IITA Research for Sustainable Agriculture in Africa

Laurence D. Stifel

This is the third consecutive year that I have the privilege to address you at International Centers Week concerning the work of IITA.

In 1987 you reviewed and endorsed IITA's Strategic Plan. The Plan included significant new priorities and strategies for an integrated program of research and international cooperation. It was a year of enormous change at IITA, with major staff retrenchment, a new financial management system and a restructuring of the personnel system.

In 1988 you reviewed and approved IITA's Medium-Term Plan. It was a year of consolidation at IITA. We rebuilt the top management team and the many organizational changes under way started to coalesce.

The year 1989 has been an exciting year in which we have been rebuilding the scientific team and launching the initiatives in the Medium-Term Plan. My two deputies have taken the lead in this process, Ken Fischer in research and Jacques Eckebil in international cooperation and training.

My last two presentations at Centers Week focused on our plans for the future. This year, I want to tell you what we are doing now, particularly with reference to our research program.

In my last presentations I emphasized our new directions in outreach activities, what we call International Cooperation, because of the

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critical need to strengthen national agricultural research systems in Africa and because of the new mechanisms developed by IITA that carry us farther downstream for a transition period than is customary for an international center. The ultimate test of our work, of course, is whether it is adapted to local conditions and whether the best materials move onto farmers' fields.

I believe that our firm commitment to collaboration with national agricultural research systems is clear, especially to members of the Special Program for African Agricultural Research (SPAAR). Today I hope to demonstrate that this downstream work does not compromise the quality of science at IITA, nor does it lessen the urgency of our upstream work, our intermediary role in applying the scientific strengths of the advanced laboratories to the solution of African problems.

Twenty-two years ago, long before sustainability became a burning issue, the founding fathers of IITA had a vision of a new institute in Africa to develop sustainable agricultural systems to replace bush fallow, or slash-and-burn, cultivation in Africa and to increase the productivity of the key food crops in these systems. Today, I want to convey to you (1) how our scientists are grappling with the problem of sustainability, (2) how the new priorities in the Strategic Plan are changing IITA's research agenda, and (3) how scientific breakthroughs are advancing us toward our research goals.

Research Focus

I will start by reminding you of our four program elements of focus:

- focus on the lowland humid and subhumid tropics of Africa
- *focus on the smallholder or family farm*

- focus on farming systems, and
- focus on agroecological zones.

Then I will turn to a discussion of our research in the two major zones, the humid forest and the moist savanna. In the context of the humid forest, I will explain how we conceptualize and integrate our work to increase the productivity and sustainability of smallholder farming systems. I will conclude with reference to the problem-oriented upstream research centered at IITA headquarters in Ibadan.

The first element of focus is the farming systems of the lowland humid and subhumid tropics of Africa. Most of these lowland environments are found in West and Central Africa. Adoption of this strategy led to the termination of field projects with IITA scientists in Asia, South America and the Caribbean. This decision reduces diffusion of research effort and increases focus on a region of acute need. It does not compromise IITA's status as an international center.

The second element of focus is the inculcation of a farming systems orientation throughout IITA. During the Strategic Planning Study we recognized that the existing organization and, to some extent the philosophy of our research, constituted an internal constraint to such a holistic approach. One commentator likened IITA to a series of independent columns that had evolved over some 15 years without any connecting links. We considered the model used successfully by many of our sister centers, that of multidisciplinary independent commodity programs. But this seemed inadequate to deal with the complexity of the African environment. The critical decision was made to integrate all IITA research around the challenge of sustainable food production systems.

The commitment to a farming systems orientation in our research required new institutional mechanisms to facilitate scientific collaboration between resource management and commodity improvement scientists. Central to this process is the integrative function of the new crop-based systems working groups which provide linkages and feedbacks between scientists in the study and improvement of smallholder farming systems.

We are encouraging scientists to consider their research as contributions to an integrated effort to improve farming systems, a reorientation that would amount to a new paradigm of work at IITA. The most difficult management task is to change how scientists think about their work and to accept values that differ from what they have been accustomed to in the past. The change at IITA will be facilitated by the recent appointment of many excellent, generally younger scientists, including some outstanding women. To give one example, in the last three years, the percentage of intercropping experiments rose from 25% to 58% of all experiments in the farming systems or crop management research group. These organizational innovations to promote integration are under continuing review as we seek to improve their effectiveness.

IITA's third element of program focus is on the smallholder or family farmer. This policy represents a departure from the previous assumption that the products of IITA research were scale neutral. While some of the technology generated at IITA is of equal value to large and small farms, we recognize that research must be designed specifically to enhance the productivity of the farming systems used by African smallholders. I will give examples of how this decision is changing our research priorities.

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

The fourth and last element of focus is upon the major agroecological zones of the region. As we developed our Strategic Plan, it was clear that major researchable issues varied on the largest scale by agroecological zone. Accordingly, we have planned to decentralize research to small substations in the key zones for our work. In addition to our headquarters station in the transition zone between the forest and savanna at Ibadan, we are locating one research substation in the humid forest zone, primarily for research on cassava and resource management involving agroforestry and fallow management systems; another in the moist savanna for maize-based systems, and a third in the dry savanna for work on cowpeas in sorghum and millet-based farming systems. In our research on rice-based cropping systems, we also recognize the distinct inland valley ecosystem which occurs in all ecological zones.

Decentralization of IITA's research is a logical stage in the evolution of the Institute. In the first stage of IITA's history, it was apparent that commodity research could make the greatest contribution to sustainability by developing germplasm resistant to major diseases for use by national systems. With

access to genetically diverse germplasm and sophisticated research support, the commodity scientists could do this work most effectively at IITA headquarters.

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

I will illustrate how we have started to implement our Medium-Term Plan by describing some of our current activities and achievements in two major ecological zones of West and Central Africa, beginning with the humid forest zone.

The Humid Forest Zone

The humid forest zone is characterized by high rainfall, from around 1,500 to more than 4,000 millimeters each year, and with six to nine humid months when rainfall exceeds evaporation. Half or more of the West and Central African rainforest has acidic soils with low capacity to hold nutrients. While secondary forest cover helps mitigate the effects of intense rainfall and maintain stable recycling of nutrients, cultivation removes many of the nutrients during forest clearing, and later in harvested produce. It also exposes the soil to the effects of rain, heat and sunlight, and, as you know, this commonly leads to rapid degradation of the soil. Nowhere is the need for sustainability more acute than on these fragile, acidic soils.

Despite these difficulties, many parts of the West African forest zone are intensively cultivated and support large numbers of people. In fact, the forest zone of West Africa contains almost half the total population on less than 40% of the land area, and it has some of the highest rural population densities in the region. Moreover, Africa's total population, growing at the fastest rate in the world, is expected to expand threefold by the year 2025.

The indigenous farming systems which have evolved in the forest zone have remained productive because of strategies which maintain and restore the soil's productivity—complex cropping patterns and sequences, mixtures of tree crops and annuals, home gardens and, most importantly, by the regrowth of natural vegetation during fallow periods of 5 to 20 years.

Growing population densities and increased intensity of land use have caused those fallows to be shortened to as few as two or three years, resulting (see Diagram 1) in

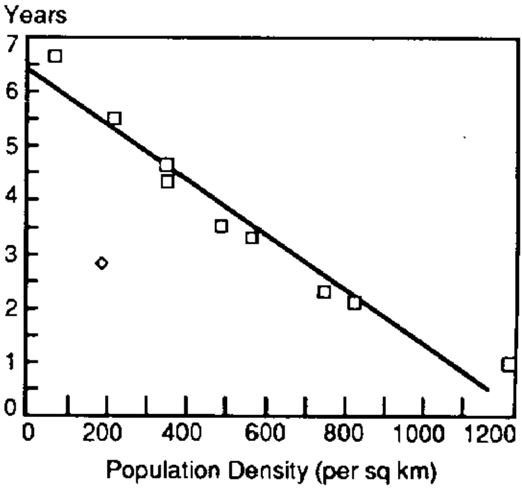


Diagram 1. Relationship between population density and length of fallow (years) in Imo State, Nigeria

sharply declining soil productivity. The regression line shows that the length of fallow in Imo State of Nigeria is a direct function of population density. Behind the statistics is the cruel fact that traditional farming systems are being destabilized, forcing desperate farmers to cultivate marginal lands or to destroy the forest reserves in a vicious circle of human and environmental impoverishment.

Now I turn to the conceptual model we have developed as a means of understanding how research can contribute to the efforts of smallholders in the forest zone to escape subsistence agriculture and to move onto a trajectory leading to more productive and sustainable agriculture. Working at a center established to deal with sustainability, we have a special responsibility for this problem. I ask for your patience, while I attempt to articulate where we are in this process. The model may appear simple and obvious, especially to those of you experienced in tropical agriculture in Africa. Nevertheless, it reflects vigorous internal discussion that is helping to build a consensus among our scientists concerning how to conceptualize our central mission.

Diagram 2 (see centerfold) attempts to capture three phases of development of the farming system, from traditional to intermediate to commercial. Like any model, this is a highly stylized simplification.

The vertical axis shows that the biological output of the system provides benefits in the form of:

1. increased short-run production, and/or
2. greater sustainability.

I refer to the benefits in terms of alternatives to emphasize that acceptable technologies must minimize the tradeoffs between short run production on the one hand and conservation on the other. Identifying such convergence is a major goal of the increased farming systems

orientation at IITA. Research must keep these goals in balance.

The horizontal axis shows the mix of resources entering the system as one moves from a traditional system to a modern, commercialized system in which the smallholder increasingly uses purchased inputs.

Some of these inputs are the product of research—and in a sense the horizontal axis defines a continuum of researchable issues for IITA. Therefore, we have indicated some of the research inputs required at each phase.

I will describe the three phases depicted in diagram 2, emphasizing again that they are merely suggestive—a single farmer might at any one time be engaged in practices characteristic of more than a single phase in his farming system.

The vast majority of African farmers are in the first phase. The subsistence pattern of the lives of resource-poor farmers in Phase I must be transformed by technologies which stabilize output by reducing risks. Such stability requires crop varieties resistant to diseases and insect pests and tolerant of adverse environmental factors. It requires biological approaches, such as the biological control of pests, pathogens and weeds, that avoid the need for chemicals and which work with nature to solve farmers' problems. It requires technologies that protect output from postharvest loss, and improve product utilization.

Of course, there is a price to pay for stable output in a system where once there was risk and instability. By raising the output of the traditional system, the system itself is destabilized. The removal of risk leads to increased production and that requires added inputs.

Thus, the resource—poor farmer is driven to make inputs to his system to sustain

production increases that follow risk avoidance.

Assuming that the farmer can afford it, the simple addition of fertilizer to the system might be thought sufficient to achieve these ends. This would permit the smallholder to jump over Phase II and enter Phase III. While that would be a short-term possibility to increase production, numerous examples from the humid tropics have shown that this is not a long-term solution. This point is illustrated in Diagram 3. It has been prepared from experimental data gathered from seven years of annual cropping without fallow at Ibadan, in the transition zone. The addition of fertilizer raises maize yield initially, but this is not sustainable. The soil is rapidly degraded as organic matter is mineralized and nutrients are leached to depths beyond the reach of crops; the soil becomes increasingly acid, it loses structure, becomes compacted, and in the worst case is itself eroded.

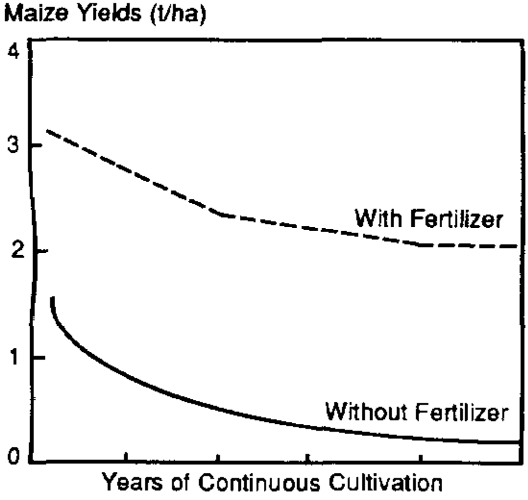


Diagram 3. Relationship between length of continuous cultivation and maize yields at IITA, Ibadan

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

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

- vegetative cover to minimize soil surface degradation
- nutrient recycling from lower to upper soil layer where they are available to shallow-rooted crop species
- nitrogen fixation by leguminous tree species of the fallow
- organic matter accumulation at the soil surface and the improvement of water infiltration and of moisture and nutrient retention.

Our research in Phase II seeks technologies which couple these internal biological processes with improved intercropping systems which enhance stability and increase productivity.

Diagram 4 shows experimental results of maize production in alley farming systems at IITA. Alley farming has all of the elements just described; it minimizes the conflict between production and conservation inherent in traditional bush fallow, because it merges in time but separates in space the fallow and cropping cycles. This allows a two to three-fold increase in cropping intensity, and this output can be sustained.

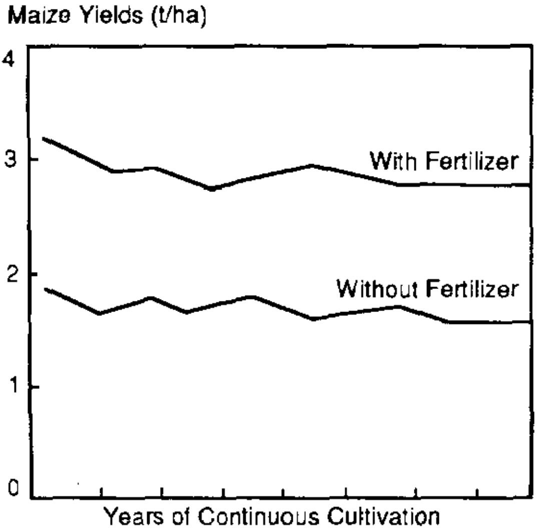


Diagram 4. Sustainability of maize production in alley farming systems at IITA, Ibadan

The lower curve shows that resource-poor farmers can sustain intermediate levels of production in an improved management system like alley farming using internal inputs. But these systems face agronomic and biological limits that can be overcome only with modern external inputs.

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

Of course, the variation between smallholders in their access to and use of resources is continuous. We have identified

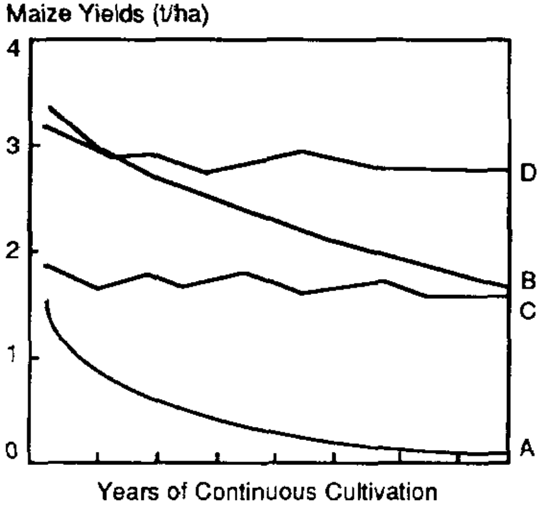


Diagram 5. Relationship between maize yields and different options for continuous cropping

these phases in the progression merely to model the transitions required and to help understand the appropriate technologies. Diagram 5 brings together the four cropping options that we have discussed. Curve A reflects the rapidly declining productivity of traditional farming without fallow and Curve B shows that fertilizer inputs can delay but not prevent degradation of the land. We seek to advance the farmer to a sustainable farming system such as alley farming shown in Curve C. Curves A and C exemplify Phases I and II of the initial diagram. Most African smallholders are in Phase I or II, and it is on this part of the research continuum that we focus most of our research effort. Our ultimate objective is to help the family farmer progress to the even higher level of benefits illustrated by Curve D, thus optimizing the productivity of an increasing volume of external inputs while sustaining the resource base.

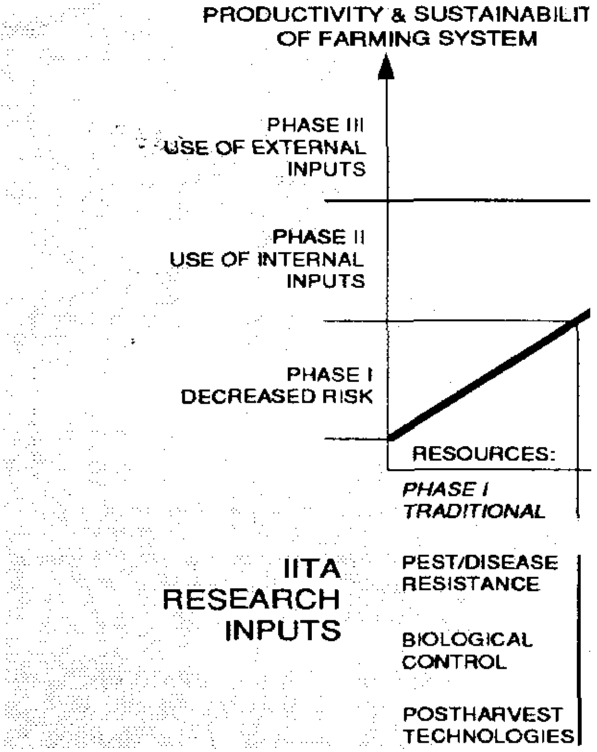
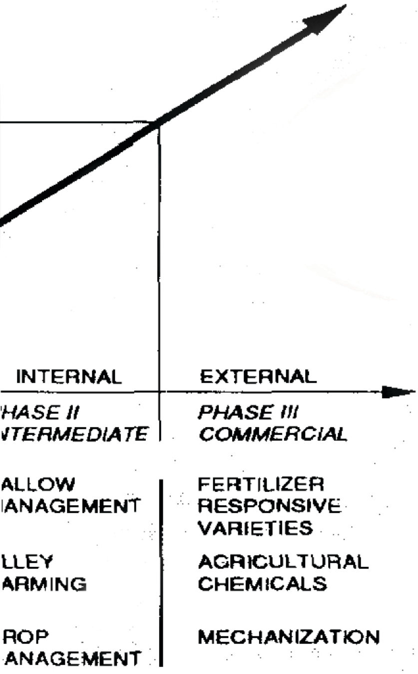


Diagram 2. Phases of development of
(see discussion on page 8)

Research in the Forest Zone

I have described the humid rainforest and how we conceptualize our work there. I now will describe three IITA research programs of special relevance to this zone—agroforestry, cassava and plantains.

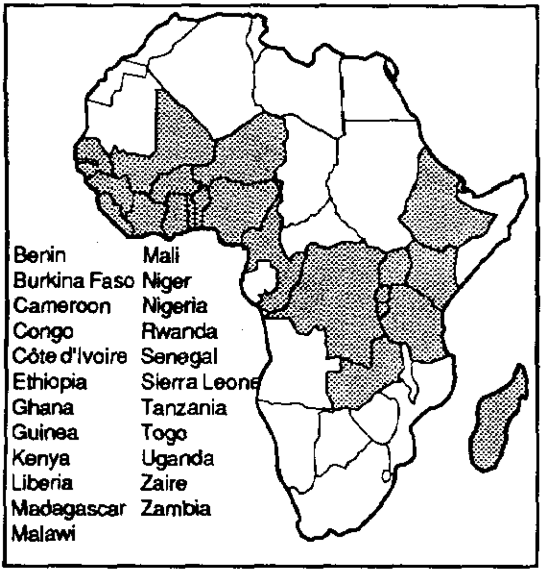
Agroforestry appears to be inseparable from any intervention designed to achieve sustainable food production in this zone. Among the possible agroforestry interventions, alley farming is the most promising to have been developed by IITA. It will be an important component of research at IITA's humid forest substation. While on-station research in the transition zone at Ibadan has produced



farming system, and IITA research inputs

technologies for widespread on-farm testing, there are still unanswered problems associated with the acid soils of the forest zone which require on-station research. For example, germplasm collection and evaluation are necessary to identify trees or shrubs with the required attributes of "alley species" and which thrive on acid soils.

I am pleased to report the successful establishment of the Alley Farming Network for Tropical Africa (AFNETA) in which IITA collaborates with ICRAF, ILCA and 23 countries from all parts of Africa, as you see on the map (overleaf). From a series of alley farming research proposals prepared by



Collaborating countries in the Alley Farming Network for Tropical Africa

national programs in the network, a single unified proposal has recently been submitted to IFAD for funds to finance in-country research. We have recruited two network coordinators, the second because of the unexpected enthusiasm for the network from African countries and donors alike.

We are often asked whether, after so many years of research, farmers are using alley farming or why they are not. IITA and ILCA have over 100 alley farming plots in individual fields trying to find answers. In all cases we are exploring how to minimize the conflict between farmers' short-term needs for production and the longer-term benefits of sustainability. Studies are under way on the economic value of the hedgerow species, on "carrier cash" crops to make hedgerow establishment more attractive, and on hedgerow management techniques for weed control. In moving to on-farm research, scientists are now examining results through

the filters of the farmers' objectives, economic profitability and adoption potential.

We know that intercropping of complex mixtures plays a central role in improving farming systems in the forest zone. We will have a cassava breeding program at the same humid forest substation to adapt cassava to the acid soils and to improve the labor productivity of the cassava-based systems.

We are able to decentralize our cassava improvement program because the major pest constraints—virus, bacteria and mealybug—have been overcome by past work at our Ibadan and Cotonou facilities. Despite the notoriously poor statistics on cassava, we know that our improved stable varieties continue to spread through the cassava belt of Africa.

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

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

Commercial farmers growing cassava for the market, on the other hand, prefer profusely branching, bushy cassava because it smothers weeds when grown as a sole crop, just as it would smother any crop in an interplanted mixture. This attribute, valued because it

decreases labor requirements, is expressed most obviously in IITA varieties which hold their leaves well because they are resistant to diseases which cause premature leaf fall.

IITA's cassava breeder and agricultural engineer cooperate in addressing diverse utilization requirements. For example, there is variation within the African cassava belt in the cyanide content of cassava tubers. In many regions the so-called sweet cassava is preferred because it is low in cyanide, and can be easily processed for consumption; in other regions the preference is for products that are prepared by fermentation and heating which drive cyanide out of the grated or ground tubers of bitter cassava.

I cannot leave cassava without reference to an example of the biological approach to solving smallholders' problems; there can be no better case than the biological control of cassava mealybug in Africa. I believe the story is well known to all of you—the collaboration with CIAT and the Commonwealth Institute for Biological Control and with many other organizations; the exploration in Central and South America; the discovery of the tiny *E. lopezi* wasp and its introduction into Africa after quarantine by CIBC in England; and release of the wasp over the African cassava belt where it has decreased mealybug populations below the level of economic damage.

Without inputs of any kind from the African farmer, the application of high quality biological control science has resulted in savings of food for the poor valued in the billions of U.S. dollars.

As a result of our Strategic Planning Study, we have increased research on plantains, an important component of farming systems in the humid forest zone. According to the TAC paper prepared for this meeting on the possible

expansion of the CGIAR, bananas and plantains are the second most economically important crop category in Africa, surpassed only by cassava. Plaintains are an ideal crop for small-scale farmers because they fit easily into their farming systems, they reduce degradation of the soil, and they produce high yields.

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

Black Sigatoka disease is the overriding constraint on plantain production worldwide. Its fungal spores are dispersed by wind and water and are thus beyond the control of plant quarantine measures. It causes plantain leaves to wither, resulting in sharply reduced yields. Losses can be so high that the crop is no longer economical to grow.

The disease was accidentally introduced into Central Africa recently; it appeared in Gabon and spread rapidly to the north, first to Cameroon, and in 1986 to Nigeria. It can be controlled by fungicides, but at a high cost beyond the means of African farmers. There are no known resistant varieties.

IITA's strategy for research on black Sigatoka has two major thrusts.

First, East African cooking bananas have been screened for reaction to the disease, and some have been found which are resistant. Those acceptable to consumers are being multiplied and distributed by the national program in Nigeria. Although West Africans are unfamiliar with cooking bananas and much prefer plantains, these resistant clones are

potential alternatives if plantains are destroyed in West Africa, and we are testing them in the region in collaboration with the International Network for the Improvement of Banana and Plantains (INIBAP).

Second, IITA has established the first plantain breeding program in Africa with the chief objective of breeding plantains resistant to black Sigatoka. In a lecture I gave nine months ago at the Nigerian Institute of International Affairs, I explained the reason for this decision in the following words.

> Recalling the disastrous impact of the rosette disease on groundnut production in northern Nigeria, officials from the Federal Ministry of Agriculture supported IITA's plans to launch an urgent research campaign to control black Sigatoka. At our substation in eastern Nigeria, we have started breeding to develop varieties resistant to the disease. It took IITA 10 years to develop resistance to streak virus in maize which is a much simpler crop for breeding purposes. Time may be running out for plantains. There is tremendous pressure on our agricultural scientists to save plantains for the millions of smallholders who depend on them for their subsistence and livelihood.

I am very pleased to be able to report to you today that in 1989 we have had an important breakthrough in this work, much earlier than could have been expected. Our plantain breeder has succeeded in making artificial crosses between susceptible plantains and resistant cooking bananas and he has obtained viable seed.

Here is a photograph of the hybrid seeds obtained from the cross between triploid plantain and diploid banana resistant to black Sigatoka. In the petri dishes are embryos cultured from some of the hybrid seeds. The embryos were later transferred to the field as young plants.

From about 100 seedlings raised from the hybrid seeds, three plants appear to be resistant to black Sigatoka and have the characteristics of plantains. If Sigatoka-resistant plantains can be extended widely to smallholders in the humid forest zone, this will be another example of the enormous impact possible from biological approaches that remove risks and sustain production.

The Moist Savanna

Now I turn to discussion of the second major agroecological zone, the moist savanna of West Africa. With almost 45% of the area but only 30% of the population, it has considerable potential for arable crops. Bright sunshine during the growing season, with warm days and cool nights, results in high photosynthetic potential. Furthermore, the soils of the moist savanna are generally more responsive to improved inputs and management than those of the humid forest zone.

Increases in output and in the demand for new technology, especially yield-enhancing technology, are likely to be closely related to the development of improved market access and infrastructure. The lower population densities in most of the area imply that pressure on resources is less severe, but in some cases the lower population may constrain increased production because of labor shortage. As a result, labor saving mechanization technologies may be attractive, especially in those areas where there are significant opportunities for market production.

I discussed a conceptual model of smallholder development in the context of the humid forest zone. That model could be adapted to the different characteristics of the savanna but I will not take time to do that today.

All of IITA's mandated commodities except plantain are grown in the moist savanna, but we have placed special emphasis on maize there because of its great potential for increased production.

Twenty years ago maize was hardly known as a food crop north of the forest/savanna transition zone in West Africa. Now it is widespread in the moist savanna, particularly in Nigeria and Ghana, where it is increasingly replacing sorghum as the staple cereal crop.

For example, in a recent survey of four villages in Nigeria's northern Guinea savanna zone, where sorghum has traditionally been the staple food crop, maize was reported as the dominant cash crop in all four villages, and the dominant crop grown for food in three of the four. Almost all the maize being grown was found to be improved varieties; indeed, in three of the four villages there was no local maize.

I would like to take a moment here to quote from a letter I just received from the recently retired head of Nigeria's maize research program.

> I took over leadership of maize at the National Cereals Research Institute in 1981. The eight years which followed were the most dramatic for any crop in Nigeria. National production rose from about 1 million tonnes to about 4.0 million tonnes. National average production rose from about 500 kg/ha to about 2.0 t/ha. The hybrid maize program was executed to an admirable point. Seed companies were functioning. A national seed law was in place. A national varietal release mechanism was in place. The nationally coordinated research program designed along the lines of the national maize breeders meeting was functioning. In all these, we cooperated closely with others in order to make these happen. I like to feel I made a small

contribution. And I urge you to keep up the good work. Please express my personal thanks to the program at IITA for all its help when I was in maize. I wish you success in your future endeavours.

Yours sincerely,

C.E. Ago

Parenthetically, I should add that I have never met Mr. Ago but I plan to visit him when I return in order to thank him for this letter.

This highly significant spread of maize into the moist savanna followed early success in breeding for resistance to lowland rust and blight diseases. IITA released varieties in the 1970s that were promoted by World Bank development projects which made seed and fertilizer available to farmers. Subsequently IITA and CIMMYT developed maize adapted to the moist savannas of West Africa and resistant to streak virus. Most recently our emphasis has been on resistance to the parasitic plant *Striga*.

Striga has co-evolved with sorghum and pearl millet in the West African savanna zone. Although it causes much damage to those crops, it does not entirely destroy them. On the other hand, as maize spreads into the moist savanna, it is frequently killed when it encounters *Striga* for the first time. Finding host-plant resistance to the parasite is an important component of both our maize and cowpea research programs, which include plans to recruit a *Striga* biologist.

The solution to *Striga* in Africa will probably be a combination of increased levels of crop resistance or tolerance, combined with practical integrated pest management. Both require research to learn more about the basic biology of various *Striga* species in Africa.

I made reference earlier to the impact of biological control on cassava in Africa. Among other targets for the biological control of pests

of IITA's mandated crops is the larger grain borer, a pest of maize. It recently entered Africa from South America and, although not yet widespread in West Africa, the damage it has caused in Tanzania is alarming. IITA has started a collaborative program in South America to search for the natural enemies of this very important pest.

A task ahead is to sustain the production increases made possible by these remarkable achievements in maize. Even where fertilizer is available, continued use in a sole-cropped system is environmentally unsound, and there is a need for the development of sound crop rotation systems. In this context, IITA's successful adaptation of soybeans to tropical Africa provides a potentially important crop for these maize-based systems.

Now I will discuss IITA's research on cowpeas which is applicable to both the moist and dry savanna zones. Our early work on the crop resulted in a range of improved material with multiple resistance to several pathogens, resistance to the cowpea storage weevil, and some resistance to field pests such as aphids and flower thrips. These were significant advances for grain production from sole crops in which insect pests were controlled with insecticides. And the resistance to storage weevil, once it is widely incorporated in farmers' varieties, will have the potential to eliminate postharvest losses commonly as great as 60% of stored grain.

As a result of the Strategic Plan, IITA has reduced research on cowpeas for sole-crop production dependent on the use of insecticides because this technology is normally not available to the smallholder. We are now breeding cowpeas for adaptation to the traditional cereal farming systems of the savanna zones, and that meet the dual needs for grain and fodder. Rather than the erect,

determinant plant types that are appropriate for sole-crop production, cowpeas adapted to cereal systems are widely spreading, prostrate forms. Their spreading growth helps to smother weeds, and their response to day-length ensures that they flower at the end of the wet season in their own locality, so that their grain matures in dry weather.

IITA has recently established a small research substation at Kano in northern Nigeria in collaboration with the Institute of Agricultural Research to breed cowpeas for the sorghum/pearl millet systems of the region. A breeder and a crop physiologist, strongly supported by a cowpea pathologist at the Ibadan headquarters, are working with scientists in the national program and with ICRISAT's farming systems program to ensure that they have an appropriate research agenda. Work at Kano complements that of an IITA cowpea breeder at the ICRISAT Sahelian center at Niamey, Niger, who has worked for some years on cowpeas in millet-based systems of the Sahel.

Historically, cowpea grain yields from intercropped mixtures have been around 300 to 400 kilograms per hectare and the haulms for livestock feed have always been an economically important product of the system. Our first goal is to breed cowpeas which, while retaining their local adaptation, are resistant to the major diseases of the savanna zone and yield 600 to 800 kilograms per hectare of grain without use of insecticides.

I will conclude my discussion of the agroecological orientation of our research with a recent report on promising resistance to *Striga*. Some years ago we started collaborative research on mechanisms of cowpea resistance to *Striga* with scientists at the Long Ashton Research Station, University of Bristol. In their study of germplasm from Botswana, they

identified a high degree of tolerance or even resistance to three strains of the parasite which attack cowpeas in the savanna and Sahelian zones. In Kano last month, I saw experimental fields heavily infested with *Striga*. The early generations of crosses that incorporated the Botswana germplasm were conspicuously flourishing compared with local varieties with severe *Striga* damage.

Research at Headquarters

In summary I have highlighted the changing emphasis in IITA's research agenda. Focusing on more productive and sustainable farming systems means decentralization of our research and increasing complexity of our agenda. This change can occur because of earlier work at Ibadan headquarters that addressed problems that were less site-specific. However, strong innovative research programs must continue at headquarters to harness new technologies and scientific thinking to address some of the more obdurate constraints that remain.

For example, a breakthrough in producing cowpea resistance to post-flowering insect pests would revolutionize production, giving the potential for smallholders to produce 1 ton or more of grain per hectare. It is for this reason that we have developed strong links with Purdue University in the United States and the University of Naples in Italy for collaborative research in which the advanced methods of biotechnology are being applied to pest resistance in cowpeas.

The opportunities are illustrated with research on the trypsin inhibitor gene for host plant resistance to insects. This gene was responsible for resistance to the cowpea storage weevil found in one of the 15,000 cowpea germplasm lines in the IITA collection. A private firm has recently used the gene to

introduce insect resistance into a genetically engineered tobacco plant. IITA has retained rights for research into the application of this gene to the improvement of crops in our mandate. This is an example of the great value of large and well-studied, safely preserved germplasm collections in the CGIAR system and of the potential for collaboration with the private sector in the use of biotechnology.

The importance of continuing work at Ibadan is exemplified by two exciting scientific breakthroughs made by IITA cassava scientists during the past year. The first was the discovery of apomixis in the progeny of crosses between cultivated and wild cassava. Apomictic cassava sets seed without fertilization, so that plants grown from apomictic seed are identical to the parent. The significance of this is that, with further development, the international distribution and multiplication of improved clonal genotypes by seed will be possible, with greatly decreased phytosanitary risk; looking to the future, the possibility exists that one day cassava hybrids can be propagated by seed with enormous impact on cultural practice.

In the second discovery, we have for the first time found natural, sexual tetraploids and triploids among the products of diploid interspecific cassava crosses. In this slide the plant on the left is a tetraploid, the one on the right a normal diploid cassava. These polyploids appear to be more vigorous than normal cassava, with larger tuber yields. More importantly, as in other crops, natural polyploidy of the kind we have in cassava enlarges the genetic variation which is vital to plant breeding. Partially fertile, they open new avenues in cassava improvement strategy, such as polyploid breeding and new access to genetic diversity in related wild cassava species.

I have briefly mentioned the value of biological control. We believe that much is yet to be learned about "biological resources" for pest management. IITA's capacity for this is well recognized. Our new facilities at Cotonou provide a base for research to ensure that African farmers continue to benefit from such environmentally sound methods of pest management.

To conclude my presentation, I would like to quote from the TAC paper on possible expansion of the CGIAR system.

"If present trends continue, malnutrition and poverty will be a common attribute for the majority of people in sub-Saharan Africa in the year 2025."

This is a stark challenge that should remind us of the social purpose of our scientific research.

At IITA in Nigeria we are in constant contact with the brutal reality of poverty and deprivation. I like to quote the prayer of a friend, a priest, and a great man, Father Ted Hesburgh, that captures our views:

Lord,
To those who are hungry
Give bread, and
To those who have bread,
Give a hunger for justice.

At IITA we believe that poverty must not be extrapolated into the future. The CGIAR is a great institution because its ultimate objective is the reduction of poverty, and because it permits scientists of the highest calibre at IITA and the other centers to join in a collective effort to contribute to that more just world we all seek.