Annual Report 1997

International Institute of Tropical Agriculture

IITA

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

IITA is governed by an international board of trustees and is staffed by approximately 80 scientists and other professionals from over 30 countries, and approximately 1,300 support staff. A large proportion of the staff are located at the Ibadan campus, while others are at stations in other parts of Nigeria, and in Benin, Cameroon, and Uganda. Others are located at work sites in Côte d'Ivoire, Ghana, Malawi, Mozambique, Tanzania, Zambia, and Zimbabwe. Funding for IITA comes from the CGIAR and bilaterally from national and private donor agencies.

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

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

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

INTERNATIONAL INSTITUTE OF TROPICAL AGRICULTURE

ANNUAL REPORT 1997

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From the Director General


Dr. Lukas Brader

For IITA, 1997 was a year of extremes. The Institute's excellent research is benefiting more farmers in Africa, who, with improved technologies, get more income through production systems that minimize environmental impact.

At the same time, the Institute had to face potentially serious financial shortfalls: there were continuous cost increases and a reduction in unrestriced core funding. Notwithstanding these difficulties, we have decided that, for the time being, the Institute will maintain the existing broad crop portfolio and decentralized research structure. This approach is needed so that we can effectively address the research needs of our ecoregion.

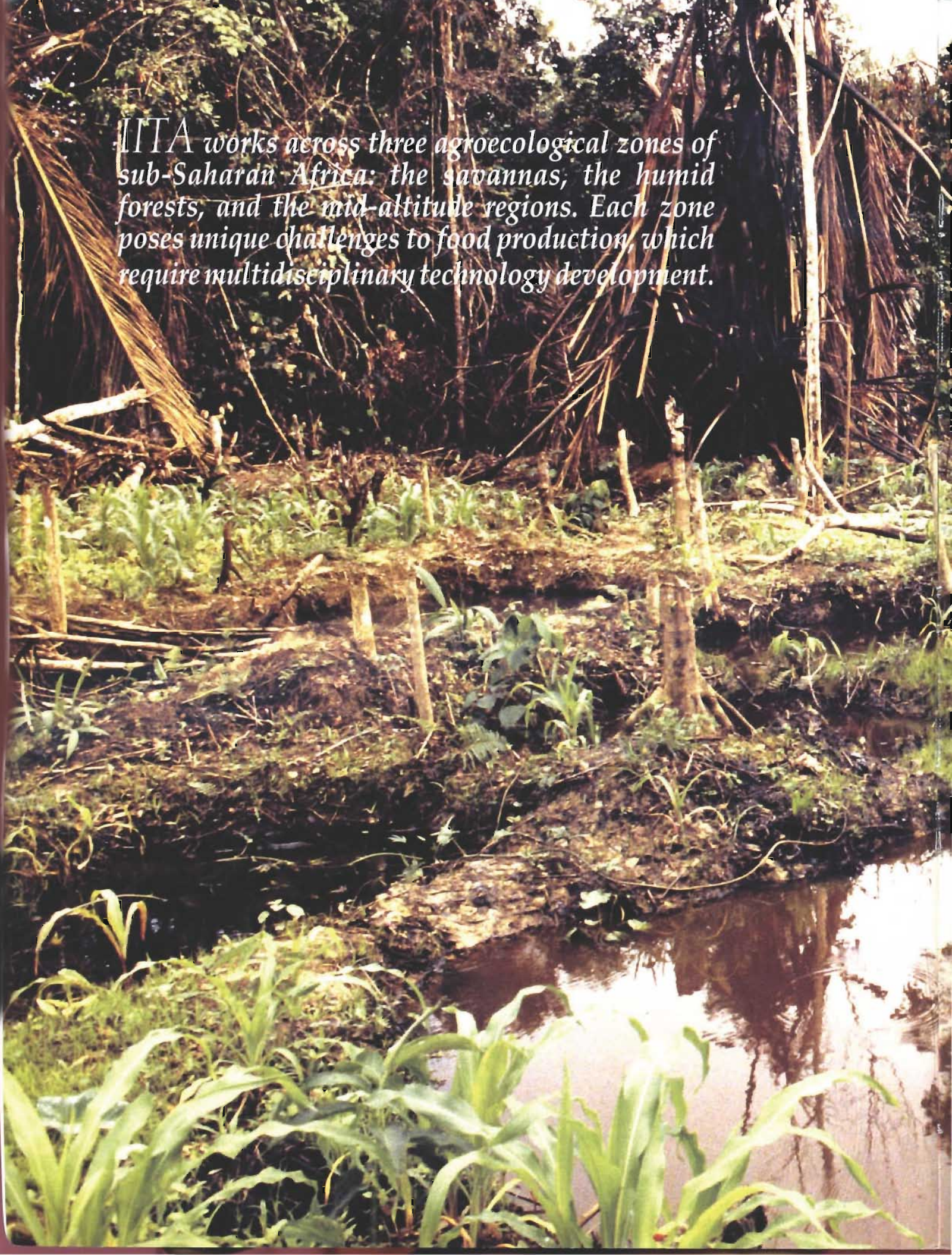
In particular, our Humid Forest Station is carrying out extensive research in the humid forest benchmark area in Cameroon. This serves both the Systemwide Alternatives to Slash-and-Burn Program and the Ecoregional Program for the Humid and Subhumid Tropics of sub-Saharan Africa (EPHTA).

The station in Namulonge, Uganda is working closely with the African Highlands Initiative, while our station in Kano, Nigeria links into the moist savanna benchmark area of EPHTA and serves also for joint IITA/ILRI/ICRISAT research activities. Support to the benchmark area in Benin is provided from our station at Cotonou.

This year was also marked by a Center Commissioned External Review (CCER) of our cereal/grain legume projects. The CCER team of five experts was complemented by a national agricultural research and extension systems team. Extensive field visits and discussions allowed for an excellent analysis of the work undertaken. The team highlighted the progress made and, particularly, the successful development of a systems approach to crop improvement, plant health, and production problems. The review noted that for the three main projects, excellent progress is being made in reaching the objectives. It also made constructive recommendations on further integration of biotechnology and plant genetic resource research.

Towards the end of the year, we had a two-day planning meeting with the Conférence des responsables de la réchérche agronomique africains (CORAF). This allowed us to streamline our respective activities and to avoid duplication. A memorandum of understanding was developed, including a strategy adopted to integrate the various research networks in West and Central Africa.

IITA existed 30 years in 1997. Given the overall financial situation, the festivities were limited to social activities for all the staff. At 30, IITA has become somewhat leaner than it was, for example, 10 years ago, but it is also more experienced and has learned to do more with less. Thus, the Institute is in good health, and I am confident that it will continue to evolve and produce excellent results in a changing environment.



IITA works across three agroecological zones of sub-Saharan Africa: the savannas, the humid forests, and the mid-altitude regions. Each zone poses unique challenges to food production, which require multidisciplinary technology development.

CID

Margaret Quin Acclaims 1997 "A Year Of Progress"

The Crop Improvement Division (CID), headed by Margaret Quin, continued its well-focused research agenda in 1997.

During the late 1980s IITA developed maize that yielded well in *Striga*-infested fields. Since 1993 the Institute has focused on reducing *Striga* emergence.

"The aim was to cause *Striga* to be less able to develop on maize. This isn't easy, but we stuck to it, and by 1997 we had really made progress. This has significantly contributed to maize's sustainability potential," Quin explained.

Adapting cassava to dry areas progressed. IITA now has cassava green mite-resistant varieties which stay green and retain a good leaf canopy during the dry season.

Adapting soybean to African soil ranked high in 1997. "There was definite progress in selection for acceptable grain and fodder yields using no phosphorus fertilizer. This built on IITA's nitrogen fixation record. Because of IITA, soybean is becoming farmer friendly, especially when considering crop rotations," Quin said.

In 1997 IITA's yam program expanded into Tanzania and Uganda, where many of the growers are women. Farmer participatory evaluation of improved yam germplasm is ongoing.

"Last but not least, cowpea transformation with candidate genes for insect resistance was achieved," she said.

"In 1994 IITA won the King Baudouin Award for producing black-sigatoka-resistant plantain hybrids, but they lacked qualities that consumers like. We now have hybrids with high yields, larger fruit, and better pulp color that resemble, more closely, preferred plantain.
It's a major advance with high potential."

Maize wild relatives get a stranglehold on *Striga*

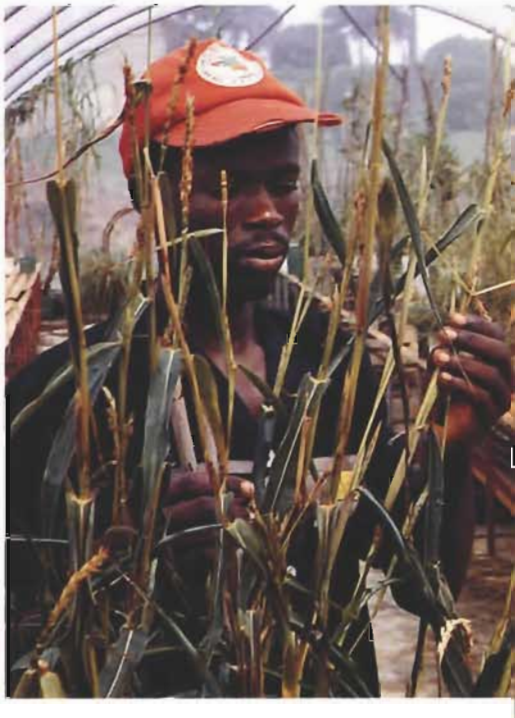
Striga *species, a flowering plant indigenous to Africa, has a terrible reputation. The Food and Agriculture Organization of the United Nations estimates that the parasite causes annual losses in excess of US$7 billion, adversely affecting over 100 million African people in West Africa alone.*

It is no wonder that *Striga* is a major threat to agriculture. One plant can produce 50,000 to 500,000 seeds, which remain viable for up to 14 years in the soil. These seeds are virtually microscopic. After germination, the seedlings can grow three to seven days in the absence of a host. If they attach to a host, such as the root of a maize plant, the parasite grows underground for up to seven weeks prior to breaking through the soil. The scenario fits a science-fiction thriller, except this is for real.

Most of the damage to the unfortunate host plant occurs underground, making it difficult for farmers to determine the actual cause of the damage. Was it a pest or a disease? Symptoms of parasitism resemble drought stress accompanied by severe plant stunting, and they can all add up to 100% yield loss.

The Striga problem in Africa is intimately associated with intensification of land use.

Resembling a battlefield, the struggle between Striga and a maize crop shows the victor: Striga



Elite tropical maize has low resistance to Striga. A maize wild relative, though, Zea diploperennis, is highly resistant. IITA scientists backcrossed the resistant genes, thus incorporating them into adapted maize genotypes

The *Striga* problem in Africa is intimately associated with intensification of land use. Traditional African cropping systems have included prolonged fallow, rotations, and intercropping, which kept infestations at tolerable levels. However, as population pressures increase and markets develop, demand for food production increases and land use intensifies.

Integrated control

Components of successful control are to prevent the influx of *S. hermonthica* seeds into fields and reduce their density in the soil, reduce parasitism, and prevent parasite reproduction. Perhaps easier said than done, one might think, but IITA has developed an integrated control strategy that starts with the use of parasite-free planting material, and then focuses on crop rotation and nitrogen-fixing legume cultivars that have been selected for efficacy in reducing the density of *Striga* seeds in the soil. In short, the legume, such as soybean, causes the microscopic seeds to abort in their development. This focus is reinforced by the use of managed biological control and high-yielding adapted maize with resistance to *Striga*.

This last element has proven difficult to achieve in the past because elite tropical maize has a low resistance to *Striga*. This caused scientists to begin looking for wild relatives of maize that were resistant to *Striga*. They found it in *Zea diploperennis*, which has high resistance to the parasite. Through a process of backcrossing, the resistant genes were incorporated into adapted maize genotypes.

Unfortunately, *Striga* resistance is a quantitatively inherited trait, involving many genes, and it is difficult to transfer this trait efficiently to locally adapted cultivars through backcrossing.

To accelerate progress in incorporating the resistance genes from *Z. diploperennis* into adapted maize, a marker-assisted selection project was developed in 1997 by IITA, the Centro Internacional de Mejoramiento de Maize y Trigo (CIMMYT), Mexico, the Kenya Agricultural Research Institute (KARI), and the University of Hohenheim. This project is funded by the Rockefeller Foundation.

Through the use of molecular markers to identify resistant backcross material at the gene level, scientists are optimistic that they are on their way to getting highly resistant, adapted maize into an integrated control program. Such a program would provide a major advance in the control of *Striga*.

Pink Striga hermonthica carpets a farmer's field. But the beauty of the flowering plant belies its devastating effects on maize, a staple in sub-Saharan Africa. The weed parasitizes maize roots, thereby injuring them, leading to extensive yield loss

IITA spurs doubling of cassava use in Nigeria

Per capita food production in Africa has been declining partly due to rapid population growth, soil degradation, periodic droughts, and a weak technological base. Despite this, Nigeria, the most populous country on the continent, produces more cassava than any country in the world.

Per capita cassava production in Nigeria has increased from 130 kg in 1980 to 260 kg in 1994. This rise has been credited to the adoption of improved, high-yielding varieties by cassava farmers. These varieties, many attributable to IITA, are mostly adapted to the humid forest and moist savanna zones of Nigeria.

IITA continues to develop germplasm with drought tolerance, good leaf retention in order to provide fodder for livestock, and low cyanide content requiring minimal processing.

But the fact remains, increase in cassava production will benefit farmers only if the demand is maintained or increased. In order for this to happen, cassava growers and product-makers must take advantage of existing markets or create new ones. Only when cassava is linked to these markets will increased production translate into increased income and better welfare for the people.

Increase in cassava production will benefit farmers only if the demand is maintained or increased.

Workers at a cassava processing plant near their farms in Ogun State, Nigeria, spread cassava 'grits' in the sun to evaporate moisture, in preparation for milling it into flour

High-quality cassava flour produced in a village, packed in 50-kg bags, is loaded for transport to a factory, where it will be made into bakery products. Because of cassava flour's long shelf life, as opposed to fresh roots (two to three days), it can be stored for up to six months

Creating new markets

IITA is addressing this by developing technologies to improve cassava processing and utilization. These technologies have made it possible to expand cassava processing in rural areas and produce products with a high market value for urban users. These technologies and processes have been introduced to women's groups, small-scale cassava farmers, and processors.

Industrial users of cassava flour are substituting between 10% and 50% cassava for wheat flour in the making of products such as biscuits and noodles. One factory has switched from the use of sugarcane molasses to cassava flour for the production of ethanol. This reduces production costs.

Home caterers use cassava flour to make confectioneries such as cakes and doughnuts. Some home caterers use up to 100% cassava flour for making traditional baked products.

Between October 1995 and September 1996, three biscuit and one noodle manufacturer surveyed used an average of 60 metric tons of cassava flour and 612 metric tons of wheat flour monthly. The cassava flour cost is half that of wheat flour, which is often imported, expending foreign exchange.

IITA has determined the functionality of cassava flour and starch across a range of cassava varieties. One practical outcome of this research is that a number of recipes have been developed by IITA to demonstrate the flexibility of cassava flour in baking. These recipes are starting points for caterers and home bakers to develop products of their own.

Still, there are problems in the cassava flour production business. An IITA survey in several Nigerian states showed the top five problems to be the high cost of cassava, the lack of capital, drying in the rainy season, shortage of labor, and an inadequate supply of fresh roots.

The trend, though, is toward more use. IITA continues to develop the cultivars and technologies needed to make cassava production and processing vital parts of the economies of Nigeria and other countries in sub-Saharan Africa.

Optimizing crop rotation sustains productivity in moist savanna

The moist savannas of West and Central Africa have high potential for crop and livestock production. The region may be the emerging breadbasket of sub-Saharan Africa.

Savanna soils are generally low in organic matter and nitrogen; therefore nitrogen deficiencies in maize are common. Genotypes with improved nitrogen-use efficiency can increase productivity of maize-based cropping systems when they are combined with improved soil fertility, crop rotation, organic manure, and inorganic fertilizers.

IITA scientists had to develop low nitrogen-tolerant maize that performed at least as well as or better than available varieties when grown under higher level of nitrogen.

Selected families (34) from the low N-tolerant pool, grown with no nitrogen inputs, had a mean grain yield of 3.2 t/ha, compared with 2.4 t/ha for the commercial hybrid.

If the aim is to reduce dependence on fertilizer, the use of soybean in management systems shows potential.

The role of soybean

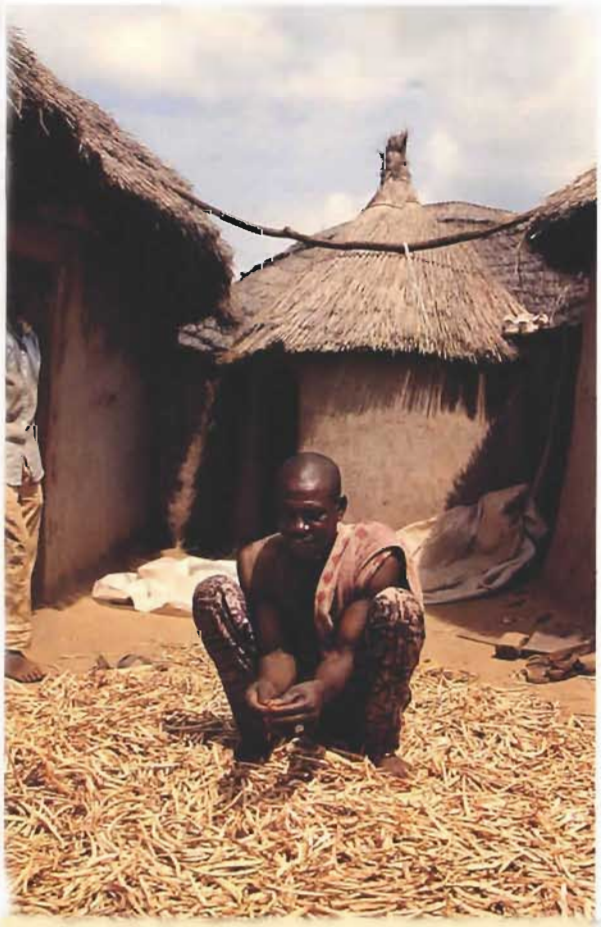
Improved soybean varieties can also increase the productivity and sustainability of maize-grain legume cropping systems because grain legumes can reduce reliance of maize on nitrogen fertilizer.

The new traits developed maximize nitrogen derived from the atmosphere (Ndfa) and optimize fodder production. By combining the traits, soybean varieties were developed that have a high and stable grain yield, which maximize nitrogen and organic matter contribution to the soil and benefit the subsequent crop.

The other new trait increases *Striga hermonthica* germination, reducing the parasite's seed bank for the next maize crop.

Trials compared the performance of the six best soybean breeding lines with that of a check variety. Tgx 1829-1E had a Ndfa of 52.5 compared to the check variety's 36. Variety Tgx 1892-1E gave vastly improved yields over the check variety: 1809 kg/ha vs. 1193 kg/ha for grain, and 2312 kg/ha vs. 1750 kg/ha for fodder.

The improvement in both grain and fodder yield indicates that this new variety will give more soybean grain yield (thus quick income and greater nutrition) and show more return of organic matter and nitrogen to the soil through fodder.



The sun provides energy for plant growth, and it is also used after harvest to evaporate moisture from cowpea pods, allowing them to be stored

The bottom line

Statistics show that different soybean residue management techniques and varieties can improve subsequent maize grain yield, although they are not as effective as small amounts of nitrogen fertilizer. For example, with no fertilizer, a maize crop following previous maize yielded 686 kg/ha; maize crops planted after five different soybean varieties yielded 1174, 1328, 1330, 1232, and 1381 kg/ha, and maize crops with 20, 40, and 60 kg/ha added nitrogen yielded 1937, 2070, and 2203 kg/ha, respectively.

Maize grown after soybean had significantly higher shoot dry weight and grain yield than that growing in former maize plots. This depended on the soybean cultivars.

Compared to maize, maize grain-yield increase following soybean was variable, but the main effect of previous soybean crops was positive, even though the soybean was not inoculated and the above-ground soybean residues, except harvest litter, were removed from the fields.

As is common in sub-Saharan Africa, animal traction provides motive power in agriculture. In Kaduna, Nigeria, a farmer uses cattle in plowing to control weeds in his soybean field (above). Soybean seeds are separated from pods by threshing. Soybean and soymilk are rapidly becoming major food staples as well as industrial commodities in West Africa largely as a result of IITA soybean varieties (below)

In trials conducted in farmers' fields, the yield increase following the medium-duration soybean variety was similar to that from 40 kg of nitrogen per ha as urea applied four weeks after planting to maize preceded by maize. Thus, if the aim is to reduce dependence on fertilizer, the use of soybean in management systems shows potential.

Cowpea is another source of soil nitrogen. There are substantial increases in maize yield if it is grown immediately after cowpea, as the nutrients in cowpea roots, litter, and vines become available during the subsequent season.

The benefits of double cropping cowpea with early maize accumulate over time, but soil phosphorus must be adequate for the legume to have an effect.

Landraces winning the race against cassava mosaic disease

The most widespread and economically damaging crop disease in Africa is cassava mosaic disease (CMD). The virus causing this disease is spread by the whitefly. It costs the continent an estimated US$2 billion a year in crop losses. IITA is responding.

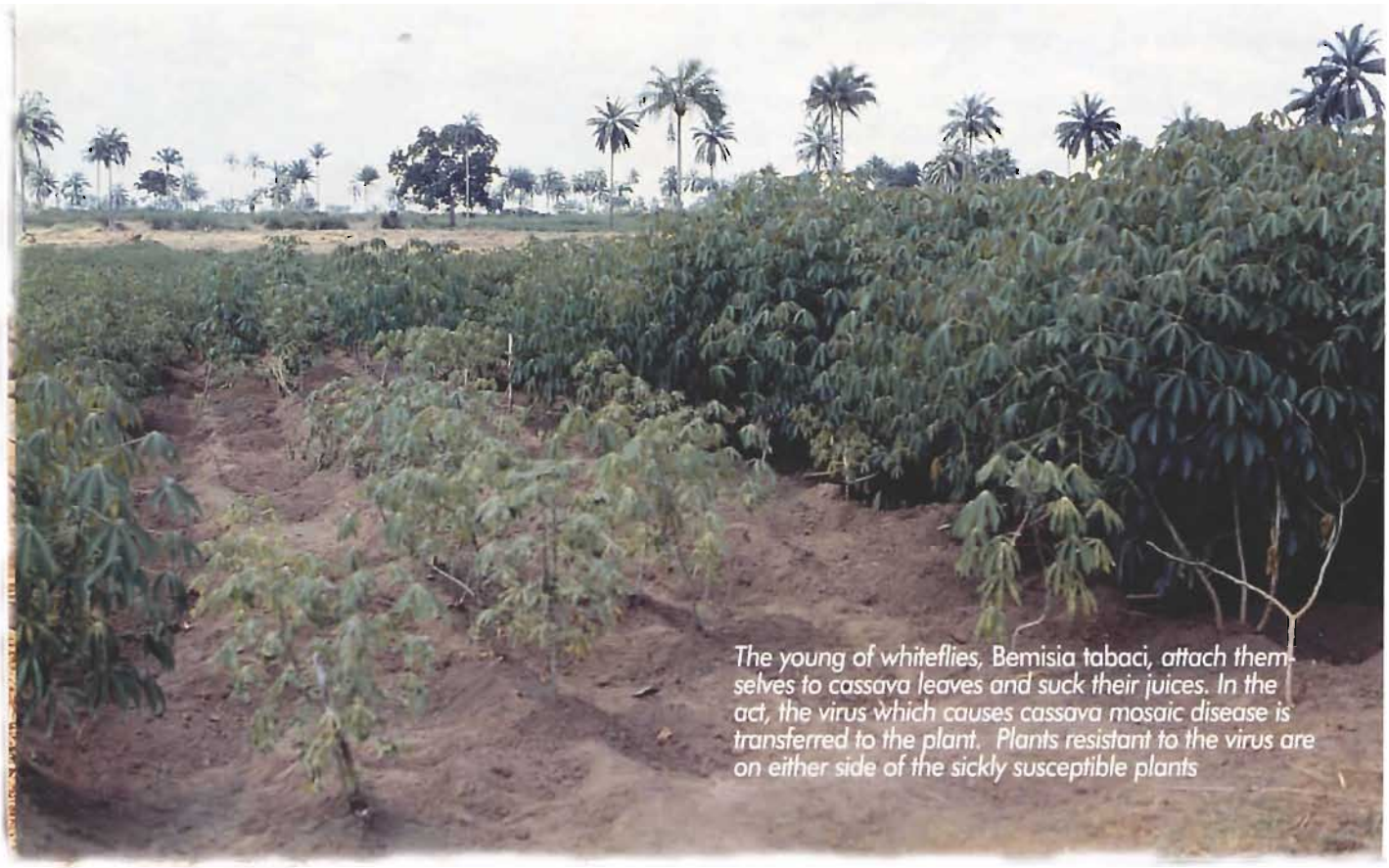
Viruses are insidious. In order to infect either plants or people, they have to reproduce themselves, which they can't do on their own. Molecularly speaking, they have figured out how to replicate themselves, thereby causing chaos in cells that are not resistant to them.

Viruses commandeer a host's DNA, which is the molecular basis of heredity of both people and plants, and use the DNA's reproductive capacity to produce an assortment of systemic diseases.

IITA helps its partners

Today, thanks to more than a quarter century of research by IITA scientists, farmers throughout Africa are planting new cassava varieties with

Sustainable multiplication and distribution of certified cassava planting material from improved genotypes is fundamental to the acceleration of impact at the farm level.



The young of whiteflies, Bemisia tabaci, attach themselves to cassava leaves and suck their juices. In the act, the virus which causes cassava mosaic disease is transferred to the plant. Plants resistant to the virus are on either side of the sickly susceptible plants

better resistance to highly destructive viruses. Over the years, this was accomplished by deploying a source of resistance that was derived from an interspecific cross between cassava and a wild relative.

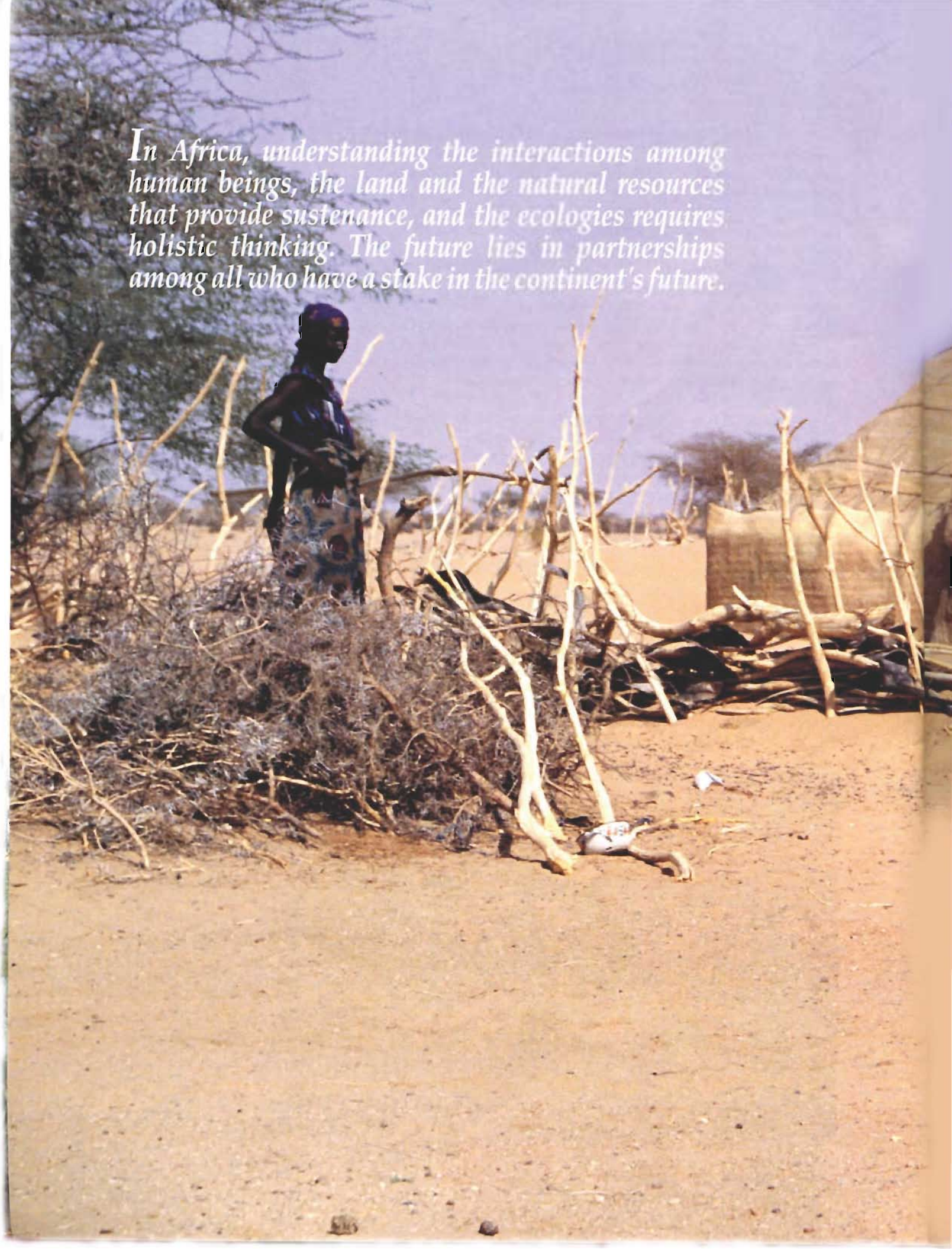
More recently, African cassava landraces have also contributed new genes for resistance to the disease. For the past seven years, IITA scientists and national program partners from Benin, Ghana, Nigeria, and Togo have collected resistant landraces in West Africa to further diversify and expand the gene pool of African-adapted germplasm. These were incorporated into IITA's breeding populations, which produced offspring with heightened resistance to CMD and some other diseases. In addition, several CMD-resistant landraces were also resistant to the cassava green mite.

Cassava farmers in Africa, using these improved materials, could obtain yields up to five times those of many local susceptible cultivars when diseases are severe. However, sustainable multiplication and distribution of certified cassava planting material from improved genotypes is fundamental to the acceleration of impact at the farm level.

To facilitate this, IITA is distributing improved genotypes to national partners for testing under local conditions. In addition, the Institute has engaged in a project with Centro Internacional de Agricultura Tropical (CIAT), Colombia, to map the genes conferring CMD resistance, and to develop molecular markers for the trait.

The outcome will assist the incorporation and enhancement of resistance to the disease in African, Central and South American, and Asian cassava gene pools. It will also provide a means, through indirect selection, for developing CMD-resistant germplasm, adapted to Latin America and Asia, which could be deployed should the virus and vector come together on these continents.

A young woman, clutching freshly harvested cassava leaves, with ease and grace balances a yam on her head. Cassava leaves contain protein, vitamins, and minerals (above). Making gari, done almost exclusively by women in Nigeria, involves peeling and grating storage roots, then fermenting the mash, pressing to remove liquid, sieving, and then frying (below)



In Africa, understanding the interactions among human beings, the land and the natural resources that provide sustenance, and the ecologies requires holistic thinking. The future lies in partnerships among all who have a stake in the continent's future.

RCMD

Common Goals Drive RCMD's Research Agenda

The Resource and Crop Management Division, headed by Horst Grimme, has four projects under its research umbrella: Short Fallow Stabilization, Agroecosystem Development Strategies, Improving Postharvest Systems, and Farming Systems Diversification.

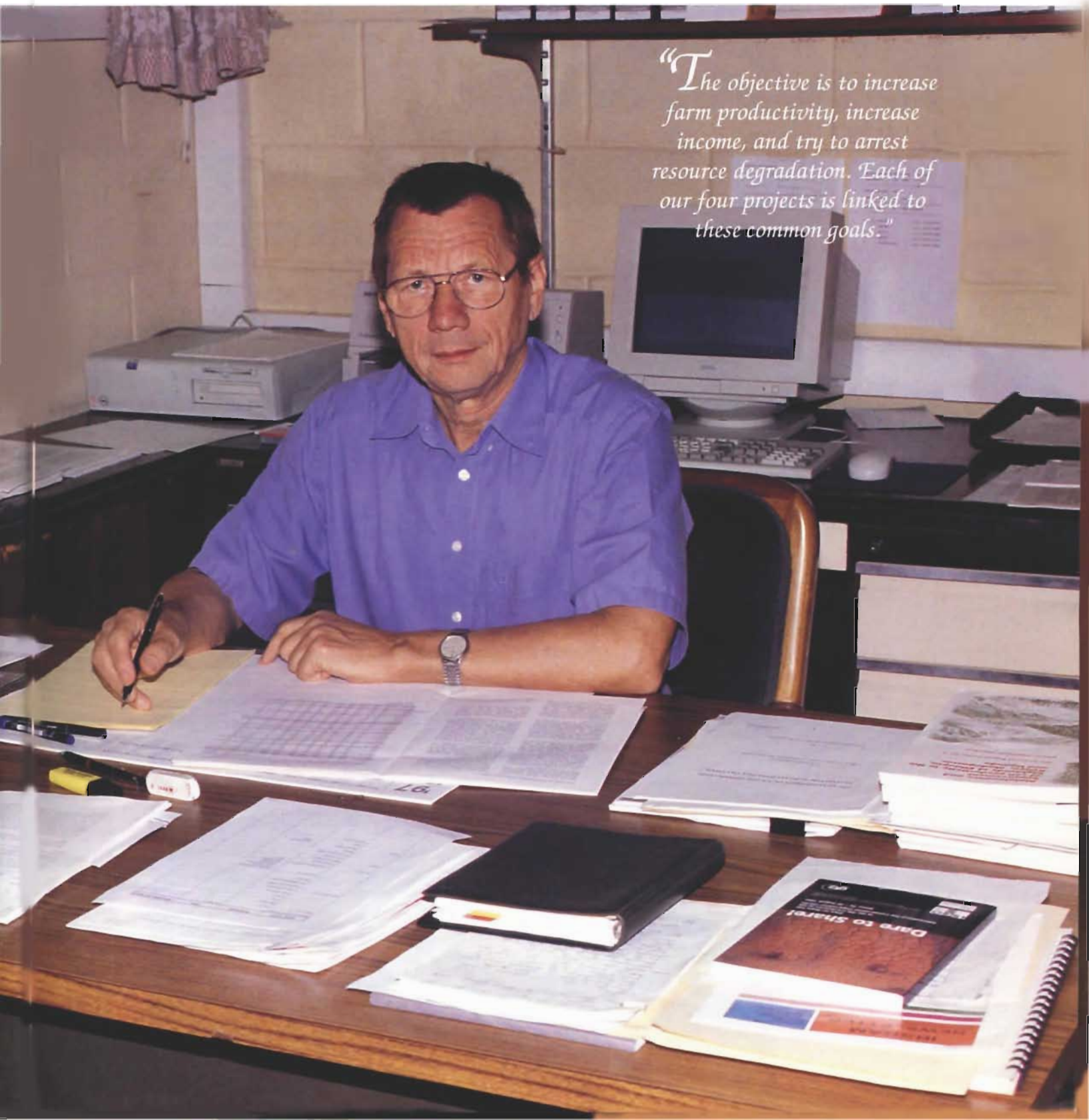
The Short Fallow Stabilization project's humid forest component is concentrated in areas where population growth and intensified land use have forced farmers to reduce fallow periods.

"Soil fertility must be regenerated. But any fallow technology to regenerate fertility has to be well adapted and acceptable to farmers. Growing herbaceous legumes shows a lot of promise in this regard," Grimme explained.

The Agroecosystem Development Strategies project works closely with EPHTA, the Ecoregional Program for the Humid and Subhumid Tropics of sub-Saharan Africa. Like EPHTA, it assists farmers to increase productivity and food security through sustainable production technologies.

"Our postharvest work also increases food security by enhancing crop handling, product development, and reducing loss. Some 60 postharvest devices have been engineered by the unit," Grimme added.

Farmers are much the focus of the Resource and Crop Management Division. "Our projects are aimed at increasing smallholder productivity and cash income. To get farmer acceptance, though, the farmer has to be involved from the beginning," he said.



"The objective is to increase farm productivity, increase income, and try to arrest resource degradation. Each of our four projects is linked to these common goals."

Intercropped cowpea and millet struggle to survive in nutrient-depleted soil, reflecting the breakdown of nature's self-sustaining system. This is compounded by drought and diseases

Restoring nutrients to sub-Saharan soils

Land-use intensification can be sustained only if the nutrients depleted during cultivation are replenished.

Population growth and the rising aspirations for the well-being of rural populations lead to clearance of large areas of forest, an extension of the cropping phase, a shortening of the fallow period, and subsequent soil fertility decline. This nutrient mining results in the breakdown of nature's self-sustaining system. Beside nutrient mining, topsoil removal, due to water and wind erosion, is one of the greatest threats to sustainable agricultural production in sub-Saharan Africa.

IITA scientists are applying biological processes to restore soil fertility and protect the soil by adapting germplasm to adverse soil conditions, enhancing soil biological activity, and optimizing nutrient cycling to minimize external inputs and maximize efficiency of their use.

In this paradigm, soil organic matter (SOM) plays a substantial role in maintaining soil fertility by providing nutrients through decomposition, retaining moisture, helping maintain soil structure, buffering available nutrients, and binding toxic substances. Crop residues play an important role in maintaining soil fertility because they provide nutrients through decomposition.

However, soil organic inputs alone cannot sustain agricultural production. Sustainable crop production in the majority of soils in West Africa requires the continuous addition of organic materials, minimal soil disturbance, judicious fertilizer and lime use, multiple cropping that includes perennial crops, fallowing, and rotation of crops.

The bottom line is to maintain improved soil nutrient balance by promoting utilization of locally available sources of plant nutrients.

Nutrient management systems

Related to the use of soil organic matter to restore fertility is another factor which balances nutrients.

Population growth in Africa has precipitated the clearance of great areas that were formerly forest and balanced ecosystems. The challenge is to preserve this land against nutrient depletion and to make it productive for food crops and raising livestock

Called balanced nutrient management systems (BNMS), it has proven potential to raise cereal yields in sub-Saharan Africa five times. At present, yields are on average less than one tonne per ha, about one-fifth what could be obtained with good plant nutrient management.

With the prevailing farming systems, though, this average yield is bound to drop to even lower levels because of the irreversible mining effect of plant nutrients from the stressed soils. This critical, vicious cycle can no longer continue. That's why IITA has launched an integrated approach to overcome the food supply shortfall in West Africa. The research is funded by the Belgian government.

The BNMS for maize-based systems in the moist and humid forest of West Africa builds on the achievements of previous SOM projects. However, it looks at the problem from a much wider angle, encompassing all major nutrients. Inorganic inputs may be appropriate. The farmer's perspective is considered, too.

The goal is to curb the various cycles of plant nutrient depletion in maize-based farming through integrated nutrient management geared to land-use practices which are economically viable, ecologically sound, and socially acceptable. The bottom line is to maintain improved soil nutrient balance by promoting utilization of locally available sources of plant nutrients, maximizing their nutrient-use efficiency and thus reducing the need for external, costly soluble fertilizers.

A research project to test this concept will increase production and quality of farm products, diversify land use, increase farm incomes, generate employment, and protect land resources and the natural environment.

Crop residues can help restore soil fertility and protect soil. The loss of soil nutrients and erosion are great threats to sustainable agricultural production in sub-Saharan Africa

Alley farming's future brightens

IITA has developed and is promoting alley farming as a production alternative to slash-and-burn shifting cultivation.

The system involves the cultivation of food crops between hedgerows (alleys) of multipurpose trees or shrubs, usually legumes. The legumes have deep roots that help in fixing nitrogen and nutrient cycling; their nitrogen-rich leaves can also be used as green manure and as fodder for livestock. By reducing the amount of land needed to be cleared for farming, alley farming saves natural vegetation.

With these acknowledged advantages, much enthusiasm was generated about the technology. However, the lack of immediate success, measured in terms of widespread farmers' adoption, led to skepticism about its relevance and adoptability. To assess the adoption of the technology and farmers' current management practices, IITA conducted surveys in Benin, Cameroon, and Nigeria, some 10 years after the introduction of this new technology.

Evidence from the studies shows that earlier skepticism about the adoption potential of the technology appears unjustified. Farmers are adopting the technology in villages characterized by (a) high land-use pressure, (b) soil fertility decline, (c) erosion problems, and (d) firewood and fodder scarcity. Farm-level adoption patterns vary across the three case-study countries.

Solving the constraints to alley farming technology requires that researchers focus on technology modifications that will make the technology more flexible and adaptable to farmers' preferences.

In Nigeria, of the 223 farmers surveyed, 208 (93%) had heard about the technology, of which 66% had either initially adopted or experimented with it. Some of the initial adopters abandoned it, but 53% of these farmers continue to use it.

In Cameroon, of the 820 farmers surveyed, 256 (31%) had either initially experimented or adopted the technology. Of this group, 238 farmers (93%) continue to use it.

In Benin, of the 288 farmers surveyed, 225 (78%) had heard about the technology. Of the latter, only 72 farmers (32%) had either experimented or initially adopted it. Current level of use among this group is encouraging, as 93% continue to use the technology.

A farmer uses his machete to cut hedgerow legumes for use as green manure. The prunings, when strewn on the soil, also reduce runoff and erosion

In Africa, trees are being used more and more for staking material, firewood, and fodder. Here an enterprising farmer aloft gives his livestock assistance by cutting off branches (left). Cowpea, bountifully growing between a nitrogen-fixing herbaceous legume, is tended by a farmer. Alley farming is seen by more farmers in Africa as an alternative to slash-and-burn cultivation (above). Alley farming is an integated system that sustains fertility of farmlands by imitating the self-renewing natural process of the forest. It also reduces the amount of land needed to be cleared for farming, thus conserving natural vegetation (below)

As farmers look for a better match of the technology with their resources and preferences, they have made important modifications to alley farming. The most significant is the use of fallow phases. For example, in Nigeria, of the sample farmers currently using the technology, 93% had made changes to the technology, of which 83% added a fallow phase.

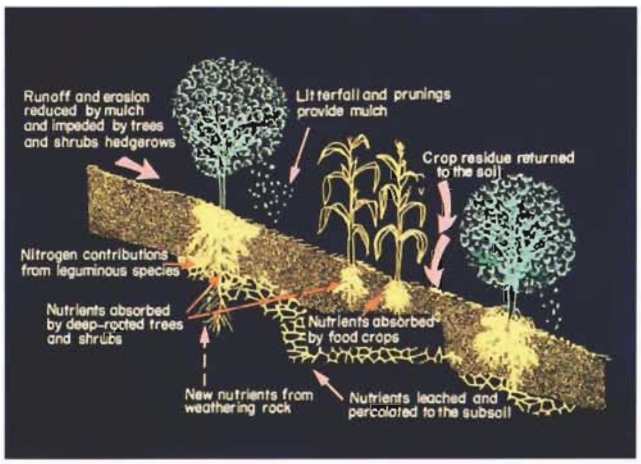
Reasons for not adopting the technology now are traceable mainly to technology-related constraints. These include high labor demands, tree-crop competition, lack of knowledge about management, and hard-to-get leguminous trees and shrubs.

Land tenure, often believed to constrain adoption, wasn't a major problem in the three countries and appears to be overemphasized. It is thus highly unlikely that changes in land tenure to increase rights under private ownership of land will significantly change current adoption rates.

Also, if alley farming is not being adopted by some farmers, it is not due to lack of secure property rights alone. Farmers can be encouraged to take advantage of alley farming. If alley farming or other agroforestry technologies provide significant income, farmers, as rational people, will reallocate land under their ownership to take advantage of the economic benefits. But they must be convinced of the benefits.

Solving the constraints to alley farming technology requires that researchers focus on technology modifications that will make the technology more flexible and adaptable to farmers' preferences.

As researchers recognize and integrate these farmer modifications in future technology designs, adoption should increase. Such modified systems would need to be targeted to areas where incentives for land-use changes, i.e., land-use pressure, soil fertility decline, erosion, and fuelwood scarcity exist or are likely to occur in the near future.



IITA and ILRI: collaborating for future generations

IITA is collaborating with the International Livestock Research Institute (ILRI), Ethiopia, to develop ways in which crop-livestock systems can function synergistically, without damaging the environment.

This joint-center effort has arisen because of increasing demands for crop and livestock products in sub-Saharan Africa. Human population there will top one billion within 20 years. Feeding so many will place great demands on agriculture.

Unfortunately, growing more crops, which requires more land, results in less fallow land. This uncropped land, though, allows the soil to recover its fertility and is commonly grazed by livestock. Such livestock vs. crop competition has the potential to severely degrade the natural resource base, which could be disastrous.

Cattle grazing natural pastures supplemented with legumes gained up to 140 g a day during the dry season.

ILRI and IITA scientists believe they have found a partial solution to this situation: herbaceous legumes. The use of legumes is not new, of course. What is new is their multiple use, amidst changing conditions, in maintaining soil fertility, controlling weeds, pests, and erosion, and in providing feed for livestock.

For example, it's been found that species of *Stylosanthes*, *Centrosema*, and *Aeschynomene* can produce substantial quantities of nutritious fodder for livestock. This is especially so during the dry season, when the naturally available feed resources are of very

Crop-livestock farmers feed their small ruminants on Stylosanthes guianensis, a nutritious herbaceous legume that improves soil fertility and boosts cereal crop yields. It is used in many areas of the tropical world for fodder

Cowpea fodder is transported for storage. It will be ready for use during the dry season

poor quality. At the same time, these legumes also enrich the soil to benefit future crops, and some species can contribute to weed control or *Striga* reduction.

Legume options

In sub-Saharan Africa, appropriately managed forage legume pastures, as demonstrated in on-station trials, can support up to eight times as many cattle as native pasture and can more than double subsequent crop yields. Trials have shown that, with maize, crop yields following forage legumes were equivalent to those obtained by applying 90 kg of nitrogen fertilizer per hectare to natural fallow plots.

Also, cattle grazing natural pastures supplemented with legumes gained up to 140 g a day during the dry season. Those grazing only natural pasture lost 58 g a day. Such differences in weight gain, which can amount to as much as 30 kg in one dry season, have important, positive implications for the survival and productivity of the animals.

The researchers believe that by testing a number of herbaceous legume species, they can present options to farmers, so that they can choose what suits them best; for example, options for crop yield, weed control, *Striga* reduction, or livestock nutrition, etc.

Another major aspect of sustainable crop-livestock integration on which scientists from the two institutes are collaborating is concerned with the quantity and quality of residues from crops such as cowpea, maize, soybean, and cassava, which can be produced without detracting from grain or tuber yield.

After grain harvest, the remainder of crops (such as leaves, pods, and stems) can be used as a source of feed for livestock. Cowpea residue is already recognized by many farmers as a valuable feed; scientists from both institutes have identified dual-purpose varieties, thereby providing the maximum returns for farmers' investments.

Biotechnology is being considered as a tool to further enhance breeding and selection to improve crop residue quality.

These options provide opportunities to improve natural resource management through integrated crop-livestock systems. For example, animal manure contributes to soil fertility, an important attribute in view of increasing shortages of inorganic fertilizers.

Crop and livestock integration will impact on the welfare of future generations and the preservation of the environment. IITA and ILRI are pioneering ways to ensure that such integration has a positive role in sustainable agriculture.

Pueraria cover crop was simultaneously established with cassava, intercropped with maize (photo taken six months after sowing)

Simultaneous cropping with *Pueraria*

After experimenting with many legume cover crop species for soil fertility improvement, IITA soil scientists have developed a soil fertility improvement technology without fertilizing: simultaneous cropping with Pueraria phaseoloides.

Pueraria as a herbaceous legume cover crop improves the fertility of the soil through nitrogen fixation as well as nutrient cycling from the subsoil and stimulation of activity of soil biota.

Over the years, IITA has increased productivity and enhanced sustainability of agroecosystems, partially through research on land and soil management. From the results of two decades of research on tropical soils and the ecological and social setting in which farmers cultivate their crops, IITA soil scientists have concluded that the essential principle in preventing or retarding soil degradation is to integrate appropriate fallow vegetation, such as leguminous cover crops, with food crops.

Pueraria seeds are planted at the same time as the maize/cassava intercrop. Later the *Pueraria* is cut down to a quarter of a meter in height. The second year involves an entire fallow of *Pueraria* regrowth. Before the next cropping season it is suggested that *Pueraria* be incorporated, though burning may be favored by the farmer's tradition.

Pueraria as a herbaceous legume cover crop improves the fertility of the soil through nitrogen fixation as well as nutrient cycling from the subsoil and stimulation of activity of soil biota.

The legume helps control soil erosion and it also reduces weeds. It is well suited to West and Central Africa's bimodal rainfall regions. It grows slowly initially, but withstands drought and thrives where the moisture-holding level of the soil is high. Because of the slow growth, *Pueraria* does not compete with associated food crops during the establishment period. And because of its ability to survive in the dry season, *Pueraria* can thrive at the onset of the rainy season, overgrow weeds, and accumulate a large amount of shoot and root biomass with no extra labor during the subsequent year.

Comparing systems

According to a long-term trial without the use of fertilizers and pesticides in Ibadan, Nigeria, the maize grain yield in the *Pueraria* simultaneous cropping was maintained at 2.5 t/ha after the third cycle, whereas in the sole maize/cassava continuous cropping and cropping with natural regrowth there was a rapid decline to below 0.4 and 1.5 t/ha.

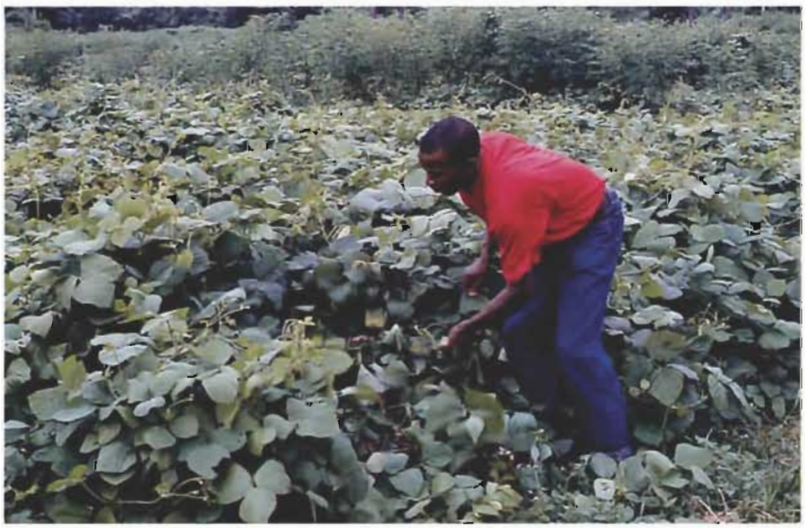
There was a higher cassava tuber yield with the *Pueraria* simultaneous cropping (14.2 t/ha) than in the natural regrowth cropping (10.1 t/ha) and sole continuous cropping (6.6 t/ha) after the third cycle.

Importantly, the *Pueraria* simultaneous cropping not only increased crop production, but also maintained soil fertility. With the *Pueraria* simultaneous cropping the soil organic carbon and mineral nitrogen stabilized very close to that of the secondary forest. The nutrient budget analysis indicated a positive balance for nitrogen in the *Pueraria* simultaneous cropping if the *Pueraria* residue is incorporated before cropping maize/cassava, assuming maize grain and cassava root yield will be sustained at about 2.5 and 15 t/ha, respectively.

The soil-available phosphorus was still not depleted after seven years of cropping because the phosphorus taken up from the subsoil by *Pueraria* can compensate for that removed by maize grain and cassava roots.

There was no decrease in soil pH under *Pueraria* simultaneous cropping. The number of earthworms with the *Pueraria* simultaneous cropping, an important soil-quality measure, conformed to that of the secondary forest.

This research implies that a self-sustainable food production is possible using the *Pueraria* simultaneous cover cropping. The technology is ready for off-station trials in West and Central Africa.



During the fallow stage, Pueraria adds nitrogen to the soil, thus restoring its fertility

Farmers' perceptions of soil degradation

The nature of farming is such that farmers are highly aware of the environmental conditions in which growing crops and tending livestock occur. This makes sense, because food and income losses can occur from their not being aware of constraints and failing to take action when possible.

A study was conducted by IITA, in collaboration with Nigeria's Institute of Agricultural Research, to determine just what soil conservation issues in particular are continually assessed by farmers. It was done in the northern Guinea savanna of Nigeria. A total of 181 farmers in 15 villages, including village chiefs, were interviewed. The interviews lasted less than half an hour. The questions were open-ended and conversational in nature.

Chiefs were asked what the limitations were for crop production. In decreasing importance, the answers were fertilizer availability and cost (with cost less important), insect infestation, drought, lack of access to roads, nonavailability of machinery, and weed infestation.

More than a quarter said that unproductive fields exist in the village, but they did not attribute

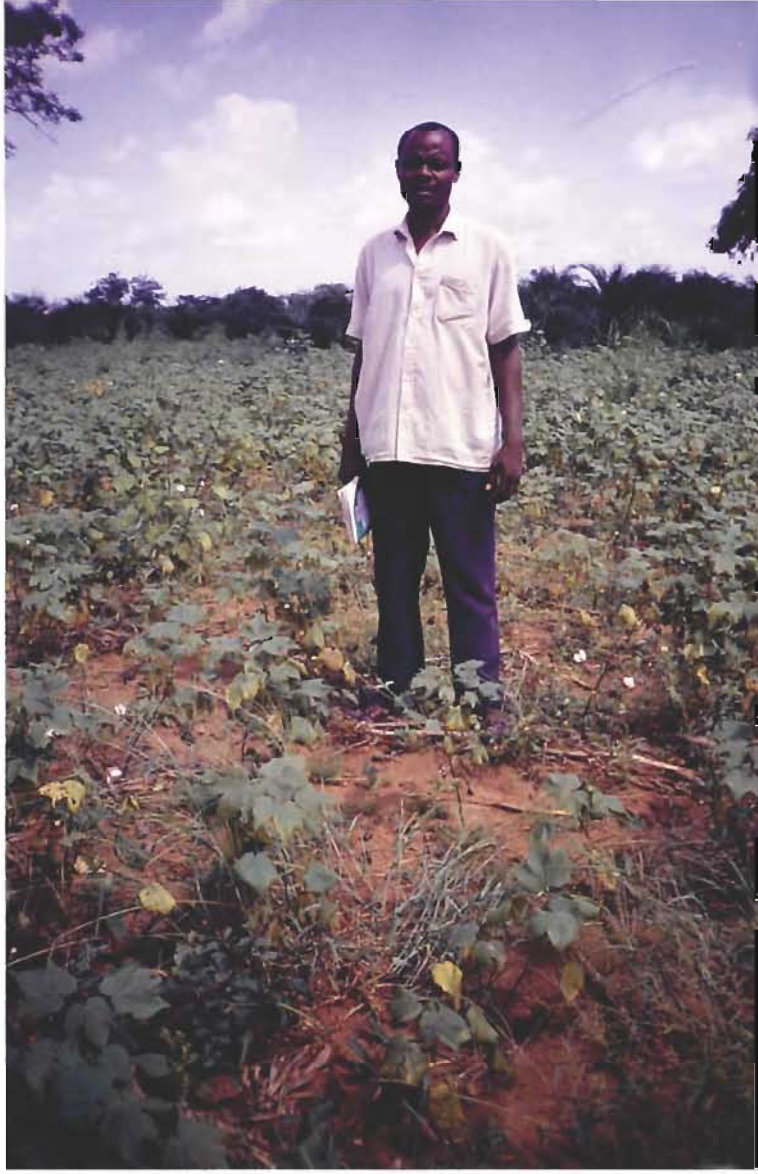
Farmers were asked what they perceived as farming practices that made them better farmers than others. The most common responses were management of resources, good planning, and hard work.

In Katsina, Nigeria, rows of maize and sorghum (foreground) abruptly end before a chasm cut through the field by rampaging runoff. Shifting cultivation is a major cause of erosion, and it is on the increase in sub-Saharan Africa

their existence to farming practices. Only half of them thought that sufficient good land would be available in the future. Slash-and-burn cultivation was practiced in the villages by 87% of the chiefs. The procedure used was to gather the trash or crop residue and set it on fire. This released nutrients and controlled weeds and insects.

Nearly 90% of the chiefs were aware of gullies, visible signs of erosion, and soil degradation. Only about 20% said they did anything about them.

Livestock and crop-livestock interactions were also assessed. Livestock was perceived mainly as a source of food and income by chiefs. They were also ranked high for their social value during traditional ceremonies, followed by their use for traction and as suppliers of manure. Rarely were livestock perceived as potentially harmful to soil, especially during the long, dry season when no cover is left to protect surface soil.



In Benin, a village agricultural agent, himself a farmer, stands in his cotton field. He uses the teaching guide he holds to help his farmer neighbors solve crop production problems

Need for fertilizer

For farmers, though, the causes for poor yield can be categorized as those that are most important at present, and those that are expected to increase or decrease with time. Currently, lack of fertilizer and *Striga* were perceived as the main causes for poor yields by 88% of farmers. Lack of fertilizer was the only cause for poor yield which farmers believe will grow worse.

Insect problems, other pests, and diseases were perceived as lessening. Except for *Striga* and climate conditions, most causes given for poor yield were related to soils with runoff, i.e., inherently poor soil fertility, erosion, waterlogging, and loss of soil fertility.

Farmers were asked what they would like to have in order to improve their farming. Fertilizer was number one. The use of tractors and the availability of bank loans were second and third on the farmers' wish list. Thus, other soil-related causes were viewed as minor problems, possibly due to the current lack of fertilizer. This corresponds to scientific evidence that no conservation practices can completely replace fertilizer for restoring fertility in the long run.

Moreover, crop rotation and adequate crop establishment were perceived as necessary for adequate yield. For instance, farmers consistently planted on ridges to facilitate crop establishment.

Farmers were asked what they perceived as farming practices that made them better farmers than others. The most common responses were management of resources, good planning, and hard work.

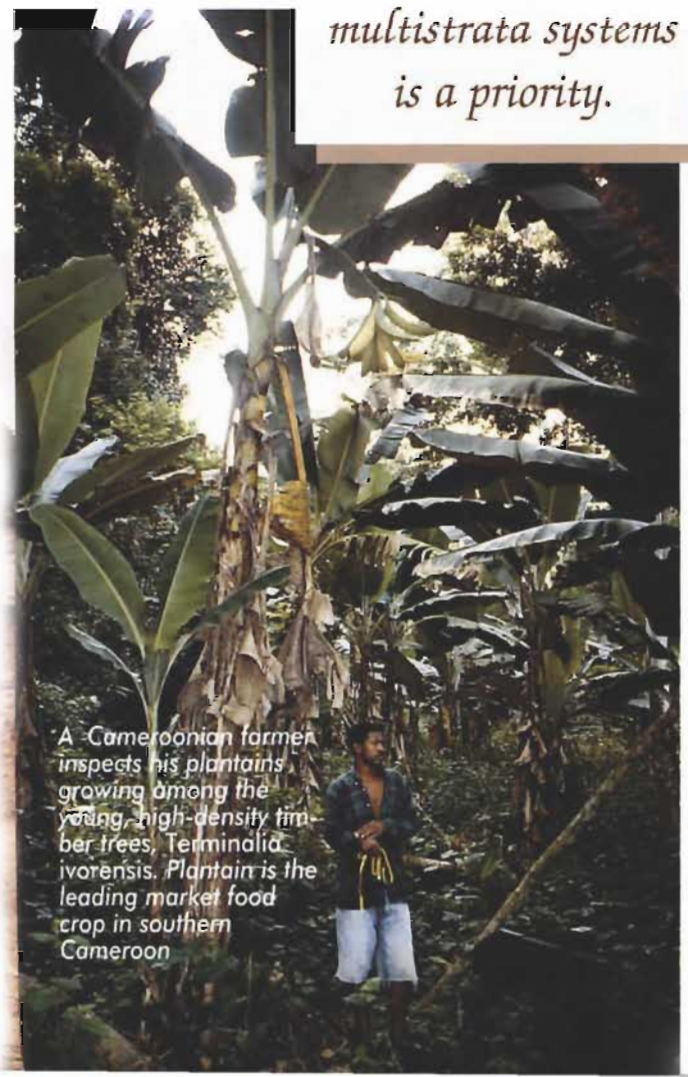
Mimicking the forest: multistrata systems for the humid tropics

IITA, in collaboration with farmers and national and international research institutes, is developing systems that can increase the productivity and income of smallholders.

In the humid tropics, the development of multistrata systems is a priority. These systems, which integrate different annual and perennial crops, mimic the natural forest structure where vegetation forms several strata.

Although there is high demand for timber, fruits, nuts, and medicines, farmers have been reluctant to invest land and labor in new tree-based systems where the first harvest is often years away. Multistrata systems, therefore, are being developed which include annual food crops to provide income during the start-up years before the tree crops are harvested; they also prevent the bush from invading the young tree stand.

In the humid tropics, the development of multistrata systems is a priority.



A Cameroonian farmer inspects his plantains growing among the young, high-density timber trees, Terminalia ivorensis. Plantain is the leading market food crop in southern Cameroon

In southern Cameroon, cocoa farmers are integrating upper canopy fruit trees such as *Dacryodes edulis*, the African prune, into their plantations and wish to add selected food crops as a lower stratum. Others are interested in growing oil palm and fruit trees with under-storey food crops. Forty such fields in five forest margin benchmark villages have been planted by farmers in partnership with researchers from IITA's Humid Forest Station and the Cameroonian Institute of Agricultural Research and Development. The effect and preference of frequency of annual cropping, introduction of nitrogen-fixing cover crops and hedgerows, and the use of chemical fertilizers are being addressed.

Aware of the predicted timber shortage from Cameroon's permanent forests, IITA and Cameroon's National Forestry Institute are investigating the potential of integrating timber and food crops. This would allow farmers to plant timber trees and grow crops between them at establishment and once after each routine tree thinning, i.e., when the less vigorous trees are cut every five to ten years. The postthinning periods, with reduced competition and greater light, provide niches for cropping. This mimics traditional systems where crops like cocoyam and

An old, low-density Terminalia ivorensis plantation, towering over plantains. IITA scientists are assessing the effects of timber tree densities and low-input soil management regimes on the growth and yield of plantain

plantain are planted in forest gaps created by fallen trees.

Prototype systems

At IITA's Humid Forest Station, prototype multistrata systems were established in six- and 17-year-old *Terminalia ivorensis* plantations in 1995. The effects of timber tree densities and low-input soil management regimes were assessed on the growth and yield of plantain, the most important marketed food crop in southern Cameroon.

Initial results are encouraging. Plantain bunches were heavier under tree stands with a 65% canopy cover compared to sole timber tree stands with about 15% cover. Bunches of up to 30 kg were harvested. Greater bunch yield was associated with a markedly lower degree of damage from black sigatoka disease. However, yields per hectare per year were lower, as greater shade prolonged the beginning of flowering. Shade in high tree density plots also reduced the vigor of the aggressive arable weed *Chromolaena odorata*, allowing less aggressive forest species to establish, thus reducing weeding labor. Beneficial soil fauna, such as earthworms and soil-feeding termites, maintained their activity almost at the same level as in undisturbed forest, contributing to favorable soil properties.

Farmers and researchers have recognized the advantages of diversifying the production base in the humid tropics through the establishment of multistrata systems. A suitable combination of food crops adapted to the multistrata environment and early yielding fruit trees, oil palms, and timber trees is crucial to ensure a continuous flow of revenue and reduce the need to exploit natural forests.

Sub-Saharan Africa has great potential for sustainable agricultural production. Its various ecosystems are naturally balanced. Enabling farmers to maintain the balance is crucial for the future.

PHMD

Peter Neuenschwander Finds That Success Breeds Success

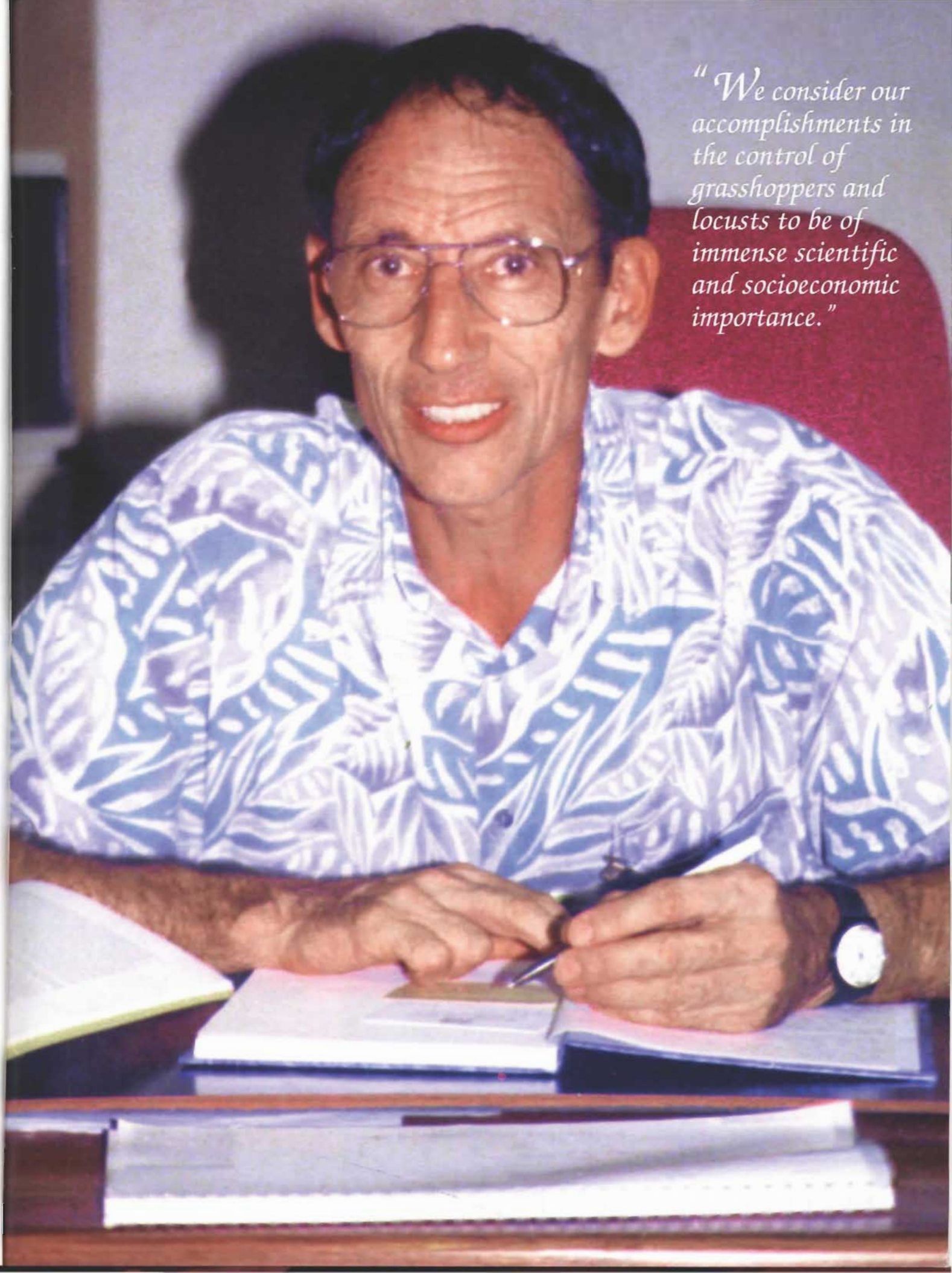
The Plant Health Management Division (PHMD) came into existence because of IITA's success in bringing the cassava mealybug under biological control in Africa. Its combining research and biological control, host plant resistance, and habitat management makes it unique in the Consultative Group on International Agricultural Research (CGIAR).

In 1991, in the reorganized structure of IITA, PHMD was given a big role. Since 1994, it has been headed by Peter Neuenschwander. "We're responsible for all integrated pest management projects, which assures collaboration across the different divisions. We work on all mandated crops in the humid and subhumid zones of Africa, some of which are extended into the dry savanna and even the Sahel," he explained.

Apart from the division's contribution to the continuous improvement of Integrated Pest Management (IPM) through research and implementation, recent successes brought major achievements. These involve biological control of the cassava green mite, mango mealybug, larger grain borer, *Striga* management, and the development of the first commercial entomopathogen for use against grasshoppers and locusts.

"We consider our accomplishments in the control of grasshoppers and locusts to be of immense scientific and socioeconomic importance," Neuenschwander noted. "The damage that these pests cause to crops, especially in Africa, is staggering. Since the use of chemical pesticides is undesirable worldwide and economically prohibitive in sub-Saharan Africa, use of environmentally friendly natural enemies to control them is in touch and in tune with the time."

IITA also promotes IPM activities across the entire CGIAR in the form of the Systemwide Program on Integrated Pest Management.



"We consider our accomplishments in the control of grasshoppers and locusts to be of immense scientific and socioeconomic importance."

Integrated strategies to reverse plantain losses in Ghana

A Gesellschaft für technische Zusammenarbeit (GTZ)-funded IITA project is responding to declining plantain yields in West and Central Africa. The aim of the project is to develop integrated management strategies, incorporating cultural and biological control, that are appropriate for smallholder plantain farmers, so as to reverse the decline in yields and plantation life.

Despite the importance of plantain as a preferred staple in Ghana, the area of production has decreased by up to 14% in recent years due to poor management, low soil fertility, short fallows, and an extensive pest and disease complex. Poor yields have led to abandonment of the crop in traditionally important plantain-growing areas.

The ultimate benefit of the project will be seen in increased plantain production and prolonged plantation life, which will contribute significantly to food security and sustainable agriculture in the region.

The analysis of the situation began with a participatory rural appraisal to determine farmers' perceptions of the constraints to plantain production in Ghana and Nigeria. The appraisals were followed by diagnostic surveys to determine the distribution, severity, and dynamics of pests and diseases, taking account of ecological factors and farming practices.

The preliminary evaluation highlighted the importance of nematodes, weevils, and black sigatoka as major constraints to plantain production. These results were confirmed by on-station trials, showing that infestation by a combination of nematodes and weevils can cause losses of 85%. The problems of nematodes and weevils are compounded by the repeated use of infested planting material.

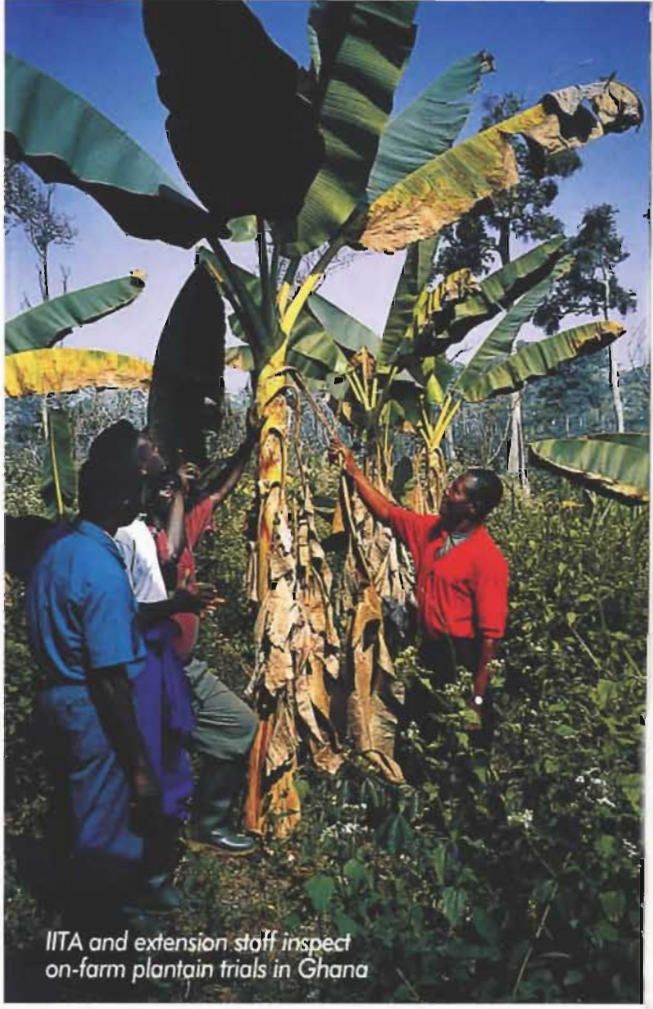
Tunnelling damage on a plantain pseudostem caused by the banana weevil Cosmopolites sordidus

Plantain Enemies in Southern Cameroon

Mycosphaerella fijiensis, a leaf fungus that reduces photosynthetic area, is the causal agent of black sigatoka and can cause up to 80% yield reductions

Radopholus similis, a nematode that causes necrotic lesions on the roots leading to uprooting of the plant, particularly after bunch emergence when the plant is already unstable

Cosmopolites sordidus, the banana weevil, causes significant losses by damaging the corm through burrowing. In severe cases, this causes breakage at the base of the stem



IITA and extension staff inspect on-farm plantain trials in Ghana

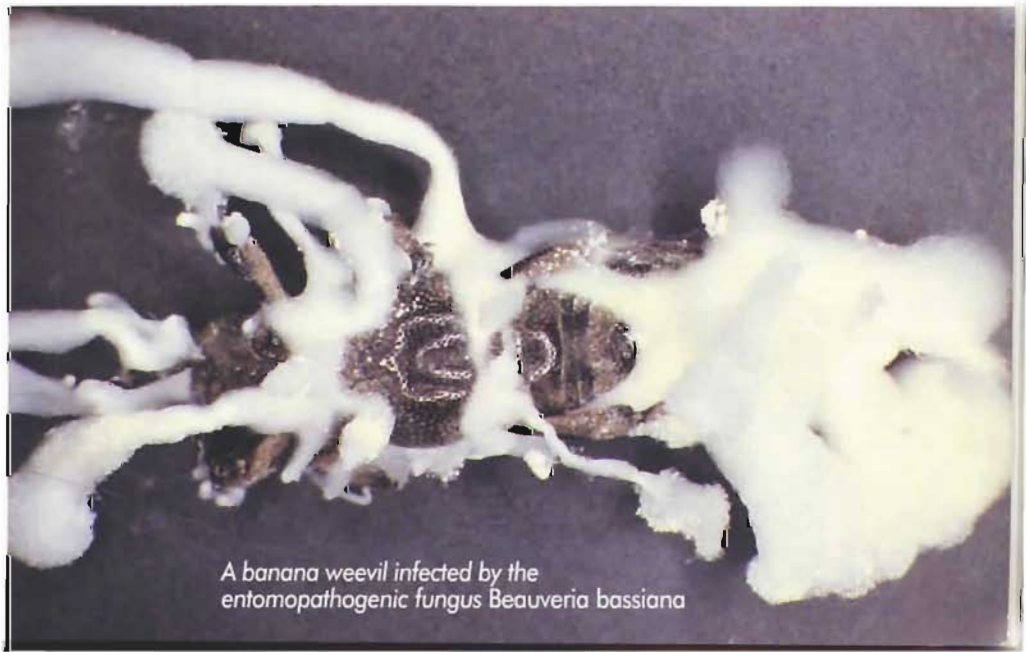
Multifaceted project

IITA, in collaboration with farmers and the Ghanaian Ministry of Food and Agriculture (GMoFA), is developing low-cost techniques to disinfect planting material, followed by rapid multiplication in village nurseries. Considerable success has been obtained with the use of clean planting material and improved management.

Another promising effort involves the use of a fungus to control the banana weevil. A highly virulent strain of the fungus *Beauveria bassiana* (from Uganda) has been identified and can be mass-produced in the laboratory. Preliminary field trials show weevil mortality ranging from 53 to 81%, compared with 7 to 8% mortality in the untreated control.

The project has other offerings. It includes graduate training for several Ghanaian scientists. Short-term training is provided for collaborating GMoFA staff who assist farmers in improved plantain management. Moreover, the project is strengthening linkages between IITA and national programs in Ghana, while collaboration with a complementary project in East Africa enables information exchange between the two regions.

The ultimate benefit of the project will be seen in increased plantain production and prolonged plantation life, which will contribute significantly to food security and sustainable agriculture in the region.



A banana weevil infected by the entomopathogenic fungus Beauveria bassiana

IPM helps farmers increase cowpea production

Most cowpea farmers in sub-Saharan Africa are confronted with low yields, caused by insect pests and diseases. Over the past few years, however, this picture has been gradually changing due to the establishment of a regional pest management project.

Among the most promising technologies are varieties resistant to Striga, aphids, and bruchids.

Known by its French title, Protection ecologiquement durable du niébé, or PEDUNE, it aims to increase cowpea production in the Sahel and African savannas by applying ecologically sustainable pest control. By its nature, integrated pest management is 'by farmers' and not 'for farmers,' so farmers' participation in this project is one of the key features.

During the last 15 years, IITA, in collaboration with the national agricultural research systems (NARS), has developed a number of efficient pest control technologies for cowpea, mainly based on resistant, higher-yielding varieties. Unfortunately, several surveys with the NARS revealed that until 1994 most of these technologies were yet to be adopted by farmers.

In order to increase adoption by farmers, IITA, with financial assistance from the Swiss Development Corporation (SDC), initiated the pilot phase of PEDUNE in 1994. An essential feature of the pilot phase, which started in Benin, Burkina Faso, Mozambique, Niger, and Nigeria, was to carry out diagnostic studies at the farmer level aimed at understanding the major socioeconomic circumstances which influence technology transfer.

Pilot project

A participatory evaluation of the pilot phase, which ended in 1996, revealed promising results and was thus the basis for continuing and

Intercropping of sorghum with cowpea traditionally (opposite page) and with an IITA-improved cowpea variety (right). The improved variety increases soil fertility, which greatly enhances the sorghum's growth

expanding the project to include four new countries: Cameroon, Ghana, Mali, and Senegal.

The second phase of the project started in 1997 and focuses on five areas: dissemination of proven technologies; training of farmers, extension agents, and scientists; farmer-managed on-farm trials to validate technologies; on-station applied research on priority areas; and monitoring and evaluation of project performance and rate of adoption.

Among the most promising technologies are varieties resistant to *Striga*, aphids, and bruchids; improved storage techniques using solar drying; and the use of botanical pesticides in the field and in storage.

Strong linkages and collaboration among various disciplines and institutions are essential for the project's success, so emphasis is also placed on improving exchange of information and expertise, e.g., by encouraging exchange visits and short-term attachments for national project scientists.

Solarization is used prior to storage to disinfect cowpeas of bruchids, small beetles that bore into the seeds, damaging or rendering them inedible

IITA's insect pathology program: applying LUBILOSA's lessons

Using chemical pesticides for the control of insect pests is increasingly unacceptable because they pollute and adversely affect the health and habitat of humans and wildlife. Biopesticides are an alternative.

Until the mid-1980s, the principal means of controlling locusts, for example, was the use of persistent synthetic insecticides. However, because of concern about environmental damage and risks to human health and livestock, persistent chemical insecticides lost acceptibility. Nonpersistant chemicals, with little residual activity, became widely used instead.

The Food and Agriculture Organization (FAO) of the United Nations accepted a dossier on the results, and the LUBILOSA mycopesticide was recommended by the pesticide referee group for locust control.

Because these chemicals kill largely by direct spray contact only, they are less effective and often require several applications to achieve control. This increases cost and environmental damage, and puts humans and livestock at risk.

For these reasons, especially during the 1986-89 locust plagues in Africa, a big donor investment was made in finding alternatives.

Almost a decade ago, IITA, in collaboration with the International Institute of Biological Control (IIBC) of CAB International, the Comité permanent inter-état de lutte contre la secheresse dans le Sahel (CILSS), Gesellschaft für technische Zusammenarbeit (GTZ), and West African national partners, began work on biological control. Early on, the use of *Metarhizium flavoviride* was picked up by the LUBILOSA project, a French acronym for "biological control of locusts and grasshoppers."

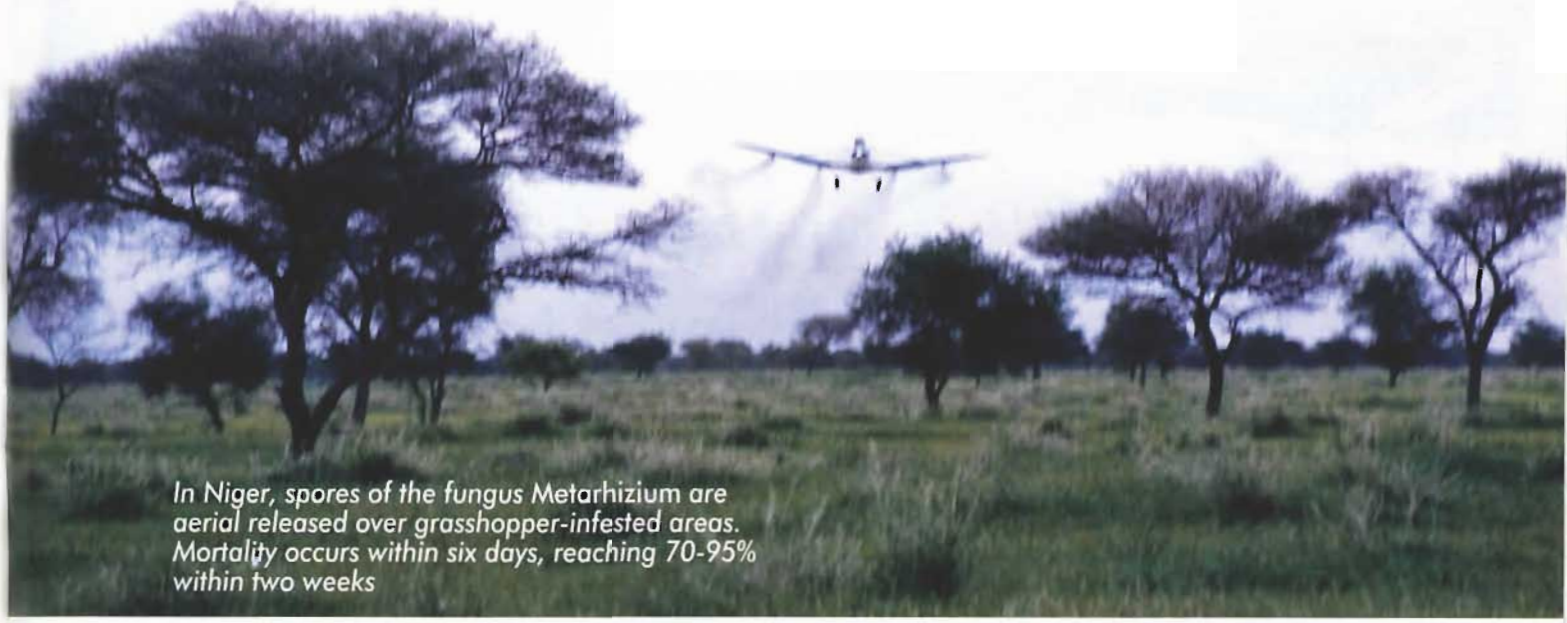
Metarhizium anisopliae infecting the larger grain borer Prostephanus truncatus

Metarhizium is a fungus. It is applied in an oil mixture to avoid rapid drying of the spores. The fungus, which occurs naturally throughout Africa, has no adverse effects on mammals, including humans.

In the ongoing third phase, IITA leads the socioeconomic evaluation of *Metarhizium*, runs a comprehensive field trial program, studies *Metarhizium* impact on nontarget invertebrates, and produces fungal spores.

Safe fungus

The efficacy of *Metarhizium* was demonstrated to international standards against variegated grasshoppers (*Zonocerus*



In Niger, spores of the fungus Metarhizium are aerial released over grasshopper-infested areas. Mortality occurs within six days, reaching 70-95% within two weeks

variegatus), rice grasshoppers (*Hieroglyphus daganensis*), the Sahelian grasshopper complex, and the Senegalese grasshopper (*Oedaleus senegalensis*).

Mortality started six days after applications and reached 70-95% after 14 days. There was no reinvasion of the treated plots. Desert locust (*Schistocerca gregaria*) and hopper bands were also killed.

Ecotoxicological laboratory and semifield tests, following the approved testing scheme of the US Environmental Protection Agency, revealed no harm by *Metarhizium* on several groups of beneficial and other ecologically important insects. Also, in large-scale operations in Niger, the nontarget fauna of the Sahel was shown not be at risk. This also demonstrates the advantage, from the environmental point of view, of the biological product over chemical pesticides such as fenitrothion.

Other positive effects included secondary recycling of the pathogen after a single spraying. In other words, the fungus multiplies on the dead grasshoppers, increasing the killing action. This has significant consequences for the economics of biopesticide use.

The Food and Agriculture Organization (FAO) of the United Nations accepted a dossier on the results, and the LUBILOSA mycopesticide was recommended by the pesticide referee group for locust control. Transferring the technology to commercial partners in Europe and Africa has already begun, and it will lead to industrial mass production for application in Africa in a short time.

An economist is helping guide the complexities associated with commercial development of the technology.

Future uses

Because biological control poses less risk to humans, animals, and the environment, it is preferred over chemical insecticides. For this reason, IITA's insect pathology program is looking beyond LUBILOSA, to apply entomopathology to other pests. These include trials against Moroccan locust, brown locust, migratory and red locust, and implementation of the use of *Metarhizium* for *Zonocerus* control in humid-zone countries.

LUBILOSA has opened a door to the future of entomopathology in sub-Saharan Africa. This includes many fascinating research avenues; for example, production of mycopesticides in liquid fermentation and the use of protozoans, viruses, and bacteria.

For some of the pests, classical biological control using pathogens may be possible; for others, development of a biopesticide is preferred. Scientists are exploring using pathogens in biocontrol of the cassava green mite, against the larger grain borer, the banana weevil, and termites. A termite-active isolate of *Metarhizium anisopliae*, received from the International Centre for Insect Physiology and Ecology (ICIPE), was tested against four species of termites, both as a repellent and as a mortality agent. Each of these insects costs African farmers millions of dollars annually in crop losses.

BioNet International and IITA's insect taxonomy role

BioNet International supports conservation and the wise use of the environment. This global network is dedicated to achieving realistic self-reliance in taxonomy within developing country subregions. It pools expertise, experience, information, technologies, and infrastructures to support sustainable agricultural development.

BioNet is an initiative of CAB International, and it provides systematic backing for biodiversity. By strengthening taxonomic capabilities, it removes impediments to the development of integrated pest management systems and effective quarantine, which adversely affect diversified agricultural production in the developing world. Network hubs are focused on the Caribbean, southern Africa, the South Pacific, South Asia, Southeast Asia, and recently East and West Africa.

Plans are on the drawing board to include South America, Meso-America, the Nile Basin, China, and the Middle East. The network encourages South-South and North-South cooperation.

Plans are on the drawing board to include South America, Meso-America, the Nile Basin, China, and the Middle East.

Biosystematics of arthropods, nematodes, and microorganisms (fungi, bacteria, and viruses) are the biological focus of BioNet. Recognizing the importance of sound taxonomic foundations for sustainable agricultural development, IITA has taken the lead to play a central function in establishing the West African node, to be known as WAFRINET or West African Net.

A drawer with Lepidoptera caught at one lighttrap site in Benin provides insights about moth diversity in West African environments

Collaborative and regional networking

IITA is thus playing a catalytic role in fostering regional expertise through active networking. In concert with scientists from 11 francophone and six anglophone West African countries, a two-year program has been outlined

A cetoniid beetle acquisition awaiting integration into IITA's reference collection at the Biological Control Center for Africa, Cotonou, Benin

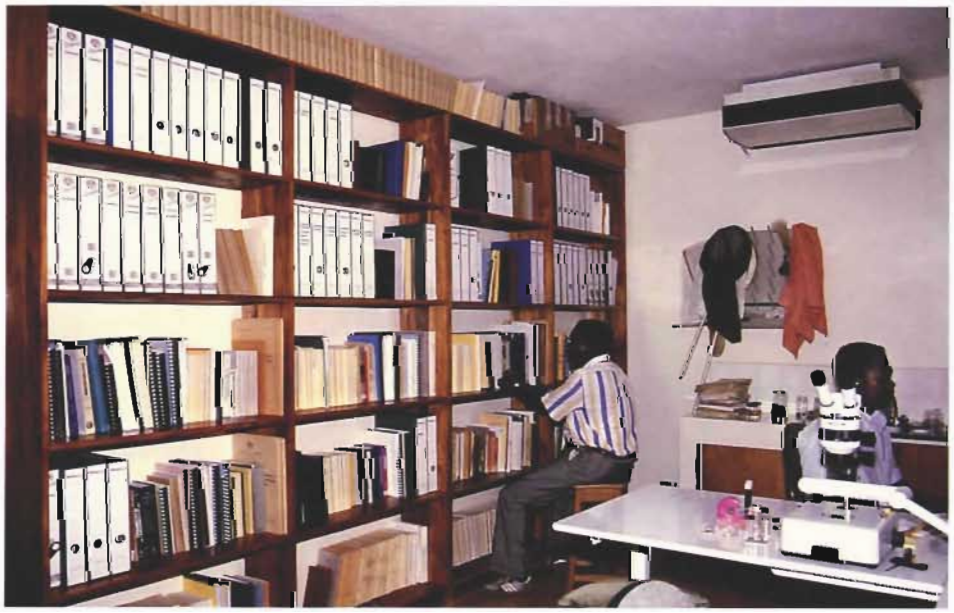
emphasizing information and communication, training of biosystematists, rehabilitating collections and other sources, and developing and using new technologies, especially electronic aids to identification.

IITA's unique institutional facility was established, in particular, with financial support from Austria. Linked with BioNet, it is providing an efficient information service, covering traditional taxonomy, molecular techniques, new records, and current pest distribution data. Information on natural enemies/biological control and bioremediation agents can ultimately be accessed through the network's databases. IITA will thereby keep participants up to date in its fields of expertise.

IITA's Plant Health Management Division trains science graduates in general and in applied taxonomy. This is done through joint courses at overseas universities and institutions, and at local subregional academic and scientific centers. It leads to joint MSc and PhD degrees. Technician-level instruction is also offered through the network.

Information is vital to such an undertaking. Communication services provide key institutions with minilibraries and databases, computer equipment, and electronic communications systems, including E-mail capacity and Internet access.

The global network is supported by a consortium of developed-country expert centers, and it is managed by a coordinating committee and a technical secretariat in the CAB International headquarters in the UK.



The 200-square-meter Insect Museum at IITA's Biological Control Center for Africa houses an insect reference collection of some 35,000 specimens and 2,100 identified species itemized in databases. With an acquistion of more than 5,000 specimens a year, the museum contains one of the largest insect collections in West Africa

Taking its nutrients directly from the water in which it floats, the water hyacinth has become a nuisance in warm regions throughout the world

Partnership for food: the Technology Testing & Transfer Unit

IITA's Technology Testing & Transfer Unit operates on the principle that developing ecologically sustainable pest control technologies and transferring these technologies to farmers within various farming systems is a dynamic process.

The Technology Testing & Transfer Unit (TT&TU), established in 1990 with funding initially from Germany and later from Austria and Switzerland, is guided by a philosophy as much as by objectives. As a guiding principle, collaboration between IITA and national scientists must be based on reciprocal trust and equal rights. TT&TU considers a project as being entirely owned by the national program.

Also, personal dialogue and interaction are more important than letters, faxes, and mail. Collaboration is based always on personal contacts and mainly determined by the interaction of individual personalities. This is the foundation of TT&TU's approach to strengthening national plant protection programs.

Based on an evaluation of its activities since its inception, the unit's objectives have been largely achieved. A solid informal network of information by various forms of contact has been established throughout sub-Saharan Africa.

The national agricultural research and extension systems will have to take the initiative themselves and introduce their requests for support according to their concrete work plans.

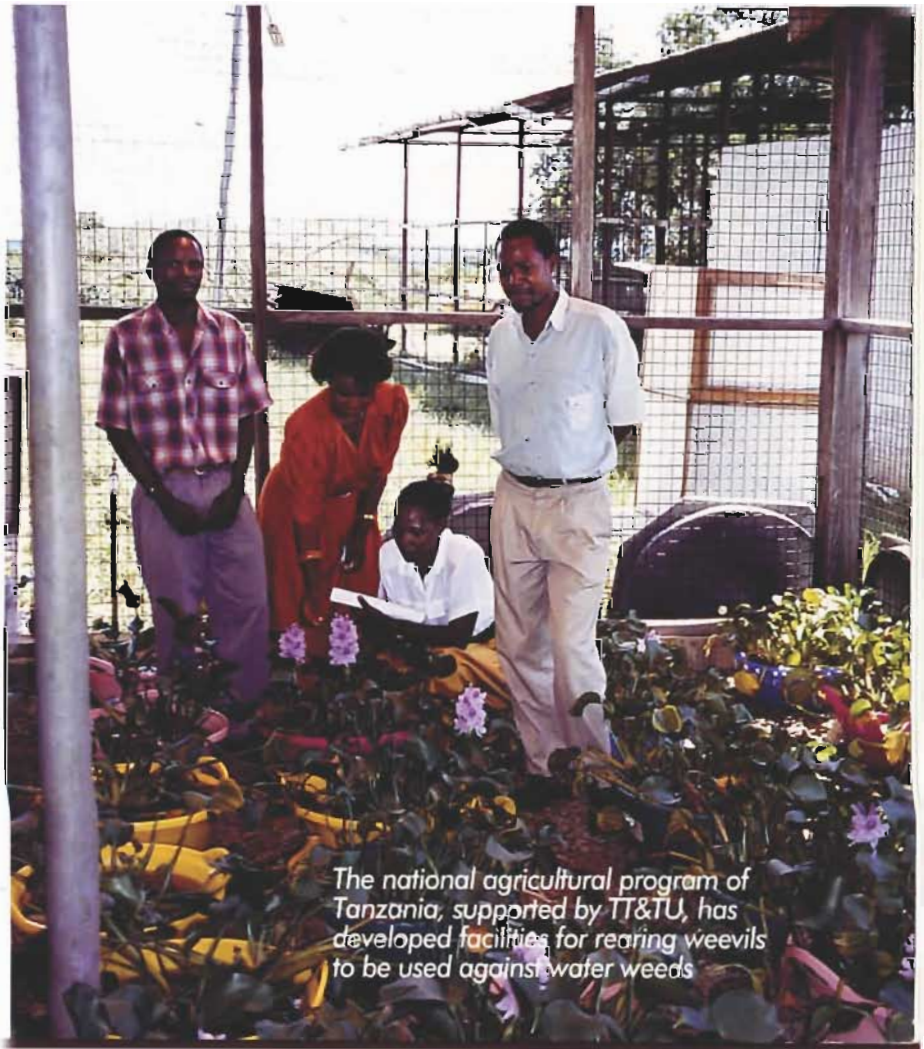
The next phase

The unit is already well into its next phase. TT&TU will continue to support national agricultural research and extension systems to help them test and implement biological control measures, adapt other integrated pest management (IPM) measures, and achieve sustainability through training and information sharing.

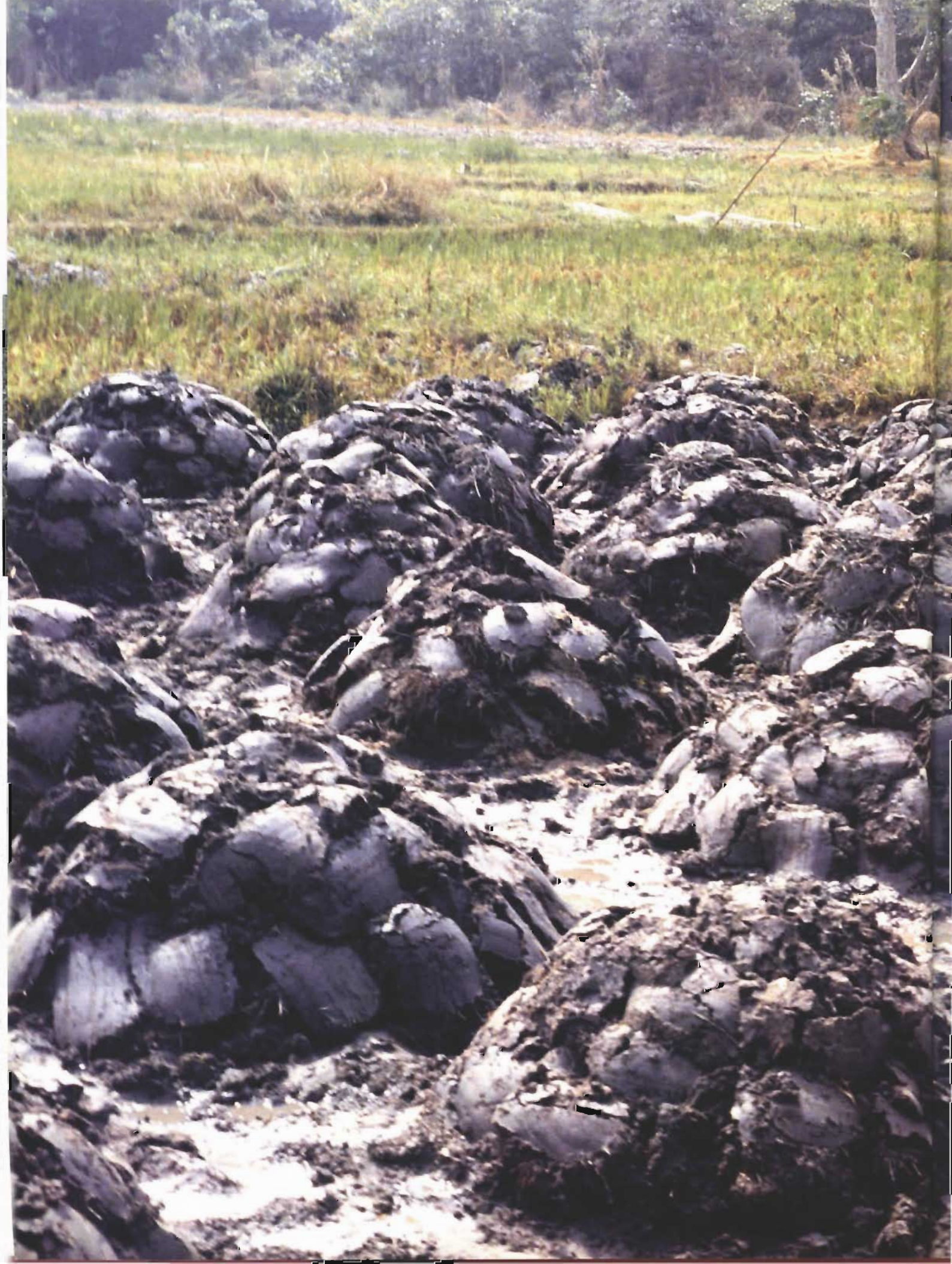
In keeping with the philosophy of equality, participants will not be selected to cooperate in the project. The national agricultural research and extension systems (NARES) will have to take the initiative themselves and introduce their requests for support according to their concrete work plans.

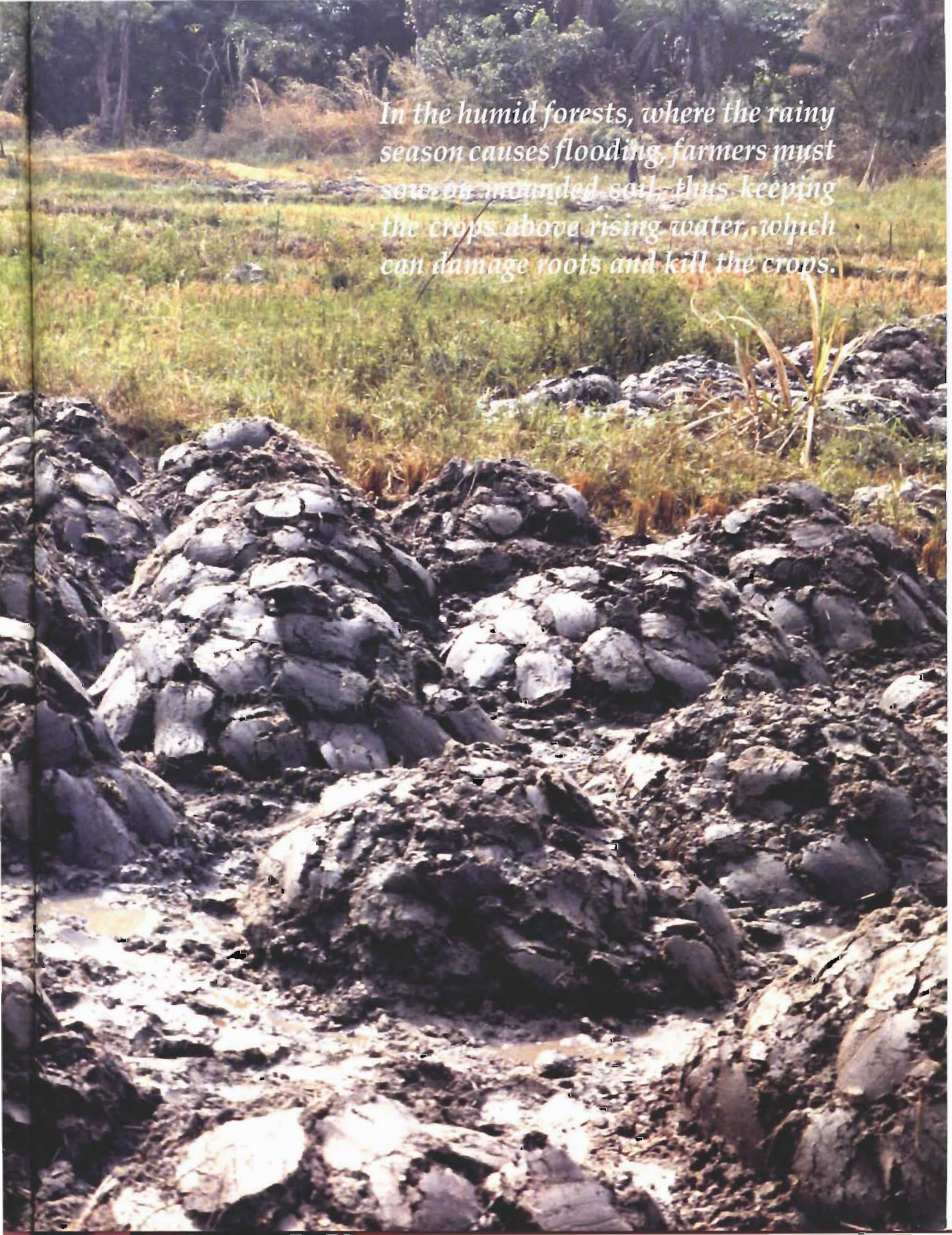
Also, the project will stress that all potential local resources for funding and equipment have to be exhausted before external support is given. This breaks any possible form of paternalism and conforms with the philosophy that help for self-help is paramount. Therefore, the unit trains national scientists and technicians; characterizes ecosystems and the socioeconomic status of farming systems; conducts prerelease surveys and local rearing of beneficial agents for field release; does on-station and on-farm technology testing; and assesses the impact of technologies by assisting and improving the collaboration between national scientists and their counterparts in IITA's Plant Health Management Division.

Future collaborative research activities will continue to focus on technology testing and transfer with regard to IPM of cassava, cowpea, and maize. Special effort will be made on the biological control of cassava green mite, flower thrips, and pod borers on cowpea, maize stem borers, and the larger grain borer. New collaborative IPM projects are being developed with NARES on water hyacinth, mango mealybug, and *Striga*.

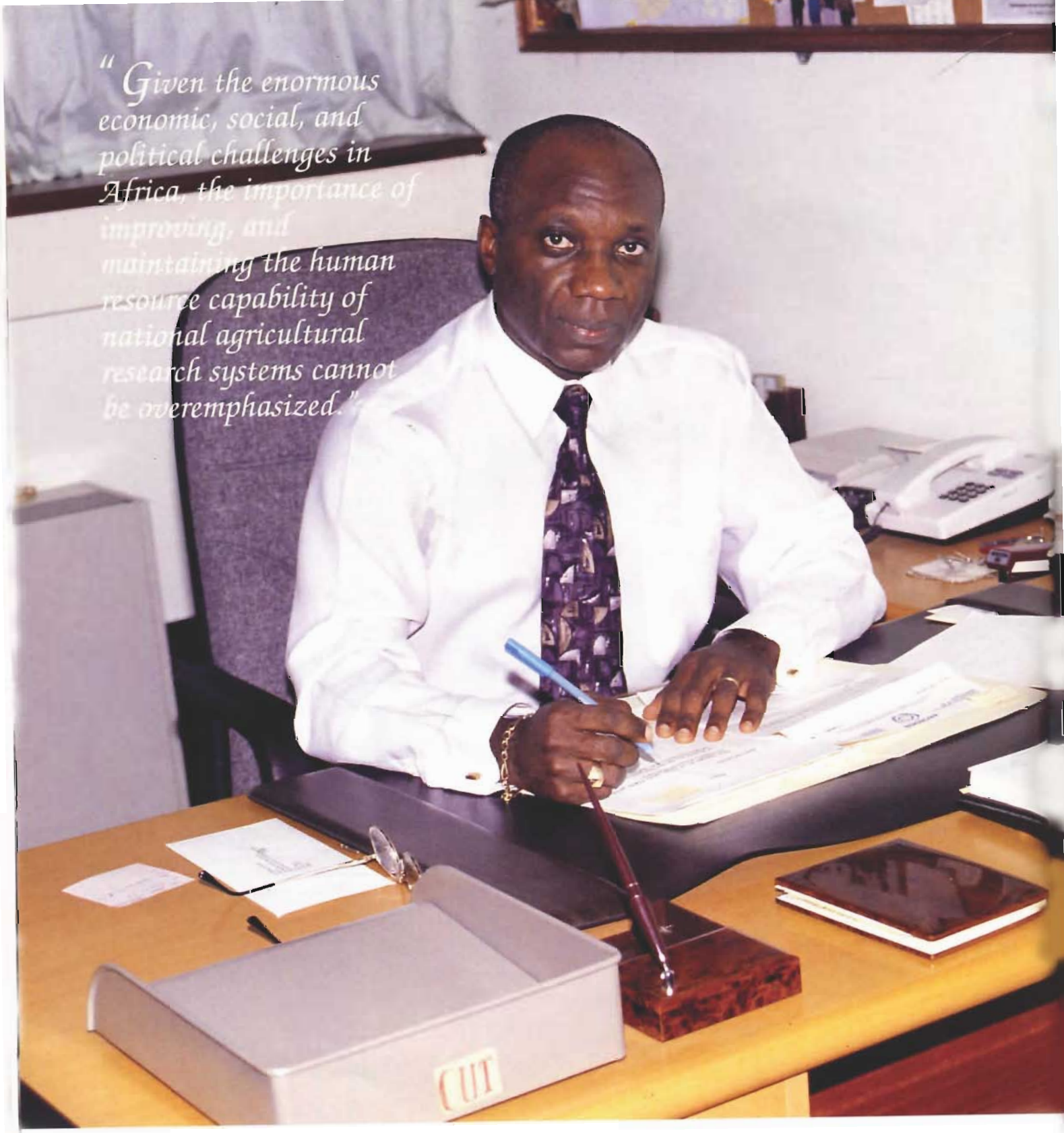


The national agricultural program of Tanzania, supported by TT&TU, has developed facilities for rearing weevils to be used against water weeds





In the humid forests, where the rainy season causes flooding, farmers must sow on mounded soil, thus keeping the crops above rising water, which can damage roots and kill the crops.


"Given the enormous economic, social, and political challenges in Africa, the importance of improving, and maintaining the human resource capability of national agricultural research systems cannot be overemphasized."

Michael Bassey Praises Training In Technology Transfer

Michael Bassey, director, IITA's International Cooperation Division, praises training as "the bedrock of IITA's support to national programs." Under his leadership, IITA has intensified its in-country training.

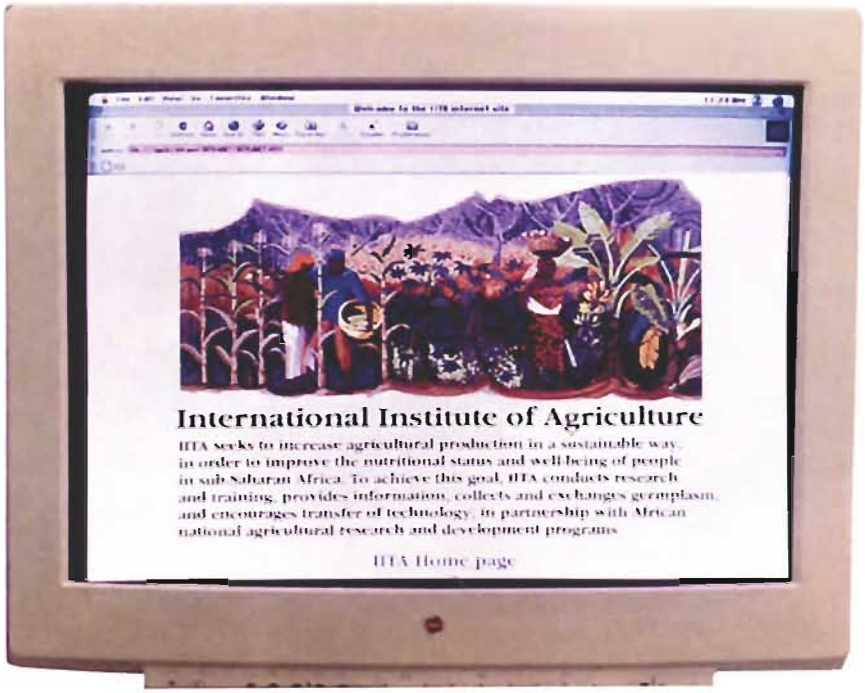
Bassey believes that this capability can be maintained by using available training resources and preparing national programs to take lead roles in reseach-related training. Group training is the best way to accomplish this, he noted.

"Group training strengthens national programs so they can conduct the research essential for their own development. We encourage sustained advancement in research because it enhances collaboration."

In the past three years, IITA has trained more than 2000 technicians and scientists from sub-Saharan Africa, with an increasing proportion being women. Approximately half of these were trained at off-campus sites.

Research networks are a major conduit for training and dissemination of technology. Bassey stressed the networks' role: "Networks interconnect and channel technology; they also provide the organizational structure for training. IITA is among the few institutes which have invested significant core resources to bolster national research capacity."

In Bassey's view, training and network-strengthening go hand in hand. "Networks are a partnership, and the essence of a partnership is sharing responsibilities. As a good partner, one of IITA's major responsibilities is to train national collaborators in research, program management, and leadership."



In 1997 IITA established a home page on the World Wide Web. The initiative, along with the Institute's participation in AfricaLink, a US Agency for International Development project to link African researchers through E-mail with IITA and other IARC resources in Africa, reflects the International Cooperation Division's objective to improve the dissemination of information

El Niño, NARS, and IITA News on the Web

El Niño's anticipated effects on weather and agriculture in eastern and southern Africa led IITA to prepare a plan to mitigate the disruption of root and tuber crop production.

Responding to a request from the US Agency for International Development, IITA focused its plan on cassava and sweetpotato. It was developed with the Southern Africa Center for Cooperation in Agricultural Research (SACCAR), the Association for Strengthening Agricultural Research in Eastern and Central Africa (ASARECA), and the International Potato Center (CIP).

The plan involved use of improved germplasm, rapid multiplication, and use of appropriate postharvest technologies. IITA is working through regional networks to implement production activities in selected countries.

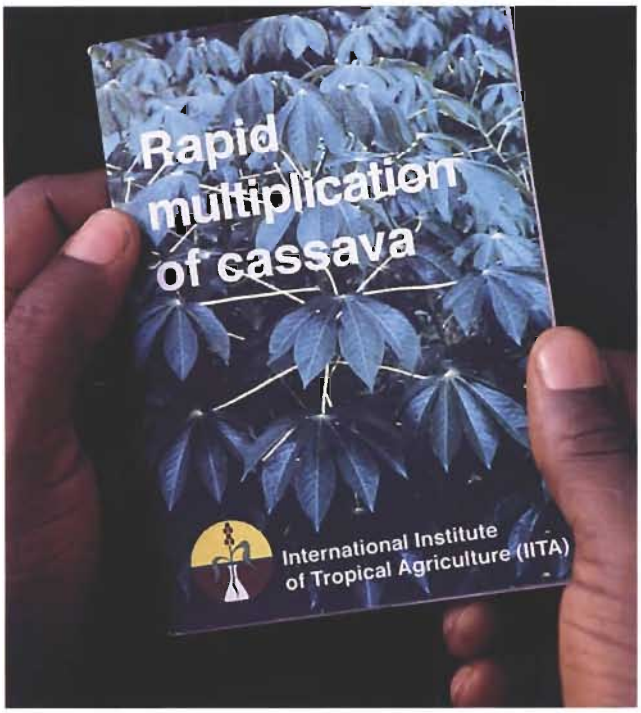
National program collaboration

1997 was a milestone in IITA's work with the Conférence des responsables de la recherche agronomique africains (CORAF), which coordinates agricultural research in West and Central Africa. Both pledged to strengthen collaboration, which is expected to enhance the adoption of IITA technologies.

The primary objective of the International Cooperation Division is to develop long-term research strategies with national agricultural research systems in Africa.

CORAF, based in Dakar, Senegal, was established in 1977 to oversee research in the French-speaking countries of Africa. Its mandate, now covering anglophone and francophone countries in West and Central Africa, is to ensure food security. Strengthened CORAF-IITA collaboration is expected to lead to better management of research resources.

IITA was approached by the International Fund for Agricultural Development (IFAD) to provide training and technical assistance to Zanzibar's Food Crops and Cash Crops Commission. This involved smallholders who grow cassava and sweetpotato, and the operation of a soil and plant laboratory and tissue culture laboratory. Rapid multiplication and distribution of cassava and sweetpotato planting material were high on the agenda. The project is supported by the World Bank. To further assist national programs, IITA's Training Unit produced a pocketbook entitled "Rapid Multiplication of Cassava."



Recognizing the wide need, IITA's Training Materials Unit produced "Rapid Multiplication of Cassava." The handy pocketbook (US$5) provides step-by-step instructions for increasing cassava planting material

In Ghana, another World Bank-financed, IFAD-executed project involving IITA was aimed at improved production, marketing, and processing of roots and tubers through adoption of new technology. As of the end of 1997, it had not yet been funded.

IITA, responding to the Democratic Republic of Congo's (DRC) need for seeds, delivered 12.4 metric tons of maize and top varieties of soybean seed to the country, in cooperation with World Vision International, within the framework of the US Agency for International Development-funded "Seeds of Change" program. The seeds are from plants bred by IITA for use in agroecological conditions in the major production areas of the DRC; they have good resistance to the prevailing diseases. They are being multiplied by the national agricultural sector and distributed to farmers.

World Wide Web

1997 saw IITA establish a site on the World Wide Web. The initial concept and design of the Web site evolved through the efforts of computer and graphics specialists, writers, editors, scientists, and others in the Institute. IITA's Internet address is http://www.cgiar.org/iita

The home page has six headings which are hypertext reference links; i.e., each heading is linked to another subheading that contains information about that particular heading. The links are research, information (IITA publications and library), partnerships, about IITA, news, and the CGIAR. The home page also contains information about IITA mandate crops and research divisions.

Being on the Internet helps meet the objective of improving the dissemination of IITA's research results. The primary objective of the International Cooperation Division is to develop long-term research strategies with national agricultural research systems in Africa.

For the Record

Research Highlights

IITA's work is organized around 16 multidisciplinary research projects and one project for the dissemination of results to national research systems. Some projects focus on production systems for specific crops or crop combinations, in some cases for a specific agroecological zone. Others are thematically oriented, cutting across commodities and agroecological zones.

IITA also serves as the convening organization for two international programs of the CGIAR: the Ecoregional Program for the Humid and Subhumid Tropics of Sub-Saharan Africa and the Systemwide Program for Integrated Pest Management.

The following section presents the goal and research highlights of each IITA project for 1997. The summaries are not exhaustive of the work begun or completed during the year; rather, they describe some key scientific results and are intended to give readers an idea of the breadth of research themes and problems being investigated by IITA scientists.

Project 1
Short Fallow Stabilization

Goal

Increase farm productivity and arrest resource degradation due to land-use intensification through sustainable short-fallow systems.

Highlights

- Herbaceous legume evaluation trials (single and mixed legume species) were established on low P soils with and without P application. The legumes included 12 accessions of *Mucuna pruriens*, 21 accessions of *Lablab purpureus*, 25 accessions of *Aeschynomene histrix*, and 54 accessions of *Centrosema pascuorum*. Preliminary results indicate large variation between species accessions for their adaptability to low P soils.
- The herbaceous legume seed collections of ILRI and IITA have been collated into a comprehensive list of some 388 seedlots. During 1997, 171 seedlots, totaling over 100 kg, were distributed to NARS and IARC scientists, mainly in West Africa.
- The center for cover crop seed and information exchange was established in Cotonou (with IDRC/IITA funding) to support cover

crop seed and information exchange in West Africa. As a first task, several tonnes of *Mucuna* seed were produced for distribution to collaborators.

- Research was undertaken at Ibadan to measure benefits of 13 herbaceous legumes for subsequent maize. On average, subsequent maize grain yield was increased by 70%, compared to the natural grass fallow.
- Field studies were conducted to investigate the influence of three *Mucuna* varieties and two levels of fertilizer on the control of *I. cylindrica* during the year of cover crop planting and one year later. After one growing season, *M. pruriens* var *utilis*, *M. cochinchinensis*, and *M. pruriens* var IRZ reduced *I. cylindrica* shoot density by 50, 76, and 68%, and shoot dry matter by 72, 92, and 79%, respectively. Maize grown one year after *Mucuna* required 50% less weeding than plots without *Mucuna*. Maize grain yield was higher in plots previously seeded to *Mucuna* than in plots without *Mucuna*.
- *Calliandra calothyrsus* hedgerow fallows and well-established *Pueraria phaseoloides* fallows can significantly suppress the growth of *Chromolaena odorata* and associated natural fallow species. At the end of 2 years of fallow, there was an 80% reduction in ground cover and a 90-95% reduction in biomass of these naturally occurring species compared to unplanted fallows.
- A legume-based system close to the farmers' practices was evaluated over a period of 2 years. Maize and legumes were intercropped in the first year, and cassava/maize intercrop was rotated in the second year. Results from the first year data showed that the legume-based systems are economically attractive.
- In 1997, farmers designed trials to integrate *Mucuna* into their maize-based systems in the northern Guinea savanna zone. A pre-maize *Mucuna* system was preferred, although many are also in favor of a maize/*Mucuna* relay system. Farmers recognized *Mucuna*'s ability to improve the soil, and to reduce weeds (including *Striga*).
- Using georeferenced databases on the importance of maize in the cropping systems and suitability of soils to support sustainable maize production, target domains for short-fallow systems were proposed. They show that cereal-based short-fallow systems are likely to have high, medium, and low impact on 386, 256, and 527 million hectares, respectively, in SSA. Potential adoption domains were also mapped. These will assist in selection of sites within the benchmark area for technology development and identify potential pilot sites for technology targeting.

Project 2
Agroecosystem Development Strategies

Goal

To guide ecoregional research and policies for poverty alleviation and sustainable development of agroecosystems in the subhumid and humid zones. Activities feed directly into the Ecoregional Program for the Humid and Subhumid Tropics of Sub-Saharan Africa (EPHTA).

Highlights

- Security over land tenure had a positive impact in Benin Republic on the adoption of *Mucuna*, though the technology is an annual crop, probably because farmers perceived its positive long-run effects on the improvement of natural resources.

About 70% of the total labor input required in cassava farming is on postharvest activities, most of which is contributed by rural women and children. Significant factors that positively influence adoption of improved cassava-processing technologies are the proportion of cassava processed, type of products, mechanization of land preparation, and the number of women with city life experience.

A farmers' survey on the use and availability of organic and inorganic fertilizers was conducted in 5 villages in the derived savanna ecoregional benchmark and 2 villages in the NGS ecoregional benchmark area. The results showed that inorganic fertilizers are used by most farmers in both benchmark areas, but that application rates vary widely between farmers, fields, and crops. Organic amendments are less commonly used, and only on specific fields.

A rapid appraisal of 2009 community-based organizations (CBOs) was completed in 475 villages. The survey shows that traditional credit-solidarity groups (tontines) (43%) and religious organizations (44%) form the overwhelming majority (87%) of village-based organizations in southern Cameroon. The study shows a strong association between the presence of NGOs and the emergence of both farmers' federations and common initiatives groups at the local level. The information gathered from the surveys is now being used in the development of broad-based partnerships with farmers' organizations and communities in the forest margin benchmark area of southern Cameroon.

Representative farm models have been built for that area. Each model will be used to evaluate potential financial and economic benefits of the new crop and natural management technologies being developed and tested in the benchmark area.

A household characterization survey was conducted in 15 villages among 225 households of the forest margins ecoregional benchmark area of southern Cameroon. Results show that, in general, households in areas with high land pressures have intensified their production systems to a much greater degree than in areas with low land-use pressure.

Project 3

Biological Control and Biodiversity

Goal

To enhance the livelihood of resource-poor farmers and maintain sustainability of farming systems through biological control and preservation of biodiversity.

Highlights

A large-scale aerial application of *Metarhizium flavoviride* against the Senegalese grasshopper was carried out, in collaboration with the Niger Plant Protection Service. Farmers preferred the mycopesticide to the chemical pesticide.

Collaborative trials with a Malian NGO demonstrated good control of Sahelian grasshoppers with mycopesticides applied by village brigades.

Ecotoxicological studies demonstrated the low negative environmental impact of the mycopesticide. The registration process for it has been initiated.

- The mass-production unit was run at full capacity, demonstrating the technical feasibility of the developed production process. Negotiations with commercial companies are well under way, and commercial production is scheduled to start in 1998.
- Participatory field trials in southern Benin demonstrated control of the variegated grasshopper at very low doses in individual fields. Reduced crop loss is estimated to be higher than the cost of biocontrol, making individual purchase and application of the biopesticide attractive.
- Biosystematic capabilities were consistently enhanced, reflected in the extent of the identification service offered, the accumulation of voucher insect specimens, and the availability of collection databases, complemented by a large reference bibliography.
- In 1997 it was documented in southern Benin that the two serendipitously introduced parasitoids, *Encarsia haitiensis* and *E. guadeloupae*, had brought under control the spiralling whitefly *Aleurodicus dispersus*, a new exotic pest of cassava and ornamentals.

Project 4

Integrated Management of Legume Pests and Diseases

Goal

To reduce the risk of crop losses in farmer's fields in sub-Saharan Africa by means of integrated pest management technologies that increase cowpea and soybean productivity in a sustainable manner.

Highlights

- Higher levels of resistance identified for flower thrips (initial progeny testing from crosses conducted under intense natural population) and PSBs in cultivated cowpea.
- Multiple pest resistance confirmed in elite cowpea breeding lines, and resistant varieties to CoBB identified.
- Preliminary results from feeding bioasssays on transgenic cowpea plants using MPB neonates indicated some level of successful transformation with *Bt* protoxin *Cry* IA genes.
- Resistance to MPB confirmed in new gene products and secondary metabolites from African yam bean obtained locally.
- A drastic disruption of the utilization of fat in the process of oogenesis in MPB in *Vigna oblongifolia* (e.g., TVNu 42) explains biochemical basis of resistance.
- MPB resistance of TVNu 72 (*Vigna vexillata*) mainly biophysical (trichomes and/other podwall characteristics). *C. tomentosicollis* resistance due both to biophysical (trichomes) and biochemical factors.
- Survey data from over 200 cowpea fields in Benin indicate very low population levels for the local strain of the thrips parasitoid *Ceranisus menes* (Hym, Eulophidae).
- Overall mortality of *M. vitrata* larvae due to pathogens 13%, higher percentages on plants with prostrate growth habit.
- Semiselective medium and polyclonal antibodies for detection of CoBB bacteria developed and tested.

- Pathogen diversity of *Xanthomonas campestris* pv. *vignicola* determined pathologically, biochemically, and genetically; host ∞ pathogen interactions studied, no races identified.
- Genetic diversity of *M. phaseolina* strains from various origins characterized.
- Existence of symptomless virus infection demonstrated; consequences for breeding programs and virus indexing assessed.
- Over 120 cowpea lines screened for resistance to viruses, including cowpea aphid-borne mosaic, blackeye cowpea mosaic, cowpea mottle, cucumber mosaic, and southern bean mosaic viruses, and the results sent to the breeder for pyramiding of resistance.
- Heat treatment disinfects contaminated seeds (CoBB and *M. phaseolina*).
- The combined use of solar drying and improved storage for cowpea demonstrated at PEDUNE pilot sites.
- PEDUNE countries have conducted trials with different formulations of neem for both field and storage applications.

Project 5

Integrated Management of Maize Pests and Diseases

Goal

To reduce pre- and postharvest losses of maize caused by insects, diseases, and fungal grain contaminants. IITA scientists work with NARES partners to diagnose constraints, test resistant germplasm, and explore options in host plant resistance, habitat management, and biological control. Combinations of control options are assembled in an integrated pest management (IPM) package and tested with the participation of scientists, farmers, and socioeconomists.

Highlights

- First discovery of oospores of the maize strain of *Peronosclerospora sorghi*, indicating that removal of crazy top at the early stage of development will preclude oospore development.
- A deployment strategy to saturate an area with DM-resistant maize variety was initiated in 9 villages across 2 local government areas of Ogbomoso in Oyo State, Nigeria. About 25 ha of land was planted and 6 tonnes of seeds generated from selected farms.
- Following establishment of an East African strain of the larval parasitoid *Cotesia sesamiae* on *Sesamia calamistis* in southern Benin, first releases have been made in eastern Nigeria.
- New candidates for redistribution BC against *E. saccharina* and *B. fusca* were identified in West and South Africa, respectively.
- Data from the trapping network has confirmed the biological control of *P. truncatus* by *T. nigrescens* in southern Benin and has revealed serious *P. truncatus* infestations in northern Benin.
- Weather-driven population models for *P. truncatus* and *S. zeamais* have been completed, and these will be linked via grain damage rates to a grain loss model for stored maize.
- Atoxigenic isolates of *Aspergillus flavus* were identified from each of four agroecologies of the Benin Republic, and characterized as to

their vegetative compatibility. Initial trials indicated good biocompetitive fitness of two of the isolates against toxic strains of *Aspergillus* spp.

The causal agent of a maize disease new to the region was identified as the basidiomycete, *Marasmiellus* spp. The symptom of the disease, a horizontal banded leaf blight, was seen in Ghana, Nigeria, and Cameroon, and was reproduced in Koch's postulates by spraying a mycelial suspension on 12-day-old maize plants.

Project 6

Integrated Management of Cassava Pests and Diseases

Goal

Increase cassava productivity in sub-Saharan Africa.

Highlights

Exotic predatory mites, released for the biological control of the cassava green mite (CGM), showed excellent establishment and spread in West Africa. In field trials, the predators reduced CGM populations by an average of two-thirds and increased cassava yields by a third, resulting in farmer benefit estimated at US$70 per ha. Based on these results, an Africa-wide biological control of the pest was initiated. The virulence of exotic isolates of the pathogenic fungus, *Neozygites floridana,* was evaluated and the indigenous pathogenic fungus, *Hirsutella thompsonii,* isolated for experimental releases.

Cassava root yield losses to the cassava mosaic disease (CMD) pandemic in western Kenya were estimated at 42%. Characterization of epidemiology and diagnoses of the whitefly vector were initiated in diverse agroecologies in West and Central Africa (Benin, Cameroon, Ghana, Nigeria), EARRNET countries (Kenya, Rwanda, and Uganda) and SARRNET countries (Malawi, Mozambique, Tanzania, and Zambia), largely within the framework of the system-wide IPM initiative.

Yield loss of 20-30% due to cassava bacterial blight (CBB) was recorded in resistant TMS 30572 and susceptible varieties comparing 2 infection levels. CBB epidemiology trial results stressed the importance of soils and weeds as inoculum sources of the bacteria and of variegated grasshopper in the transmission of the disease.

Yield loss of 30% was recorded for cassava brown streak disease in Tanzania and Malawi, with the variety TMS 30040 and five locally selected clones showing resistance to the disease.

Two new diseases of cassava, *Curvularia* leaf and stem blight on field and stored cassava stems and *Nattrassia* root and stem rot, were reported and their prevalence determined in Benin and Nigeria.

ELISA-based CMD diagnostic technology was decentralized to NARS, and PCR-based technology was established to detect new cassava mosaic virus variants.

Twelve women scientists from West and Central Africa completed postgraduate training in cassava IPM and extension methods. Eleven NARS technicians from 5 SADC countries were

trained in cassava IPM, and farmer field school training was conducted at 25 sites in West and Central Africa.

- Cassava information resources were produced. These included geo-referenced distribution maps of plant protection constraints in Ghana, Benin, Nigeria, and Cameroon; GIS maps of the distribution and characteristics of CMD in Uganda and the wider Lake Victoria basin; cassava IPM extension materials; and directories of personnel, institutions, cassava projects, databases of gray literature, bibliographies, and cassava references.

Project 7
Improving Plantain- and Banana-based Systems

Goal

Development and dissemination of improved technologies for sustainable Musa production in different ecologies of sub-Saharan Africa.

Highlights

- Geo-referenced databases. A diagnostic survey of pests and diseases in Uganda has been completed.
- Knowledge of pests and diseases enhanced. Identification of banana streak virus in Benin, Ghana, Kenya, Malawi, Nigeria, Tanzania, and Uganda confirmed its widespread occurrence. Also, a new virus, tentatively named banana die-back virus, was identified in Nigeria.
- Distribution patterns for nematode species were determined in Ghana, Nigeria, Rwanda, and Uganda.
- Yield losses from pests and diseases determined. Yield loss in plantain (AAB) from nematodes and weevils in Ghana was established. More than 75% of plants infested with both nematode and weevil failed to reach maturity, and there was an overall yield loss of 85% from both pests.
- Yield losses in East African highland bananas (EAHB) (AAA) from weevil increased with crop cycle, reaching 50% in the 4th year, while lesion nematodes caused a 30–40% yield loss in EAHB, but no detectable yield loss in cooking/beer banana (ABB).
- IPM strategies available. Pseudostem traps reduced weevil numbers in on-farm trials in Uganda, and endophytic fungi isolated from banana corms caused egg mortality under laboratory conditions and reduced weevil damage in nursery trials.
- Utilization of germplasm enhanced. Breeding capability was fully established in East Africa, following transfer of breeding technology from IITA-Onne. A first diploid hybrid, derived from highland banana and with black sigatoka resistance, was selected for use in EAHB breeding.
- Characterization of host plant tolerance and resistance to nematodes, including the identification of 4 resistant and tolerant hybrids, was achieved.
- Improved genotypes and populations available. Eight new triploid and tetraploid plantain and banana hybrids were selected, based on high bunch weight, large number of hands per bunch and

large fruits, black sigatoka resistance, and good growth habit. Selection for BSV resistance/tolerance has identified 4 promising banana and plantain hybrids.

- Virus indexing techniques were developed to ensure that IITA's plantain and banana hybrids can again be distributed to other African countries.
- NARS capability enhanced. Twenty-eight national scientists were trained in *Musa* breeding, nematology and/or entomology, and the use of BSV diagnostics.

Project 8

Integrated Management of Striga and Other Parasitic Plants

Goal

To reduce infestations of parasitic plants with a focus on Striga spp. The project is implemented in collaboration with NARES. Through integrated management practices, emphasizing cereal rotations with selected nitrogen-fixing cultivars of legumes, crop yield losses due to parasite infestations are reduced while soil conditions are improved.

Highlights

- A very positive external review recommended that a world center for parasitic plant research be developed at IITA.
- Demonstration of an integrated crop and land management program for *Striga hermonthica* control was conducted in the moist savanna of Nigeria. Crops planted in this season included cultivars of soybean, cowpea, and cotton selected for their ability to stimulate *S. hermonthica* seed germination. Improved tillage and weed control practices were also implemented. A successful field day was conducted for farmers, NARES, and NGOs to observe the demonstration and learn about integrated *Striga hermonthica* control.
- Significant *Striga hermonthica* seedbank reduction was again demonstrated in farmers' fields, using rotations with selected soybean cultivars.
- Incorporation of acetolactate synthase (ALS) inhibitor resistance into open-pollinated IITA maize lines and inbreds was completed.
- Ethylene-producing bacteria were identified and successfully tested for their ability to stimulate *S. aspera*, *S. gesnerioides*, and *S. hermonthica* seed germination. Results showed that 2 isolates of *Pseudomonas* sp. were more effective than the definitive synthetic germination stimulant (GR24) in stimulating parasite seed germination.
- Over 1600 progeny from 5 maize populations were screened under artificial infestation with *Striga hermonthica* in replicated trials. Partially inbred lines from TZL Comp. 1 C3 with very low *S. hermonthica* emergence in the field were selected. Six STR populations were multiplied for on-farm trials, with funding from the Korean government, to be organized by PASCON in 1998. A tolerant early maturing cultivar, EVDT 97STR, as well as EV-IWDSTR, and a resistant inbred (1102), will be available for regional testing in 1998.

- Seventy-five S2 lines were extracted from a backcross population derived from *Zea diploperennis* and initial crosses were made for molecular mapping of resistance in a Rockefeller-funded project in collaboration with CIMMYT and KARI. These lines were also sent to CIMMYT and KARI, Kenya for evaluation under natural *S. hermonthica* infestation.
- A survey on farmers' harvest practices related to *S. hermonthica* seed contamination of crop seeds was completed on about 80 farmers' fields cropped to cereals. A large proportion of cereal seed samples was found contaminated before and after harvesting. The results confirm the role of the farmer's harvesting method in the contamination of crop seeds and the spread of *S. hermonthica* with crop seeds.
- A total of 25 improved cowpea breeding lines were developed with resistance to *Striga gesnerioides*. A project on cowpea resistance to *S. gesnerioides* has been funded in collaboration with the University of Virginia, USA.
- Hybridization and cytological studies with *S. hermonthica* and *S. aspera* showed that the 2 species differ by only one haploid chromosome, they hybridize readily, and that hybrids can be found in fields where the 2 species are sympatric.

Project 9
Improving Postharvest Systems

Goal

To increase the income-generating capability and improve the nutritional status of farmers, processors, and consumers in both the rural and urban communities of Africa.

Highlights

- Results from monitoring surveys in the third year of the Soybean Utilization Project in Nigeria, Ghana, and Côte d'Ivoire showed increasing interest in the use of soybean at the household level.
- A socioeconomic analysis of improved postharvest processing showed that the majority of equipment significantly improved income generation. The most remunerative equipment had the capacity for multi-crop applications.
- Adoption of the high-quality cassava flour technology is increasing in Nigeria, and there is evidence that similar activities have started in Tanzania. Developed at IITA, the technology is being disseminated through NGOs, extension agents, and from farmer/processor to farmer/processor.
- Surveys in Nigeria revealed that cassava is being used as the raw material for several commercial-scale processed products, including biscuit manufacturing, starch extraction, noodle production, and industrial distillation into alcohol.
- Results from a study on yam chips processing was completed in Benin, Nigeria, and Togo. This investigation showed that yam processing was highly profitable when developed with specific varieties and in association with short fallow systems.
- Tests on the efficiency of cassava-processing equipment, in Uganda and Kenya, led to the development of a number of modified designs in processing equipment for root crops.

- Cassava processing plants were established in three districts of Uganda. The projects were designed to develop stronger linkages between IARCs, national programs, NGOs, and community-based organizations (CBOs), and this approach proved to be highly effective, with an internal rate of return of 30% in the first year.
- Four training courses were held on manufacturing and servicing of improved agro-processing equipment for 32 technicians in Benin, Ethiopia, Ghana, Guinea, and Togo.
- A workshop was organized in Nigeria, which brought together industrialists, cassava producers, NGOs, extension agents, extension services, and government agencies for product quality.

Project 10
Farming Systems Diversificaton

Goal

NARES and international system scientists develop, with farmers, new, diversified, and complementary income-generating enterprises in West and Central Africa.

Highlights

- **Multistrata systems.** Focused group interviews with 79 villages in the forest margins benchmark area and the East Province of Cameroon were conducted to examine the reaction of cocoa farmers to recent relative price declines in the cocoa market. Farmers were observed to have diversified their holdings in three ways: diversification from tree crop cultivation into food crops (most common), diversification within the plantation through an increased inclusion of fruit trees, and diversification into other tree crops.
- **Speciality crop systems.** A survey of over 500 market women in the humid forest zone of Cameroon indicated that average daily earnings selling indigenous vegetables were significantly lower than those for exotic vegetables, such as tomatoes and cabbage. However, indigenous vegetables offer a particularly important employment option for the lower economic rungs of urban and rural women in Cameroon.
- Cassava leaves are an important leafy green vegetable in Central Africa. Six cassava clones with different plant architectures were selected to investigate the possibility of increasing edible leaf production. Preliminary results indicate big differences in the production of edible leaves. Although pruning facilitates leaf harvest by women, monthly harvests can lead to a significant drop in leaf yield. Pruning also decreases subsequent tuber yields.
- **Inland valley systems.** Cowpea variety IT90K-284-2 was shown to be a good crop for diversification of crop production in inland valleys of the northern Guinea savanna benchmark area in Nigeria. Over 2 years of testing on farmers' fields during the dry season, it produced more than 1 t/ha of grain, even without insecticide application, and a net revenue of approximately US$500/ha.
- **Mixed farming systems.** The incipient market for crop residues is expanding in the Guinea savannas of West Africa. An

economic analysis showed that the future of the market for crop residues is constrained by the transportation cost, which was found to represent 47–58% of their total cost.

A survey was conducted with 150 farmers in northern Nigeria to assess the impact of a cattle fattening program on the socioeconomic well-being of the participating farmers. It showed a net benefit of US$113 per cattle fattened or about US$450 per farmer per year. The findings suggest that income generation could be increased if the cost of feeding could be reduced and the supply of both veterinary services and medication could be improved through a credit facility program in favor of cattle fatteners.

Reciprocal benefits from crops and livestock in a mixed farming system were investigated from a survey of 150 agropastoralists in two areas at different gradients of resource-use intensification in the northern Guinea savanna of Nigeria. The productivity of the system was threefold higher in a market-driven area than in a population-driven area. Crop and livestock enterprises yielded the highest returns to land at higher cultivation intensity, while the returns to labor were the highest at low cultivation intensity for areas with poor and good market opportunities. In areas where land becomes scarce and labor abundant, increased intensification in resource use is driving farming systems towards greater crop-livestock integration and productivity.

Project 11
Cowpea-Cereals Systems Improvement in the Dry Savanna

Goal

To develop adoptable crop varieties and agronomic practices for the Sudan savanna and Sahel, which will increase the total productivity of the dominant farming systems. The project integrates research by scientists from IITA, ILRI, and ICRISAT who are working on grain legumes, cereals, and livestock in the dry savannas of West Africa. Research institutes in Nigeria (IAR/ABU) and Niger (INRAN) are also active members.

Highlights

Constraints analysis. Survey of cowpea fields in the Sudan-Sahelian region in 1996 and 1997 indicated a decreasing gradient of *Maruca* pod borer pressure from high rainfall areas to low rainfall areas, but an increasing pressure of aphid, thrips, *Striga gesnerioides*, and drought.

Improvement of local landraces. From 150 local landraces of cowpea screened in 1996, 9 were crossed with donor parents for incorporation of genes for resistance to aphid, thrips, bruchid, *Striga*, *Alectra*, and viruses by the backcrossing method.

Improved grain-type cowpea varieties. A total of 746 new cowpea breeding lines were evaluated for grain and fodder yields in different cropping systems. A number of lines showed considerable resistance to several biotic constraints and yielded between 1.5 and 2 t/ha.

Improved cowpea varieties for intercropping. Several new improved breeding lines yielded 50 to 200% higher than local varieties under intercropping with millet and sorghum, without insecticide spray.

Research Highlights

Screening method for drought tolerance. A simple method (using a shallow box for seedling screening) has been developed, which discriminates between drought-tolerant and susceptible lines of cowpea. Using this method, 2 types of drought-tolerant lines have been identified and their genetics studied.

Early maize and soybean varieties. The variety trials in 1996 and 1997 have shown that improved extra-early-maturing maize varieties can yield over 3 t/ha in areas with about 600 mm rainfall, and early-maturing soybean varieties produce 1.5-2.0 t/ha grain yield without insecticide, rhizobia inoculum, or fertilizer.

Farmer-to-farmer diffusion of improved cowpea seeds. Preliminary results of IITA/GTZ farmers' participatory seed multiplication and diffusion program have shown great promise for rapid distribution of improved cowpea seeds. Three kg seed of one improved cowpea variety was given on credit to each of 36 selected farmers in June '97. By Dec '97, a total of 6672 kg seed had been produced by these farmers. Similarly, farmer-to-farmer diffusion of an improved cowpea variety has increased cowpea cultivation in the dry season from 1 farmer in 1993 to over 2000 farmers in 1997 in northern Nigeria. Socioeconomic studies revealed that the main driving forces of dry-season cowpea were membership in farmers' association; high grain yield; farm size; and contact with extension workers.

Project 12
Improvement of Maize-Grain Legume Systems in the Moist Savanna of West and Central Africa

Goal

To enhance the productivity of maize-grain legume systems in the moist savanna by improving crop varieties and the management of cropping systems.

Highlights

The maize breeding team of scientists based in Côte d'Ivoire and Nigeria made significant advances in the development of both open pollinated varieties and hybrids with higher levels of N-use efficiency (NUE) and drought tolerance. The 10 best families selected from the low N tolerant pool had 60% higher grain yield under N stress and 19% higher yield under high N than the commercial hybrid. These results confirmed the progress that was reported for this trait in 1996.

The improvement of maize for NUE is expected to have a major impact on both the productivity and sustainability of maize-grain legume systems in the moist savanna, with the majority of producers not able to obtain adequate quantities of N fertilizers.

About 200 soybean breeding lines were evaluated for total nitrogen produced through fixation (from the atmosphere). This has enabled selection of breeding lines that produce high grain yield and also contribute nitrogen to the production systems even when the grain is harvested. Several breeding lines have been identified with grain yield equal to the best check and producing 50% to 75% higher fodder yields. These new breeding lines have the potential to considerably improve the productivity and sustainability of the farming system.

Strip cropping maize with improved varieties of cowpea gave encouraging results for both maize and cowpea grain yields with no insecticide spray. Both maize and cowpea were planted at the beginning of the rainy season, as this helps the cowpea to escape the time when the most damaging insects are present in high numbers.

Response of key maize and soybean genotypes could be predicted with simulation models in diverse cropping systems in on-station studies. Using models, we can suggest ways for maximizing nutrient-use efficiency in various agroecologies. Initial on-farm experimentation and modeling suggest weaknesses in current understanding of physiological processes as well as interactions among N and P nutrients. Regional analysis, combining simulation and geographic information system (GIS), shows large areas of potential impact for soybean-maize rotational systems in West Africa. Models and GIS tools are being combined to develop a decision-support system that can be used by NARS to help identify the appropriate maize-grain legume systems for testing and dissemination.

Project 13
Improvement of Yam-based Systems

Goal

To ensure that farmers achieve a sustainable increase in the productivity of yam-based production systems through adoption of improved technologies. The project develops relevant technologies targeted at enhanced productivity of such systems, in partnership with NARES.

Highlights

Gender implications for the development of resource management technologies for yam production were investigated in a survey of more than 600 yam growers in the southern Guinea savanna of Nigeria. Women were observed to be heavily involved in yam production, contrary to conventional belief. For both sexes, yam was mainly grown in newly cleared land from long fallow and for a continuous period of less than 3 years. The major constraints in yam production for both sexes were pests and diseases in the field and during storage. Other constraints were weeds, declining soil fertility, lack of staking materials, and labor. It was concluded that the practice of growing yam first on newly cleared land and avoiding continuous yam cultivation may have more to do with the control of pest and pathogen buildup than with declining soil fertility.

In studies at IITA, Ibadan, *Scutellonema bradys* (yam nematode) caused 60% loss of marketable tubers under low nematode pressure, and 100% loss under high pressure. Both situations led to complete loss of planting material.

A survey of yam viruses in Nigeria revealed the presence of yam mosaic potyvirus (previously reported from Nigeria); *Dioscorea alata* potyvirus and cucumber mosaic cucumovirus (previously reported in yams in West Africa); *Dioscorea alata* badnavirus and *Dioscorea dumetorum* potyvirus (not previously reported from Africa). Three new viruses, tentatively named *Dioscorea* mottle, *Dioscorea* mild chlorotic, and *Dioscorea* necrosis viruses, have been isolated from their natural *Dioscorea* spp. hosts. Diagnostic techniques have been developed for all yam viruses found to date in Nigeria.

- A protocol to ensure the safe international movement of *D. alata* germplasm was developed. Consequently, two genotypes of *D. alata* were certified for international distribution for the first time. Eleven new genotypes of *D. rotundata* were also certified for international distribution.
- Over 6,300 virus-tested plantlets, representing 22 genotypes of *D. rotundata*, were delivered to NARS in 7 countries while 6,767 minitubers, produced from virus-tested plantlets of the same species, were distributed to NARS in 8 countries.
- The development of yams in Uganda got a major boost during the year. More than 140 farmers (including 104 women) from 3 districts were trained in techniques for rapid field/nursery multiplication of yam planting materials. Twenty-six varieties of introduced *D. rotundata* and 7 local varieties of *D. alata* and one of *D. cayenensis* are under rapid field multiplication. Over 84% of 3,000 virus-tested plantlets of *D. rotundata* were successfully established, following a fresh introduction of 22 genotypes from IITA headquarters.
- Prerelease varietal trials in Nigeria, conducted in partnership with the National Root Crops Research Institute, confirmed the superiority of 3 IITA-derived hybrid clones of *D. rotundata* over popular local varieties used as checks.

Project 14

Cassava Productivity in Lowland and Mid-Altitude Agroecologies of Sub-Saharan Africa

Goal

To develop, evaluate, and promote improved and adapted cassava germplasm for the lowland and mid-altitude agroecological zones of sub-Saharan Africa, and to develop agronomic and other practices to ensure sustainable cassava production and utilization. Interaction with national programs is fostered through long-established links in West and Central Africa, two root crop research networks (EARRNET and SARRNET) covering East and Southern Africa, and cassava research at the East and Southern Africa Regional Center (ESARC) in Uganda.

Highlights

- Efforts to broaden the genetic base of cassava in SSA continued, with the distribution of 497,000 seeds of broad-based improved populations (2,764 families) with multiple pest resistance and special traits to national programs in 21 countries. IITA also received 30,000 seeds derived from landraces of 8 SSA countries and 70,000 seeds from CIAT with adaptation to the semiarid, mid-altitude, and subtropical ecologies, respectively.
- Improved genotypes incorporating resistant genes from African landraces, combining acceptable agronomic and end-user characteristics with very high levels of multiple resistance to cassava mosaic disease (CMD), bacterial blight (CBB), anthracnose (CAD), and green mite (CGM) have been developed. Forty-one of these genotypes were virus tested and certified, and a total of 344 genotypes are now available at IITA for international distribution. Of these materials, IITA distributed 21,040 in vitro plantlets to 9 collaborating countries. In addition, the production and delivery was completed of 18,090 certified cassava in vitro

plantlets to the Angola Seed of Freedom Project, through World Vision International.

- Sourcing seeds from broad-based germplasm at IITA, Ibadan, the EARRNET/ESARC regional germplasm program in Serere, Uganda distributed a total of 1,222 promising clones to the national programs of Rwanda (593 clones), Kenya (555 clones), and Uganda (74 clones) for further evaluation under local conditions.
- Collaborative work with the International Livestock Research Institute for smallholder crop-livestock farming systems showed large variations in root and foliage yields and nutritive value.
- Early-bulking varieties continue to be identified from IITA germplasm. In Nigeria, genotypes adapted to dry-season cropping in the inland valley ecosystem could give average yields of 25 tonnes/ha and dry-matter percentage of 36% in a 6-month period.
- Nineteen participants were trained on rapid multiplication of cassava and sweetpotato in Rwanda, in an effort to resuscitate research and development of these commodities.

Project 15

Molecular and Cellular Biotechnology for Crop Improvement

Goal

To advance the efficacy of genetic improvement and germplasm dissemination beyond the norms associated with the application of conventional breeding and diagnostic techniques. The project makes new molecular and cellular tools and products available to collaborating scientists working on IITA's mandated crops.

Highlights

- Roots and plantlets were obtained from 3-week and 7-week-old immature seeds, respectively, in *D. alata*.
- Transgenic cowpea lines were produced with constructs containing *Gus* reporter genes, *Bacillus thuringiensis* genes coding for the *Cry* IAb and *Cry* IAc insecticidal crystal endotoxin. The transgenics are being characterized and evaluated for insect resistance.
- Putative genomic and cDNA fragments corresponding to lectins, thionin, phenylalanine ammonia lyase (PAL), and chalcone synthase (CHS) genes associated with pest resistance have been isolated from African yam bean, wild cowpea, and/or cultivated cowpea. Most of the fragments correspond to the predicted size.
- Affinity chromatographic procedures have been used to purify lectins from African yam bean and *V. vexillata*.
- Six mapping populations from controlled hybridizations between selected yam genotypes of *D. rotundata* and *D. alata* were developed for use in developing linkage maps. The parental lines used for generating the mapping populations were selected for their contrasting phenotypic expressions for virus and nematode resistance in *D. rotundata*, and for anthracnose in *D. alata*.
- Recombinant inbred (RI) lines developed for the genome mapping of cowpea are now available. Some DNA markers have been generated and placed on the map which presently spans 665 cM,

indicating an average map distance of 7.2 cM. Additional DNA markers are being generated for placement on the map.

- Some markers associated with quantitative trait loci (QTL) in cowpea, such as days to flowering, 100-seed weight, and days to pod maturity were identified, among others.
- Candidate microsatellite markers for parthenocarpy, earliness, and regulated suckering in plantain have been identified and will be tested further.
- IITA, in collaboration with John Innes Centre and Horticulture Research Institute (UK), developed reliable detection systems for *Dioscorea alata* badnavirus, facilitating safe movement of improved *D. alata* germplasm.
- Immunocapture reverse-transcriptase polymerase chain reaction (IC-RT-PCR), a very sensitive protocol, was developed to detect yam mosaic potyvirus.
- Scottish Crops Research Institute (Dundee, UK) donated to IITA six hybridoma cell lines raised against cassava mosaic geminiviruses. Ascetic and culture fluids were produced at IITA and distributed to 10 laboratories in Africa, thereby enhancing the capability of national programs to diagnose geminiviruses in cassava.

Project 16
Conservation and Genetic Enhancement of Plant Biodiversity

Goal

To improve the conservation and utilization of plant biodiversity to promote sustainable food production in sub-Saharan Africa.

Highlights

- Field collections were made of 330 local cassava accessions from Togo, 97 local yam cultivars from Côte d'Ivoire, and 11 wild yam and 25 wild *Vigna* spp. from Nigeria. A total of 331 accessions of yam and 44 accessions of cassava was transferred from the field genebank to in vitro cultures. A large number of indigenous yam cultivars (557) was collected in Benin Republic. A total of 388 seedlots of herbaceous legumes were identified and cataloged, by combining former ILRI and IITA collections, 171 seedlots were distributed for experiments in IITA/ILRI (42) and to NARS (74) and NGOs (55).
- User-friendly database management systems for over 37,000 germplasm accessions of cowpea, wild *Vigna* spp., Bambara groundnut, soybean, rice, yams, and cassava were developed.

Genetic diversity and heterotic groups in Guinea yams (*D. rotundata and D. cayenensis*) and their wild relative *D. praehensilis* were assessed, using amplified fragment length polymorphisms (AFLPs). Molecular markers were used for the first time to characterize landrace collections of plantains.

- Many improved breeding lines (431) and African landraces (561) of cassava are being evaluated and characterized for agrobotanical traits, and resistance to cassava mosaic disease (ACMD), cassava bacterial blight (CBB), and cassava anthracnose disease (CAD).

From a study of combining ability of *Musa* hybrids, 18 promising diploid and 6 triploid banana hybrids were identified with large bunch size, large number of hands and fruits, big fruit size, improved ratooning, earliness, and resistance to black sigatoka. A promising diploid hybrid with resistance to nematodes was identified.

Maize varieties were extracted from TZL COMP4 and TZE COMP3 and were higher yielding than varieties extracted from previous cycles of selection. Two reciprocal populations formed for the mid-altitudes were screened for resistance to maize streak virus, *Exserohilum turcicum*, and ear rot.

Four maize lines from TZPB-SR prol. C1 had over 90% prolific (2-eared) plants as well as high yield and disease resistance in the forest zone of Nigeria. Across the forest zone and savanna sites, the best line had an average yield of 6.5 t/ha, with 70% prolific plants. S_2 and S_4 testcrosses from two white maize populations (IWD and IWF) and their STR versions produced over 50% higher yield than the commercial hybrid Oba Super 1.

Some inbred lines were identified (e.g., 1102, 1309) with levels of resistance to *S. hermonthica* comparable to or better than that of inbred 1368. Hybrids generated from these lines were high yielding and resistant to abiotic stresses.

Some 25-30 S_1 families derived from early-maturing maize populations (DR-W Pool and DR-Y Pool) with drought tolerance and resistance to maize streak virus were selected for recombination.

Project 17

Improving the Dissemination of IITA Research Results

Goal

To strengthen the effectiveness of NARS in the generation and utilization of appropriate research results. Major activities are human resource development; project development and monitoring; technology transfer among NARS; information dissemination; and public awareness generation.

Highlights

Group training courses were held both at IITA and in several countries on matters such as rapid multiplication of cassava and sweetpotato, banana and plantain research, biometric applications, soil and plant analysis.

IITA played a lead role in intercenter collaboration on training. A meeting involving NARS and IARCs was held at IITA in November 1997. The intercenter training group is now called the IARCs and NARS Training Group (INTG).

The Technology Testing & Transfer Unit initiated research support in various countries in biological control of *Striga hermonthica*, mango mealybug, and water hyacinth.

As for training materials, ten IITA Research Guides (IRGs) were produced during 1997. Fifteen IRGs were distributed to 125 addresses in several countries. Collaboration on the production of training materials took place between IITA and Ghana, Côte d'Ivoire, Zambia, CIMMYT, and ICRISAT.

- Information was generated and disseminated for research purposes and for public awareness generation. There has been a substantial increase in the volume of publications available in French.
- The Library continued to provide assistance to a wide range of scientists and students.
- Public awareness is an important aspect of the corporate activities of IITA. IITA's reseach results and their impact have been presented in various fora. Information has been routinely disseminated through news releases, weekly articles in newspapers, CGIAR publications, international and local radio.
- EARRNET, SARRNET, and WECAMAN, the EU-OFAR, TT&TU, and the GTZ-supported Seed Project continued to provide a strong link between IITA and NARS in technology transfer.
- IITA-NARS interaction was further strengthened by IITA's lead role in preparing a USAID/OFDA-supported strategic plan to mitigate the effects of the El Niño weather disturbances, using cassava and sweetpotato, for countries in East and Southern Africa.
- IITA and CORAF held a meeting to discuss working relations and the harmonization of research within the West/Central African subregion. It resulted in an agreement to conduct regional research under the umbrella of CORAF, and to harmonize research networks on maize, and on roots and tuber crops.

Project 18

Ecoregional Program for the Humid and Subhumid Tropics of Africa

Goal

To assist smallholder and medium-scale farmers to improve their well-being and alleviate poverty through the use of sustainable production technologies and postharvest systems that increase productivity and food security and minimize natural resources degradation.

Highlights

- The 1997 EPHTA work plan, which focused on benchmark area development and pilot studies, was endorsed by the Program Committee (PC) at its first meeting held at IITA, Ibadan, 24-26 Feb 1997.
- Benchmark area development. All 5 countries hosting the 6 benchmark areas appointed Benchmark Area Coordinators. Several meetings were held in all benchmark areas to sensitize stakeholders and potential EPHTA partners.
- Characterization surveys. Surveys have been completed in the forest margins benchmark area in Cameroon, and in the northern Guinea savanna and the degraded forest benchmark areas in Nigeria.
- The forest margins benchmark area in Cameroon was officially launched on 26 May 1997 in Yaoundé, as was the degraded forest benchmark area in southeastern Nigeria on 6 Oct 1997 at Owerri.

- Nominations have been received from countries for membership of the 7 working groups indicated in the program document. The working groups will be formed and become operational in 1998.
- From 12 to 16 May 1997, a workshop on ecoregional research methodology was held in Cameroon. It was attended by 3 participants from each of the 6 benchmark areas, including the Benchmark Area Coordinators and each of the Pilot Site Coordinators. The workshop was also attended by a 5-man delegation from CIRAD and representatives from ILRI, WARDA, and IITA, the organizing center.
- From 15 to 19 Sep 1997, EPHTA, in collaboration with the Systemwide Programs for Integrated Pest Management (SP-IPM) and Alternatives to Slash-and-Burn (ASB), sponsored the Integrated Weed Management Workshop, which was held in Yaoundé, Cameroon. It was attended by participants from EPHTA member countries, representatives from WARDA, CIRAD, NRI, and IIBC (Britain), and IITA.

Project 19
Systemwide Program on Integrated Pest Management

Goal

To ensure, by encouraging better communication, coordination, and the adoption of more effective approaches, that CG research on integrated pest management (IPM) is more responsive to the needs of IPM practitioners, gains wider recognition, and thereby contributes fully to sustainable agricultural development.

Highlights

- Researchers from many national programs and several international centers participating in the intercenter project on whiteflies and geminiviruses, have begun field work at numerous sites in Africa and Latin America, with close support from specialist laboratories in Europe and North America. This technically and organizationally complex project is the first to be launched under the auspices of the Systemwide Program on IPM. Its successful establishment, under the leadership of CIAT, will serve as a model for future project development.
- In this first, diagnostic phase of the project, researchers in the different regions will use a common set of methodologies to assess the importance of losses associated with different combinations of crops, viruses, and their whitefly vectors. The knowledge gained will provide a sound basis for prioritizing future research efforts.
- In Africa, recognizing the urgency of the situation resulting from a highly destructive outbreak of African cassava mosaic disease, researchers involved in the project are moving rapidly to carry out analytical research and implement appropriate counter-measures. In this regard, the network of collaborators and sound knowledge base already established by ESCaPP and IITA's other root crop research and development efforts have been an important factor in facilitating the timely launch of project activities.
- A workshop on management of weeds in the farming system, convened at IITA's Humid Forest Station in September, pioneered a new mode of collaboration between the Institute and various inter-institutional initiatives. The workshop cosponsored by the SP-IPM,

EPHTA (both of which are led by IITA), and ASB (the intercenter initiative on Alternatives to Slash-and-Burn, led by ICRAF) was co-convened by IITA and WARDA. Weed scientists from national programs across West and Central Africa came together with disciplinary specialists from the involved centers and from various institutions in Europe to analyze weed problems encountered in the region, examine options for tackling them, and outline plans to carry out the necessary research. Several detailed research proposals are now being prepared within the framework of EPHTA, with plans for pilot studies at various benchmark sites in the different agroecological zones.

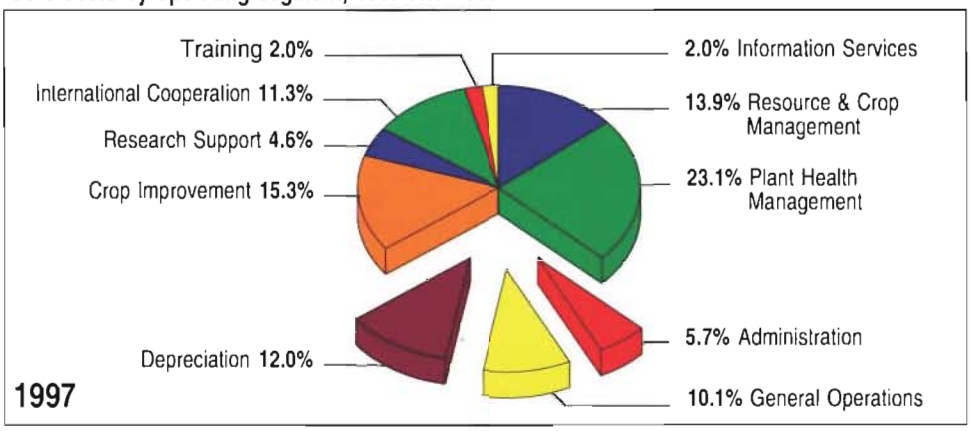
Other meetings of intercenter task forces were held, focusing on specific topics. When available CGIAR information is brought together into an authoritative document during 1998, it will provide a more reliable basis for researching and implementing sustainable pest management solutions.

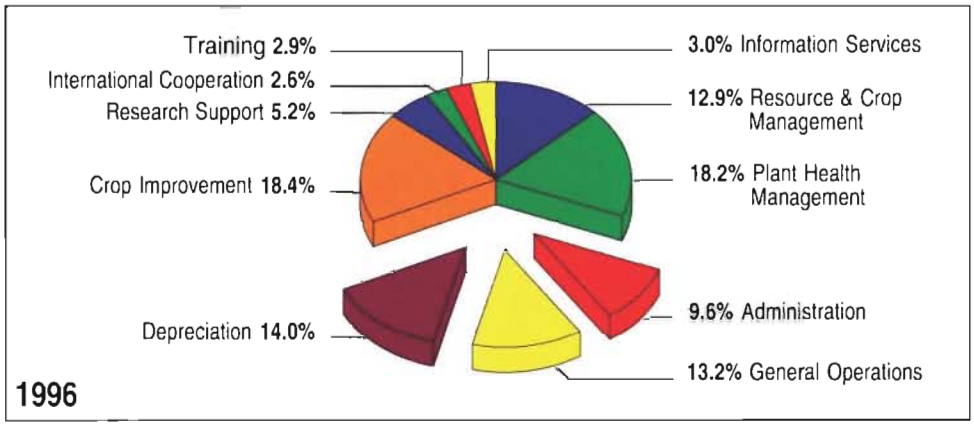
Graduate Research Completed at IITA in 1997

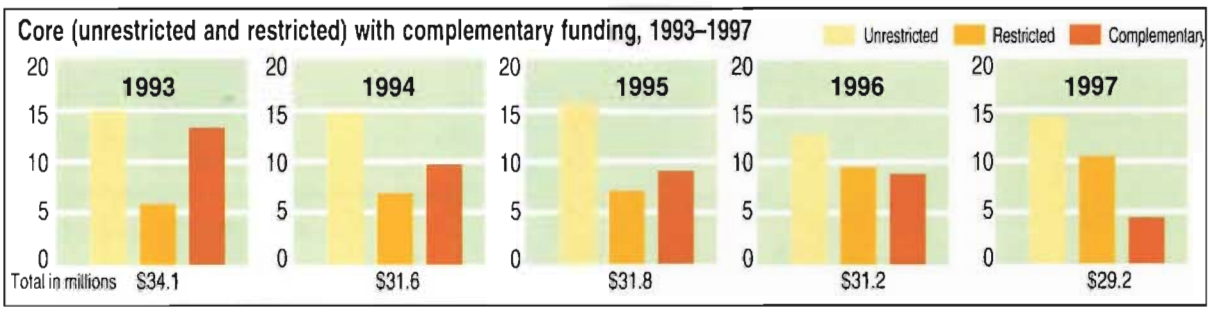
Degree	Country	Division	University	Sponsor(s) Network	Name	M/F	Research topic
Crop Improvement							
PhD	Nigeria	CID	University of Ibadan, Nigeria	IITA/Self	Daniel, I.	M	Storage of seeds and pollen grains of yams (*Dioscorea* spp.) for germplasm conservation and enhancement in crop improvement
PhD	Nigeria	CID	University of Ibadan, Nigeria	Self	Akparobi, S. O.	M	Response of cassava (*Manihot esculenta* Crantz) clones to temperature regimes
PhD	Sierra Leone	CID	Njala University, Sierra Leone	IITA	Lahai, T. M.	M	Comparative studies on yield physiology and quality aspects of cassava (*Manihot esculenta* Crantz) grown in the lowland and upland
PhD	Nigeria	CID	University of Jos, Nigeria	Self	Abimiku, S. E.	M	Genetics of resistance to *Ascochyta* blight disease of cowpea
PhD	Nigeria	CID	University of Jos, Nigeria	Self	Yilwa, V.	F	Genetics of plant type and branching habit in cowpea
PhD	Cameroon	CID	Obafemi Awolowo University, Ile-Ife, Nigeria	Self	Hankoua, B. B.	M	Micropropagation and diosgenin production of *Dioscorea dumetorum*
PhD	Nigeria	CID	University of Ibadan, Nigeria	Italian grant	Ikea, J.	M	Investigating the transformability of cowpea by particle bombardment
MSc	Belgium	CID	Katholieke Universiteit Leuven	SP	De Beule, Hilde	F	Evaluation of the damage by nematodes to the size of the root system of plants at flowering stage
MSc	Uganda	CID	Makerere University, Uganda	IITA-ESARC	Bukenya, C.	M	Utilization of cassava in a rural economy with specific reference to processing and marketing of cassava-based products
MSc	Benin	CID	Ahmadu Bello University, Zaria, Nigeria	IITA/HF	Adjadi, O.	F	Genetic variability in cowpea, *Vigna unguiculata* Walp under various crop management systems
MSc	Nigeria	CID	University of Ibadan, Nigeria	Self	Egesi, Ngozi C.	M	Taxonomy of the African wild *Vigna* gene pool: *Vigna luteola* Bentham and *Vigna marina* Merrill
MSc	Nigeria	CID	University of Ibadan, Nigeria	Self	Onibokun, A.	F	Control of bacterial contaminations in yam cultures: use of antibiotics
Plant Health Management							
PhD	Uganda	PHMD	University of Reading, UK	RF	Tusheremeirwe, W.	M	Assessment of banana pathogens in Uganda with emphasis on factors favoring development of black sigatoka
PhD	Nigeria	PHMD	University of Reading, UK	IITA	Olatinwo, R.	M	Incidence of *Stenocarpella macrospora* on maize and evaluation of potential management strategies
PhD	Eritrea	PHMD	Georg August University Gottingen, Germany	BMZ	Fessehaie, A.	M	Development of diagnostic methods for cassava bacterial blight
PhD	Gambia	PHMD	University of Reading, UK	IIBC DFPV	Sidi, S.	M	Synergistic effect of the fungus *Metarhizium flavoride* with pyrethroid and insect growth regulator insecticides for the control of grasshoppers and locusts
PhD	Germany	PHMD	Humboldt University Berlin, Germany	BMZ/IITA	Lorek, C.	M	*Prostephanus* fungal antagonists Honduras and Benin

Degree	Country	Division Network	University	Sponsor(s)	Name	M/F	Research topic
MSc	Senegal	PHMD	University of Ghana, Legon	IITA/FF	Diop, K.	F	The biology of menes *Ceranisus* (Walker) (Hym., Ghana, Eulophidae), a parasitoid of the bean flower thrips *Megalurothrips sjostedti* Trybom (Thys., Thripidae)
MSc	Nigeria	PHMD	University of Ibadan, Nigeria	Self	Odu, B.	M	Characterization of a yam potyvirus in *Dioscorea alata*
MSc	Cameroon	PHMD	University of Nigeria, Nsukka	IITA	Abang, M. M.	M	Characterization of populations of *Colletotrichum gloeosporioides* (Penz.) from yam-based cropping systems in Nigeria
MSc	Uganda	PHMD	Makerere University, Uganda	RF	Abera, A. M.	F	Timing of attack by the banana weevil and damage distribution in the host plant
Resource and Crop Management							
PhD	Nigeria	RCMD	University of Nigeria, Nsukka	GTZ/Self	Asawalam, O. D.	M	The role of earthworms in sustaining soil fertility and crop production under subhumid and humid tropical conditions
PhD	Nigeria	RCMD	University of Ibadan, Nigeria	IITA/Self	Onyia, N.	F	Movement and persistence of imazapyr in soils of the moist savanna zone in relation to control of *Imperata cylindrica* (speargrass)
PhD	Cameroon	RCMD	University of Georgia, USA	IITA	Elad, R. L.	F	The implicit valuation of resources within the African agricultural household
PhD	Nigeria	RCMD	University of Hohenheim, Germany	IITA	Ndubuisi, A.	M	Economic analysis of crop-livestock integration among the agropastoralists in the northern Guinea savanna of Nigeria
PhD	Ghana	RCMD	University of Saskatchewan, Saskatoon, Canada	IITA	Gana, B. K.	F	Evaluating the effects of land-use changes on soil quality in northeastern Ghana
PhD	Nigeria	RCMD	University of Ibadan, Nigeria	Self	Modupe, V. O.	M	Soybeans phosphorus requirements and production efficiency in the humid rain forest region of Nigeria using simulation modelling
PhD	Nigeria	RCMD	Federal University of Technology, Owerri Nigeria	Self	Asumugha, G. N.	M	Efficiency in the marketing system for ginger (a root crop) compared to cassava in Nigeria
PhD	Nigeria	RCMD	Katholieke Universiteit Leuven	KUL/SOM	Ibewiro, B. E.	M	Nitrogen availability in relation to SOM dynamics under *Mucuna* and *Lablab* cover cropping compared to *Imperata* systems
PhD	Nigeria	RCMD	Federal University of Technology, Akure, Nigeria	Self	Epebinu-Colie, F. F		Evaluation of the soil surface change of characteristics in the humid tropical zone of Nigeria
PhD	Nigeria	RCMD	University of Ibadan, Nigeria	Self	Awoyemi, T. T.	M	Gender role and productivity differential in cassava business
MSc	Belgium	RCMD	Katholieke Universiteit Leuven	BNMS Project	Delaure, S.	M	Using soil information for the characterization and selection of research domains and representative farmer fields in Zaria-Kaduna benchmark fields in northern Nigeria

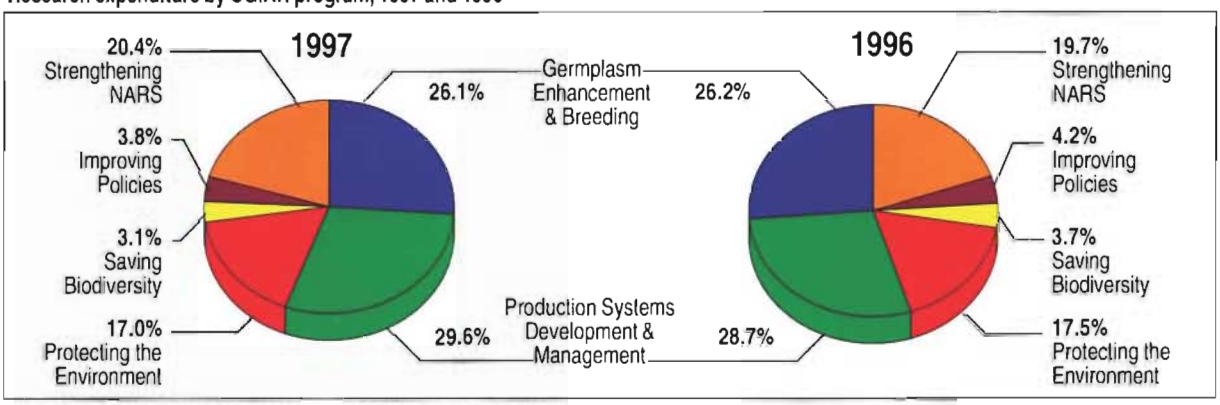
Core costs by operating segment, 1997 and 1996







Research expenditure by CGIAR program, 1997 and 1996



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

Statement of Financial Position

at 31 December
Expressed in US$ thousands

	1997	1996
ASSETS		
Current assets		
Cash and cash equivalents	20,090	19,292
Accounts receivable:		
Donors	3,287	3,488
Others	861	804
Inventories	1,249	1,444
Prepaid expenses	490	685
Other assets	189	178
Total current assets	**26,166**	**25,891**
Fixed assets		
Property, plant and equipment	74,037	71,489
Less: accumulated depreciation	(41,290)	(39,926)
Total fixed assets—net	**32,747**	**31,563**
Total assets	**58,913**	**57,454**
LIABILITIES AND FUND BALANCES		
Current liabilities		
Accounts payable and other liabilities	4,656	4,089
Accrued salaries and benefits	4,959	5,338
Payments in advance—donors	8,272	7,304
Total current liabilities	**17,887**	**16,731**
Net assets		
Capital invested in fixed assets	32,747	31,563
Capital fund	2,758	3,722
Operating fund	5,521	5,438
Total net assets	**41,026**	**40,723**
Total liabilities and net assets	**58,913**	**57,454**

Statement of Activity

at 31 December
Expressed in US$ thousands

	1997	1996
REVENUE		
Grants	29,170	31,180
Investment income	1,474	1,004
Total revenue	**30,644**	**32,184**
EXPENSES		
Research programs	20,713	20,801
Conferences and training	2,403	2,639
Information services	574	793
General administration	1,633	2,529
General operations	2,873	3,477
Depreciation	3,424	3,714
Total expenses	**31,620**	**33,953**
Excess of expenses over revenue	**(976)**	**(1,769)**

Statement of Cash Flow

at 31 December
Expressed in US$ thousands

	1997	1996
Cash flows from operating activities		
Excess of expenses over revenue	(976)	(1,769)
Adjustments to reconcile net cash Provided by operating activities:		
Depreciation	3,424	3,714
Gain on disposal of assets	267	474
Decrease (Increase) in assets:		
Accounts receivable–donors	201	(555)
Accounts receivable–others	(57)	331
Inventories	195	(116)
Prepaid expenses	195	(442)
Other assets	(11)	(47)
Increase (Decrease) in liabilities:		
Accounts payable and other liabilities	567	(236)
Accrued salaries and benefits	(379)	498
Payments in advance–donors	968	(386)
Total adjustments	**5,370**	**3,235**
Net cash provided by operating activities	4,394	1,466
Cash flow used in investment activities:		
Acquisition of fixed assets	(3,596)	(2,914)
Net increase (decrease) in cash and cash equivalents	**798**	**(1,448)**
Cash and cash equivalents: End of year	20,090	19,292
Beginning of year	19,292	20,740
Increase (Decrease) in the year	**798**	**(1,448)**

Donors

Expressed in US$ thousands

Donors	1997 Core Funding	1997 Complementary Funding	1996 Core Funding	1996 Complementary Funding
Austria	401	84	150	1,501
Belgium	1,166	-	1,253	297
BMZ, Germany	1,412	86	1,776	93
Canada	847	-	911	-
Commission of the European Communities	766	-	202	130
Common Fund for Commodities	81	-	-	-
Denmark	1,370	57	1,668	37
Food and Agriculture Organization	-	1	-	2
Ford Foundation	-	4	-	83
France	227	-	310	334
Gatsby Charitable Foundation	34	200	-	106
International Centre for Research in Agroforestry	-	69	-	97
International Development Research Centre	61	207	-	251
International Fund for Agricultural Development	258	186	136	110
International Institute of Biological Control	-	700	-	505
Italy	400	-	300	-
Japan	3,400	-	4,281	-
Korea, Republic of	50	-	50	-
Netherlands	1,232	-	1,171	-
Nigeria	47	12	6	-
Norway	1,147	-	665	
Overseas Development Administration (UK)	-	94	-	65
Rockefeller Foundation	281	129	349	94
Sasakawa Africa Association	123	-	-	128
Sweden	310	-	313	-
Switzerland	749	546	558	577
Thailand	50	-	-	-
United Kingdom	556	-	723	-
United Nations Development Programme	767	48	128	985
United States Agency for International Development	4,977	1,347	3,326	3,025
United States Department of Agriculture	-	118	-	-
University of Hohenheim	-	108	-	114
World Bank	3,447	-	3,800	90
Multiple/Other Donors	884	125	302	161
Closed Projects	-	6	-	17
TOTAL	**25,043**	**4,127**	**22,378**	**8,802**

Note:
The National Fertilizer Company of Nigeria (NAFCON) provides fertilizer from time to time as their stock allows.

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Contributions by IITA staff to scientific literature that became available during 1997, including journal articles, book chapters, papers in monographs or conference proceedings, training materials, published abstracts, and research notes or disease reports. Also included are (1) publications based on work done by IITA staff prior to their joining IITA, especially where the work reported is of interest to IITA; (2) publications by staff who have left IITA, which are based on work done while they were at the Institute.

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*Left during the year

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*Left during the year

Abbreviations and acronyms used in the text

ASB	Global Initiative on the Alternatives to Slash-and-Burn
BC	Biological control
CABI	Commonwealth Agriculture Bureau International, UK
CBO	Community-based Organization
CCER	Center Commissioned External Review
CGIAR	Consultative Group on International Agricultural Research
CIAT	Centro Internacional de Agricultura Tropical (Colombia)
CIMMYT	Centro Internacional de Mejoramiento de Maiz y Trigo (Mexico)
CIRAD	Centre de coopération internationale en recherche agronomique pour le développement
CORAF	Conference des responsables de la recherche agronomique africains
DM	Downy mildew
EARRNET	East African Root and Tubers Research Network
EPHTA	Ecoregional Program for the Humid and Subhumid Tropics of Sub-Saharan Africa
FAO	Food and Agriculture Organization of the United Nations
GIS	geographic information system
GTZ	German Agency for Technical Cooperation
IARC	international agricultural research center
ICIPE	International Centre for Insect Physiology and Ecology
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IDRC	International Development Research Centre (Canada)
IIBC	International Institute of Biological Control (UK)
ILRI	International Livestock Research Institute
INTG	IARC/NARS training group
IPM	integrated pest management
KARI	Kenya Agricultural Research Institute
LUBILOSA	Lutte biologique contre les locustes et sauteriaux
MPB	Maruca pod borer
NARES	national agricultural research and extension systems
NARS	national agricultural research system
NGO	nongovernmental organization
NRI	Natural Resources Institute (UK)
PEDUNE	Protection ecologiquement durable du niébé
PSB	Pod-sucking bug
SADC	Southern Africa Development Community
SARRNET	Southern Africa Root Crops Research Network
SP-IPM	Systemwide Program on Integrated Pest Management
USAID	United States Agency for International Development
WARDA	West Africa Rice Development Association
WECAMAN	West and Central Africa Collaborative Maize Research Network

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