the reproductive biology and the processes of polyploidization. Manipulation of ploidy levels and evaluation of the resulting genotypes to be continued.

Cassava, plantain, yam

• Resistance levels to several pests to be increased, as part of a new integrated pest management strategy.

• Efficiency of breeding methodologies to be improved, especially for yams and plantains.

• Cytogenetic and biotechnological techniques to be applied in characterizing genotypes, elucidating phylogenetic relationships, and improving efficiency in selecting for desirable genotypes.

• Investigations of the inheritance, biochemistry and/or physiology of agronomic and quality characteristics, and stress reactions of the plant to be continued.

• Basic research to be conducted in partnership with advanced laboratories on somatic embryogenesis, somatic hybridization, anther and pollen culture, and genetic transformation and regeneration.

• Increase tuber yields.

• Make yams look and taste better to consumers and keep longer before spoiling.

• Build up genetic resistance to major diseases and nematodes.

• Improve the tuber's shape in order to make it easier to harvest and handle.

The first steps toward attaining these goals are collecting yam germplasm, characterizing it and evaluating the results for usefulness, and preserving it for breeding research. IITA preserves 1,200 samples of yam genetic material in test tubes, and others in the field.

By 1988 breeders had succeeded in their quest to produce high-yielding varieties of "water" yam that can resist foliar necrosis, a disease which causes premature loss of leaves. Tests of water yam and "white" yam in four different zones in 1990, with the National Root Crops Research Institute (NRCRI) in Nigeria, have shown yields of 30 tons per hectare, which is more than half again as large as yields of the best local varieties.

A new aid to yam characterization was confirmed with the 1990 results of tissue culture research. Biochemical profiles of five yam enzymes were clearly defined under electrophoresis.

International collaboration

Cassava, yam, and plantain germplasm has been exchanged among Latin American, Asian, and African (cassava only) countries during more than two decades.

In Cameroon, Rwanda, and Zaire since the 1970s, IITA has trained over 40 scientists, 1,000 technicians and extension agents, and 4,000 farmers' association members in its largest-ever collaborative root crop projects. In Nigeria, NRCRI and the National Seed Service have worked with IITA in developing and releasing improved cassava and sweet potato. IITA scientists have been working on root crop improvement in those countries, as well as in Ghana and in Malawi.

International collaborative testing of cassava has become a regular part of research procedure. Apart from that activity, during 1990 IITA distributed over 75,000 true cassava seeds to research programs in 20 African countries for their evaluation and selection under local conditions. Virus-free plantlets of 39 cassava lines in test tubes were distributed to 16 African countries. In the same way, 7 plantain lines were shipped to 8 African countries. Five white yam varieties were propagated and sent to 21 African and Pacific countries—marking a milestone in yam research.

Networking scientists, technicians and policymakers throughout tropical Africa have promoted root crop research through information exchange, study tours, and other activities. IITA variously participates in and helps coordinate activities of the Eastern and Southern African Regional Root Crops Network (ESARRN), the Cassava Biotechnology Network, the African Plant Biotechnology Network and the International Plant Biotechnology Network. IITA collaborates with the International Network for the Improvement of Bananas and Plantains (INIBAP).

During 1989 IITA turned over its responsibility for the improvement of sweet potato to a sister institute, Centro International de la Papa (CIP).

Tomorrow's role for yam ancestors

Discovery of the genetic forebears of the two most widely grown food yams of West Africa opens the way to new research for breeding improved yam varieties. IITA analysis of yam genetic material has shed new light on the relationship between today's cultivated yams and their wild relatives, and suggests leads for improvement work.

Different species of the yam (genus *Dioscorea*) originated independently in three tropical zones of the world—three species in West Africa (*D. rotundata, D. cayenensis, D. dumetorum*), two in Southeast Asia (*D. alata, D. esculenta*), and one in America (*D. trifida*). The "yam zone" in West Africa, stretching eastward from the Bandama river in central Côte d'Ivoire to the western flanks of the Cameroon mountains, yields about 90% of the world's yam harvests. (This zone includes the most densely populated parts of tropical Africa.) Nigeria alone is responsible for some 70% of global harvests, and probably cradles the center of origin of Africa's varieties: in the several valleys along the Niger river. Over the many centuries of domesticating the yam, the various peoples who cultivated the crop developed complex social systems that gave yam a prominent role.

Scientists have devoted relatively little research to yams for several reasons. Most varieties rarely flower, which limits opportunities for breeding by conventional methods. The countries which depend on yam cannot afford budgets of the scale required for basic research. Other staple crops exist, such as cassava, which can less expensively meet the rising demand for food caused by population growth.

New approaches have created new opportunities for breeding research to penetrate such problem areas. Analysis of yam DNA and genetic structure can point the way to improvement of varieties, in terms of improved yields, resistance to pests (diseases, nematodes, and insects), and other desirable characteristics.

IITA scientists have applied the analytical techniques of restriction fragment length polymorphism (RFLP) to elucidate the relationship between the two types of yam most widely consumed in the African yam zone: the "white" yam (*D. rotundata*) and "yellow" yam (*D. cayenensis*). They analyzed chloroplast DNA and ribosomal DNA in 26 plant samples from cultivated varieties and wild species. From the similarities evident in the genetic structures, they concluded that the white yam was most probably domesticated from one of three wild species: *D. abyssinica, D. praehensilis*, or *D. liebrechtsiana*. The yellow yam was most likely a hybrid of the white yam and one species from another set of wild relatives: *D. burkilliana, D. minutiflora, D. smilacifolia*, or *D. togoensis*.

Since those wild progenitors normally reproduce themselves sexually, breeders are hopeful that the "shy flowering" habit of cultivated yam can be overcome through use of genetic material from them. Other desirable genetic traits may likewise be introduced into the domesticated species, through both conventional and biotechnological methods of gene transfer.

Because wild species hold new value for improvement work, their conservation becomes an evermore important objective for agricultural scientists. IITA began, during 1990, to add wild yam species to its collection of cultivated yam genetic materials. The task is all the more urgent because the habitat of most wild yams lies within the lowland forests, which are rapidly being cut down for farming by an expanding rural population.

Grain legume improvement

Protein-rich grain legumes (pulse crops)—mainly cowpea, peanut, bambara groundnut, field beans, and, in recent years, soybean—are important in many parts of Africa where diets are otherwise scanty in protein and other essential nutrients. Because they can produce their own nitrogen requirements from the air and can leave a substantial deposit in their stems and leaves as fertilizer for the next crop, these legumes are key components of sustainable agriculture in the savannas of Africa.

IITA's grain legume improvement program conducts research to improve cowpea and soybean crops and their utilization by small-scale farmers in the range of agroecological zones from the humid forest to the dry savanna (see map on page 2).

Cowpea

Cowpea (*Vigna unguiculata*) in Africa is traditionally grown as a subsistence crop. It is drought-tolerant and thrives in poor soils.

In the mixed farming systems of the arid Sahelian regions, cowpea is the main legume and a major source of human food and livestock fodder. It is a secondary crop in the moist savanna or semi-arid zones, grown together with other food or fiber crops: millet, sorghum, maize, cassava, and cotton.

In food preparation, cowpea is utilized as dry seed, green seed, green pods, and green (young and tender) leaves. Livestock, particularly cattle, eat the haulms (dried stems and leaves, gathered after the seeds are harvested).

Cultivation of the crop has become more attractive with the results of research by national programs of African countries and IITA. Cowpea varieties with improved yields, early maturity, and resistance to some diseases and insect pests are being grown over larger areas and in more different zones than before, from arid to humid. IITA has the global responsibility among international institutes to conduct research on cowpea.

Reducing risks. The aim of cowpea research at IITA is to reduce the risks in cultivation for the farmer, whose productivity and income will thereby increase.

IITA scientists look at cowpea as part of a cropping system with its particular requirements for adaptation to various stresses and for resistance to insect and disease pests. From 1988, the main breeding objectives have been:

- Adaptation in form, structure, and organic functioning, for suitability in intercropping with cereals.
- Improved drought and heat tolerance, especially for the millet cropping system of the semi-arid zones.
- Multiple pest and disease resistance to be bred into varieties adapted to local growing conditions.

Because conventional breeding and sources of genes from cowpea collections have not been successful against insect pests in some cases, the program is placing greater reliance on genetic improvement through crossbreeding with wild species—or "wide crosses". Wide crosses with a wild cowpea (*V. dekindtiana*) for resistance to pod-boring and pod-sucking bugs have been advanced to the sixth generation. Some of the results looked promising in 1990 field evaluations.

Akara, a fried cake of cowpea flour, is a popular street food in Nigeria.

Putting cowpea viruses on the map

Virus diseases are a universal source of concern in cowpea research and production, yet virologists are only beginning to know enough about them to be able to design an adequate strategy against them.

Eight viruses have been reported to afflict cowpea (*Vigna unguiculata*) in various parts of Africa, with varying damage to crops in the field. National programs have invested to different degrees in research on their occurrence and control. But no one as yet has put this knowledge together, to show what geographical or ecological relationships might explain their occurrence in any particular place, or what viruses might threaten plans for developing new cowpea varieties for different areas. What drives IITA's virologists to investigate these issues is the need to prevent future epidemics, through building resistance into new cowpea varieties and improving crop management practices.

From their surveys in Nigeria and selected places elsewhere in western and southeastern Africa during the past 15 years, IITA virologists have discovered that agroecological factors seem to delimit the occurrence of cowpea viruses throughout the continent. The results have been compiled in the accompanying map, which shows where the four most important cowpea virus diseases have been encountered within the distinctive African agroecological zones: three viruses transmitted by beetles (cowpea yellow mosaic, cowpea mottle, and southern bean mosaic) and one virus carried by aphids (cowpea aphid-borne mosaic). The zones are denoted on the map by length of growing season, according to available sunshine and rainfall.

The surveys followed the field performance of elite IITA cowpea lines, especially their susceptibility to the four viruses and their adaptation in general to their growing environment. The surveys encompassed locations in western Africa (Benin, Burkina Faso, Cameroon, Ghana, Niger, Nigeria, Togo) and southern Africa (Botswana, Mozambique, Swaziland, Zambia), where national programs had planted virus disease "nurseries" of cowpea lines having known susceptibility or resistance to those viruses. Disease symptoms in the nurseries would show the local occurrence of the viruses and would help, in the case of elite lines, in evaluating the effectiveness of resistance breeding.

All four viruses may be found among cowpeas in the humid forest, forest-savanna transition, and moist savanna lowlands of West Africa. The three beetle-transmitted viruses appear to be absent, however, from the drier zones—the dry savanna and Sahel—as well as from the mid-altitude zones of southeastern Africa. In these latter zones, where most of the continent's cowpea is grown, only the cowpea aphid-borne mosaic virus appears to afflict the crop.

In addition, surveys in East Africa about 20 years ago have documented occurrences of cowpea yellow mosaic virus in Kenya and Tanzania, and cowpea aphid-borne mosaic virus in both those countries and Uganda. These occurrences follow the general agroecological pattern found in IITA surveys.

Survival. All four viruses survive the dry seasons, when no cowpeas are growing, by shifting abode to a similar crop or weed species, or to a wild relative of cowpea.

Cowpea aphid-borne mosaic virus has been found in a subspecies, *V. unguiculata* subsp. *Dekindtiana*, which is a close wild relative of cultivated cowpea. The virus can "preserve" itself in the seeds of this wild cowpea, and reemerge with the new growing season. The same virus, or a closely related strain, is also found in African yam bean, which is grown in the moist savanna and forest-savanna transition zones of central and eastern Nigeria.

From evidence that some strains of cowpea yellow mosaic virus infest leguminous weeds, such as *V. reticulata* or other *Vigna* species, IITA virologists assume that the virus survives the dry seasons by taking refuge in such species in the humid forests and forest-savanna transition zone, or wet valleys in the savanna.

While no wild reservoir has been found for cowpea mottle virus, bambara groundnut (*V. subterranea*) provides a handy alternative host species for the virus, which is transmitted through its seeds. Bambara groundnut is grown together with cowpea in the moist savanna.

In light of the dynamism shown by these viruses in their survival over the agricultural year, the accompanying map of virus occurrence in agroecological zones has added value for the virologist and plant breeder, as a framework on which to mark seasonal associations as well. New information about virus occurrences and climate change can help to chart virus behavior, enabling breeders to endow new varieties with the kinds of resistance needed for improved production in specific regions.

Research directions

• Investigation of the biology of the parasitic weed striga, leading to implementation of a striga control project, under a cross-program team. The striga population to be reduced and resistance to be bred into cowpea as well as maize varieties.

Cowpea

• Improvement of local cowpea genotypes to continue, incorporating a stable resistance to diseases and insect pests; for mixed cropping with cereals (millet, sorghum, and maize) in the savanna.

• Improvement in cowpea grain types with a wide range of maturity periods to continue; to meet diverse needs in different agroecological zones.

• Technical support for national programs and networks of cowpea scientists in western, central, and southern Africa; emphasizing technologies for incorporating resistance to diseases and insect pests into local varieties. Priority given to collaboration with the Semi-Arid Food Grains Research and Development (SAFGRAD) cowpea network and support for the Southern African Development Coordination Conference (SADCC) cowpea project.

Soybean

• Breeding to combine resistance to insect pests and early maturity (to provide an 80–130 day range of maturities) with other desirable traits, for different zones.

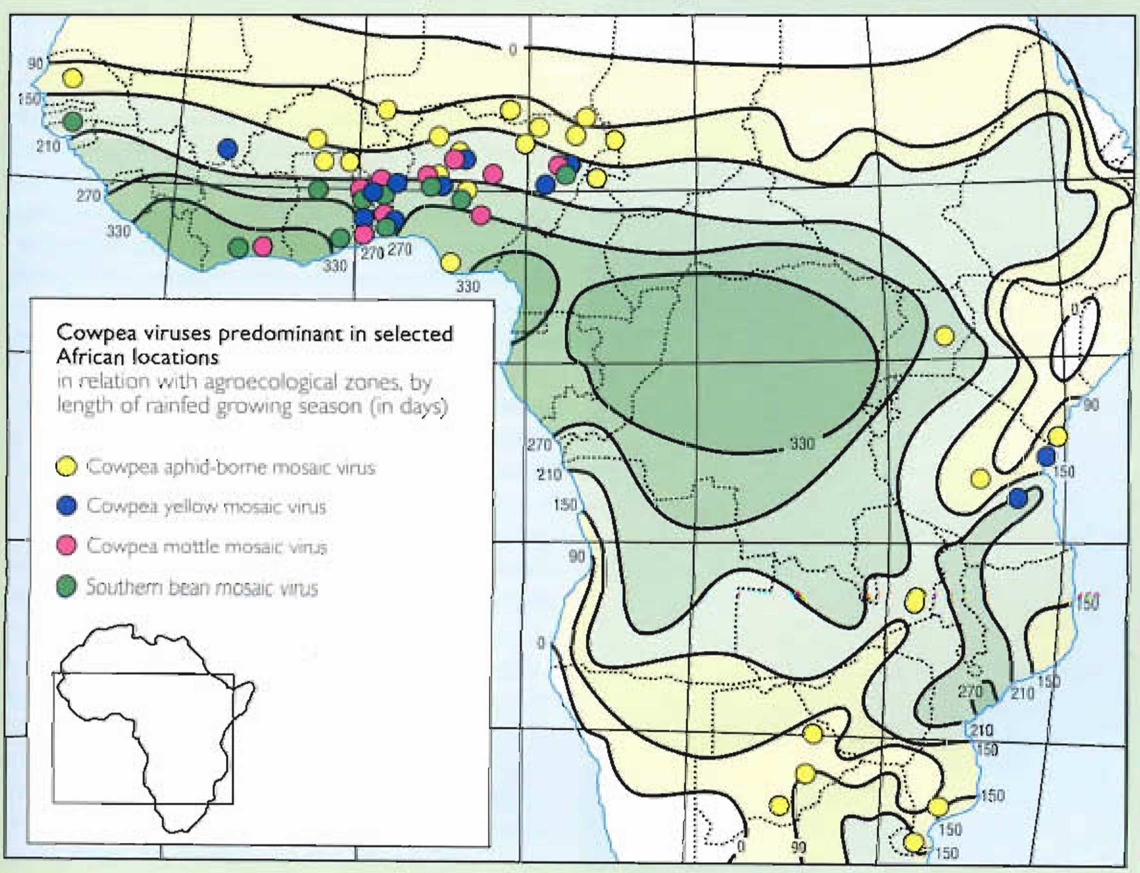
• Identification of sources of resistance to frogeye leaf spot disease, and of the different strains of the causal organism. Mode of inheritance of resistance to be determined.

• Maintenance breeding to retain the traits of stable and high yield, good nodulation with bacteria in the soil, resistance to the main diseases, nine-month storage capability of seeds, resistance to buckling under the weight of high pod yields, and resistance of pods to shattering and dispersing seeds before harvest.

• Development of ways and means of combining soybean with traditional food preparations, for domestic and small-scale industrial use, to continue in Nigeria and Ghana with national programs, supported by the International Development Research Centre (IDRC) and the Japan International Cooperation Agency (JICA). Simple, low-cost processes also to be developed for soybean products simulating meat, fish, and cheese.

• Joint research on intercropping sorghum and soybean, and on crop rotation systems with soybean, to continue with the Institute for Agricultural Research (IAR), Zaria, Nigeria, and the International Crop Research Institute for the Semi-Arid Tropics (ICRISAT), with field testing in the Nigerian dry savanna.

• Investigation of soybean production, utilization, and marketing by Nigerian farmers and small-scale industries.



Cowpea viruses predominant in selected African locations
in relation with agroecological zones, by length of rainfed growing season (in days)

With advanced laboratories in Italy (University of Naples and the Germplasm Institute, at Bari) and the USA (Purdue University), IITA in 1987 began biotechnology research for resistance to postflowering insect pests and to the cowpea bruchid, a storage weevil. The Italian government has supported this basic research. IITA has contracted the biotechnology research with Purdue University as a joint project.

Genetic mapping has started at the University of Minnesota, Purdue University, and IITA, using the restriction fragment length polymorphism (RFLP) method. To date, 69 linkages of the genetic code have been marked on cowpea DNA. Botanical classification of *Vigna* species also continues on an RFLP basis. When the map is completed, the research team will identify which markers pertain to which particular traits—primarily the desired genes for resistance to insect pests and diseases.

The results will prepare the way for producing new hybrids—and make the crop less risky and more profitable to farmers in the tropics.

Soybean

IITA has always attached great importance to improvement of soybean (*Glycine max*) for the tropics, and more recently to research on soybean processing and its utilization in human diets. (See Research Highlights article "Making a home for the soybean in Africa".)

In setting research aims, IITA grain legume scientists have given priority to:

- Resistance to the main diseases and insect pests.
- Maturity periods which accord with climate and cultivation patterns in each agroecological zone where soybean is grown.
- Processing technologies suitable for home and small-scale industrial use.

If people know what foods soybean can be used in and how to make them, this nutritious legume (40% protein and 20% oil) will generate a strong demand in the marketplace. Farmers will need to produce greater amounts of soybean for the benefit of all.

The best agroecological environments for soybean production are similar to those for maize and sorghum: the moist savanna and "mid-altitude" zones in the savanna in particular.

In 1990, several lines were identified with a high level of resistance to the fungal disease of frogeye leaf spot and to bacterial pustules, both of which are spreading and becoming economically damaging in most soybean-growing areas. Over half the potential yield of one susceptible local variety was lost to frogeye leaf spot in trials, while the improved resistant variety maintained its high yields under heavy disease pressure.

Dietary need. The importance of improving the protein content of African diets has been the guiding principle of work on soybean utilization. IITA scientists have aimed to improve technology for household and small-scale uses, as well as the food products made with such 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 dishes. In many parts of Nigeria, soy flour is becoming very popular in home cooking.

Research on medium-scale industrial processing has led four companies in Ghana and Nigeria to collaborate with IITA in designing and building screw presses for soybean oil extraction. By 1990, three companies in Nigeria were using such locally made 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

Maize is an attractive crop for small- and large-scale farmers alike. It takes relatively little labor to grow, yet returns high yields, especially if fertilizers are used. In the Nigerian moist savanna zone, maize (*Zea mays*) is enjoying a "boom" as a cash crop, and is taking over much of the southern range of the millet and sorghum belt. (See Research Highlights article "A new maize modernizes savanna farming".)

IITA's maize research program aims to develop varieties that will reduce the risks of intensified production for farmers. Maize scientists can do so through:

- Improving their understanding of the main pests and environmental stresses, through "pathosystem" research.
- Breeding resistance to those pests and stresses into high-yielding plant types with good grain quality and the right mix of growing characteristics.

National program scientists in the region collaborate closely with IITA scientists in all aspects of this research. New technologies from these joint efforts will thus be acceptable to target user groups.

Durable prize-winner

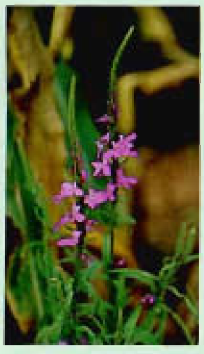
IITA's development of resistance to maize streak virus, which won the King Baudouin award for international agricultural research in 1986, is a well-known example of the "pathosystem" approach. In a 10-year team effort, entomologists and virologists studied the life cycle and ecology of the virus and its vector, the leafhopper *Cicadulina*, to provide breeders with the tools to devise novel screening techniques and a breeding strategy which identified a highly stable kind of resistance. The success of this effort lies in the durability of the resistance, which was based on a combination of many genes.

New strains of maize streak virus could evolve from viruses in native grasses surrounding maize fields, and overwhelm the IITA resistance. Against that possibility, wild grasses showing symptoms of the virus were collected during 1990 in Nigeria. None of the viruses isolated from those specimens was as virulent as the maize isolate itself, and none was able to overcome the resistance in the maize. Moreover, samples of maize streak virus collected from western, eastern, and southern Africa have shown a remarkable genetic similarity, which indicates that the IITA resistance can be expected to remain durable.

Collaborating programs in other African countries are beginning to use the research technologies in order to adapt the results to their own settings. Zaire joined Togo in 1990 as one of the first countries to succeed

Maize harvests are increasing in western Africa's moist savanna—here, in Burkina Faso.

Please save the savanna from that witch



Tawny maize fields ripple in the wind at harvesttime, across the moist savanna of northern Nigeria. Twenty years of maize breeding for Africa have yielded varieties well-adapted to this region, and farmers have found that they can tap new markets with their expanding harvests. This scene is ripe for devastation by the "witchweed" striga, against which maize has little natural defense. But IITA breeders have already delivered varieties with moderate resistance to the weed, and, teamed with other scientists, seem well on their way to developing effective striga control for the savanna.

Striga parasitizes the region's main cereals (sorghum, millet, maize, upland rice) as well as grain legumes (cowpea, soybean, groundnut). The whole crop can be lost in a severely infested field, forcing the farmer to abandon it.

The threat to maize is greatest of all. Most of the other crops which striga preys on evolved in Africa together with the parasite, and thus developed a measure of genetic resistance long ago. Maize came to the African savanna only 30 years ago, and has little native resistance. Whatever protection science can give it must come from external sources.

Although it is a plant, striga resembles a fungal pathogen in many ways. It produces hundreds of thousands of tiny seeds, each weighing only 5 micrograms, in just one square meter of an infested field. The seeds remain dormant until chemically triggered by the host plant to germinate. The striga root attaches itself to the roots of the host plant with a haustorium, a foot-like appendage similar to fungal attachments. The "witchweed" can then flourish at the expense of its host, which it slowly poisons.

Research in advanced countries has found several means of controlling striga, such as nitrogen applications at a high rate, herbicides, managed fallows, and fumigation of the soil to induce a suicidal germination. These means are too costly for African farmers, so in 1982 IITA launched a search for control technologies which suit the region.

IITA breeders have screened thousands of maize lines from all over the world for genetic material resistant to or tolerant of the most widespread species in Nigeria, *Striga hermonthica*. Selection for tolerance or resistance has succeeded—moderate levels are already available in hybrid and open-pollinated varieties of different grain types and maturity periods, well-adapted to savanna growing conditions.

But these resistant or tolerant varieties still accommodate some striga in their midst, so striga

in using IITA-style screening for maize streak virus with minimal facilities. IITA also assisted Cameroon and Ghana in developing their screening capability.

"Witchweed". The parasitic weed *Striga hermonthica* threatens the new successes of maize in the Nigerian savanna, the zone holding highest potential for large-scale maize production, and is a growing threat in Zaire. Research and breeding for resistance or tolerance to striga, on the pathosystem model, have high priority in IITA's maize work. (See "Please save the savanna from that witch" inset above.)

Downy. The pathogen currently ravaging forest-zone maize is downy mildew, a fungus. Plants infected early suffer a 100% loss in yield, since ears cannot form. The disease has become epidemic in southern Nigeria—by 1990, it had struck in several states. In central Zaire, downy mildew is likewise becoming epidemic.

Excellent genetic resistance is available, however, developed jointly by IITA and Nigeria's Institute of Agricultural Research and Training (IAR&T), and breeders continue to work on improvements in varieties for the forest zone. In trials of large (half-hectare) plots, yields of the resistant varieties are not reduced, while susceptible varieties—which are widely grown—are severely affected. IITA helped IAR&T hold a workshop during 1990 to inform local authorities about the epidemic and how to combat it with resistant varieties.

Fungi are notorious for their ability to evolve new strains that can overcome existing types of genetic resistance. Understanding of a fungus's potential for mutation or variability of strain can help in preventing a breakdown of the resistance. In 1990 IITA began a worldwide study with the University of California at Davis on strain variability of downy mildew, on maize and sorghum.

seed continues to build up in the soil, a risk to future crops. Hence, a new phase had to open in the quest for protection, to include a multi-sided attack on the striga plant. Breeders were joined by other scientists: agronomists, pathologists, economists, biologists, computer modellers—to orchestrate a set of plant characteristics for maize, farming practices, and biological control activities, reinforced by improvements in scientific knowledge and research techniques, which together will control the striga threat.

In the first year of shared effort, 1990, the earlier breeding advances were complemented with new research on farming practices which promote or discourage the pest, and with models of striga population dynamics and of the suitability of control technologies.

Resistance breeding continues together with research in the other striga disciplines. Priorities for research activity are listed below.

Research priorities

- Expand the work to include other important striga species, particularly *S. asiatica* and *S. aspera*.
- Increase the number and diversity of field sites by developing more collaborative links with affected countries.
- Increase the level of tolerance/resistance to striga, and broaden its genetic base by screening land races and wild relatives of maize.
- Improve our understanding of resistance mechanisms, and devise screening techniques for them.
- Continue on-farm diagnostic studies to learn how farmers are currently coping with striga, and how striga is adapting to the recent changes in cropping patterns in the savanna. That will yield more clues for control methods.
- Study the mechanisms by which nitrogen appears to inhibit striga, and find ways to increase the efficiency of control using small, economic doses of nitrogen fertilizer.
- Identify more "trap plant" species that cause suicidal germination of striga and are economically viable for savanna farmers.
- Gain a better understanding of the basic biology, life cycle, and epidemiology of striga, to reveal novel opportunities for its control.
- Assess the potential of biological control strategies against striga, utilizing insects and nematodes.
- Explore the opportunities for using biotechnology to (a) transfer resistance genes from indigenous grasses into maize, and (b) measure strain variability in striga populations at the molecular level, to assess its chances of overcoming resistance through genetic change.

Grain drain. Stored maize suffers huge losses from insect pests, particularly in the forest zone. With the help of a visiting scientist from the Republic of Benin, D. K. Kossou, studies of *Sitophilus* grain weevils found that maize stored on the cob—the traditional method—suffers less damage from weevils than shelled maize. The longer husk leaves of traditional varieties hug the cob more tightly than do the shorter, looser husks of modern varieties, thus affording the stored ear better protection from pests. Accordingly, breeding strategy in 1990 included selection for longer husks, and characteristics that contribute to weevil resistance in the grain itself.

In the past decade another storage pest of maize, the larger grain borer (*Prostephanus truncatus*), entered West Africa from Central America. It has become a serious problem in Togo, and has spread to neighboring Ghana and Benin. Two IITA programs, on maize improvement and on biological control, are working with national and international institutes in Togo, Benin, and Nigeria to find ways to head off the threat. Organisms possibly useful in biological control are being hunted in South America, where the pest originated.

Biological and ecological studies of other pests—stem borers and ear borers—and their natural enemies continued during 1990. Resistance to stem borers poses one of the most difficult challenges to breeders. Breeding for forest-zone maize included resistance to these pests, with several maize populations showing modest progress in selection. To date, only moderate levels of resistance are within reach; hence, IITA breeders are exploring the possibilities for biotechnological means to obtain a novel type of resistance.

Dieting. Low nitrogen levels in the soil and the high cost of nitrogen fertilizers persuaded IITA in 1988 to try breeding varieties which require less nitrogen to grow.

Yields of trial lines under high and low applications of fertilizer are being compared, and measurements which reflect the plant's efficiency in using soil nitrogen are being analyzed.

Good eating? Eating quality has not been a big issue in developed countries, where maize is fed to livestock or used as an industrial material. It is a key issue for research in Africa, however, where maize is a main dish in people's daily diet.

IITA started to characterize maize varieties in 1990 for their grain traits—such as oil content, ease in milling, types of starch. The first year's work reveals that maize contains enough genetic variation to enable breeders to produce different combinations of grain quality characteristics. Oil content appears to be high in most varieties, so they would be prone to deteriorate in storage. Breeding can overcome such a defect.

In breeding work, conversion of the grain type of some improved varieties to a softer kernel continued, utilizing the "floury" gene from traditional, unimproved types of maize. A soft grain is preferred in many areas for its ease in milling and high flour yield. Started in 1987, this project benefited from the work of Ghanaian visiting scientist Baffour Badu-Apraku, who reported in 1990 on his genetic findings from his year-long stint.

Uses. The results of pathosystem research find their practical use in the hands of the breeder, who utilizes them in developing new varieties with the desired characteristics. The breeder works with two types of maize: open-pollinated varieties, which farmers can propagate on their farms each year, and hybrid varieties, which yield better but which cannot produce their own seed for the next year's crop. The two complement each other in breeding strategies. From open-pollinated populations come lines with genes for specific traits. Desirable genes can be "fixed" in these lines into unchanging form, a genetic resource in developing new hybrids or open-pollinated varieties.

Green or new maize provides food to be eaten fresh, not stored, during the "hungry season" before other crops are mature enough to be harvested.

Research directions

• Improvement in understanding of the biology and control of striga, through a cross-program project with a twofold approach: to reduce the striga population and improve host plant resistance.
• Strengthening of national programs and regional maize networks, emphasizing transfer of technologies for screening for resistance to maize streak virus and striga.
• Improvement in understanding of small-scale farming systems, through close collaboration between IITA's maize program and savanna systems group.
• Development of maize varieties adapted to regional growing conditions, emphasizing high yields with stable resistance to foliar and ear diseases and maize streak virus, resistance to stem borers and storage insects, improved grain types and a range of maturity periods, to meet the needs of the lowland and mid-altitude tropics.

Outreach projects

An maize scientist is linking colleagues in Sahelian countries in a regional network sponsored by the Semi-Arid Food Grains Research and Development (SAFGRAD) project. Institutions in the different countries serve as "lead centers" for particular research topics, and share their findings with the rest of the network. In 1990 IITA'S SAFGRAD maize coordinator assembled trials of early-maturing, drought-tolerant varieties and distributed them among 16 countries in West and Central Africa. He also organized various study tours, exchange visits, and training programs for scientists and technicians.

In Cameroon, an IITA maize breeder has worked with the National Cereals Research and Extension (NCRE) project for seven years, helping to train counterpart scientists as they developed high-yielding varieties for the mid-altitudes zone, where most Cameroonian maize is grown. IITA assistance has helped NCRE to succeed in developing maize genetic materials to the final testing stages.

In Zaire, the national program has recommended an IITA improved variety, "Babungo 3", to replace an earlier variety susceptible to maize streak virus, for the vast southern Shaba mid-altitudes. In the last year of collaboration with the bilateral aid project, Recherche agronomique appliquée et vulgarisation (RAV), an IITA breeder and entomologist completed their work in developing high-yielding varieties resistant to maize streak virus, using IITA materials. The shared efforts have helped to stabilize yields especially in late plantings, which are customary for poor smallholders with little labor at their disposal. Babungo 3's streak resistance pays off in late plantings because the disease builds up as the season progresses.

Reaching the farm. IITA provides breeder's seed, training, and technical advice to seed producers nominated by governments, as a way to help push new varieties out the end of the research pipeline toward farmers' fields. Seed companies help to extend the impact of the research by making the new varieties available where the demand is.

In Nigeria, IITA has helped establish two successful seed companies and, in 1990, was requested to support a national project to strengthen seed multiplication and distribution, by supplying breeder's seed of downy mildew-resistant varieties and assisting with training in seed production.

Rice with maize is a successful combination for some farmers in northern Nigeria.

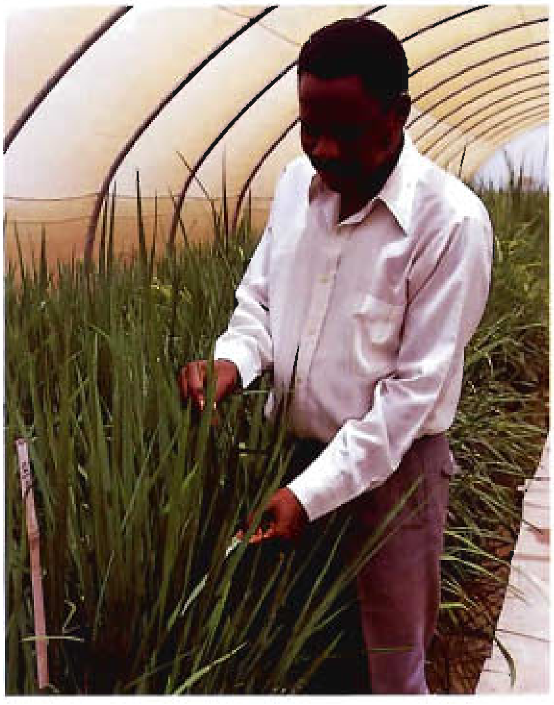
Rice research

During its last year of existence, the IITA rice research program concentrated on conserving the advanced germplasm, or genetic materials, it has developed over the past 20 years, and on duplicating the collection for transfer to the West Africa Rice Development Association (WARDA) at Bouaké, Côte d'Ivoire. Some breeding work during 1990 maintained the momentum of improvement research during this transfer period.

WARDA is placing a breeder of irrigated rice at IITA, in order to take advantage of the field and laboratory facilities and keep in close contact with Nigeria, WARDA's biggest rice producer. The breeder will also help in linking IITA's inland-valley research group with WARDA's program.

Breeding. For inland valleys, 24 promising new advanced breeding lines were identified during 1990, which have high-yield potential, good eating quality, resistance to the fungal diseases of blast and hull discoloration, and, in some, resistance to iron toxicity. For upland areas, five new lines were selected. For irrigated areas, six new lines were selected. One irrigated line shows moderate resistance to rice yellow mottle virus disease. Enough of its seed has been produced for interested countries to test on their own. New germplasm sources of resistance to the virus have become available from Kenya.

Many national programs were drawn closer into the breeding process as second-generation rice hybrids were distributed to them for testing and selection under local conditions in their own environments. The Rwandan and Cameroonian programs received products of IITA genetic crosses with global sources for cold tolerance, for adaptation to their mid-altitude zones. Similarly, populations of advanced breeding lines for resistance to iron toxicity were sent to Côte d'Ivoire, Ghana, Guinea, Liberia, Nigeria, and Sierra Leone after review and selection of the seed by their own breeders.



Rice research head at NCRI, E. Imolehin, studies the African rice gall midge problem in an IITA-designed screenhouse at Badeggi.

Gall midge. The African rice gall midge was first recorded in Nigeria 35 years ago, but did not become a major pest until 1988 when it devastated 50,000 hectares of rice fields in eastern Nigeria. Together, IITA and the National Cereals Research Institute (NCRI) at Badeggi, IITA's chief local collaborator in rice, mounted a campaign against the pest from 1989 onward.

IITA has spearheaded research on the ecology of the pest and its natural enemies, and begun developing a strategy for managing the threat. NCRI leads the development of rice varieties resistant to the pest's attack. State agricultural development projects provide land and manpower for experiments. A total of 11 local, state, federal, and international agencies, as well as individual farmers, have linked up with network activity, sharing information and conducting joint surveys, training, and public awareness drives. In 1990, the first "monitoring tour" for all Nigerian collaborators was held at Ikot Obong, the most badly attacked area that year, in the eastern state of Akwa Ibom.

Networking. IITA continued to support rice improvement work for the region by providing research facilities to the International Network for Genetic Evaluation of Rice (INGER-Africa), which is based at the International Rice Research Institute (IRRI). During 1990, 27 African countries received seeds of upland, lowland, irrigated, and mangrove swamp types of rice. INGER will analyze the results of their trials, for their use in breeding work.

Biological control

Biological control at IITA began in 1979 as an urgent experiment to combat the cassava mealybug and the cassava green mite, two 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, a staple food of some 300 million people. The conventional, chemical response—frequent dousings with potent insecticides—would have been ecologically brutal, socially unacceptable, expensive, and most probably unworkable.

A biological alternative, enlisting nature's own agents and mechanisms to keep pest populations in tolerable balance, appealed to IITA as the "right" solution. On their home ground in South America, mealybug and mite populations are naturally controlled by such antagonists as parasitic wasps and lady beetles.

A decade of Africa-wide research and campaign action was crowned in 1990 with the King Baudouin award for international agricultural research, shared with IITA's sister institute Centro Internacional de Agricultura Tropical (CIAT). Meanwhile, the IITA biological control program has come to play a key role in IITA research strategy. The application of biological control strategy to other crop/pest problems must rest on a full understanding of the ecology and life cycle of the various pests and their antagonists. In 1990, computer programs at IITA simulated the workings of such ecosystems, and included all living and environmental components that the crop and pest interact with. Field and laboratory research are adding to this new holistic understanding of ecosystems, which will form the basis for sustainable systems of plant protection being designed. (See "Plant protection" inset in this article, overleaf.)

Making a meal of mealybug larvae

The mealybug (*Phenacoccus manihoti*) is present at low levels in its native ecosystem. Arduous field research in South America had identified that pest's primary natural antagonist: *Epidinocarsis lopezi*, a parasitic wasp, which lays its eggs in mealybug larvae. The wasp's larvae consume their mealybug hosts as they develop. 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 simplicity. Success in distributing *E. lopezi* required no effort from networks of extension agents, nor from individual farmers. IITA entomologists bred many thousands of wasps, which were broadcast from airplanes or released on the ground with governmental collaboration in the affected countries.

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, to virtually subeconomic levels in many areas. By 1990, natural enemies of the mealybug had been released at about 160 sites in 20 tropical African countries. The parasitic wasp *E. lopezi* has made itself at home over more than 2.7 million square kilometers in the 25 countries of the continent's cassava belt.

Over the past few years control efforts have aimed increasingly at eastern and southern Africa, the last areas of the mealybug's invasion. During 1990, national programs in eight countries conducted mealybug surveys, releases of natural enemies, and follow-up activity with IITA guidance and support. Good control with *E. lopezi* is reported from most treated areas. In four countries of West and Central Africa, national programs made follow-up assessments with IITA assistance in 1990. Biological control scientists started to investigate a few of the mealybug predators which have established themselves in only some of the ecologies in which cassava grows.

Stalking the spider mite

The spider mite *Mononychellus tanajoa*, or cassava green mite, is the most important pest of cassava after the mealybug, and likewise came to Africa from the American tropics. Exploration for natural enemies in its home ground during the 1980s turned up more than 50 mite predators and one pathogenic fungus as potential agents of biological control—of which 10 predaceous mite species were brought to Africa for experimental release.

Plant protection — sustaining protector as well as plant

All living organisms, plants, and animals on earth are related by their interactions: what they take from each other and the environment, and what happens as a consequence of taking. The different demands of each one have implications for the activity of all the others within its sphere of interaction.

A plant's interactions as part of a cropping system are depicted in the accompanying diagram. Farmers are part of those interactions as they exploit the plant world in order to harvest crops. If scientists want to help farmers to increase their harvests, the first step should be to understand all the related elements in the cropping system being manipulated. On the basis of this understanding, scientists can devise efficient ways to increase the "take" and to sustain that improved harvest for the future.

We human beings need to know how to sustain our improvements for the indefinite future, if we want to keep things within our control ecologically and to stay on top within the system.

Pest/plant interactions

In solving a pest problem, the importance of an understanding of the whole picture of plant/pest interactions becomes apparent. Both pest and its natural enemies interact with a plant in different ways, which vary according to the plant's growing habit, its stage of development, and its environment and climatic conditions.

The plant's ability to withstand pest attacks and compensate for damage depends on many aspects which govern its growth—among them, length of its growing cycle (particularly of the plant parts that are damaged), the number and kind of diseases and/or insect pests attacking it, any form of resistance mechanism it may have, type of growing habit (whether annual or perennial, early- or late-branching, or leafy/non-leafy), its age, vigor, and the actual soil and other environmental conditions which prevail.

The way the pest feeds is very significant for the plant in compensating for damage and recovering. The cassava mealybug, for example, taps the plant's sap, which can be highly detrimental over a long period because it reduces plant growth. The damage caused by the variegated and the elegant grasshoppers, on the other hand, which feed directly on the leaves and bark over a short season, might be more easily overcome, depending on the length of exposure to the pest and growing habit of the plant (whether profusely branching and leafy or not).

Indeed, the growing habit of the cassava plant is crucial to its response to attack and recovery. If plant growth is affected by a leaf-feeding enemy (the grasshopper, or the cassava green mite) or a sap-sucker (cassava mealybug), the plant will respond by producing new leaves on lateral shoots. How fast this response comes, and how many shoots the plant produces, depend on its growing habit.

Growing habit: key factor. Generally, among cassava species, two different types of growing habit can be distinguished: a late-branching type and a profusely branching type.

The first type, whose branches form late, tends to produce the right amount of leaves it needs for the roots it is developing underground. The second, early-branching type tends to put out far more leaves than it needs for producing its potential volume of root flesh. This latter type can, therefore, afford to lose more of its leaves to pests or drought, for example, without sacrificing its root growth, than the first type can.

As growing conditions improve, the late-branching type does not produce more branches or leaves; instead, its energies go to developing the root. The early-branching type, however, does produce more branches and leaves with improvement in growing conditions. So, in the absence of pests and diseases in a favorable environment, the late-brancher is the superior yielder. But in that same setting the early-brancher produces proportionately more organic matter, in the form of stems and leaves, which can be left in the fields after the harvest and help in maintaining soil fertility.

After seven years of campaign effort, two of the mites, *Neoseiulus idaeus* and *Typhlodromalus limonicus*, both from northeastern Brazil, have become established in Benin, West Africa, and have already brought down the numbers of cassava green mite. During wet seasons when their target species becomes scarce, both find alternative food: *N. idaeus* another mite species, and *T. limonicus* a plant product exuded by cassava leaves.

Consequences

When cassava plants grow poorly, mealybugs do not grow big. In turn, the parasitic wasp *E. lopezi*, which IITA has released in an Africa-wide program to control mealybug populations, spawns males inside its host mealybug larvae, if the hosts are small. (It spawns females if the hosts are large enough to support the usually greater demands of female development.) Naturally, the fewer females that are produced, the smaller is the population of parasites and the better the mealybug fares.

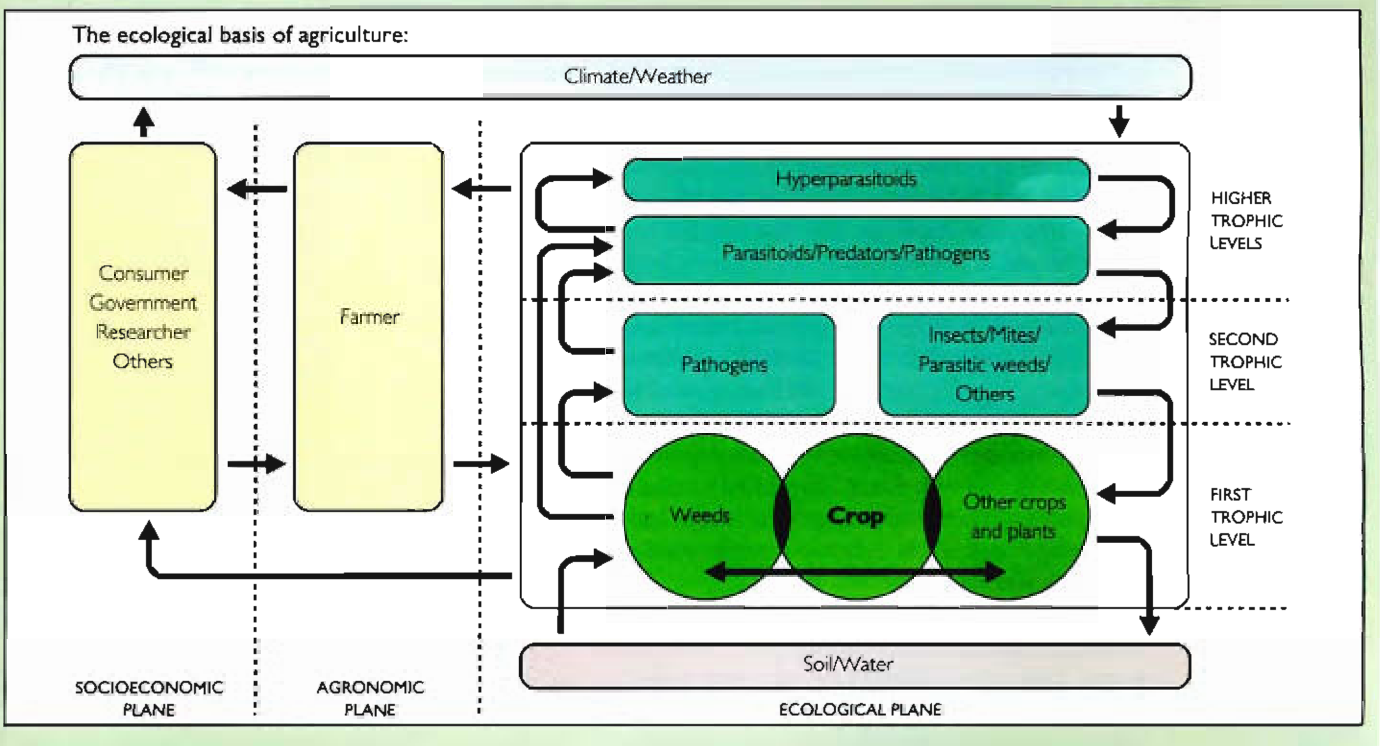
Thus, poor plants show higher degrees of mealybug infestation and of plant damage than does vigorously growing cassava. The efficiency of biological control is reduced on plants with severely reduced growth.

The plant and the biological control agent are also directly related in respect of cassava varieties—those "susceptible" and those "resistant" to pest attack. Susceptible cassava varieties show the highest densities of cassava mealybug in the field, but the lowest parasitization rates; because the "quality" of the mealybug populations (smaller-sized mealybugs) reduces parasite fecundity by inducing the wasp to breed males rather than females. On the other hand, resistant cassava varieties have the lowest mealybug densities, which show the highest extent of parasitization.

Basic research

Such basic research will guide future IITA strategies for crop protection and help in planning for farmers to exploit agricultural production in an efficient and sustainable way.

The practical side of crop protection involves sharing of the research results as feedback to breeders, agronomists, and other scientists who are participating in the design of new farming technologies. Everyone involved in manipulating the sphere of cropping interactions should also contribute in interpreting feedback and building up understanding of the interactive system.



The predaceous mites appear to have become established in East Africa as well: *N. idaeus* in Kenya and *T. limonicus* in Burundi.

With this breakthrough, current losses of as much as one-quarter to one-third of the cassava harvest can possibly be saved, according to South American experience. National programs in other countries are

Research directions

• Reorganization of plant protection activities institute-wide into a new biological and integrated plant protection program.
• Cassava mealybug: follow-up work in areas already controlled. Special efforts to be mounted in the few remaining pockets. Technical assistance in rearing to be given to national programs.
• Cassava green mite: releases of predators in main agroecological zones. Multiplication, release, and monitoring activities to begin in several national programs. Integrated control projects for mites and for cowpea pests to begin in three or more countries. Degree and technical training to reach 25 and 50 people, respectively.
• Exploration, quarantine, introduction and experimental release of natural enemies of cowpea thrips.
• Maize pest complex: importation and testing of natural enemies of larger grain borer and others. Field trials to begin for systems management practices, mostly crop rotation. Striga research: basic systems analysis, and identification and analysis of factors influencing outbreaks, to be conducted.
• Banana and plantain pest complex: completion of diagnostic survey in East Africa and initiation in West and Central Africa.
• Weed biological control projects: initiation of preliminary research, including *Imperata* and *Chromoloena*.
• Locust and grasshopper project: advanced implementation of field trials. Development of multiplication techniques for pathogens to be prepared for transfer to national programs.
• Selective support to national biological control programs. Special funds available to assist eight countries, with additional requests pending.
• Technical training (five-week sessions) for 48 specialists during 1991 under a training project sponsored by the Organization for African Unity (OAU) and funded by United Nations Development Programme (UNDP) and Food and Agri-culture Organization (FAO). New project to be prepared for 1992.
• Training to continue for MSc and PhD degrees; at least four new students per year.

releasing new batches of predators in different agroecological zones, and are studying the biology, behavior, and ecology of the cassava green mite and its natural enemies.

To the original pair of enemy targets, IITA has added the complexes of cowpea pests and maize pests, the mango mealybug, and locusts and grasshoppers, which are pests of a number of crops in the savannas. Possibilities for biological control of the parasitic weeds *Striga* and *Imperata*, and the banana and plantain weevil, are being explored.

New findings from ecosystem analysis indicate that classical biological control is a possibility for many species of the cowpea pest complex. Natural enemies of thrips, major cowpea pests, were identified. A computer model of the plant has been developed and was superimposed with thrips during 1990. Studies of postflowering pests, diseases, and striga have commenced, to provide data for a comprehensive plant/pest model.

The maize pest complex, including stem borers, cob borers, diseases, and weeds, especially striga, poses a devastating threat as maize cultivation intensifies in forest and savanna zones across West and East Africa. Research is revealing the extent of the damage caused by stem borers and cob borers in West Africa. Research on stem borers was extended to eastern and southern Africa in 1990 at the request of governments. Centro Internacional de Mejoramiento de Maíz y Trigo (CIMMYT) and IITA are planning a joint control program against the larger grain borer, an insect pest introduced from Mexico or Central America to East and West Africa a decade ago and which now causes significant losses in stored maize in many African countries.

Using campaign methods and national programs from the cassava mealybug project, control of the mango mealybug has succeeded from Côte d'Ivoire to Zaire, with few exceptions. Detailed follow-up studies are assessing biological and economic impacts. The few remaining pest pockets are also being studied in preparation for a final assault in 1991 with a new natural enemy introduced from India.

Microbial control of locusts and grasshoppers was planned during 1990 as a joint project with the International Institute of Biological Control, UK. Laboratory and field tests are under way to identify effective fungi, bacteria, and other pathogens. Simple multiplication and application techniques are being developed for national program use. The biology and ecology of grasshoppers and their natural enemies are being studied.

Research support services

Genetic resources

The genetic resources unit is responsible for IITA's germplasm collections of food legumes, cereals, and root and tuber crops. IITA has a world mandate to preserve and document germplasm of cowpea and yam, and of the African land races of two cultivated rice species, *Oryza glaberrima* and *O. sativa*. To improve the genetic diversity available to plant breeders, IITA's genetic resources specialists collaborate with national programs in Africa to collect the wild relatives of cultivated species.

The unit maintains a germplasm collection of 15,200 accessions of cowpeas (*Vigna* species) and 1,500 of wild *Vigna*, 12,500 of rice species, 2,000 of yams (*Dioscorea* species), 1,400 of soybean (*Glycine max*), 1,200 of maize (*Zea mays*), 2,000 of bambara groundnut, and hundreds of miscellaneous species. A separate collection in the root, tuber, and plantain improvement program holds 2,000 lines of cultivated and wild cassava (*Manihot esculenta*), 1,000 clones of sweet potato and over 400 clones of plantain and banana (*Musa* species) in in-vitro cultures.

Exploration and collection. In Nigeria during 1990, eight wild yam species were surveyed and collected in eight of the southern and eastern states, along with cultivated species from Gongola state. An exploration project in Ghana collected samples of wild cowpea, and cultivated yams and cassava. Exploration for cassava will continue there during 1991. In the Republic of Benin, a collaborative survey with national scientists collected a total of 751 samples of cultivated legumes, cereals, and root and tuber species and their wild relatives.

Germplasm diversity. Study of agrobotanical and physiological characteristics of the two African rice species in 1990 revealed a clear separation of *O. sativa* into two groups, corresponding to the indica and japonica differentiation in Asian rice. Differentiation in *O. glaberrima* has not yet been established.

Collaborative studies are bringing to light the extent of diversity in the primary gene pool of cowpea and in the genetic evolution of the species. Findings indicate that wild *Vigna* has much to contribute to cowpea improvement. Some of the genetic materials are potential sources of resistance to pod-sucking bugs, flower thrips, and leaf miner. (See the grain legume improvement article.)

Genetic inheritance. Knowledge of how plants inherit specific traits or characteristics can provide useful examples for application in related species, or help in developing strategies for using the genetic materials concerned.

IITA scientists have begun to study how the genetic immunity of *O. glaberrima* to rice yellow mottle virus is inherited, in order to gain an understanding of how the high susceptibility of *O. sativa* to the virus can be supplanted with immunity. For cowpea, IITA entomologists have found that hairiness of the pod can discourage pod borers and pod-sucking bugs, so the plant geneticists are investigating how the hairy trait can be bred into cowpea varieties which are smooth.

Biotechnology research

The new IITA biotechnology research laboratory, funded mainly by the Italian government, was formally dedicated in November 1990. The unit will help in linking African research needs and facilities with advanced laboratories in developed countries. The dedication of the unit coincided with a workshop on the theme of "Biotechnology: enhancing research on tropical crops in Africa", with 120 participants from 24 countries. The workshop heard 50 papers during eight technical sessions. Recommendations were adopted which will guide IITA in setting priorities for its biotechnological research activities.

Some objectives of IITA's commodity improvement programs cannot be easily realized by conventional breeding; for example, host-plant resistance to insect pests, which requires biotechnological transfer of genes from wild species or even unrelated organisms to cultivated plants.

The unit has four broad areas of research:

- cell and tissue culture
- cytogenetics and wide crosses
- diagnostics
- restriction fragment length polymorphism (RFLP) techniques.

The unit is participating in the collaborative studies to explore possibilities of transferring the resistance genes from the wild species *V. vexillata* and others to cultivated cowpeas. Since an increasing number of wild species will be used in breeding programs, several wild cowpeas have been tested for virus resistance. Excellent sources of resistance to cowpea mottle virus have been identified in *V. vexillata*, whereas only tolerance to this virus has been found so far in certain cultivated cowpeas. It should be possible to select wild species as donors with combined resistance to insect pests and viruses whenever wide crosses are possible.

Work on yam germplasm during 1990, with the root, tuber, and plantain improvement program, involved study of DNA variability in yam, using RFLP analysis. It resulted in a new understanding of the origins and evolution of cultivated yam species. (See "Tomorrow's role for yam ancestors" inset on page 40.)

Recent developments in biotechnology permit the production of reagents for detection of pathogens, in the form of monoclonal antibodies and cloned complementary DNA (cDNA). Moreover, the sensitivity and specificity of diagnostic tests can be highly improved by the use of these reagents. In collaboration with Agriculture Canada, Vancouver Station, 12 cowpea aphid-borne mosaic virus isolates from Nigeria have been used in characterizing strains of the virus using polyclonal and monoclonal antibodies. A panel of mouse monoclonal antibodies was also raised. Using this system, four serotypes of the virus have been differentiated. IITA is helping national programs on the use of monoclonal antibodies in their own laboratories to identify locally prevalent strains of the cowpea aphid-borne mosaic virus.

With the Scottish Crop Research Institute, Dundee, many weed species and crops with typical whitefly-transmitted diseases have been tested using a panel of monoclonal antibodies developed against African cassava mosaic virus. Several plants reacted with monoclonal antibodies samples which can detect whitefly-transmitted geminiviruses. However, these geminiviruses were not identical with that virus. Further studies are in progress to characterize geminiviruses in weed species.

With the University of Illinois, *Panicum* streak virus has been characterized and compared with maize streak virus.

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 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. (See "Putting cowpea viruses on the map" inset on page 42.) 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.

Achievements. During 1990, the unit continued to test the resistance of elite cowpea and rice genotypes from the breeding programs to newly recognized viruses or virus strains.

Collections of wild rice as well as *O. sativa* germplasm resistant to rice yellow mottle virus were tested against the IITA standard isolate of this virus and another isolate obtained from a rice-growing region within Nigeria. An isolate earlier obtained from *O. longistaminata* was included in the studies.

Results have shown that the new isolates of rice yellow mottle virus do not differ significantly from the IITA standard isolate for resistance screening purposes. However, there were significant differences between isolates in respect of reactions to certain accessions of *O. longistaminata, O. barthii, O. glaberrima, O. punctata,* and *O. eichingeri*, the originally African *Oryza* species.

Comparative studies of locally occurring strains of the cowpea aphid-borne mosaic virus have shown that the types of viruses which occur in the main cowpea growing areas of the dry savanna differ, to some extent, from isolates of this virus routinely used at IITA for resistance screening studies. The majority of accessions, however, have reacted in a comparable manner.

IITA virologists made significant progress during 1990 in characterizing viruses occurring in bananas and plantains (*Musa* species). The cucumber mosaic virus was found to be the most commonly encountered and has been shown to be responsible for conspicuous chlorosis and mosaic symptoms.

Some apparently new viruses isolated from IITA's mandated crops and associated weed species were characterized or purified for the production of antisera to be used for diagnostic purposes. Several antisera have also been made available to national program scientists on their request.

A project with the International Development Research Centre (IDRC), Canada, is assisting national programs in Africa in identifying viruses in their major food crops. Once national program scientists have been trained in the use of monoclonal antibodies, 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 scientists and graduate students doing thesis research here on the applications of mathematics and statistics to agricultural research. Scientists and students are assisted by the unit 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 particular research.

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. As resources permit, the IITA biometrician provides assistance to other research institutions and to Nigerian universities.

During 1990 the statistical classification of experimental sites continued, using results from 18 internationally conducted series of maize trials. Data from three large-scale sample surveys were filtered and analyzed, while other varied and nonroutine experiments were also analyzed.

The unit depends on continuous improvements in its computer software to keep up with the volume and complexity of IITA's mathematical and statistical work. In 1990, further extension and improvements were made to programs for the analyses of smaller sample surveys, genetics studies, and design generation.

In March 1990, the IITA biometrician attended the first East African biometrics group meeting at Nairobi, Kenya.

Analytical services

The analytical services laboratory analyzes soil, plant, and water samples submitted by IITA researchers and their collaborators for various physical and chemical properties, which ultimately affect the success of crops grown in the originating areas. Plant samples are analyzed for primary and secondary nutrients, and for micronutrients, which determine plant growth and indicate species adaptibility to the environment.

Training in soil and plant analysis was given to 30 laboratory supervisors, technicians, research scholars, and students.

Acquisition and processing of data will be further automated in order to establish a laboratory information management system.

The soil and plant analytical laboratories network of Africa (SPALNA) was inaugurated in 1990. The network will help improve soil, water, and plant analytical services in Africa, through equipment maintenance and repair services, supply of chemicals and spare parts, training, quality control, and promotion of good laboratory practices.

Research farms

The research farms unit carries responsibility for the development and management of IITA's experimental farms and test locations in the various agroecological zones of West Africa: at Onne, Kano, and Ikenne in Nigeria, Cotonou in the Republic of Benin, and Mbalmayo in Cameroon, and numerous smaller sites in all zones.

The research farms staff collaborates with resource management scientists on studies of soil-conserving tillage methods. For sustainability of IITA farms, most trials are planted with no-till methods that reduce soil erosion and degradation. Gully erosion is controlled by the use of graded contour banks. Sheet erosion is minimized with the use of no-till planting and also of tied ridges for root and tuber crops. Good soil structure and acceptable levels of organic matter are maintained by planted fallows of *Mucuna utilis* every second or third year, but where soil erosion and degradation are extreme, the use of *Pueraria phaseoloides* as a fallow crop for several years has been found effective.

The unit also multiplies improved crop varieties developed by IITA scientists and their collaborators, distributing up to 50 tons of seed annually to government seed services, seed companies, and farmers in Nigeria and other African countries. At Ibadan, the research farms unit maintains a demonstration area, where the latest crop varieties and farming technologies were demonstrated to around 1,000 visitors during 1990.

West African training. A three-week course was held in 1990, on surveying for soil conservation, maintenance and calibration of machinery, and farm workshop planning and management. The goal was to improve support for experimental farms of national research programs in the region. Seventeen research farm managers participated, who came from five countries of West Africa. The University of Arkansas, USA and the International Crop Research Institute for the Semi-Arid Tropics (ICRISAT) assisted IITA in running the course. Follow-up visits, several months after, revealed the considerable usefulness of the course. Similar courses are planned for 1991 and 1992.

A screenhouse construction team is being organized to cater for the numerous requests for assistance in constructing IITA-designed screenhouses for the institute's research sites and national research farms.

West African research farm managers learn survey techniques in the 1990 course.

International cooperation

The special role of international cooperation at IITA is to enhance the collaborative process with national agricultural research systems of adapting and applying improved technologies for farmers' needs.

Cooperation strategies . . .

The principal means by which IITA strengthens agricultural research 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, to address common problems and issues.
- **Research liaison scientists.** The medium-term plan provides for three research liaison scientists, each with specific responsibilities for a group of countries.
- **Resident scientist teams** in specific countries collaborate with national colleagues to meet research problems and needs, and to strengthen research capabilities.
- Training. The training program comprises graduate research fellowships, short-term courses, and short-term attachments to acquire specific skills in IITA research programs. Short-term fellowships are also arranged for visiting scientists from national programs for collaborative research over periods of up to 12 months.

During 1990, IITA operated 19 special projects in 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

Networking projects include the second phase of SAFGRAD, and ESARRN and AFNETA. These networks have elected steering committees which coordinate and plan their activities.

AFNETA organized a trainers' workshop for four regional and one national center during 1990, and published three issues of *The Afnetan* newsletter. AFNETA commenced collaborative research projects with 20 African countries aimed at the development of sustainable cropping systems based on alley farming principles. (See "Alleys across Africa" inset, page 26.)

ESARRN activities during 1990 included germplasm exchange, workshops, and scientific exchange visits among member institutions. In Malawi, IITA cassava lines were hybridized with the best local selections. IITA provided additional lines in tissue culture form for multiplication for various projects. Two graduate students completed their MSc degrees with ESARRN support. Altogether 47 technicians were trained in-country and at IITA.

The SAFGRAD maize research network supported several of its member countries in testing of improved germplasm and crop management techniques. It sponsored technical training and exchange visits.

The SAFGRAD cowpea research network received feedback on 42 regional trials. Those repeated in national programs during 1990 performed well. National scientists benefited from group training, exchange visits, and interaction with IITA scientists in research planning. New varieties continued to gain wide acceptance in West African countries after being

Training course participants demonstrate yam flour sifting with IITA-designed equipment at a farmers' field day, at Iwo, Nigeria.

Table 1. Bilateral and multilateral special projects, 1990

Project		Donor(s)	Total staff	Life budget US$ million	1990 budget US$ million
Institution-building	NCRE II/Cameroon (terminated December 1990)	USAID	19	14.31	3.93
	RAV/Zaire (terminated September 1990)	USAID	1	8.12	1.44
Resident scientist teams	Ghana grains development	CIDA	1	1.12	0.11
	Ghana smallholder	IFAD	1	0.80	0.25
	Cameroon root crops (terminated June 1990)	GCF	2	0.70	0.12
	Congo kindamba	IFAD	-	0.40	0.11
	SADCC cowpea project	EEC	3	1.78	1.34
Research networks	SAFGRAD	USAID	2	4.08	1.15
	ESARRN	USAID/IDRC	2	2.70	0.40
	AFNETA	CIDA/IDRC	2	3.17	0.66
		USAID	-	1.00	-
		DANIDA	-	0.07	0.46
		IFAD	-	1.20	-
Other research	On-farm/adaptive research	EEC	3	2.79	1.53
	Soybean utilization	IDRC	-	0.16	0.05
	Legume viruses	IDRC	-	0.46	0.13
	Utilization of cassava flour	AGCD	-	0.64	0.23
	Dynamics of soil organic matter	AGCD	-	0.16	0.12
	Postharvest technology	FF	-	0.21	0.15
Training projects	Human resources development	UNDP	-	0.78	0.35
	Women agricultural professionals (East/Southern Africa)	FF	-	0.28	0.17
	Women agricultural professionals (West/Central Africa)	FF	-	0.79	0.34
Totals			**46**	**45.72**	**13.04**

developed in the network, including Suvita-2 which was developed in Burkina Faso and is being widely cultivated in Mali.

Research liaison. During 1990, the IITA research liaison scientist helped to start operations for an on-farm adaptive research project on cassava, cowpea, maize, rice, and soybean varieties which had been developed in an earlier EEC-supported project. Fourteen West and Central African countries are participating with trials of a selection of the crops, most of which began during the year. Two research projects on cowpea insect pests also commenced in the dry savanna of Nigeria, in collaboration with the Institute for Agricultural Research, Samaru: a survey, as a basis for control measures, and a minimum pesticide protection/yield-loss trial.

IITA finished its tenth year of continuing involvement with Cameroon's NCRE project, which has had a double impact: helping Cameroon to strengthen its own research capacity and to become a producer of technologies which can benefit other African countries as well as itself. The IITA team of scientists works on four staple cereal crops—maize, rice, sorghum, and millet—at stations in Cameroon's six different agroclimatic zones. Among many research achievements to date, two maize and five rice varieties have been improved, adapted, and released to farmers. Twenty-one staff scientists have received fellowships for higher degree study, while many more technicians have received training at IITA.

Completion of IITA's role in Zaire's RAV project (1985–1990) marked the seventeenth year of collaboration with Zairian research programs that have produced high-yielding, disease-resistant cassava, maize, and grain legume varieties. Hundreds of village groups received planting materials and training through extension agencies linked with the RAV research effort. IITA collaboration with Zairian scientists continues on cassava problems, including crop improvement and plant protection, and on maize, soybean, and cowpea research.

IITA completed its part in Cameroon's national root crops improvement program in June 1990. The program succeeded in developing a large quantity of improved cassava and sweet potato as planting material

Acronyms cited in the text

AFNETA	Alley Farming Network for Tropical Africa
AGCD	General Administration for Cooperation and Development
CIAT	Centro Internacional de Agricultura Tropical
CIDA	Canadian International Development Agency
CIP	Centro Internacional de la Papa
COSCA	Collaborative Study of Cassava in Africa
CTA	Technical Centre for Agricultural and Rural Cooperation
DANIDA	Danish International Development Agency
EEC	European Economic Community
ESARRN	East and Southern Africa Root Crops Research Network
FAO	Food and Agriculture Organization of the United Nations
FF	Ford Foundation
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
IFAD	International Fund for Agricultural Development
ILCA	International Livestock Center for Africa
INIBAP	International Network for the Improvement of Bananas and Plantains
NCRE	National Cereals Research and Extension Project
RAV	Applied Agricultural Research and Outreach Project
SADCC	Southern African Development Coordination Conference
SAFGRAD	Semi-Arid Food Grains Research and Development Project
UNDP	United Nations Development Programme
USAID	United States Agency for International Development

for further multiplication and distribution to farmers. The improved cassava showed yields twice as high as those of local varieties, although some problems with root rot, "cookability" and taste remained for further investigation. Improved sweet potato was an over-all success in performance and acceptability. Researchers and technicians received in-service training, 2,400 farmers were trained, and 500 extension agents attended training courses.

In the legume component of the 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 color, 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. The project has resulted in release of three cowpea varieties. Exotic soybean varieties were also screened for the selection of high-yielding, early-to-medium-maturing varieties which combine traits favorable for tropical cultivation, including disease resistance. Researchers and technicians received in-service training and 30 extension staff attended in-country training courses.

In the Ghana smallholder rehabilitation and development program, highlights of 1990 included selection of four IITA cassava varieties for trials in farmers' fields by Ghana's crop services/extension department . Twenty varieties of "poundable" cassava were selected from seedlings for further evaluation. The program sponsored in-country and external training courses, including a 10-week root crops course.

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. A marketing survey measured the acceptability of soybeans in Ibadan produce markets, revealing that the total number of soybean retailers had increased from 1 in 1987 to 419 in 1990. Extruded soybean products were introduced for home use in selected areas and development of small-scale processing technology continued.

The SADCC cowpea research project was launched during 1990 with the signing of an agreement between IITA and the Mozambique government. The project aims to develop cowpea genotypes with suitable resistance and eating quality characteristics. Research began at Maputo and nurseries were distributed to all national collaborators.

IITA is working with the Katholieke Universiteit Leuven in formulating a cassava flour for making bread. Preliminary work in 1989 had included screening of cassava clones for making composite flours and developing technologies for wheatless bread for African consumers. The project completed its second year in 1990, and a second phase is being developed.

Self-development

To realize the potentials in their own programs, national agricultural research institutions in tropical Africa are sharing with IITA the responsibilities for research and for self-development in human resources. Such a collaborative orientation in training should enable national programs increasingly to carry out their own research and training.

Training in research for African agricultural professionals has always formed an essential part of IITA's outlook. No proposal to develop or transfer technology from IITA fails to consider the training objectives of the participating countries.

IITA's strategic plan (1989–2000) set the following guidelines for development of its training program:

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

Since 1971 IITA has organized individual and group training for close to 7,000 researchers, most of whom have come from African countries.

Individual training seeks to enhance 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, IITA initiated the graduate research fellowship program in 1988, to support graduate students in conducting their research with IITA scientists. During 1990, 14 new graduate fellowships were awarded, 3 of them to women. Six fellows concluded their research at IITA. During the year IITA scientists supervised 50 PhD and 30 MSc trainees, of whom 16 were women.

Internships provided specialized training in research during 1990 for 21 interns (one of them a woman) from national programs, ranging in length from two weeks to six months.

Group training. During 1990, 251 technicians and scientists participated in 14 group training courses at IITA, which collectively amounted to 55 weeks of training. Some 179 persons participated in regional or in-country courses in Benin, Ghana, Guinea, Malawi, Niger, and Sierra Leone. (See table 2 for a summary of courses and trainees.)

The majority of group course participants were Africans, of whom 80% came from West and Central Africa. The trainees came from 32 African countries: 18 in West and Central Africa, 13 elsewhere in the region. About 29% of all group course participants at IITA came from French-speaking countries.

Of the total of 190 trainees at Ibadan, IITA provided 73 with scholarships, principally from West and Central Africa. FAO and UNDP provided funding for the 61 trainees at Cotonou. Demand for off-campus training came principally through two networks: AFNETA and ESARRN. The networks funded training for about 10% of their participants.

Evaluation activities, part of a new evaluation and impact assessment process being established in the training program, covered 10 of the courses given during 1990 in various locations. Together with University of Arkansas staff, IITA made follow-up visits to participants in the 1989 group course in research farm management from Ghana, Gambia, and Nigeria.

Women in training. During 1990, 31 women (over 12% of the participants) took part in IITA group training courses, while 19 women (11%) participated in regional or in-country courses. Of the 80 graduate trainees at IITA in Ibadan, Cotonou, and elsewhere during 1990, 16 were women (25%).

In 1990 IITA obtained funds for a project to train African women for leadership roles. Ten agricultural professionals from West Africa will receive grants to study for MSc or PhD degrees in African universities. IITA will collaborate with Winrock International in executing this Ford Foundation-funded project. Awardees will participate in Winrock's African women leaders in agriculture and environment program.

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 with ICRAF, ICLA, IBSRAM, INIBAP, ICRISAT, CTA, University of Arkansas, and other institutions in course planning, development of training materials, course presentation, and 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. National programs and IITA together offer training that is increasingly organized, conducted, and sustained by those programs, with the goal of strengthening national and regional capacities for research and training.

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.

Table 2. IITA group training in 1990

	Weeks	Trainees total	Trainees women	Countries*
IITA Ibadan				
Advanced soil and plant analysis	4	13	2	10
Alley farming for research trainers	3	20	0	5
Biotechnology training workshop	1	18	5	8
COSCA village and institution-level cassava survey	2	16	2	7
Cowpea and soybean research and technology transfer	6	18	3	10
Maize research and technology transfer	8	16	3	11
On-farm experimentation	2	19	1	9
Plantain research and technology transfer	3	13	4	8
Research farm management	3	17	0	5
Root crops research and technology transfer	8	24	2	12
Sustainable food production systems	3	16	3	10
Ibadan subtotal	51	253	51	-
IITA Cotonou				
Biological control (3 courses) Cotonou subtotal	12	61	6	23
Regional/in-country				
Alley farming research (anglophone West/Central Africa)	2	29	0	5
Alley farming research (francophone West/Central Africa)	2	24	4	10
Alley farming research (Nigeria)	2	27	2	1
Root and tuber crop production research (Guinea)	2	18	0	1
Root and tuber crop production research (Malawi)	2	34	4	1
Root and tuber crop production research (Sierra Leone)	1	31	2	1
Training and communication skills (UNDP; regional)	2	16	7	5
regional/in-country subtotal	13	179	19	32
Group training total	**68**	**430**	**50**	**32**

*Total number of countries in each instance

Information services

Nigerian print and electronic media representatives were enlisted as supporters of agricultural development, in the newly formed media forum for agriculture. While most members of the forum are journalists, some are researchers, extension personnel, policymakers, and agricultural information specialists. Members represent a wide range of organizations involved in agricultural development, including research institutes, banks, farmers' organizations, extension agencies, and commercial farms.

Through the forum, IITA is trying to involve both public and private sectors in dissemination of findings by the various agricultural research organizations in Nigeria, thereby helping to promote farmers' adoption of new and improved technologies. The forum launched the food action media service (FAMS) during 1990, with three arms: FAMS Bulletins for the print media; FAMSTEL for television, and Radio FAMS for radio.

IITA achievements received extensive coverage during 1990 in Nigeria and, to some extent, internationally. International coverage included feature programs of the British Broadcasting Service (BBC) and Deutsche Welle (the Voice of Germany). Selections from IITA's press coverage were reproduced in three volumes of *IITA in the News* which have been distributed widely.

IITA participation in fairs, exhibitions, and other public events in Nigeria included, for the first time, the Kaduna international trade fair, and the Shell Petroleum health and environment week in Warri. Many businessmen, farmers, and representatives of agro-allied industries visited IITA to obtain advice, information, and samples of improved seeds. About 60 groups of students from polytechnic institutes and faculties of agriculture visited IITA during 1990.

Library services. The in-house database was enhanced through the addition of 3,029 retrospective and 9,359 current records of various types of publications. The library acquired 1,898 books and 5,218 journal issues. Four additional databases on compact disk (CD-ROM) were acquired. Use of library facilities during 1990 was reflected in the 115 recipients of selective dissemination services, and 93 scientists who receive the weekly journal service contents. The number of books borrowed increased from 10,138 in 1989 to 17,152 in 1990, as a result of increased awareness of services and revision of lending policy.

Training in library management and automation was given to staff of other libraries, and to some lecturers and students of higher institutions in Nigeria. Assistance to national research institutions continued in the form of literature searches, interlibrary loans, preparation and supply of bibliographies, donations of duplicate publications, and provision of general information. A total of 482 entries was contributed to the AGRIS database and 332 of them have already appeared in AGRINDEX—the international agricultural information system coordinated by the Food and Agriculture Organization of the United Nations (FAO).

Publications. During 1990, four editors were responsible for issuing 51 publications with a total of about 2,700 printed pages. Another 35 titles were being processed at the close of the year. The editors informally reviewed and edited several thousand manuscript pages of scientific and administrative documents. The publications unit acts as secretariat for the IITA publications review panel, which received 63 manuscripts during 1990 for review before submission to scientific journals, or presentation at conferences.

Graphics output during 1990 amounted to some 4,000 pages of camera-ready artwork. The printshop produced approximately 2.5 million plate impressions during 1990, being about 200,000 impressions per month on average.

During 1990 staff photographers went on 180 field shoots. They processed some 10,000 slides of their own shots and those of other IITA staff. Nearly 5,000 color prints and 20,000 black and white prints were produced. Users of the slide collection, including trainees and editors both local and foreign, made a total of 155 consultations with the staff to select slides for lectures, demonstrations, or publications.

Mailing list entries were updated and new addressees recruited with a questionnaire survey. The unit began selective dissemination services with mailings of *Cowpea Genetic Resources* to 1,500 addressees, as well as a regular mailing of the first issue of the periodical *IITA Research* to 7,000 addresses.

Annexes

IITA
STATEMENT OF FINANCIAL POSITION
31 December 1990

		Expressed in US$ thousands
ASSETS	1990	1989
Cash and short-term deposits	8,644	6,936
Accounts receivable:		
Donors	7,862	8,058
Others	363	503
Inventories	2,544	3,627
Other assets	209	178
Property, plant and equipment	58,356	55,768
	77,978	75,070

LIABILITIES AND FUND BALANCES		
LIABILITIES		
Accounts payable and other liabilities	7,639	8,094
Accrued salaries and benefits	3,071	3,053
Payments in advance – donors	3,974	3,465
	14,684	14,612
FUND BALANCES		
Capital	58,356	55,768
Capital development	1,224	976
Operating	3,714	3,714
	63,294	60,458
	77,978	75,070

IITA

STATEMENT OF ACTIVITY

For the year ended 31 December 1990

Expressed in us$ thousands

REVENUE	1990	1989
Grants	35,333	31,218
Other income	613	619
	35,946	31,837

EXPENSES		
Research programs	21,694	18,342
Conferences and training	2,290	1,883
Information services	1,039	1,432
General administration	3,593	3,522
General operations	3,248	2,886
Property, plant and equipment	3,054	3,634
Exchange (gains) / losses	380	(263)
Total expenses	35,298	31,436
Allocation to capital development fund	648	401
Allocation to operating fund	-	-
	35,946	31,837

IITA

STATEMENT OF CHANGES IN FINANCIAL POSITION

For the year ended 31 December 1990

Expressed in US $ thousands

SOURCES OF FUNDS	1990	1989
Excess of revenue over non-capital expenses	3,702	4,035
Decrease in accounts receivable – donors	196	432
Decrease in accounts receivable – other	140	60
Decrease in inventories	1,083	834
Decrease in other assets	-	59
Increase in accounts payable and other liabilities	-	1,096
Increase in accrued salaries and benefits	18	-
Increase in payments in advance – donors	509	349
	5,648	6,865

APPLICATION OF FUNDS		
Purchase of property, plant and equipment	3,454	4,634
Increase in other assets	31	-
Decrease in accounts payable and other liabilities	455	-
Decrease in accrued salaries and benefits	-	588
	3,940	5,222
INCREASE/(DECREASE) IN FUNDS	1,708	1,643
CASH, BEGINNING OF YEAR	6,936	5,293
CASH, END OF YEAR	8,644	6,936

DONORS 1990

Expressed in US$ thousands

Donors	Core funding	Special project funding
African Development Bank	350	-
Australia	119	-
Austria	90	500
Belgium	548	544
Canada	1,698	145
China	10	-
Commission of the European Communities in Nigeria	91	738
Denmark	151	77
Finland	251	-
Food Industry Crusade Against Hunger	-	25
Ford Foundation	100	98
France	295	-
Gatsby Charitable Foundation	-	203
Germany	1,420	53
India	24	-
International Development Research Centre	-	734
International Fund for Agricultural Development	-	923
Italy	632	808
Japan	2,963	-
Netherlands	761	596
Nigeria	57	6
Norway	731	-
Rockefeller Foundation	531	-
Sweden	327	-
Switzerland	792	224
United Kingdom	823	-
United Nations Development Programme	206	-
United Nations University	-	2
United States Agency for International Development	5,485	6.615
University of Hohenheim	-	175
World Bank	4,073	13
Other contributions	-	319
Closed and miscellaneous projects	-	7
Total	**22,528**	**12,805**

Professional staff

Management and support services

Executive management

L. Brader, PhD, director general
L. D. Stifel, PhD, director general *
S. A. Adetunji, PhD, special assistant to director general
J. Cramer, BA, executive assistant to director general
J. H. Davies, BSc, director, office of the director general
J. P. Eckebil, PhD, deputy director general, international cooperation
K. S. Fischer, PhD, deputy director general, research
F. C. McDonald, MS, assistant to deputy director general, research
W. P. Powell, BSc, deputy director general, management

Administrative and auxiliary services

C. A. Enahoro, manager, Ikeja guest house
C. Inniss-Palmer, specialist english teacher
A. Jackson, deputy head, international school of IITA
N. Jackson, head, international school of IITA
A. R. Middleton, BSc, manager, international house
R. I. Olorode, security manager
D. J. Sewell, manager, aircraft operations
O. Sholola, ACA, audit senior

Budget and finance

D. A. Governey, FCA, director, budget and finance
B. A. Adeola, FCIS, accountant
O. E. Adepoju, ACA, senior analyst, accounting procedures
A. A. Akinbola, BSc, senior technical analyst
C. A. Babalola, ACA, senior analyst, accounting procedures
R. O. Balogun, FCCA, finance manager
J. E. Bolarinwa, MBA, payroll accountant
P. O. Etuk, MBA, budget and planning coordinator
E. D. Greene, MSc, materials manager *
G. R. McIntosh, CMA, procedures manager, financial information systems
R. Obikudu, MBA, materials manager
S. J. Udoh, AMNIM, chief accountant
D. Wheeler, CPA, project manager, financial information systems *

Computer services

L. J. McDonald, LLB, computer manager
N. N. Eguzozie, BSc, computer programmer
T. D. Oluyemi, MSc, computer programmer

Human resources

J. Thackway, MA, director, human resources
T. A. Akintewe, MD, senior medical officer
J. O. Badaki, MBA, employee relations manager
J. B. Elegbe, MSc, manpower development manager
F. O. A. Osinubebi-Cole, MD, medical officer

Information services

S. M. A. Lawani, PhD, director
Y. A. Adedigba, MA, head, library services
A. O. Adekunle, MSc, editor
R. O. Adeniran, MLS, principal librarian
K. Atkinson, MSc, editor and head, publications
A. A. Azubuike, MLS, principal librarian
T. Babaleye, MCA, public information manager
E. Nwulu, MSc, audiovisual specialist
B. O. Ojurongbe, BSc, production manager
T. T. Owoeye, MLS, editor
J. O. Oyekan, BSc, head, public affairs *
D. R. Mohan Raj, PhD, senior science writer and editor
F. N. Ubogu, MLS, principal librarian
R. Umelo, BA, editor

Physical plant services

J. G. H. Craig, director
E. O. Akintokun, research vehicle services officer
A. K. Bhatnagar, assistant director
A. C. Butler, building and site services officer
P. G. Gualinetti, construction site engineering services officer
E. Ojinere, heavy equipment/fabrication services engineer *
A. Oyedeji, electrical services engineer
S. W. Quader, electronic services officer

** Left during the year (1 April 1990 – 31 March 1991)*

Research and support services

Biological control program

H. R. Herren, PhD, director

D. T. Akibo-Betts, East/Southern Africa regional coordinator *

J. B. Akinwumi, MSc, engineer

W. N. O. Hammond, PhD, entomologist, West/Central Africa regional coordinator

T. M. Haug, MSc, mass rearing specialist

B. Mégevand, MSc, mite and mass rearing specialist

P. Neuenschwander, PhD, entomologist

F. Schulthess, PhD, bioecologist

A. Wodageneh, PhD, training officer, FAO

J. S. Yaninek, PhD, entomologist

Associate experts

C. Boavida, MSc, ecologist

H. M. Dreyer, MSc, ecologist

C. Gold, PhD, associate scientist

M. Tamo, MSc, ecologist

Postdoctoral fellows

A. Paraiso, PhD, pathologist

T. G. Shanower, PhD, entomologist

Grain legume improvement program

S. R. Singh, PhD, director *

K. F. Cardwell, PhD, plant pathologist

P. Q. Craufurd, PhD, crop physiologist, Kano station

K. E. Dashiell, PhD, breeder

D. A. Florini, PhD, plant pathologist

L. E. N. Jackai, PhD, entomologist

O. Nakayama, PhD, JICA expert (soybean postharvest scientist)

B. R. Ntare, PhD, breeder and liaison scientist to CRISAT, Niger *

G. O. Myers, PhD, breeder

H. O. Ogundipe, MSc, food technologist

B. B. Singh, PhD, breeder and officer-in-charge, Kano station

I. Watanabe, PhD, plant physiologist, Kano station

Postdoctoral fellow

C. N. Akem, PhD, pathologist/breeder

Maize research program

M. Winslow PhDdirector

N. A. Bosque-Perez, PhD, entomologist

S. K. Kim, PhD, breeder

J. G. Kling, PhD, breeder

J. H. Mareck, PhD, breeder

Postdoctoral fellows

A. E. Awad, PhD, striga biologist

T. Mesfin, PhD, vector entomologist

O. M. Olanya, PhD, plant pathologist

Visiting scientists

L. Everett, PhD, maize breeder

S. N. C. Okonkwo PhD, striga biologist

Resource and crop management program

D. S. C. Spencer, PhD, director

I. O. Akobundu, PhD, weed scientist

A. N. Atta-Krah, PhD, coordinator, AFNETA

K. Dvorak, PhD, agricultural economist

H. C. Ezumah, PhD, agronomist †

M. P. Gichuru, PhD, agronomist

A. E. Ikpi, PhD, economist *

A-M. N. Izac, PhD, agricultural economist, inland valley systems

S. S. Jagtap, PhD, agroclimatologist

B. T. Kang, PhD, soil scientist

K. Mulongoy, PhD, soil microbiologist

H. J. W. Mutsaers PhD, agronomist, humid forest systems

N. Sanginga, PhD, assistant coordinator, AFNETA

J. Smith, PhD, agricultural economist, savanna systems

M. J. Swift, PhD, leader, resource management research

B. Vanlauwe, BSc, junior expert

G. K. Weber, PhD, agronomist, savanna systems

Collaborative study of cassava in Africa

F. I. Nweke, PhD, agricultural economist, team leader

G. R. Mullins, PhD, East/Southern Africa regional coordinator *

Y. C. Prudencio, PhD, regional coordinator

Postdoctoral fellows

R. J. Carsky, PhDagronomist

G. Fairchild, PhD, soil microbiologist *

Y. Mohamoud, PhD, agronomist

R. A. Polson, PhD, agricultural economist

E. Tucker, PhD, weed scientist

Visiting scientists

S. Hauser, PhD, agronomist

R. Markham, PhD, entomologist *

Associate experts

J. Foppes, Ir, agricultural economist, Onne station *

M. C. Van der Meersch, Ir, microbiologist *

Rice research program

K. Alluri, PhD, coordinator, INGER-Africa/IRRI liaison scientist

T. M. Masajo, PhD, program leader and breeder *

Postdoctoral fellow

† *On sabbatical* * *Left during the year (1 April 1990 – 31 March 1991)*

R. C. Joshi, PhD, entomologist

Root, tuber, and plantain improvement program

S. K. Hahn, PhD, director

R. Asiedu, PhD, plant breeder

F. Gauhl, PhD, plant pathologist

S. Y. C. Ng, MSc, tissue culture specialist

D. S. O. Osiru, PhD, plant physiologist *

C. Pasberg-Gauhl, PhD, plant pathologist

M. C. M. Porto, PhD, CIAT-IITA physiologist/breeder

G. D. Sery, PhD, West/Central Africa regional coordinator, INIBAP, Onne station *

R. L. A. Swennen, PhD, agronomist/breeder and officer-in-charge, Onne station *

D. R. Vuylsteke, Ir, tissue culture scientist

Postdoctoral fellows

M. Bokanga, PhD, biochemist

A. G. O. Dixon, PhD, breeder

G. Eggleston, PhD, food technologist/biochemist

R. Terauchi, PhD, yam geneticist *

Visiting scientists

K. V. Bai, PhD, cytogeneticist *

T. Ikotun, PhD, pathologist *

H. Kanno, PhD, entomologist, JICA *

Postharvest unit

L. S. Halos, MSc, research specialist

Y. W. Jeon, PhD, postharvest technologist

Analytical services laboratory

J. L. Pleysier, PhD, laboratory services supervisor

Biometrics

P. Walker, MA, biometrician

Biotechnology research unit

G. Thottappilly, PhD, virologist

Genetic resources unit

N. Q. Ng, PhD, head, genetic resources unit

S. Padulosi, Dott, plant explorer

Research farms unit

P. D. Austin, BSc, research farms development officer

D. C. Couper, MSc, head, research farms unit

P. V. Hartley, BSc, research farms engineer

Virology unit

H. W. Rossel, Ir, virologist

International cooperation

Support services

S. Auerhan, interpreter/translator *

B. Auvarc, interpreter/translator

S. Bailey, interpreter/translator *

E. F. Deganus, BSc, project development coordinator

O. B. Hounvou, interpreter/translator

C. Lord, interpreter/translator

E. Molinero, head, interpretation/translation

O. M. Ogunyinka, MSc, coordinator, monitoring and evaluation

B. F. Sali, interpreter/translator

J. C. Sentz, PhD, USAID liaison scientist *

J. B. Suh, PhD, research liaison scientist

A. P. Uriyo, PhD, project development coordinator

Training program

H. Gasser, PhD, director, training

J. L. Gulley, PhD, group training coordinator

R. Zachmann, PhD, training materials specialist

Cooperative programs

CIDA/CIMMYT/IITA Ghana grains development project, Ghana

A. M. Hossain, PhD, grain legume breeder

Gatsby charitable foundation/IITA/Cameroonian national root crops improvement program (CNRCIP), Cameroon

J. B. Abaka-Whyte, PhD, breeder and project leader *

M. O. Akoroda, PhD, agronomist/breeder *

EEC/IITA/SADCC cowpea project

R. Amable, PhD, cowpea agronomist

J. D. Naik, PhD, legume breeder

IFAD/IITA Ghana smallholder rehabilitation and development program

O. O. Okoli, PhD, breeder and root crops coordinator

Semi-arid food grains research and development (SAFGRAD) project, Burkina Faso

J. M. Fajemisin, PhD, pathologist/breeder, project leader and maize network coordinator

N. Muleba, PhD, agronomist and cowpea network coordinator

USAID/IDRC/IITA East and Southern African root crops research network (ESARRN), Malawi

M. N. Alvarez, PhD, breeder and network coordinator

J. A. Otoo, PhD, agronomist

USAID/IITA/National cereals research and extension (NCRE) project, Cameroon

* *Left during the year (1 April 1990 – 31 March 1991)*

Consultants

E. A. Atayi, PhD, chief of party and agricultural economist
S. W. Almy, PhD, social economist *
D. C. Baker, PhD, agricultural economist
V. Balasubramaniam, PhD, agronomist *
N. F. Beninati, PhD, maize breeder
O. P. Dangi, PhD, breeder *
L. Everett, PhD, breeder *
M. P. Jones, PhD, breeder *
M. Kamuanga, PhD, agricultural economist
J. Kikafunda-Twine, PhD, agronomist *
D. McHugh, MSc, socioeconomist
O. A. Osiname, PhD, farming systems agronomist
J. A. Poku, PhD, extension agronomist
A. C. Roy, PhD, agronomist *
J. T. Russell, PhD, extension agronomist *
L. Singh, PhD, breeder *
T. C. Stilwell, PhD, deputy chief of party
H. Talleyrand, PhD, cereals agronomist
C. Y. Yamoah, PhD, soil scientist/agroforester

USAID/IITA Applied agricultural research (RAV) project, Zaire

F. E. Brockman, PhD, chief of party and agronomist †
M. S. Alam, PhD, entomologist *
C. D. S. Bartlett, PhD, agricultural economist *
T. Berhe, PhD, agronomist *
L. H. Camacho, PhD, breeder *
B. Chiti-Babu, farm manager *
A. D. Florini, PhD, regional outreach specialist *
K. M. Johnson, PhD, breeder *
D. Keita, outreach specialist *
G. F. Montalban, plant superintendent *
A. O. Osiname, PhD, agronomist *
M. Seye, MA, administrative officer *
D. A. Shannon, PhD, agronomist *
W. O. Vogel, PhD, agricultural economist *

IITA Benin station

J. N. A. Quaye, MA, leader, management unit and officer-in-charge
M. N. Versteeg, PhD, agronomist and leader

IITA Cameroon station (Mbalmayo)

S. L. Claassen, MSc, farm manager
P. G. Gillman, PhD, soil chemist
N. R. Hulugalle, PhD, soil physicist

Postdoctoral fellows

D. Russell, PhD, anthropologist/Rockefeller fellow
N. W. Menzies, PhD, soil chemist

F. M. O. Agbo, wild yam collection
A. Agboola, research evaluation
M. S. Alam, maize research
C. L. A. Asadu, research evaluation
P. Ay, cassava research
R. A. Boxall, grain storage research
B. Drukker, biological control
C. S. Gold, biological control
L. S. Halos, postharvest technology
V. T. John, rice pathology
J. A. Kwarteng, training materials
A. W. Moore, editing
S. Nokoe, training materials
C. Parker, striga biology
L. W. Rooney, maize research
O. Uthman, cassava research

† On sabbatical * Left during the year (1 April 1990 – 31 March 1991)

Publications by IITA staff

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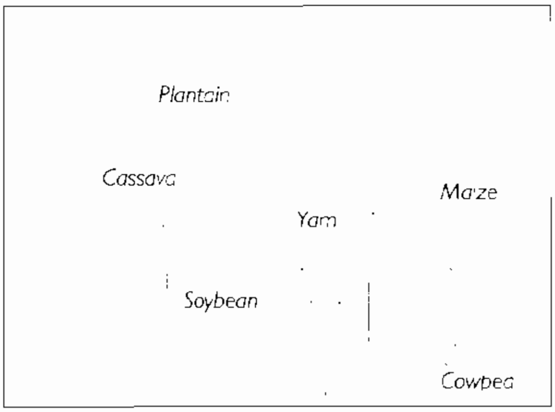

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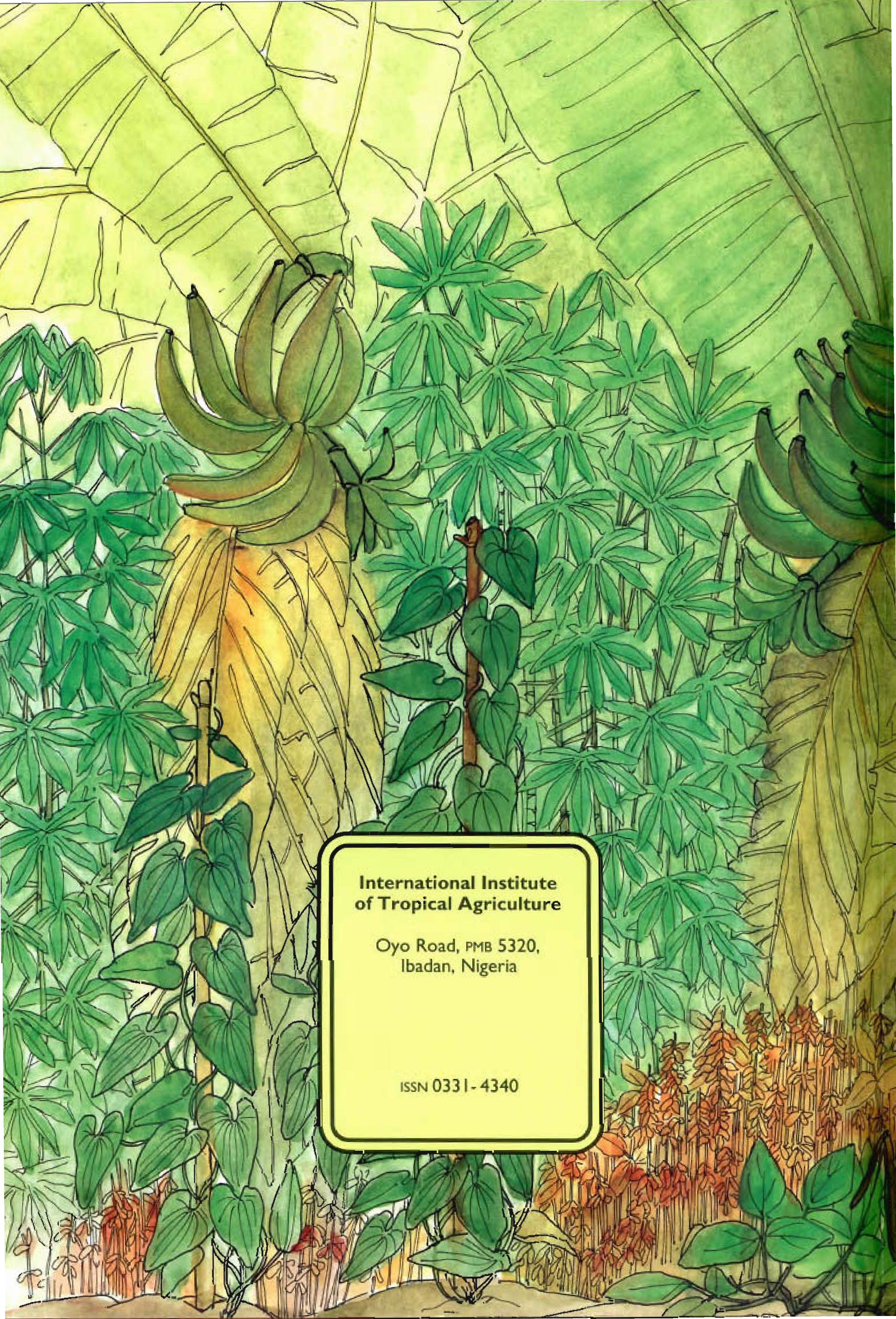

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