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Facts about IITA

Established as an autonomous, non-profit corporation on July 27, 1967, the International Institute of Tropical Agriculture (IITA) is one of the major links in a worldwide network of agricultural research and training centers. The Federal Republic of Nigeria allotted 1,000 hectares of land for the IITA site, and the Ford Foundation provided initial capital for buildings and development.

IITA is governed by an international Board of Trustees, the membership of which includes representatives from developing countries in areas of the Institute's concern.

Principal financing of the Institute (and other centers) is arranged by the Consultative Group on International Agricultural Research (CGIAR) – an informal group of donor countries, development banks, foundations, and agencies. Support for IITA's research and training core program in 1983 was provided by the Canadian International Development Agency (CIDA), Overseas Development Administration of the United Kingdom (ODA), U.S. Agency for International Development (USAID), World Bank, International Fund for Agricultural Development (IFAD), Ford Foundation, OPEC Fund for Agricultural Development, and the governments of Australia, Belgium, France, India, Italy, Japan, Netherlands, Nigeria, Norway, and Federal Republic of Germany. In addition, other donors provide funds to the Institute, particularly to support specific research or training programs.

The "geographic mandate" of IITA includes the humid and subhumid tropical zones, and the Institute concentrates its research and training in two major areas: farming systems and crop improvement of certain designated cereals (rice and maize), grain legumes (cowpeas and soybeans), and roots and tubers (yams, sweet potatoes, and cassava).

Preface

Several big steps were taken recently to forge new and stronger links with national and regional programs. We realize that the research findings of IITA, some of which are presented in this edition of Research Highlights, will be of little practical value unless they reach scientists and government agencies in developing countries of the humid and subhumid tropics and are tested and adapted to fit their conditions. In turn, the Institute depends on them to guide it toward problems which are relevant and important.

In June 1983, IITA hosted the founding congress of the International Federation of Agricultural Research Systems for Development, African Chapter, and our scientists had the opportunity to exchange views and discuss problems and needs of African nations with 27 directors and other high-ranking representatives of national agricultural research systems. Through this congress, we made additional contacts which will provide new openings for on-farm research and participation in national research planning activities.

The delegates reported that IITA's improved varieties of cassava, sweet potatoes, maize, rice, cowpeas, and soybeans are reaching farmers in various parts of the tropics. After taking a critical look at our research, they were not bashful about telling us what we were doing right or wrong.

Also during the year (September-October), the Institute was scrutinized by an external panel organized by the Technical Advisory Committee of the Consultative Group on International Agricultural Research. Every five years the mandates and work of each international center go through a "quinquennial review" which brings a wealth of scientific and research management expertise from different parts of the world. Some of the panel's recommendations have been implemented already, and we will take action on others in the near future.

You will see for the first time in this publication a brief update of our international projects which foster close linkages with national and regional programs. At present, the number of these projects involving the out-

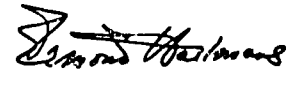
posting of IITA scientists to individual countries is relatively low because some of the projects have been handed over to national programs and others have achieved their purpose. Future projects, with emphasis on regional cooperation, are in the pipeline.

The Institute has started to expand its on-farm research in collaboration with development projects and the newly established West African Farming Systems Research Network. Our scientists are combining the achievements of the farming systems and crop improvement programs into packages of new technology for this on-farm testing.

Progress made during the year on biological control of the destructive cassava mealybug was encouraging, and we are in the initial stages of developing and testing an African-wide project in cooperation with a number of national and international organizations.

We are ahead of schedule in meeting our objectives to make insect- and disease-resistant cowpeas available to breeders in national programs. The latest line announced this year combines resistance to eight principal diseases and two major insect pests. Likewise, improved maize and rice varieties for various ecological conditions in Africa were made available to national programs in 1983. The new maize hybrids showed excellent results in trials despite drought conditions and a severe epidemic of maize streak virus.

More details on these and other research advances are included on the following pages and in our 1983 Annual Report which is available to you on request.



Ermond Hartmans
Director General

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Introducing a New Component in a Local Farming System

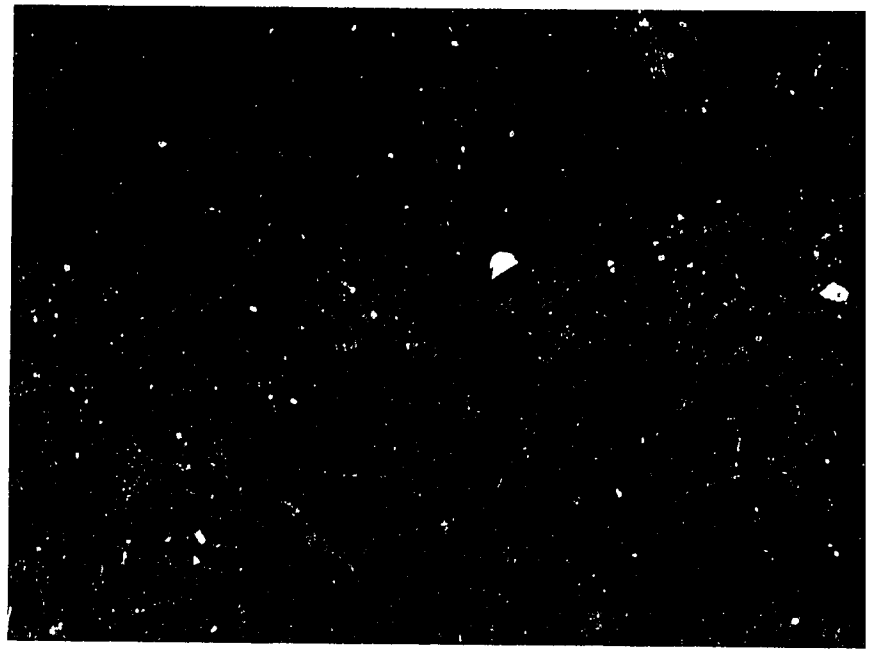
After listening to the results of an exploratory survey in the Bida, Nigeria area by IITA agricultural economists which identified an untapped potential for growing early-maturing dry season cowpeas on recently harvested rice land instead of leaving it fallow, local farmers expressed an interest in participating in cooperative trials. They chose two farmers' fields – one at Yinti and the other at Gara – and the trials were conducted by the farmers in cooperation with the agronomy section of the Bida Agricultural Development Project (BADP). The Institute, through its Farming Systems Program, assists BADP to organize and develop on-farm trials and analyze the results.

Both Yinti and Gara villages are in an inland valley area (fadama) where the land is still wet at rice harvest time in December. Although the rains stop in October, water continues to seep into the low-lying areas for a few months, thereby providing a substantial amount of residual moisture.

In early January 1983, the Yinti farmer and his three sons prepared the land and planted four IITA varieties of cowpeas. (A total of eight plots were planted, two of each variety with a split along the contour of the site for two different spraying treatments by the BADP extension staff.) The cowpeas germinated eight days after planting, and the first harvesting was done in 68 days. They were ready a few days earlier, but harvest was delayed for a field day.

Variety IT92E-60 (popularly known as a 60-day cowpea) produced the highest yield – 945 kg/ha with three insecticide sprays and 764 kg/ha with no spraying (Table 1). The yields of this variety when valued at a net farmer price of ₦1/kg compare favorably with cash costs, especially for a slack labor period (Table 2). Total cash costs, including seed and fertilizer at local

Four days after threshing his rice crop, a farmer at Yinti, Nigeria planted short-season cowpeas instead of leaving the land fallow.



More than 200 farmers and local officials attend a field day to see the results of planting 60-day cowpeas after rice on a farm at Yinti, Nigeria. Farmers have named the grain legume "Ezoworo," meaning new cowpea.

market prices and three spraying treatments, were figured at ₦110/ha. (₦1 = $1.50 U.S.)

The cooperating farmer at Yinti reports that he has been besieged by requests for seeds from farmers in the surrounding area, and he will continue to plant the crop in the 1984 dry season.

In a socio-economic context, the production of a crop of dry season cowpeas in a rice fadama area such as Yinti has these advantages:

- It can be grown during a slack labor period.
- A highly nutritious and preferred food is available during time of short food supplies, and less local money has to be spent to bring in large quantities of cowpeas from Sokoto State in the north. (Because cowpeas are important to their diet, a family of eight will spend an average of about ₦150 per year to purchase them.)

TABLE 1.
Varietal characteristics and agronomic yield data for short-season cowpea varieties from an on-farm exploratory trial at Yinti, Nigeria during the dry season (1983).

Cowpea variety	Observed season length (days)	Seed color	Yields (kg/ha) Three sprays	No sprays	average
IT82E-60	**68**	**white**	**945**	**764**	**854**
IT82E-18	83	brown	545	255	400

TABLE 2.
Economic returns from short-season cowpea varieties in an exploratory on-farm trial at Yinti, Nigeria (1983).

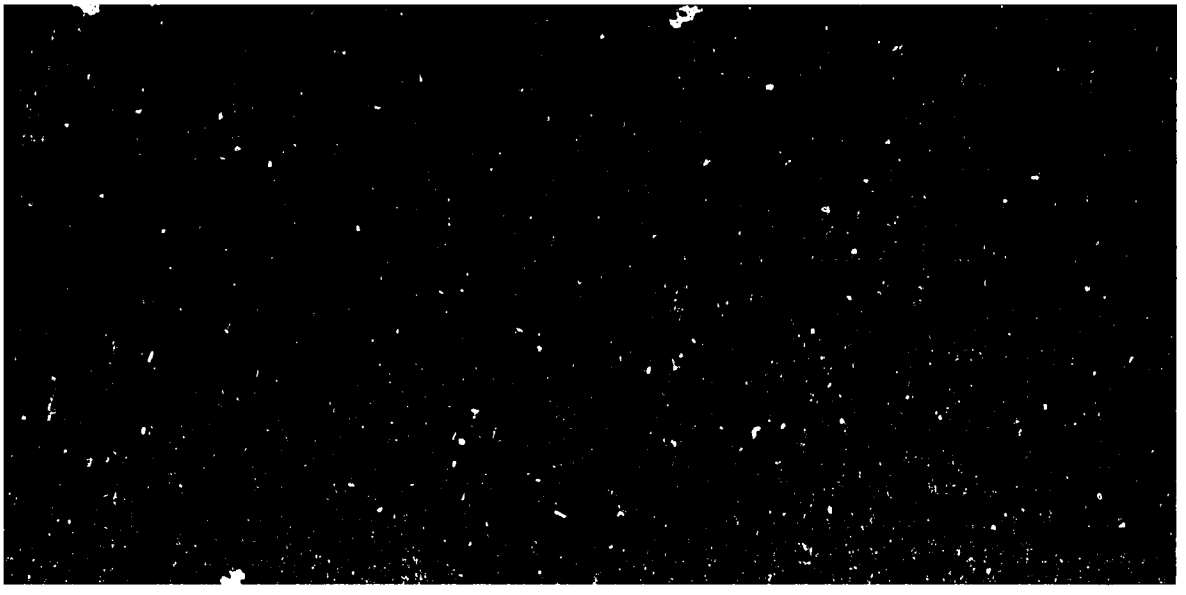
Cowpea variety	Yield 3 sprays (kg/ha)	kg/ man-day*	Total crop value (₦/ha**	Net benefits (₦/ha+)	Benefit/ cost ratio++
IT82E-60	**945**	**13.5**	**945**	**835**	**8.6**
IT82E-18	545	7.8	545	435	5.0

** Based on 70 man-days/hectare.*
*** Based on a net field price of cowpeas of ₦1/kg*
+ Assuming total costs of ₦110/ha, cost of family labor not included.
++ Total crop value divided by farmer cash costs (₦110).

- Farmers can market their cowpeas when local prices are highest and with the cash income hire labor for early land preparation and weeding.

Unfortunately, the exploratory trial at Gara was not successful, largely because the cowpeas were planted too late – in early February instead of early January – and experienced considerable moisture stress. Low production did not justify the cash inputs. However, farmers involved in the Gara site believe that earlier planting on fields with better moisture conditions will give good yields. Farmers not only from Yinti and Gara but also from other villages in the area said they will plant the cowpeas as early as possible in 1984. Their eagerness to get cowpeas planted may strengthen their preference for early-maturing, higher-yielding rice varieties.

The on-farm tests, organized around a farming systems perspective, are continuing in these and other locations to determine if a short-season cowpea enterprise may be applicable to fadama areas throughout Nigeria and West Africa where rice is grown during the rainy season. For the 1984 program, BADP plans to conduct about 30 on-farm tests at different locations.



According to a survey in Central Nigeria, farmers with low cash incomes change their production plans more often than those with higher incomes. Cereals, including maize, ranked as the top source of cash income for the low income farmers.

Comparison of Changes in Production Plans by Low and High Income Farmers

More farmers in Central Nigeria with low cash incomes from products sold change their production plans from year to year than those with higher incomes. This is one of the findings from continuous studies of farming systems and incomes designed and conducted to facilitate implementation of adaptive research programs which involve farmers field activities and management decisions. IITA, in cooperation with agricultural development projects and agricultural universities, has started on-farm adaptive research programs in various African ecological zones to accelerate feedback processes and efficient technology transfer.

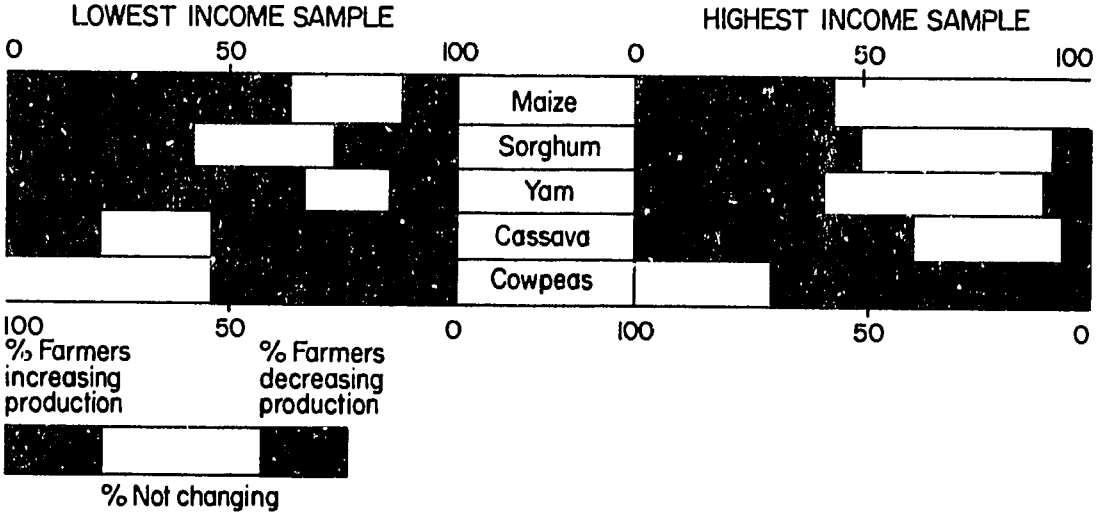
To obtain suitable information for income estimates, staff members of the Ilorin Agricultural Development Project in Kwara State of Nigeria interviewed 194 farmers in 1983 on all crops grown in the research area and on cash obtained for crops sold by individual farmers. Data were processed by IITA agricultural economists with the Institute's computer and comparisons made of farmers with different income levels. Average annual cash earnings from products sold totaled ₦1,700

($2,550 U.S.); but the variation was high with a range from zero for farmers supported by their children to more than ₦10,000 ($15,000 U.S.) for farmers employing additional laborers for most of the farm operations.

For a comparative study, incomes from crops were ranked and the farmers grouped into five different levels; each group represented 20% of the sample. It enabled economists to search for variables relevant to income differences and prepare specific additional interviews on identified problems. Data on the changes in production plans concentrated on the last two years previous to the interviews not only to reduce the bias of seasonal fluctuations but also to focus on arable crops. (Tree crops, of course, need longer periods of planning before changes can be made.) The interviewers asked each farmer which two crops he had increased and the two he had decreased the most.

The proportion of farmers changing crop production is shown in Figure 1. In the research area, mixed cropping patterns dominate and change of one crop does not necessarily mean a change in the total cultivated area. Cowpeas, for example, as an additional crop in a sorghum-yam or maize-cassava-vegetable combination were left out in the mixture. Expansion of yam

FIGURE 1.
Trends in crop production for low and high income farmers in Central Nigeria over a two-year period (1982–83).



Higher income farmers in the survey increased cassava more than any other crop and marketed it for processing into flour and "gari" shown here in a market.

production, however, relates not only to expansion of yam area but also to an increase of the crops intercropped with yam. Expansion of one major crop meant reduction of another crop for most farmers in the lowest income group. However, farmers in the highest income group were able to expand their total farming area by employing more laborers. They used cash from their long-term tree crops for labor payments and had more access to fertile land.

Low income farmers increased production of maize and yam more than any other crops; the largest decrease was in cassava and cowpeas. Most high income farmers also decreased cowpea production but increased cassava which became for them the most important tuber crop. It was marketed for processing into two popular cassava products – "gari" and flour.

Average annual income for the 20% of farmers with the lowest incomes was ₦170 ($255 U.S.); the highest 20% averaged ₦4,400 ($6,600 U.S.). Major differences existed in the importance of farm income sources (Figure 2). For the farms with the higher incomes, tree crops were Number one. (Cocoa, colanut, oilpalm, and citrus in the forest area; locust bean, shea butter tree, oranges, and other fruit trees in the savanna area).

Next in ranking came tubers, followed by cereals, vegetables, and grain legumes. For the lower income farmers, cereals were at the top, followed by vegetables, tubers, and tree crops. Grain legumes were of minor importance.

At present, the results of interviews with more than 2,000 farmers in 44 villages in three different agro-climatic zones in Nigeria are being analyzed which will show regional differences in farm income sources, changes in production plans, and other information of value in establishing priority decisions for research strategies. This study, to be completed in 1984, is a cooperative endeavor between IITA and the University of Nigeria at Nsukka.

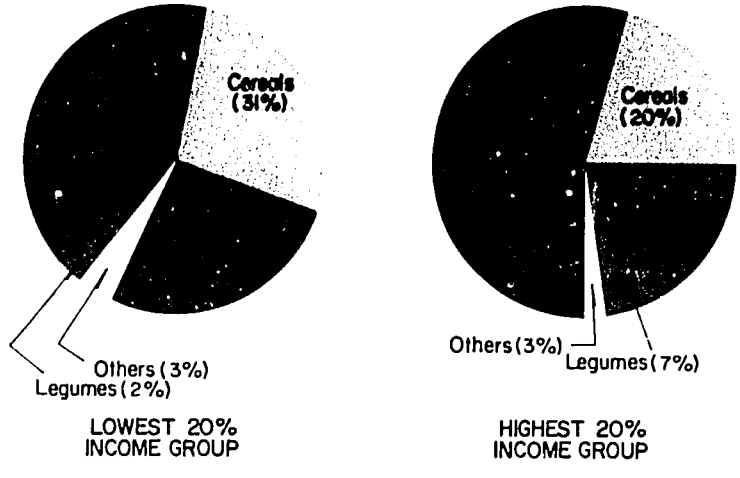


FIGURE 2.
Proportion of cash from agricultural products sold by lowest and highest income farmer groups in Ilorin (Nigeria) Agricultural Development Project (1983).

Developing Linkages between Researchers, Extension Workers, and Farmers in Cameroon

Researchers, extension workers, and farmers have been brought together in Cameroon through the efforts of a unique Testing and Liaison Unit (TLU) of the National Cereals Research and Extension (NCRE) Project. This role for TLU is particularly important because the Ministry of Agriculture has the mandate for extension and the Ministry of Higher Education and Scientific Research is responsible for research. Since both of these government agencies are vertically structured, the flow of information below the ministerial level is very limited.

TLU began full-scale operations in 1982 as a cooperative project involving farmers, Ministry of Agriculture, Institute of Agricultural Research (IRA), and IITA. Principal funding

On-farm rice trial in the North West Province of Cameroon.

A farmer in Cameroon proudly shows samples of her maize from an on-farm trial at a field day. Many of the farmers in the survey in the North West Province were women.

comes from the Government of Cameroon and the U.S. Agency for International Development (USAID). In its first two years, TLU has developed farming systems research methodologies, implemented on-farm research trials with maize and rice, trained extension agents, and helped plan and implement an agro-socio-economic survey of farmers. In each of these activities, the Unit has forged communication linkages between researchers, extension workers, and farmers.

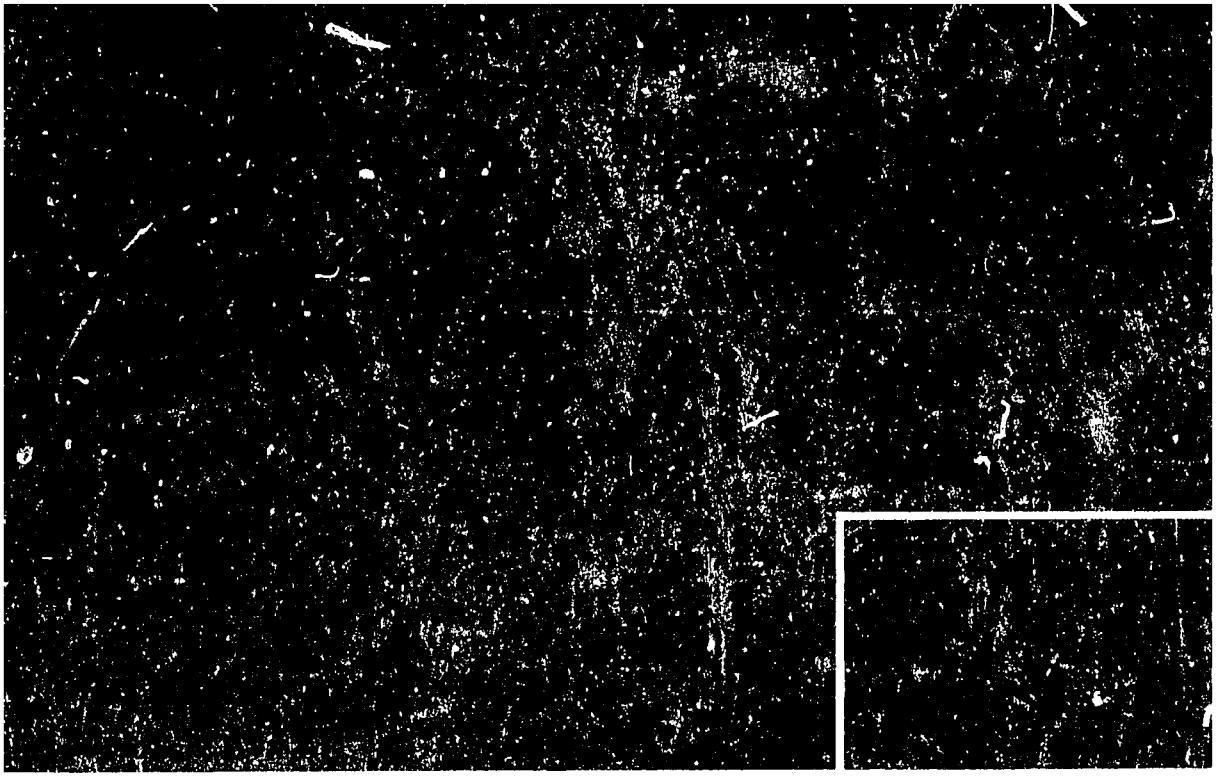
The North West Province in Cameroon, characterized by chains of mountains interrupted here and there by river valleys, was chosen for the agro-socio-economic survey. In general, the agricultural systems there follow the natural vegetative pattern with plantain and root and tuber crops predominating in the

lowland wooded zones and grain and cattle farming in the savanna areas. Forty-eight field demonstrators (men and women) of the Ministry of Agriculture were selected to conduct the 330 farmer interviews between September and December 1982, and the results were analyzed in 1983. (Many of the farmers in the survey were women.)

The interviewers found that the farming systems in the North West Province – one of 10 in the country – are extremely diverse and complex, especially with reference to cropping patterns. (For example, out of one sample of 40 farms, 37 distinct maize-based cropping systems were identified.)

Looking at averages in the survey analysis, the following are some of the principal characteristics of the typical farmer in this province and his or her farming operations: middle aged (40); only four years of schooling; large immediate family (9); food crops grown mainly for subsistence and little income from sale of farm products; fallows the land (three years after 10 years under cultivation); does not use fertilizer on maize and plants it at less than recommended density; employs family labor for most of the farm chores; considers lack of farm inputs (capital, fertilizer, tools, etc.) as the major constraint to increasing production.

The feedback of the results of the survey has provided information to plant breeders, agronomists, government officials, and others to help them focus on farmers' real problems. Furthermore, some of the specific details uncovered on farming systems and cropping patterns will be useful for future on-farm trials which are expected to have a positive impact on many farmers' fields in the province.



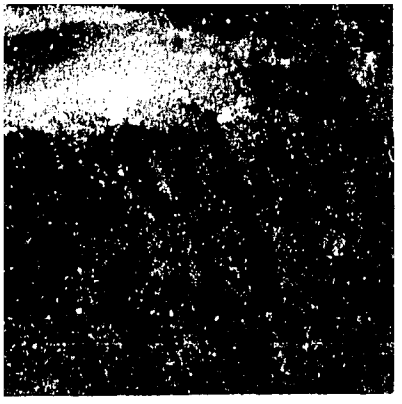
Forest land cleared with heavy machinery and the trees windrowed and burned; the shearblade (inset) was the most desirable method of clearing when all factors were considered.

Land Clearing: Costs and Changes in Soil Properties

Large areas of forest land in the tropics are being cleared at an increasing rate for arable crop production, and a major proportion of it is being done with heavy machinery. Although manual clearing is less disruptive to soil structure, it is slow and less efficient and in regions with a shortage of hired labor can be more costly than mechanical clearing. Therefore, research into mechanical methods of land clearing which result in the least alteration of soil physical properties is of major importance.

Effects of four methods of land clearing on the soil physical properties of an Alfisol were assessed during 1983. Measurements were also made on an uncleared area.

The experimental site was cleared during the 1982/83 dry



First maize crop after land clearing.

season (December to February) and changes in soil physical properties monitored during January and March 1983.

The land clearing methods used were:

- Manual clearing followed by in situ burning.
- Crawler tractor with front-mounted shearblade. The trees were cut off at ground level and burned in windrows.
- Crawler tractor with a front-mounted treepusher, followed by in situ burning.
- Crawler tractor with a front-mounted treepusher, followed by a crawler tractor with a front-mounted root rake. The trees were windrowed and burned.

Each of the land clearing treatments was either cropped with a maize-cowpea sequence or fallowed with a *Macuna utilis* planting in April using the no-till system. Weeds were controlled on the fallow plots by the application of roundup and in the cropped plots by applying paraquat and atrazin. Fertilizer was applied to maize at a rate of 45 kg N, 45 kg P, and 45 kg K per hectare as a single application of 300 kg/ha of 15-15-15 at planting.

Soil physical properties measured were soil bulk density, penetrometer resistance, water retention, saturated hydraulic conductivity, total porosity, and infiltration characteristics. Root growth was monitored at three and seven weeks after emergence for maize, seven and 20 weeks after emergence in macuna and four weeks after emergence in cowpeas.

Mechanical clearing increased bulk density, penetrometer resistance, and proportion of medium-sized pores (2-14.3 μm radius), and decreased infiltration rate, cumulative infiltration, saturated hydraulic conductivity, total porosity, and proportion of macropores (> 14.3 μm radius) (Table 3). Soil water content at a potential of 0 kPa was significantly reduced but increased at potentials of – 10 and – 33 kPa (Figure 3).

In comparison with the forested control, the magnitude of changes in soil physical properties was in this order: manual clearing < treepusher > shearblade = treepusher/root rake.

TABLE 3.
Effect of land clearing methods on soil bulk density (0–10 cm depth interval) and cumulative infiltration (1983).

Clearing method	Soil density (g cm⁻³)	Cumulative infiltration to 3 hrs (cm)
Uncleared	1.00	223
Manual	1.04	294
Treepusher	1.15	201
Treepusher/root rake	1.17	119
Shearblade	1.13	112
LSD (5%)	0.09	94

Although the differential effects of land clearing methods on the soil were reflected only in the initial pattern of maize root growth during the seedling stage (Figure 4), it was sufficient to affect grain yield. Root growth of mucuna and cowpeas was not affected by the changes in soil physical properties.

In summary, manual clearing caused the least soil compaction. Use of the treepusher alone was the least severe of the mechanical clearing methods, but it left the soil surface very uneven. Considering all factors, clearing with the shearblade was the most desirable method of mechanical clearing. In cases where costs or shortages of labor preclude the manual clearing method, clearing with a shearblade or treepusher without the root rake is suggested as a viable alternative. The root rake and root plowing were the most harmful techniques in terms of soil compaction and scraping the fertile surface soil to windrows. Therefore, these practices should be avoided.

Beneficial effects of the mucuna fallow in reversing the soil degradation which follows mechanical clearing depend on the fallow duration. However, it may be uneconomic to put all the land under a mucuna fallow immediately after a heavy investment for land development. One option would be to plant part of the land under macuna for its long-term value for soil fertility and continuous cropping.

Studies by agricultural economists showed that the cost of macuna cultivation totalled approximately $165/ha. Land clearing by the shearblade was the least expensive and fastest of

the four methods. It took less than two hours of machine time and about 19 man-days of labor input per hectare. In contrast, the manual method used 201 man-days of labor input, and with hired labor it was at least four times more expensive than the shearblade.

The gross crop value (maize + cowpeas) of the manually cleared area was the highest ($2,284/ha) followed by the area where the shearblade was used ($2,150/ha). The returns reflect a bumper first season maize crop and a drought-affected poor cowpea crop in the second season.

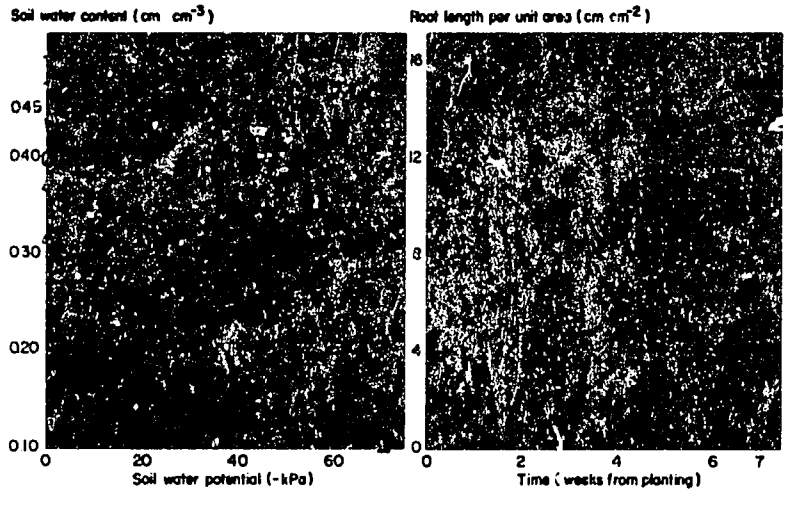


FIGURE 3 (left). Effect of land clearing methods on soil-water retention characteristics for the 0–10 cm depth.

FIGURE 4 (right). Effect of clearing methods on root growth of maize.

Nutrient and Water-Use Efficiency by Crops

Highly weathered upland soils in the humid and subhumid regions of tropical Africa are characterized by low nutrient and water-holding capacities. Low clay activity and the rapid turn-over of organic matter in these soils are primarily responsible for the low nutrient reserve, and the dominance of large pores (transmission pores, $>50\ \mu$) throughout the soil profile is among the major reasons for the low available water-holding capacity.

That combination of soil factors, together with high rainfall intensity and frequent dry spells during the cropping season in the subhumid and bimodal rainfall regions, often result in rapid changes in both nutrient and water supplies to crops. Such changes may affect their normal growth and nutrient uptake. Thus, a better understanding of these relationships is of fundamental importance to improve fertilizer and water-use efficiency.

In collaboration with the Buntehof Agricultural Research Station and the German Agency for Technical Cooperation (GTZ), two experiments were established at IITA by soil scientists in 1983. The first one was conducted on an Alfisol (Oxic Paleustalf, Egbeda Series) with maize planted in the first season (April–July) and cowpeas in the second season (August–November). The second experiment was established on a coarse-textured Entisol (Psammentic Ustorthent, Apomu Series) where maize and cowpeas were grown in rotation between seven-year-old alleys of *Leucaena leucocephala* shrubs (4 m spacing) in an alley cropping system. Soil solution probes and tensiometers were installed in the cropped fields at 10 cm depth intervals to monitor the changes in soil moisture content and nutrient concentration in soil solution as a function of time during the cropping period.

Grown in Highly Weathered Soils

Although the rainy season started late in 1983, the fields received a good distribution of rain during the crucial months of the growing season (May–June). Grain yield of maize was 4.3 t/ha in unfertilized plots and 5.2 t/ha in fertilized plots with 120 kg N, 60 kg P, 100 kg K, and 30 kg Mg per hectare.

Results from soil solution analysis showed that the bulk of the nitrate and potassium was found in the top 30 cm of the soil and their concentrations dropped to very low levels by the middle of

Monitoring changes in soil moisture and taking soil solution samples in a maize plot.

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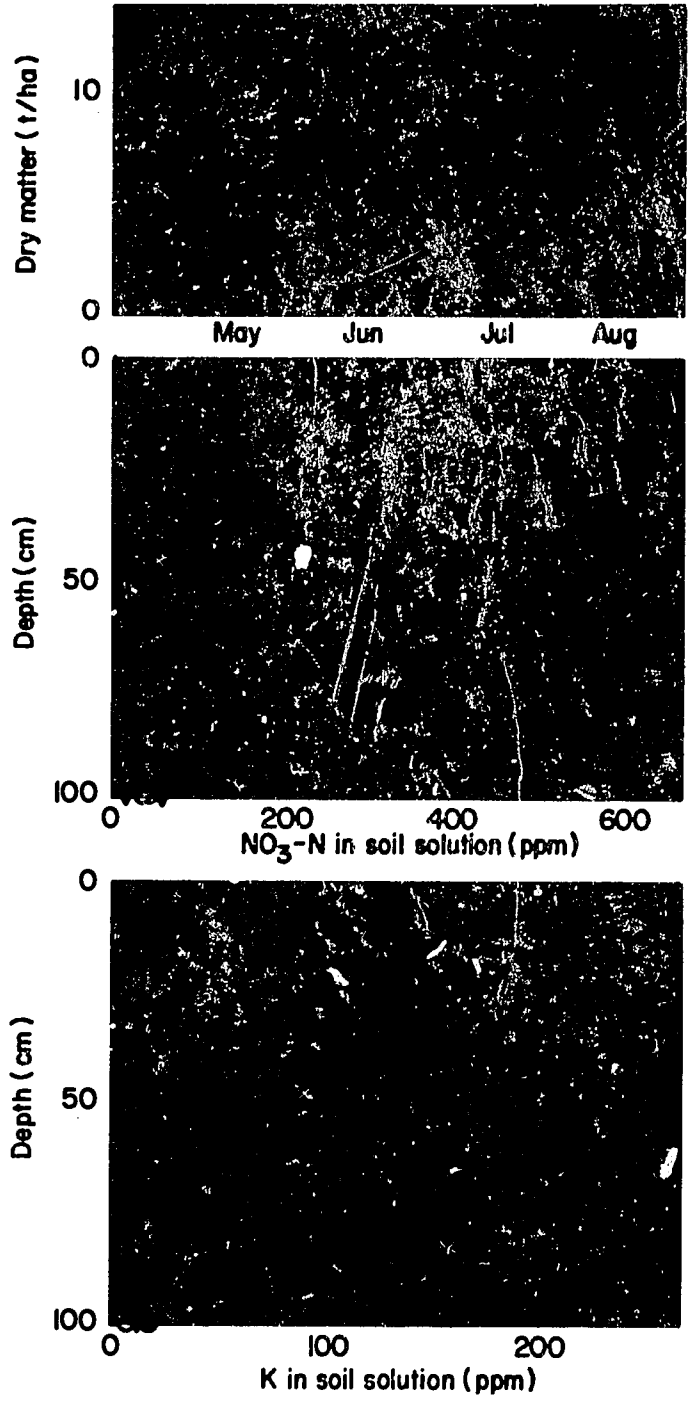
FIGURE 5.
Nitrate and potassium concentrations in soil solution in an Alfisol at IITA (Ibadan, Nigeria) at different times of the growing period of maize.

(a) Growth curve of maize. Colored points on the growth curve indicate the growth stage at which the respective nutrient concentrations were determined as a function of time.
(b) Nitrate concentrations in an Alfisol under maize. It declined rapidly to very low levels during the first half of the growing season.
(c) Potassium concentrations in an Alfisol under maize. It behaved in a similar fashion as the nitrate concentration, but the low soluble K content below 20 cm depth indicated rapid uptake by the plant and the absence of downward movement.



the growing season when only 60% of the final dry matter yield had been produced and the grain filling had just begun (Figures 5a, b, and c). Unless the crop is capable of accumulating an excess amount of mineral nutrients in the early stages of growth which can be redistributed during the later stages, additional N and K would have to be supplied. This is particularly true for soils with a low exchangeable K pool and where the rate of mineralization of soil N is at its minimal level toward the end of the first cropping season.

Moreover, if the period of low nutrient supply should coincide with the period of low soil water content, the situation would be further aggravated. This is an important factor limiting growth and yield when cultivating crops with high nutrient demand but with shallow-rooting systems, such as maize and upland rice in highly weathered soils under erratic rainfall.

There was some downward movement of nitrate in the soil during mid-season after 410 mm of rain (Figure 5b), but leaching was at a slower rate than expected in the well-drained, newly cleared Alfisol. Similar changes in No_3-N and K were observed in the Apomu soil, although the concentrations were much lower.

Changes in the soil moisture profile during the growing season are shown in Figures 6a and b. In the Egbeda soil under maize mono-culture, there was only one moisture depletion zone above 50 cm (Figure 6a). Water content in the subsoil horizons (80 cm and 100 cm depth) remained relatively high throughout the growing season.

Soil solution probes and tensiometer installations in an experimental field at IITA.

Under maize-leucaena alley cropping, water extraction patterns indicated no competition between the two crops (Figure 6b). The tensiometer readings showed that there were two zones of water depletion or uptake by plants: the first zone occurred at a depth between 0–40 cm which could be attributed to the root activity of maize; the second one between 70–90 cm was apparently caused by the water use by leucaena. Lower water use by maize in the Apomu soil than in the Egbeda soil was due to the late planting in the former field.

An important feature of these soils is the high proportion of

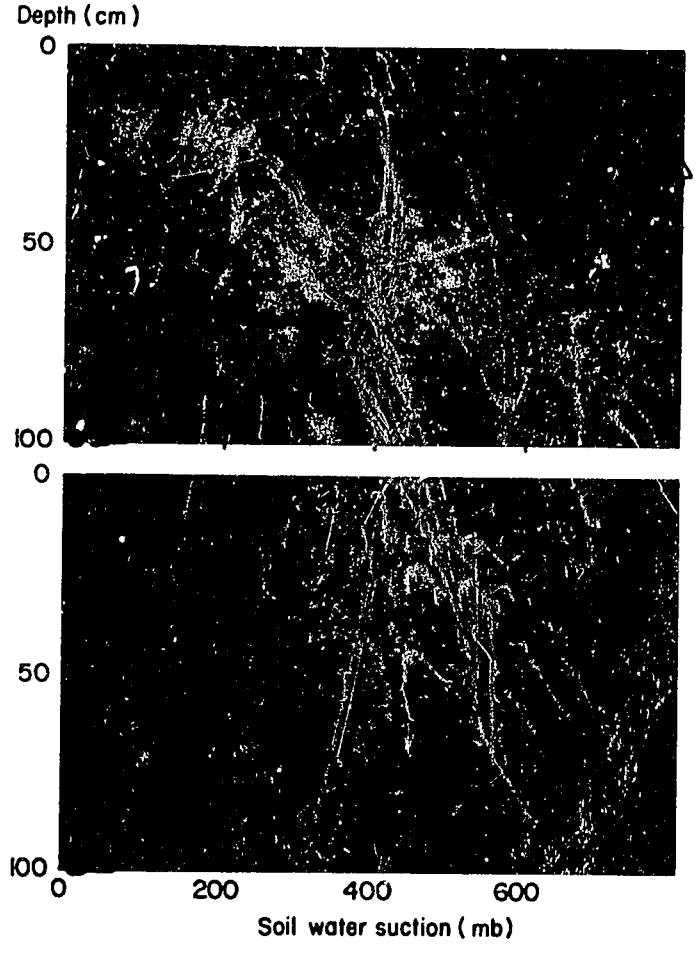


FIGURE 6.
Development of soil water suction patterns under two different cropping systems between two rain storms. High suction (in millibars) means low soil water content.
(a) Under maize monoculture, water extraction was only from the top 50 cm of the soil.
(b) Two separate maxima developed in the alley cropping field with maize as the crop plant and Leucaena leucocephala as the tree species. The water extraction maximum at 70 cm was due to the root activity of leucaena; the upper maximum was caused by maize.

macro or transmission pores (> 50μ diameter) and low available water-holding capacity. The transmission pores in the Apomu soil make up approximately 40% of the total soil volume and the available water content is in the range of 7 to 10% – equivalent to the percentage of storage pores (0.2–50 μ diameter). Transmission pores in the Egbeda soil make up about 34% of the total soil volume, and the available water content is in the range of 10 to 16%. The high proportion of transmission pores is responsible for rapid infiltration and good aeration in both fields after a heavy rain storm. However, this may not be the case when the same soil has been under continuous cultivation of annual crops with heavy equipment.

After a heavy rain (50 mm within 2 hrs.), soil moisture tensions as low as 20 to 30 millibar (mb) were recorded, but the corresponding water content in the Apomu and Egbeda soils was in the range of only 12 to 15% and 15 to 18%, respectively. This indicates that a large proportion of the pore space (transmission pores) is still air-filled.

The low water-holding capacity of the soil and the rapid drainage of excess water through macro-pores allow only a small part of rain water to be used by the crop. Therefore, adequate growth and yield depend upon a frequent soil water recharge. A possible solution to increase nutrient and water-use efficiency would be a careful adjustment of the time for fertilizer application, time of planting, and the selection of deep-rooting varieties of maize and upland rice that can use the subsoil moisture more effectively during dry spells.

Potential of *Sesbania rostrata* as a Nitrogen Source in Alley Cropping

To maintain and improve soil productivity in fragile tropical soils with low inputs, IITA scientists have evaluated over the past few years several small trees and shrubs (usually legumes with nitrogen-fixing ability) as substitutes for traditional bush fallow. Field testing of a fast-growing annual shrub (*Sesbania rostrata*) in alley cropping with rice in a hydromorphic site at IITA in 1982 and 1983 has revealed its benefits as a source of nitrogen (N) for improved rice yields.

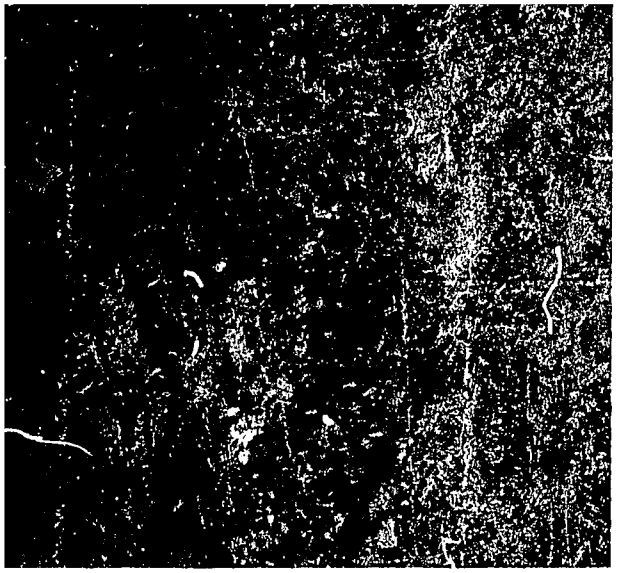
In the rice yield analyses, *Sesbania* prunings distributed evenly between rows of rice were almost equivalent to 120 kg N/ha applied as urea (Table 4). Also, the shoot N content of the rice at harvest time was 38% higher in plots that received the prunings compared with those that did not. This indicates that if rice residues were left on the land after harvest, an alley cropping system using *S. rostrata* as hedge plants would also maintain a better soil nitrogen status.

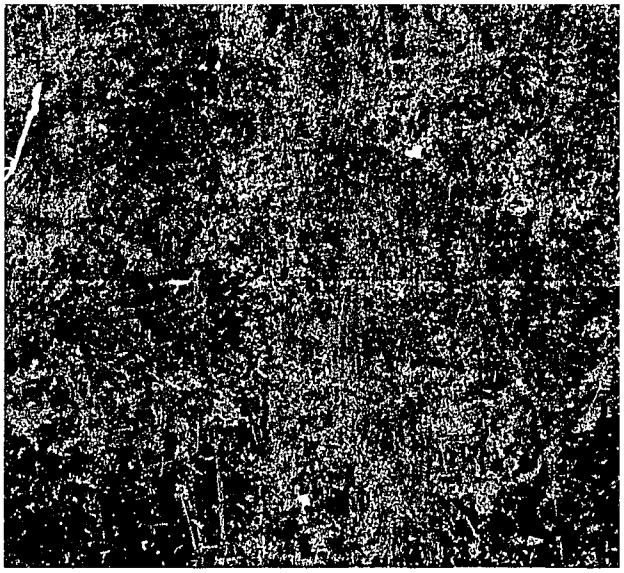
TABLE 4.
Effect of** Sesbania rostrata **prunings and urea on rice yield (kg/ha) in a hydromorphic soil at IITA.

Sesbania prunings (t/ha)*	1982 trial with rice (variety ITA 117) N fertilizer** None	added	1983 trial with rice (variety ITA 212) N fertilizer** None	added
0	5760	7610	3010	4790
3	6850	7890	4480	4710
4	7920	7950	4670	4420
Means	6810	7820	4050	4640

LSD (5%) for comparing means between treatments for 1982: 1060
LSD (5%) for comparing means between treatments for 1983: 670

* Total of two prunings collected at 8 and 12 WAP; 3 t/ha in plots planted at spacings of 10cm × 200cm, and 4 t/ha in plots planted at 10cm × 150cm spacings.
** Urea was applied in two splits of 60 kg N/ha each, at 8 and 12 WAP.

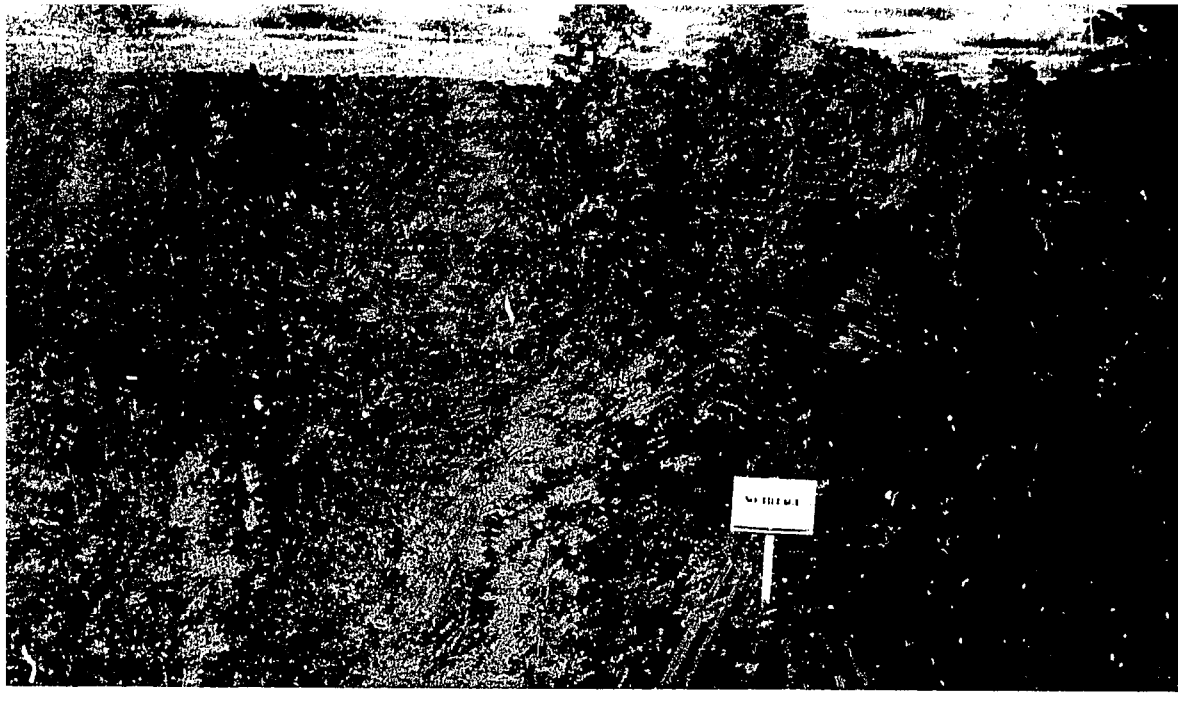




Above, the fast-growing annual shrub, Sesbania rostrata, at an early stage in alley cropping with rice. Because of its nitrogen-fixing ability, the shrub helps to maintain a better soil nitrogen status; right, S. rostrata is unique for its profuse stem nodulation.

S. rostrata thrives as a weed in waterlogged soils in Northern Africa and has good regrowth ability after cutting. It also is unique for its profuse stem nodulation with 4,000 to 5,000 nodules on a 3-meter high stem compared with less than 50 nodules usually found on the roots of this and most other legumes. Stem and root nodulation occurred freely in the field when unsterilized seeds were sown at Onne, Ibadan, and Fashola, Nigeria, with peak nodulation at the podding stage.

In the screenhouses, stem nodules were limited to the crown of the plant, probably because of the absence of pod bugs. However, profuse stem nodulation occurred when *S. rostrata* was sprayed with pure cultures of the appropriate *Rhizobium* and with water suspensions of either macerated stem nodules or soils from Nigeria.



Maize production under the no-tillage system at IITA (1983).

Effect of 24 Maize Crops on Yields and Soil under No-Till and Plowed Systems

A rapid decline in the physical, chemical, and biological qualities of fragile tropical soils under continuous cultivation is a major reason farmers practice shifting cultivation in the humid tropics and leave the land fallow for long periods. The relative duration of the cultivation and fallow phases depends on when crop yields decline below an economic leval and on the time needed to restore soil productivity. The cultivation phase is shortened when productivity declines rapidly with normal cultural practices. Because of this, an interaction between the soil properties and the cultural practices governs the relative lengths of the cultivation and the fallow phases.

The most desirable cultural practices and cropping/farming systems are those that enable a soil to be cultivated continuously with positive economic returns and without causing a severe decline in soil quality. Cultural practices that preserve a favorable soil/crop/climate balance during cultivation, similar to

that which exists during the fallow phase, will allow continuous cropping without a severe decline in soil quality.

A long-term study (1971-83) on no-tillage with crop residue mulch shows that this farming practice, which does not involve mechanical soil disturbance, can maintain economic yields of grain crops (such as maize) without causing a severe decline in soil productivity. Maize yields with the no-tillage system, based on an average of 24 consecutive crops (Figure 7), have been higher than those obtained under the conventionally plowed system. The following requirements, however, must be met for the no-tillage system to be effective:

- An adequate amount of crop residue mulch.
- Minimal soil disturbance.
- Favorable soil structure before initiating the cultivation phase.
- Not using farm equipment which could lead to soil compaction.
- Adequate and timely weed control.

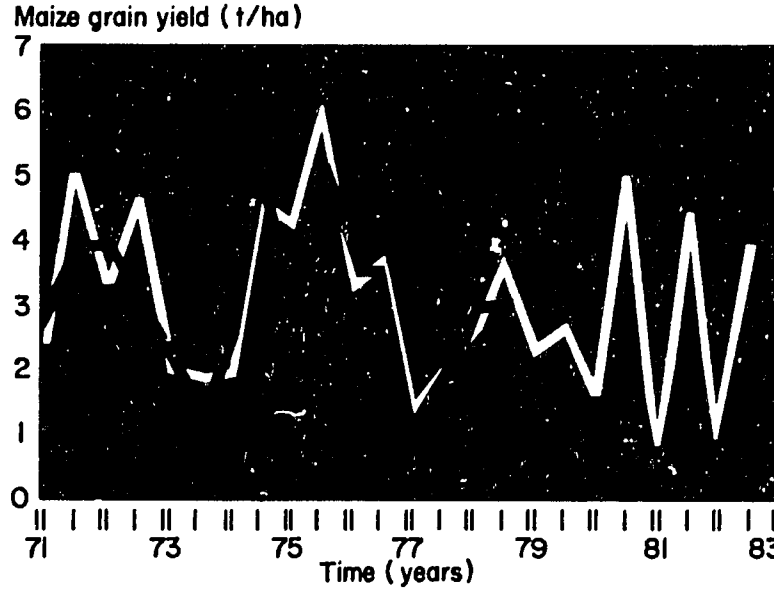


FIGURE 7.
Maize yields over 24 consecutive crops under a no-tillage system compared with a conventionally plowed system.

TABLE 5.
Effects of tillage methods on properties of the 0–5 cm soil layer after growing 24 consecutive crops of maize.

Property	No-tillage		Conventionally plowed	
Sand (%)	66.9	±2.5	70.9	±1.9
Silt (%)	11.2	±1.6	9.9	±0.8
Clay (%)	19.9	±1.9	19.2	±1.6
Gravel (%)	12.1	±2.5	27.5	±9.8
pH (1:1 in H_2O)	5.9	±0.1	5.3	±0.2
Organic carbon (%)	1.69	±0.27	1.44	±0.07
Total nitrogen (%)	0.179	±0.040	0.093	±0.007
CEC (meq/100g)	7.6[illegible]	±1.40	5.99	±0.91
Exchangeable Ca^{++} (meq/100g)	5.31	±0.64	2.87	±0.62
Exchangeable Mg^{++} (meq/100g)	0.97	±0.21	0.31	±0.08
Exchangeable K^{+} (meq/100g)	1.06	±0.46	0.32	±0.16

If all requirements of the no-tillage system are met, grain crops can probably be grown on a continuous basis with only periodic short-term fallows of appropriate grass/legume cover crops. Besides favorable yield returns with comparatively low inputs, the no-tillage system minimizes soil erosion and maintains better soil structure and chemical properties.

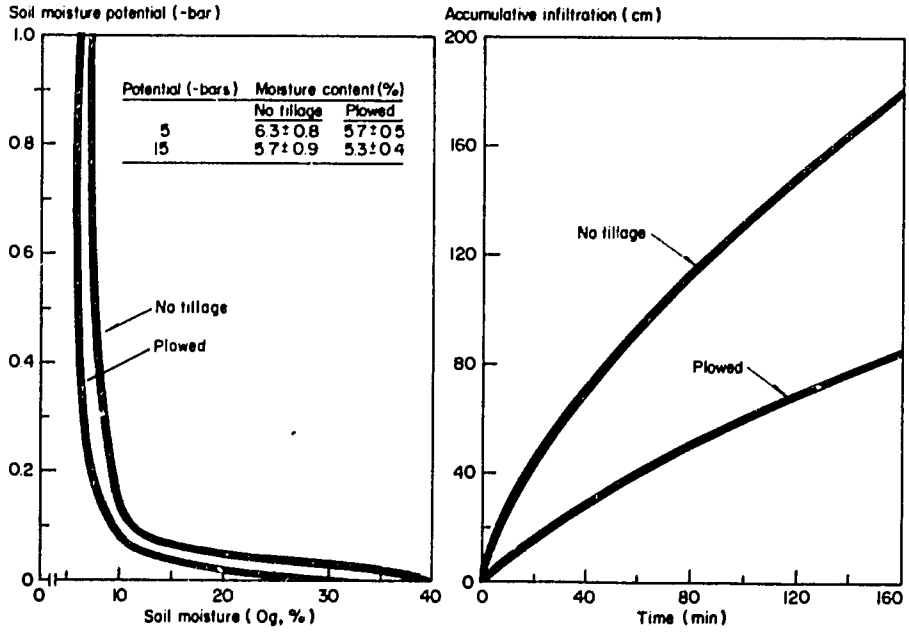
The data in Table 5 compare the mechanical and chemical properties of the 0–5 cm soil layer after growing 24 consecutive crops of maize with no-tillage and conventional plowing methods of seedbed preparation. The soil pH in no-tillage plots was about one-half unit more than that of the plowed treatment and contained 17% more organic matter, 92% more nitrogen, 85% more Ca^{**}, 3.13 times more Mg^{**}, and 3.31 times more K^{*}. The CEC was almost double that in the plowed soil.

High organic matter content and favorable soil structure allow the no-till soil to retain more available water in the root zone than soil repeatedly plowed. Figure 8 compares the moisture retention characteristics of the surface soil from plowed and no-tillage treatments. The surface soil from no-tillage treatments retained more water than that from plowed land and during periods of drought stress crops in plowed plots wilted two to three days earlier than in no-tillage.

Plowed soil is very susceptible to surface sealing. The impacting raindrops from an intense rain break up structural aggregates and the surface soil develops a semi-impermeable crust that impedes water and air movement. The oxygen diffusion rate in the no-tillage soil with mulch and in the conventionally plowed soil was measured to be 0.588 $\pm$0.140 and 0.417 $\pm$0.028 $\mu g\ cm^{-2}\ min^{-1}$, respectively. The development of surface crusts also restricts water entry into the soil. The data on infiltration (Figure 9) show the equilibrium infiltration rate was 18 and 48 cm per hour for plowed and no-tillage soil, respectively. As a result, water runoff and erosion are considerably more for plowed than for no-tillage soil.

FIGURE 8 (left). Moisture retention characteristics of the surface soil from no-till and plowed treatments.

FIGURE 9 (right). Water infiltration rate under no-till and plowed treatments.



Effect of In-Situ Mulch on Soil Temperature and Maize Producton

High temperature during germination and early growth often causes poor crop establishment in the tropics. Mulching with plant residue is an effective means of keeping soil temperatures below levels detrimental to crops, but conventional methods of mulching with plant materials are not economical with field crops, especially in large-scale production. The in-situ mulch technique, in which the mulch is the residue of a previous cover crop, appears to be an economically feasible method that could be used to prevent high soil temperatures and ensure good crop establishment. It is, of course, only feasible under a no-tillage system.

The effect of in-situ mulch from the cover crop *Mucuna utilis* was measured on a field that had been kept fallow under the cover crop during the previous year. The control (no-mulch) was created by removing the mulch. The effects of four levels of applied nitrogen were also studied.

Temperature differences between mulched and unmulched plots were not markedly different for readings taken between

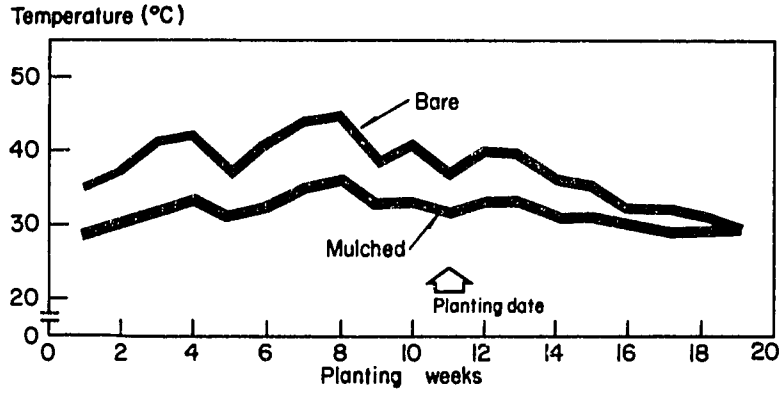


FIGURE 10.
Soil temperature changes at 14.00 to 15.00 hours with and without *Mucuna utilis* ***in-situ mulch in dry and early rainy seasons.***

08.00 and 09.00 hours but were markedly different for readings taken between 14.00 and 15.00 hours with bare plots having higher temperatures (Figure 10).

Emergence of the maize in both unmulched and mulched plots was good, but subsequent growth, as measured by plant height, was retarded in the unmulched plots (Figure 11). As the rainy season progressed and the maize canopy shaded the soil, temperature differences became less distinct. Plant height differences also became less and at tasselling the differences were not significant. Yield differences between mulched and unmulched plots were not significant at low nitrogen (N) treatments, but at 60 and 90 kg/ha N with mulch they were significantly better than mulched and unmulched treatments

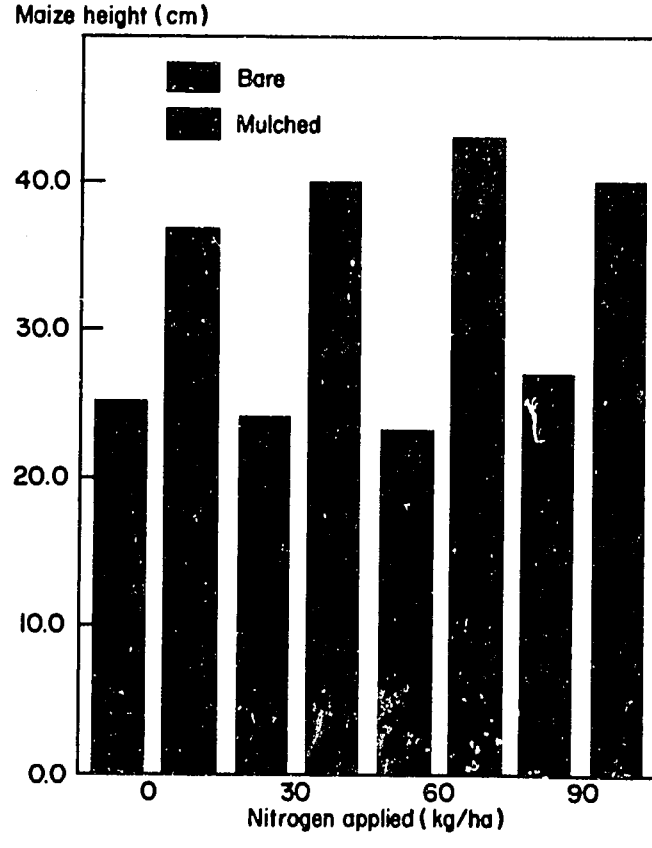


FIGURE 11.
Maize plant heights as affected by in-situ mulch and levels of applied nitrogen (N) at 22 days after planting.

Maize growing under in-situ** Mucuna utilis **mulch (left) and no mulch (right) four weeks after planting.

without added N (Figure 12). The trends suggest that in the favorable root environment created by in-situ mulch N utilization was more efficient.

In the tropics where high soil temperatures and irregular rainfall adversely affect crop establishment, soil temperature suppression and soil moisture conservation through in-situ mulch should improve crop establishment, early growth, and yields. The production of mulch in-situ from *M. utilis* is potentially a mulching technique for small and large scale production, and it can be used with different types of no-till planting equipment.

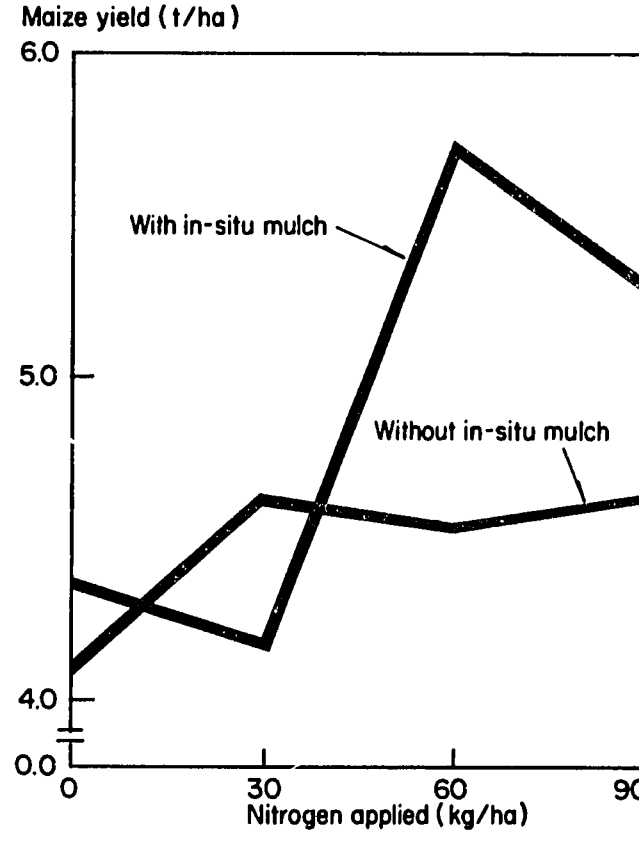


FIGURE 12.
Maize yield response to applied nitrogen with and without in-situ mulch.

Disease Resistant Maize Varieties for Mid-

Maize streak virus (MSV) is widely spread throughout Africa and causes severe yield losses in the lowland humid and savanna areas, as well as in the mid-altitude ecologies (1000–1800 m).

The first international trial with streak resistant maize varieties adapted to the lowlands of Africa was conducted last year (*Research Highlights*, 1982). However, these varieties are not adapted to the mid-altitude ecologies of Eastern, Southern, and Central African countries because of the different climatic conditions and the presence of not only MSV but also of two other major foliar diseases – highland blight (*H. turcicum*) and rust (*P. sorghi*). The latter two do not occur in the lowlands. Devloping varieties resistant to the three diseases is important because the mid-altitude ecologies are the best potential maize growing areas on the continent.

To maintain the adaptation and disease resistance of the mid-altitude germplasm and to introduce streak resistance, IITA scientists collected the best available maize varieties and hybrids from Eastern, Southern, and Central Africa and crossed them with a streak resistance source. The resultant progenies were bulked together to form a new maize population – TZMSR. It is late maturing with white grain color preferred by consumers in many countries in Africa. A combined half-sib and S_1 selection breeding procedure was followed for a number of generations, screening the materials for streak resistance under artificial infestation at Ibadan, Nigeria and for the highland blight and rust resistance in Riyom station near Jos (1300 m above sea level).

By 1982, when a good level of resistance to streak and the highland blight and rust was achieved, 250 full-sibs were produced and distributed for the first international progeny trials

Altitude Ecologies in Africa

Progeny trial performance of TZMSR – a mid-altitude streak resistant maize variety – in Zambia.

Blight resistant maize (left) and susceptible plants (right) in a field at Jos, Nigeria during the development of TZMSR.

in Zambia, Zimbabwe, Cameroon, and Nigeria. The adaptation and resistance to the highland foliar diseases in all the test locations were very good. Mean grain yield (7.8 t/ha) was similar to the mean of the best local checks (7.7 t/ha), but the average yield of the selected families in the four different locations was 9.9. t/ha – 29% higher than the best check (Table 6).

Based on these trials, six experimental varieties were developed by recombining the 10 families selected for yield performance, short plant type, and maturity. These varieties are now included in the 1983/84 International Mid-Altitude Streak Resistant Experimental Variety Trials (EVT-MSR) offered by the IITA/CIMMYT African Maize Program.

An additional streak resistant variety, EV 8344-SR(BC_3), is also included in the trials. It was developed by the joint CIMMYT/IITA work on streak resistance by converting an experimental variety from Population 44 (A.E.D. x Tuxpeno) to streak resistance by backcrossing procedures.

Hybrid maize varieties are widely used in Eastern and Southern Africa. IITA has initiated a streak resistant inbred line development program for the mid-altitude ecology. Approximately 500 lines are presently at the S_3 stage. Advanced lines will be available to national programs following combining ability tests and further selection for adaptation and disease resistance.

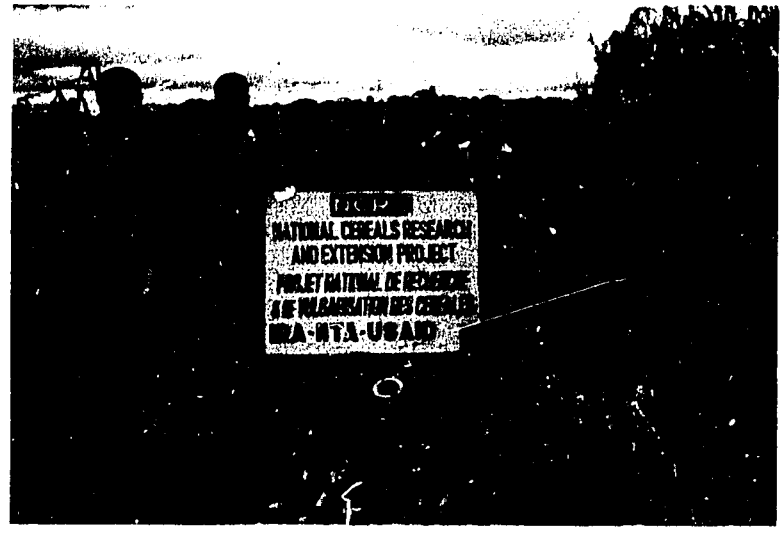
TABLE 6.
Mean grain yield (t/ha) of 250 full-sib families from mid-altitude streak resistant maize population TZMSR-W tested at four locations (1982/83).

	Zambia	Zimbabwe	Cameroon	Nigeria	Mean
Mean of population	4.9	7.3	9.0	9.8	7.8
Mean of selected families	6.2	8.8	11.6	13.2	9.9
Yield of best check	4.2	7.8	8.8	9.8	7.7
LSD (5%)	2.3	3.5	2.8	3.8	3.1
CV (%)	24	18	15	20	19

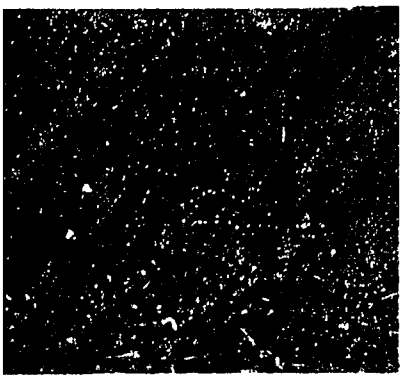
Potential for Increased Maize Production in Cameroon

Because of more favorable rainfall distribution and higher solar radiation during the growing season, the subhumid savanna regions of West Africa are better food grain producing areas than the humid forest zones in the South. This is particularly true in areas with sufficient rainfall and mono-modal distribution. In such an area in Cameroon, scientists from the IITA/IRA Cameroon/USAID collaborative project on national cereals research and extension (NCRE) achieved commendable results in 1983 in maize, rice, millet, and sorghum improvement through testing and evaluation of improved crop varieties and cultural practices both on farmers' fields and on research stations.

The NCRE project picked up Gusau TZB 81 as a promising maize candidate for the 1983 National Variety Trial and compared it with 17 other selected varieties from Cameroon, other African national programs, CIMMYT, and IITA. This trial was grown at eight different lowland locations in Cameroon,



Part of the harvest of a maize agronomy trial in North Cameroon. IITA variety TZPB produced over 7 t/ha when planted in mid-June. In palatability tests, farmers preferred this soft white variety over a widely grown yellow variety.



Drying maize variety TZB along the roadside after the harvest.

and across these locations Gusau TZB 81 was the highest yielding variety producing 7.5 t/ha – 61% above the local check and 24% over the trial mean.

Because this variety showed high yield potential in Cameroon, the NCRE team plans further testing of it in large-scale agronomy trials during the 1984 crop season. After that, it will go into on-farm demonstration trials operated by NCRE's Testing and Liaison Unit. (This variety also performed well in the savanna areas of Northern Nigeria, and, because of the encouraging results in both countries, IITA scientists have initiated a "conversion" project to incorporate streak resistance in it.)

Maize yields in a large number of trials in North Cameroon near Garoua ranged from 6 to 8 t/ha for all three varieties tested – TZPB, TZB, and Poza Rica 7843. These yields were achieved even though total rainfall during 1983 was 30% below normal.

Palatability tests conducted through the Cotton Development Authority (SODECOTON) indicated that farmers in the area strongly preferred the soft white maize variety TZPB to the yellow maize variety Samaru 123 which is widely grown by SODECOTON farmers in the area. The Authority has requested the Cameroon National Seed Production Company near Garoua to produce sufficient TZPB seeds to be distributed to farmers for the 1984 cropping season which would amount to a total maize planting of approximately 2,000 hectares in the area.

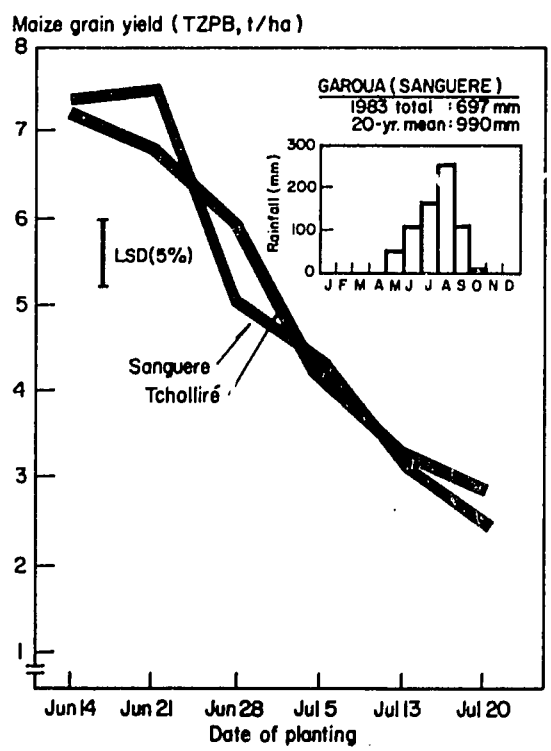
Results from agronomic trials clearly showed that high grain yield can be achieved by timely planting, adequate nitrogen fertilization, and suitable crop rotation. Time-of-planting trials conducted by NCRE agronomists at two locations (Sanguere near Garoua and Tcholliré) demonstrated that with early planting in mid-June the IITA maize variety TZPB produced over 7 t/ha. Yields declined steadily when dates of planting were later than the third week of June (Figure 13).

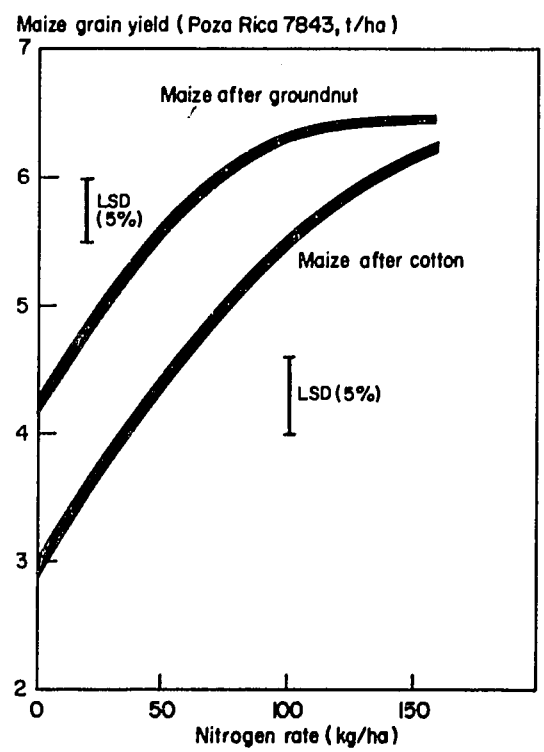
Results from a cropping systems trial conducted at a substation of the Institute of Agricultural Research (IRA) at Sanguere showed significant contribution of soil nitrogen (N_f) when maize

was planted after groundnuts, but when planted after cotton more nitrogen fertilizer was required to obtain a similar high yield (Figure 14). This suggests that a rotation system of maize-groundnut-cotton-groundnut-maize would be more profitable than continuous maize or cotton for the SODECOTON farmers in North Cameroon. Moreover, the sandy, poorly buffered soils (mainly Haplustalfs derived from sandstones) may be easily acidified under continuous fertilizer use.

FIGURE 13.
(Below left). Maize grain yields of IITA variety TZPB recorded in time-of-planting trials in 1983 at Sanguere and Tocholliré in North Cameroon.

FIGURE 14.
(Below right). Response of maize to nitrogen (urea) application in two cropping systems at Sanguere in North Cameroon (1983).





Developing Hybrid Maize for the Nigerian

Nigeria produces about 1.5 million tons of maize annually on 1.7 million hectares, but this is not sufficient in view of the popularity of maize as one of the main staple cereals for consumers and the rapid expansion of the poultry industry. Approximately 900,000 tons of yellow maize is required annually for chicken feed, and most of it is imported. In addition, maize can be a basis for local industrial production of oil and sweeteners to further decrease the need for imports.

Many large-scale farms were put into operation in recent years to increase maize production. Also, the Federal Government of Nigeria began to support a special project for hybrid maize development in 1982 under its "Green Revolution Program." It was based on IITA's hybrid maize project started in 1979 with the objective of developing inbred lines with high combining ability and adaptation to tropical stress conditions and resistance to the major African diseases. With the assistance of the Nigerian special project, research on hybrid maize was intensified. Scientists focused on developing hybrids adapted to the savanna zone – the best potential area for maize production in the country.

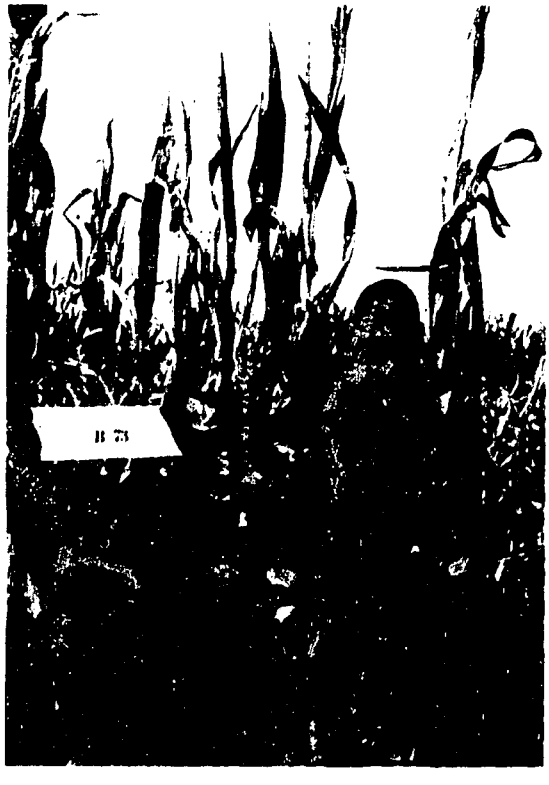
During 1982, maize breeders tested a total of 1,000 inbred lines for combining ability with the best available open-pollinated varieties. Crosses were tested in different locations. At the same time, the adaptability, vigor, and disease resistance of the lines *per se* were tested in the same locations. Based on these trials, 73 inbred lines were selected and used to produce about 400 experimental single cross hybrids during the dry season of 1982. The hybrids were sub-divided into sets of 25 entries each, including the two best available open-pollinated varieties as checks. A total of 26 sets were prepared with 21 (12 white and nine yellow) adapted to the savanna and five (two white and

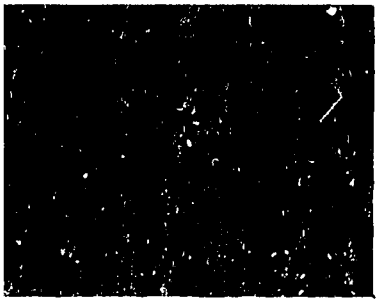
"Green Revolution Program"

three yellow) to the forest zone. Each set was planted at several locations in 4-row plots with four replications.

The 1983 cropping season was badly affected by drought, especially in the savanna area. (Only 60% of average annual rainfall, and the rains had ceased before the end of September.) Despite drought conditions, yields obtained in the hybrid trials were high. Hybrid 8322-13 yielded an average of 9.1 t/ha across four savanna locations with a range of 8.8 to 10.6 t/ha (Table 7).

Converting highly potential but unadapted inbred maize lines from the U.S. corn belt (left) into adaptable tropical inbred lines (right).





Late yellow hybrid maize harvested in Funtua, Nigeria (1983).

Also, this hybrid was high yielding (7.6 t/ha) at Ikenne – a representative site of the forest zone – which indicates its stability across locations (Table 8).

The highest yield of 12.1 t/ha was obtained at Samaru with the hybrid 8324-18. This is the highest yield recorded so far under experimental conditions in Nigeria.

Most of the hybrids are resistant to the major lowland diseases such as maize streak virus, rust, and blight. The excellent performance of the hybrid trial was especially noticeable against the background of a severe epidemic of maize streak virus in farmers' fields all over the savanna area.

TABLE 7.
A summary of selected maize hybrids for savanna areas in Nigeria (1983).

Maturity grain color	Hybrids	Av. grain yield (t/ha)	Yield ranges (t/ha)	Yield index* (%)
Late white	8322-15**	9.1	8.0–10.6	150
	8324-18	8.9	6.8–12.1	141
	8322-3	7.8	6.3– 9.3	136
	8323-14	7.5	6.1– 9.6	133
	8326-16	8.3	7.6– 8.6	129
	8321-18	8.6	5.8–11.1	128
	8321-17	8.6	6.6– 9.9	128
	8321-21	8.5	6.4–10.0	128
Late yellow	8330-16	7.4	5.7– 8.4	137
	8329-23	7.9	6.2–10.4	134
Intermediate white	8338-4	8.3	7.0–10.4	164
	8338-2	7.3	5.1– 8.9	149
	8346-1	6.7	4.5– 7.8	152
	8346-3	6.6	5.3– 7.7	150
Intermediate yellow	8341-6	8.1	7.5– 9.1	148
	8340-21	7.0	5.0– 8.0	146
	8340-23**	6.9	4.1– 8.1	140
	8341-5	7.5	5.9– 8.9	138

**Average of the two checks was used to calculate the yield index for a better comparison between hybrids of different sets.*
***Selected at both savanna and forest areas.*

A large-scale commercial maize farm in Nigeria showing the beginning of a streak epidemic which spread in farmers' fields all over the savanna area. Most of the hybrids tested in 1983 were resistant to maize streak virus.

Twenty-four hybrids were selected for further testing and demonstration in 1984 in farmers' fields over a total area of about 100 hectares. Seeds were being produced during the 1983/84 dry season, and plans call for the production of 100 tons of hybrid seed in the 1984 crop season for 5,000 hectares of commercial maize production by Nigerian farmers in 1985.

TABLE 8.
Selected maize hybrids for a forest area in Nigeria (1983).

Maturity grain color	Hybrid	Grain yield (t/ha)	Yield index (%)
Late white	8326-10	8.5	157
	8326-17	7.0	149
	8326-16	7.0	148
	8322-15	7.6	131
Late yellow	8329-22	6.6	153
	8329-15	6.1	142
Intermediate yellow	8340-23	5.5	157
	8341-12	6.0	152

Close-up of Striga infestation (with pink to mauve flowers) at the base of maize plants.

Combating Striga Infestation in Maize

Severe localized infestation of maize fields with *Striga hermonthica* – a parasitic weed – has been observed in the savanna belt of Nigeria, Cameroon, Mali, and other West African countries. The spread of Striga is of major concern because maize production has become more popular in the savanna belt and replaced sorghum and millet in many areas where rainfall is adequate.

Striga damage to maize is reflected by leaf firing, stunted plants, and poor pollen production and ear development – all of which can drastically reduce yields. This parasitic plant is difficult to eradicate by conventional means because it produces many seeds that retain their viability in the soil for many years and germinate only in the presence of the host plant.

Although resistant varieties have been developed for sorghum by ICRISAT and for cowpeas by IITA/SAFGRAD, similar work on maize did not start until 1982. Research during that year and in 1983 under natural field infestation of maize demonstrated the existence of genetic variability for resistance to Striga damage and that breeding resistant varieties is possible.

In the 1982 crop season at Gusau, Nigeria (Sudan savanna zone) significant differences in Striga ratings were found among nine parental varieties and 36 F_1 crosses. In the 1983 crop season at Mokwa, Nigeria (Guinea savanna zone), under severe drought and heavy Striga infested conditions, grain yields of some selected hybrids were approximately double the best open-pollinated check variety used in each trial set. For example, hybrid No. 8322-13 showed the lowest Striga rating (1.4) and also produced the highest yield – 3.9 t/ha or 207% of the best check (Table 9).

Some inbred lines derived from tropical × U.S. corn belt germplasm (such as Rpp TZSR-Y × N28) showed relatively low

ratings of Striga in different hybrid combinations (Table 10). They probably confer resistance genes. It is of interest to note that the selected hybrids from each of the trial Nos. 8329, 8340, and three out of the four selected hybrids in trial No. 8341 had one inbred in common – 9848, 7103, and 9499, respectively. This

TABLE 9.
Ratings of** Striga hermonthica **of some selected high yielding maize hybrids at Mokwa, Nigeria (1983).

Entry* No.	Pedigree	Grain yield (t/ha)	% best check	Striga ratings*** Hybrid	Striga ratings*** Range**
8322-13	**1368 × 9030**	**3.9**	**207**	**1.4**	**1.4–4.8**
8322-3	**1188 × 9006**	**3.6**	**187**	**2.9**	**1.4–4.8**
8329-9	9236 × 9848	2.0	251	2.5	2.0–4.8
8329-23	9516 × 9848	2.0	242	2.5	2.0–4.8
8329-22	9490 × 9848	1.7	221	2.3	2.0–4.8
8340-9	7103 × 9646	2.8	219	3.5	2.0–4.5
8340-7	7103 × 9613	2.7	211	2.0	2.0–4.5
8340-12	7103 × 9432	2.5	196	2.8	2.0–4.5
8341-12	9485 × 9613	3.4	198	2.3	2.0–4.8
8341-3	8057 × 9499	3.3	190	2.5	2.0–4.8
8341-16	9499 × 9624	3.2	183	3.3	2.0–4.8
8341-6	9450 × 9499	3.1	178	2.5	2.0–4.8

**8322, 8329, 8340, and 8341 represent different trials of 25 entries each.*
***Range of average score of 25 entries within each trial.*
****Ratings 1–5; 1 = resistant, 5 = susceptible.*

TABLE 10.
Mean Striga rating of the inbred lines in the partial diallel hybrid combinations at Mokwa, Nigeria (1983).

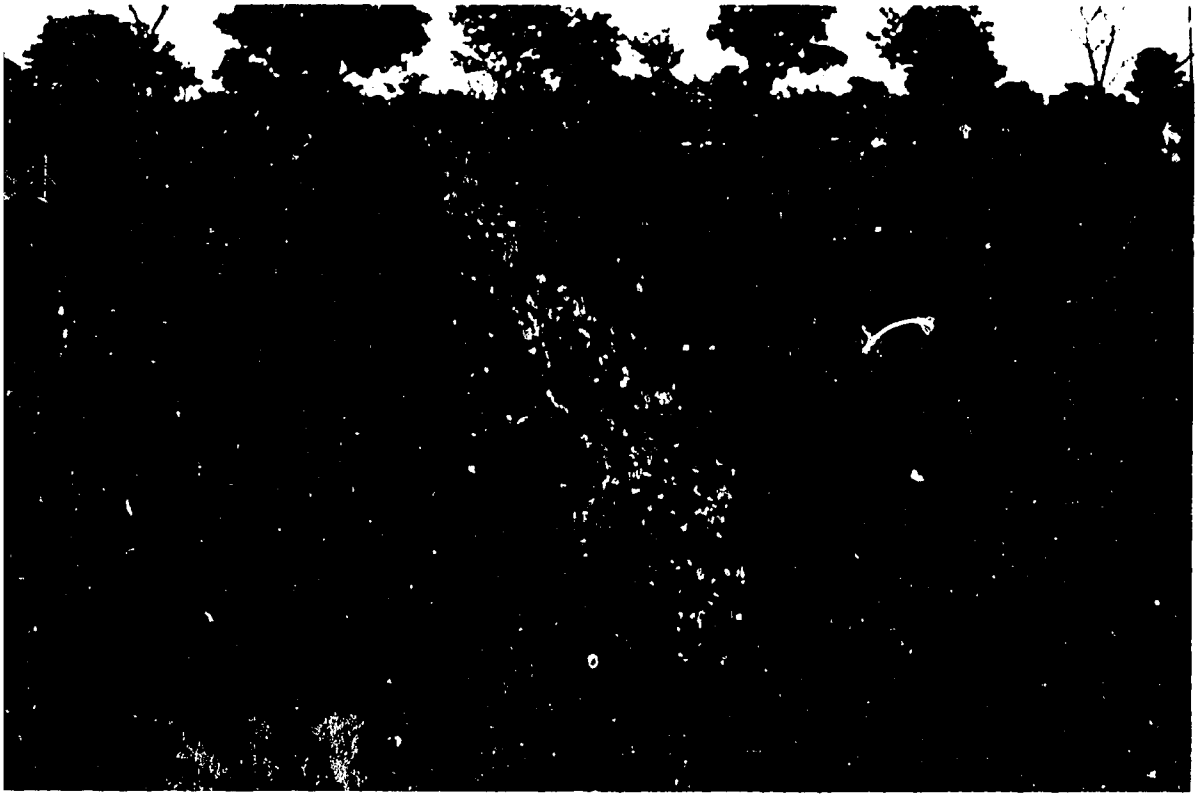
Inbreds	Origin	No. hybrid combinations	Striga rating* Array mean	Striga rating* Ranges
9089	**Rpp TZSR-Y × N28**	**8**	**2.6**	**1.5–3.5**
9090	**Rpp TZSR-Y × N28**	**9**	**2.7**	**1.4–4.1**
9006	**M017 × Rpp SR**	**12**	**2.9**	**1.4–3.9**
1190	**Across 7622 × TZSR**	**17**	**3.9**	**2.3–4.9**
1201	**Across 7622 × TZSR**	**7**	**3.9**	**3.3–4.8**
2131	**Sete Legaas 7728 × TZSR**	**6**	**4.1**	**3.4–4.6**

**Ratings 1–5; 1 = resistant, 5 = susceptible.*

confirms the potential of these lines as donors for Striga resistance.

Encouraged by the data obtained during 1982 and 1983 and the possibility to develop Striga resistant varieties and hybrids, IITA scientists are increasing their efforts to develop reliable screening techniques and selection for Striga resistance to combat the potential threat of this parasitic weed.

Striga – a parasitic weed – has destroyed the susceptible maize crop on the right, but the resistant hybrid line (8322-13) on the left had a very low Striga rating and produced the highest grain yields in tests at Mokwa, Nigeria (1983).



Left to right, *Cicadulina triangula* ***eggs in the maize leaf mid-rib and a nymph and adult leafhopper feeding on maize leaves. This leafhopper is the vector of the destructive maize streak virus disease.***

Increasing Leafhopper Numbers and Infestation Efficiency for Maize Streak Virus Resistance Breeding

Because the breeding program for resistance to maize streak virus (MSV) has greatly expanded in recent years to develop resistant varieties with different maturity range and ecological adaptation, the demand for the virus vector leafhopper (*Cicadulina triangula*) by scientists has exceeded the supply. Therefore, intensive efforts have been underway since 1982 at IITA to improve mass rearing techniques and increase the number of leafhoppers produced.

As a result, several innovations in the rearing techniques have permitted an increase in the number of artificially reared leafhoppers on a weekly basis from 15,000 in 1981 to 50,000 in 1982 to about 200,000 in 1983. Most of these leafhoppers are non-active or short distance flyers used on experimental plots. They stay and feed longer on one plant, thereby increasing the uniformity of streak infection. The very low streak infection of farmers' maize fields near the IITA experimental farm indicate that the leafhoppers are confined mainly to the IITA plots.

The innovations in the rearing techniques include:

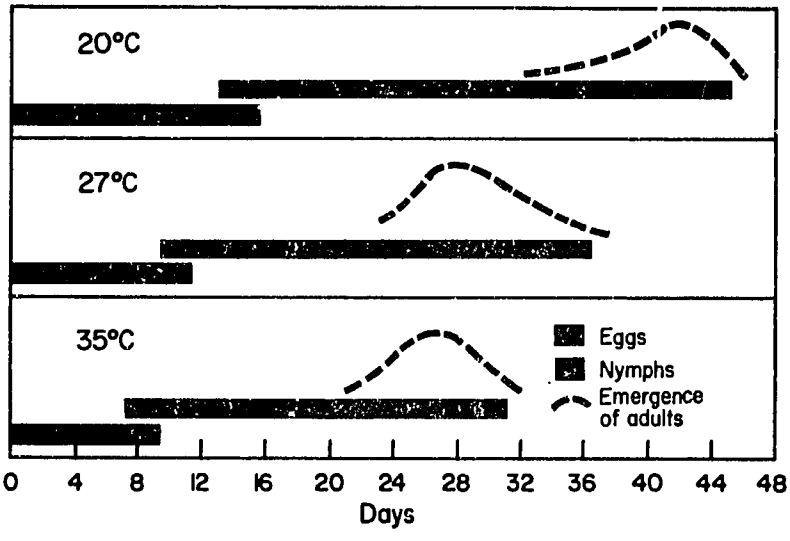
- Changing the oviposition procedure from egg laying cages to an open-air egg laying table under greenhouse conditions

increasing more than two-fold the number of pests available for egg laying on the same space. In addition, leafhoppers escaping from the rearing cages during watering, changing plants, and collection are attracted to the plants on the egg laying table.

- Replacing maize seedlings with millet plants for oviposition. Millet, unlike maize, when damaged by leafhopper feeding develops a large number of tillers which are available for later nymph feeding. This eliminates the need for laborious plant changes during nymph development and prevents the loss of nymphs during the transfer process.
- Monitoring at two-week intervals the average number of eggs oviposited allows for corrections in the number of adults released on the oviposition table.
- Taking into account slower development due to changes in temperature. Such changes affect the egg and nymphal development periods (Figure 15) and the productivity of the

Difference between streak-susceptible check and streak-resistant IITA maize cultivars in the field under artificial infestation of *Cicadulina triangula.*

FIGURE 15.
Effect of temperature on the development of *Cicadulina triangula* ***– the vector of maize streak virus disease.***



colony. More insects are released in the oviposition table during the cooler period between July and September, and a longer period of development is being taken into consideration in planning the work schedule.

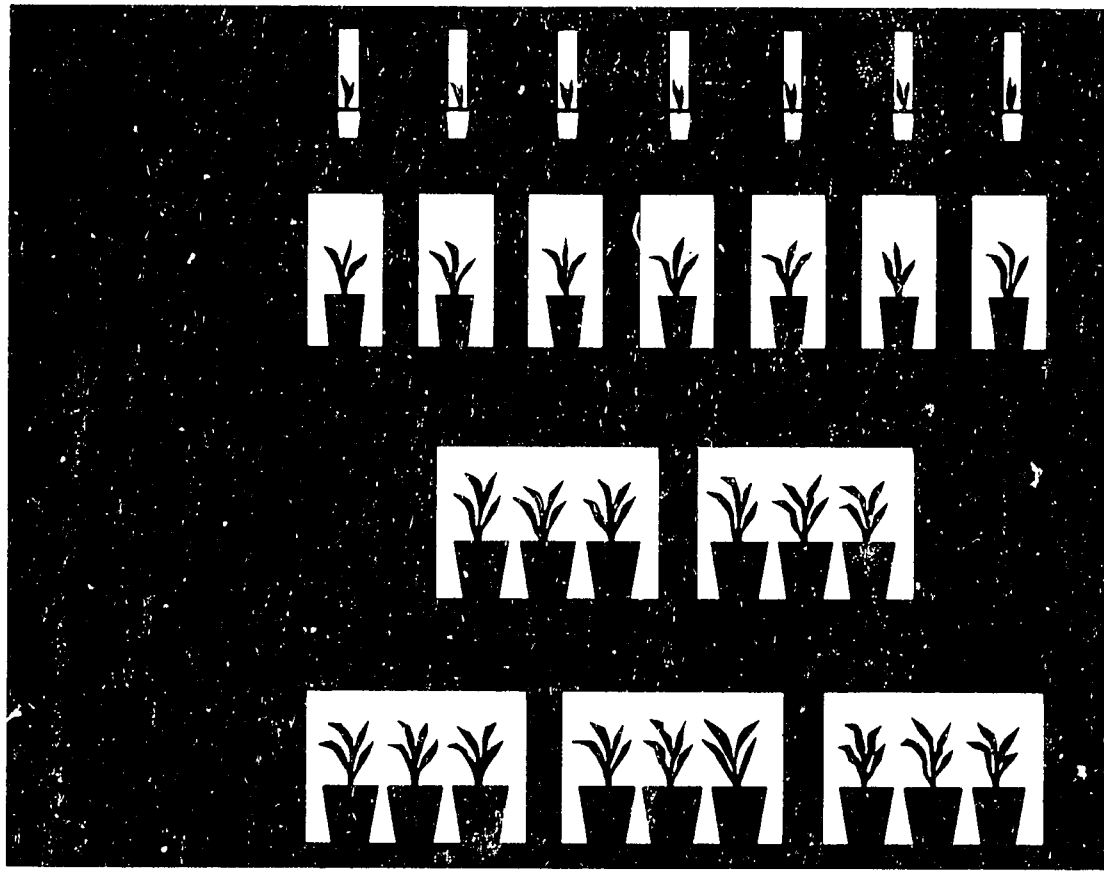
- Increasing the virus acquisition period of leafhoppers grown on millet from 24 to 48 hours doubled the percentage of active transmitters from 22 to 46%.
- Improving the genetic capabilities of the leafhopper population maintained in IITA greenhouses by individual selection of active transmitters further increased the percentage of active transmitters from 46% to as high as 80%.

The last two innovations allow the infestation of 25 to 30% more plants with the same number of leafhoppers and a 95 to 100% efficiency in field infestation.

IITA is currently helping national research programs develop their own *Cicadulina* colonies for maize streak screening. Trainees from several African countries – including Kenya, Tanzania, Zambia, Burundi, Cameroon, Togo, and Ghana – have observed

and used the techniques and methods developed by the Institute's scientists (Figure 16). These include collection of the live leafhoppers in the fields, transportation to the laboratories or screenhouses, and multiplication from an initial small population.

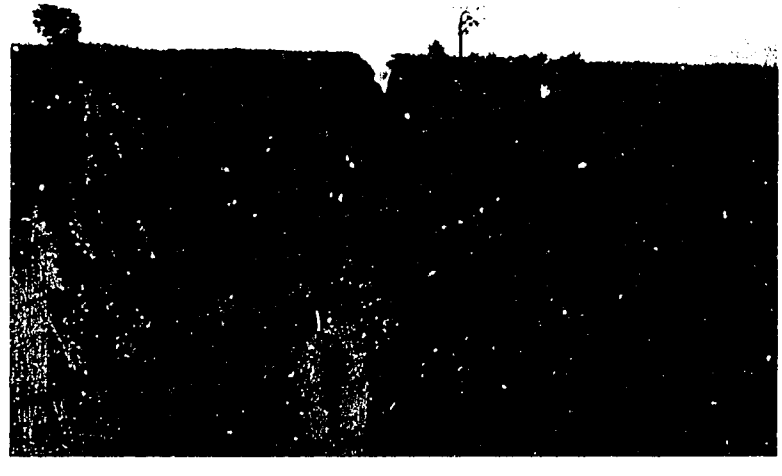
FIGURE 16.
Procedure used to develop mass rearing of an *Cicadulina* ***spp. colony for screening purposes.***



Performance of Rice Varieties on Natural Slopes of Inland Valleys

Millions of small farmers in Africa plant rice on natural and undisturbed slopes of inland valleys in undulating relief – a major land form of the humid and subhumid parts of the continent. On these slopes the environments for growing rice may vary from free draining upland to impeded drainage depending on the relief (landscape), the position of the rice plants on the relief, and rainfall pattern. Rice plants therefore may suffer stress due to lack of water at times and natural flooding at other times. Rice varieties which have been selected either for strictly upland ecosystems or strictly lowland ecosystems may not be able to adjust to the peculiar conditions of toposequence and not be flexible enough to produce satisfactory yields when planted on natural slopes of inland valleys.

To evaluate the potential of toposequence as a tool for screening rice varieties, IITA scientists evaluated the performance of seven upland and 12 lowland varieties on a no-



Toposequence with a range of ecosystems at IITA for growing rice – from a drought-prone, freely drained upland area (top of photo) to a flooded area (bottom).

tilled area of a V-shaped valley on the Institute's experimental farm during the 1983 wet season. The experiment started on June 22 and ended on November 15. The level of groundwater was monitored weekly. The soils of the area were surveyed and rice varietal response and performance along the toposequence observed.

Four distinct ecosystems were identified on the experimental toposequence (Figure 17). They were:

Freely drained upland: Groundwater table never rises up to the effective root zone of rice. Plants showed moisture stress symptoms as early as one week after the rain stopped.

Intermediate upland: Groundwater table rose as high as 20 cm below the soil surface during the peak of rainy period and

FIGURE 17.
Schematic presentation of four ecosystems in a toposequence of a V-shaped valley at IITA's experimental farm at Ibadan, Nigeria (1983).

dropped to about 80 cm below the soil surface during the dry spell. Rice showed moisture stress symptoms only when the dry period lasted for several weeks.

Intermediate flooding: Groundwater table was always in the root zone of rice. After heavy rainfall groundwater sometimes surfaced. Rice never showed moisture stress symptoms in this part of the toposequence.

Flooding: Groundwater was at the soil surface or over-flowed during most of the growing season. Signs of ferric iron accumulation were occasionally observed in this part of the toposequence.

Rice yield increased from freely drained upland to intermediate flooding and then decreased slightly in the flooding ecosystem (Table 11). The lower rice yield in the flooding ecosystem could be attributed partly to poor germination and crop establishment and partly to stresses associated with natural flooding.

Across the toposequence, yielding ability of upland varieties was more stable than that of lowland varieties, although the latter yielded much higher than the former in both intermediate flooding and flooding ecologies. Furthermore, within each varietal group, there was a distinct difference among varieties with regard to the flexibility to adapt to variation in moisture conditions (Figure 18).

TABLE 11.
Average grain yield of seven upland and 12 lowland rice varieties planted on different ecosystems in a toposequence (IITA, 1983).

	Grain yield (kg/ha)	
Ecosystem	Upland varieties	Lowland varieties
Freely drained upland	1185	[illegible]
Intermediate upland	1575	[illegible]
Intermediate flooding	2315	4129
Flooding	[illegible]	3234

With different environments ranging from drought prone freely drained upland to hydromorphic and impeded drainage ecologies, a toposequence area such as the one described here provides an ideal setup to facilitate the early identification of rice lines adapted to various ecologies in Africa.

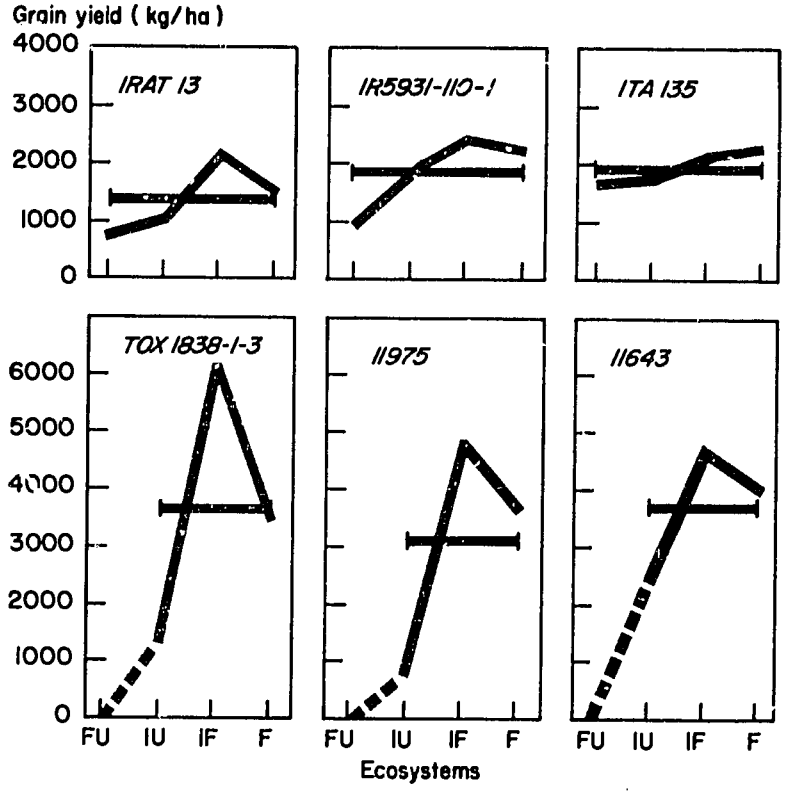


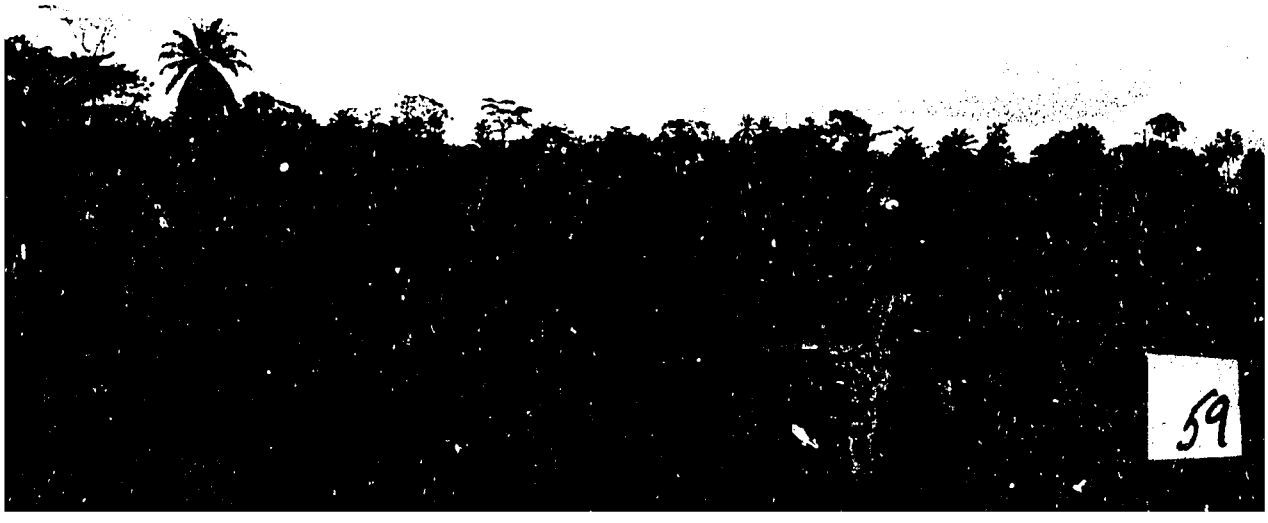
FIGURE 18.
Grain yield of three upland (top) and three lowland (bottom) rice varieties planted to four ecosystems in a toposequence of a V-shaped valley at IITA's experimental farm at Ibadan, Nigeria (1983).

Tolerance to Iron Toxicity of Selected IITA Rice Varieties

Intensifying the use of wetlands for rice and other food crops by small farmers may be a major step toward food sufficiency in tropical Africa. But to accomplish this, further research is needed to develop appropriate soil and water management technologies and practices that small farmers can adopt and to select and breed better yielding rice varieties that are more resistant to diseases and tolerant to adverse soil conditions.

Iron toxicity is a widespread problem for rice grown in inland valleys and swamps where seepage flows contain a high concentration of ferrous iron (Fe^{**}) and the soils maintain a strongly reduced (or oxygen-depleted) condition throughout the year because of a high groundwater table. In collaboration with the Anambra/Imo/World Bank Smallholders Rice Production Scheme, IITA soil scientists and plant breeders have conducted research over the past two years on farmers' fields in a small inland valley of about 20 hectares near Bende in Southeastern Nigeria to characterize the source and dynamics of reduced iron in soil. Also, they have tested lowland rice varieties for tolerance to iron (Fe) toxicity.

A view of the Bende, Nigeria inland valley developed by farmers with the assistance of the Anambra/Imo/World Bank Smallholders Rice Production Scheme. The iron toxicity experiments took place here.



The Bende experiment has shown how plant breeders and soil scientists work together in developing a field methodology for testing lowland rice for tolerance to iron toxicity.

Many groundwater tubes were installed in the Fe-toxic and non-toxic areas. The groundwater table and the concentration of ferrous Fe in the soil solution were measured weekly. A rice variety (IR 26), susceptible to Fe toxicity, was planted uniformly across the concentration gradient of ferrous Fe in the field. Based on the data of ferrous Fe concentration in soil solution monitored throughout 1982/83 and the score of Fe toxicity symptoms expressed by the susceptible variety IR 26 (bronzing and various degrees of oranging), it was possible to delineate the field into three Fe-toxic zones (Figure 19).

In Zone A, which has a mean value of soluble Fe of 50 ppm and a maximum of 80 ppm occurring during the growing season, IR 26 showed severe bronzing symptoms and gave little or no grain yield. In Zone B, which has a mean value of soluble Fe of 30 ppm and a maximum of 50 ppm, IR 26 showed severe oranging and some bronzing symptoms. The number of tillers also decreased significantly. In Zone C, which has a mean value of soluble Fe of

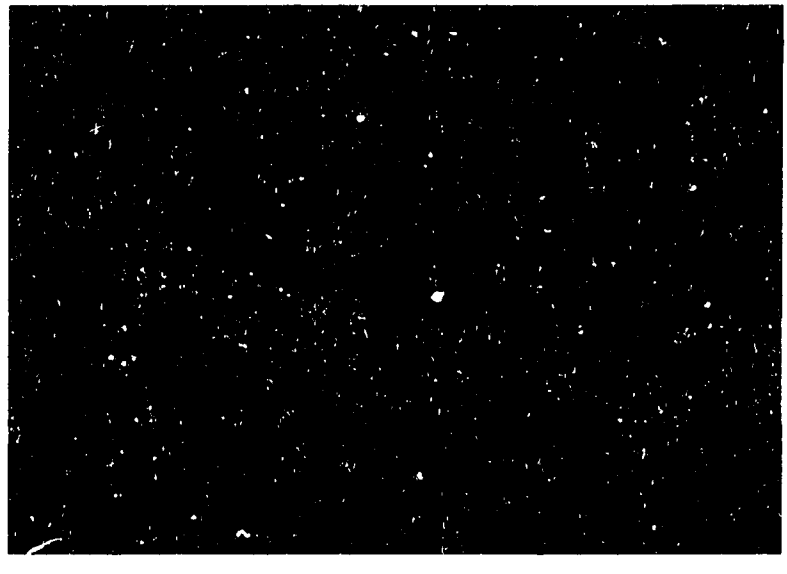
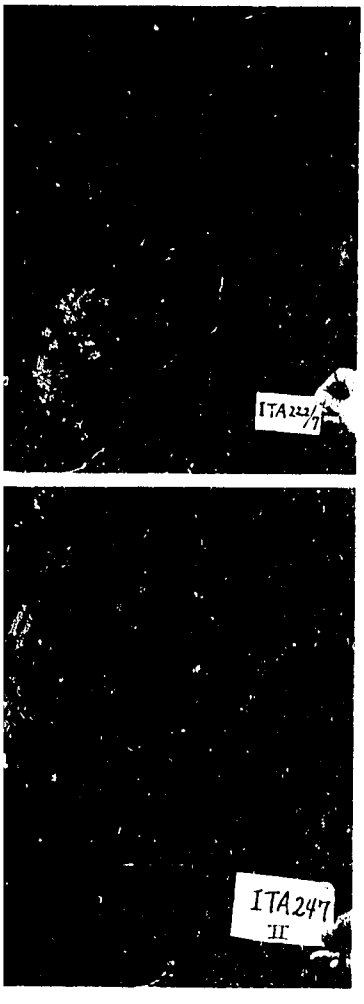


FIGURE 19.
Isolines of mean and maximum concentrations of ferrous Fe in soil solution occurring during the growing season in relation to iron (Fe) toxic zones delineated by leaf symptoms of a susceptible rice variety, IR 26. It was grown during the 1983 cropping season in an inland valley at Bende, Nigeria.



Two rice varieties grown in the high iron toxicity zone. (See Figure 19.) The susceptible variety ITA 222 shows leaf bronzing and very few tillers, the tolerant variety ITA 247 fairly normal growth.

2 ppm and a maximum of 10 ppm, this rice variety showed slight oranging symptoms but only scattered occurrence. Zone D represents a non-toxic area.

In the 1983 cropping season, 16 ITA rice selections and two introduced varieties were evaluated inside three Fe-toxic zones in the Bende valley (Figure 19). Included as checks were two highly tolerant varieties (Suakoko 8 and Gissi 27) and two susceptible (IR 26 and IR 52). The iron toxicity rating based on the severity of leaf symptoms (i.e., bronzing, oranging) was scored at 30, 60, and 75 days after transplanting.

Growth and yield data showed that only the plot located inside the high Fe-toxic Zone A depicted differential response among the 22 varieties. The low Fe-toxic area showed no significant effect on the growth and grain yield of the varieties. Response to toxicity of the varieties in the medium toxic area (Zone B) was not consistent, probably due to the variability of the ferrous iron concentration within the zone.

Mean of iron toxicity ratings taken at 30, 60, and 75 days after transplanting in Zone A is summarized in Table 12. Six ITA varieties – ITA 242, 245, 250, 238, and 247 – showed a high degree of tolerance. These varieties were derived from the cross Tox 711 (IR 5/Suakoko 8) – one of the earlier IITA crosses intended primarily to incorporate iron toxicity tolerance to improved plant type and high yielding varieties. Suakoko 8 is an IITA selection in Liberia known to be tolerant to this adverse soil problem. ITA 253 and ITA 244, which showed moderately tolerant reaction in the trial, were also selected from the IR 5/Suakoko 8 cross.

Three-year yield date obtained under non-stress conditions at Ibadan for the six varieties are also given in Table 13. Comparing the results from Ibadan with those from Bende where iron toxic conditions exist, the decrease in yield in the susceptible varieties amounted to about 90%, but less than 50% for the tolerant selections. Different parents and tolerance sources are being explored to develop diverse varieties that fit different iron toxic environments.

As reported in IITA's 1982 *Research Highlights*, Fe toxicity to

TABLE 12.
Reaction to iron toxicity of the lowland rice varieties grown in an inland swamp in Bende valley, South-eastern Nigeria.

Tolerant	Moderately tolerant	Susceptible
ITA 242 (2.0)*	ITA 232 (4.0)	ITA 233 (5.0)
ITA 245 (2.8)	ITA 253 (4.0)	ITA 123 (5.2)
ITA 250 (2.8)	ITA 244 (4.2)	ITA 121 (5.3)
ITA 239 (3.0)	ITA 222 (4.3)	ITA 231 (5.5)
ITA 238 (3.2)	BG 90-2 (4.5)	ITA 212 (5.5)
ITA 247 (3.8)	IR 5 (4.3)	ITA 230 (6.0)
Suakoko 8 (2.5) (check)		IR 52 (5.0) (check)
Giusi 27 (3.7) (check)		IR 26 (5.8) (check)

**Number in parenthesis is the mean of the scores taken at 30, 60, and 75 days after transplanting. The IRRI 1–9 scale, with 1 indicating tolerance and 9 susceptibility, was used in scoring for Fe-toxicity reaction.*

TABLE 13.
Performance of selected ITA rice lines on Fe-toxic soils at Bende valley and under non-stress conditions at Ibadan, Nigeria.

		Fe-Toxic soils Bende, 1983		Yield under non-stress conditions, Ibadan. (t/ha)			
Variety/line	Cross	Tolerance[1] score	Yield (t/ha)	1983	1982	1981	Av.
Tolerant							
ITA 245	IR 5/Suakoko 8	2.8	2.41	4.04	4.84	4.44	4.44
ITA 239	IR 5/Suakoko 8	3.0	2.81	4.73	6.19	4.05	4.99
ITA 247	IR 5/Suakoko 8	3.8	1.87	4.52	5.10	4.92	4.85
Suakoko 8 (check)	Siam 25/3* Malunja	2.5	2.61	4.23	–	–	4.23
Susceptible							
ITA 123	OS 6 mutant	5.2	0.18	3.74	5.15	4.78	4.56
ITA 121	Moroberekan/SE 363G	5.3	0.57	3.81	5.29	4.66	4.59
ITA 212	BG 90-2*4/Tetep	5.5	0.48	4.39	6.36	5.07	5.27
IR 26 (check)	IR 24/TKM 6	5.8	0.13	3.54	–	–	3.54

[1] *Mean of the scores taken at 30, 60, and 75 days after transplanting. The IRRI 1–9 scale of scoring was used with 1 indicating tolerance and 9 susceptibility.*

rice grown in a given inland valley and swamp is generally a localized phenomenon. Severe toxicity normally occurs in a field adjacent to the source of seepage flow containing high concentration of ferrous Fe, particularly when the soil is poorly drained and has a high groundwater table throughout the year.

Fluctuation of the groundwater table in the rainy season in the various sites in the Bende valley follows the rainfall pattern. But the magnitude of groundwater fluctuation varies from one site to another which is associated with soil type. Although the non-toxic zone is situated in the lowest part of the landscape (Figure 20), groundwater tubes (T) installed in this zone showed the largest fluctuations of the groundwater table throughout the year. This indicates that soils in the non-toxic area are better drained than those in the Fe-toxic area even though the latter is situated on a higher elevation. Apart from the farther distance from the seepage source, the large fluctuations of groundwater and redox potential in the non-toxic area allow the ferrous Fe in the soil solution either to drain out with groundwater or to be oxidized and precipitated as ferric oxides.

On the other hand, soils in an Fe-toxic area (Figure 20, Sites T2 and T3) remain almost permanently saturated and reduced at shallow depth throughout the year.

Thus, in the development of the lowland non-toxic area for irrigated rice cultivation, necessary measures should be taken to ensure that ferrous Fe in the seepage water from the upper slope is prevented from accumulating in the flooded rice field. This may be achieved by intercepting the main seepage flow in the upper slope and by draining the field at the end of the cropping season to allow oxidation to take place. It is important to point out that farmers in the area normally plant rice after the peak of the rainy season (mid or late-September) because of the lack of adequate flood control.

In a strongly reduced field containing toxic levels of ferrous Fe, rice plants generally show two types of symptoms on older and fully developed leaves: the bronzing symptom of acute Fe toxicity which is caused by the presence of high levels of ferrous Fe in the soil solution in a strongly reduced soil environment, and

the oranging symptom which generally occurs in a field containing moderate levels of ferrous Fe. The oranging symptom seems to be associated more with nutritional disorder due to malfunction of rice roots than a direct effect of Fe toxicity.

Rice varieties, however, show differential tolerance to high levels of ferrous Fe in the soil solution. Roots of a highly susceptible variety are simply incapable of surviving in a strongly reduced soil environment containing high levels of ferrous Fe in the soil solution. A moderately tolerant variety, however, can maintain an oxidized condition at the root tips and surfaces. The surface coating of ferric oxides decreases the effectiveness of nutrient and water uptake by roots which may be partly responsible for the leaf oranging symptoms. It has been observed that a tolerant variety not only is capable of maintaining an oxidized condition at the root-soil interface but also has a more vigorous root system.

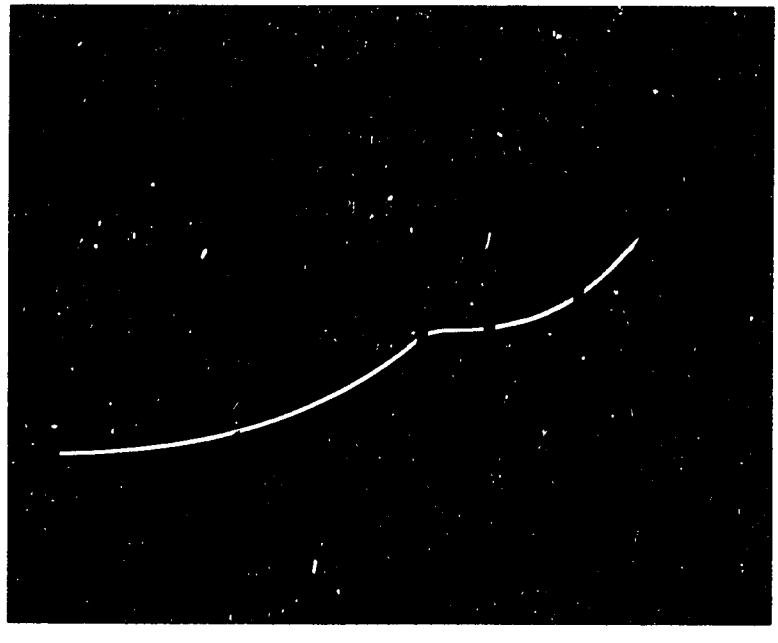
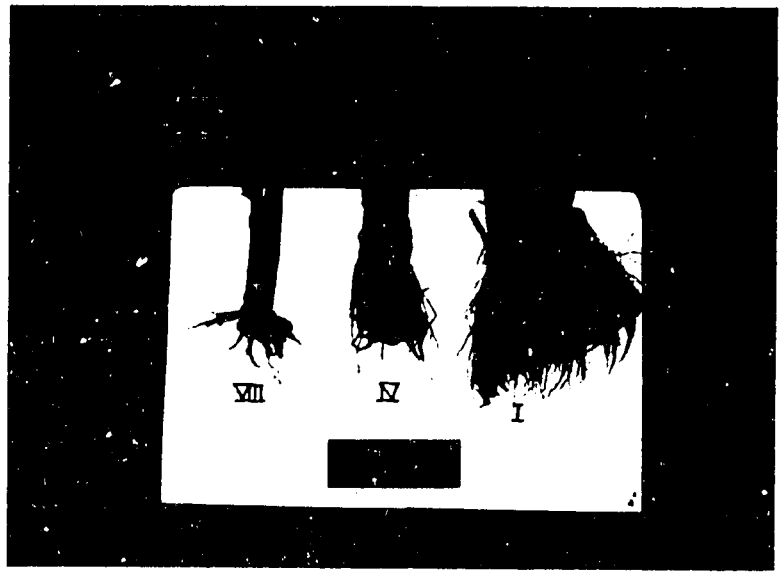


FIGURE 20.
A schematic diagram of the Bende inland valley showing the landscape, sites of groundwater tube installations, and seasonal fluctuations of the groundwater table.



Root growth of a susceptible rice variety IR 26 used as a check in the experiments. Left to right, roots from a highly iron toxic zone, a moderate toxic zone, and a non-toxic zone.

Additional studies on root growth in relation to nutrient uptake of tolerant rice varieties grown under high Fe-toxic environment are underway to better understand the mechanism of Fe tolerance and to identify key factors that can be used for further genetic improvement.

Breeding for Resistance to Rice Yellow Mottl

A farmer's field in Niger has fallen victim to rice yellow mottle virus (RYMV) disease which has spread over many areas in that country and several other rice growing nations in Africa.

The potentially devastating rice yellow mottle virus disease (RYMV), first reported in Kenya in 1966, is a distinctly African specific disease of lowland rice and widespread in East, Central, and West Africa. A joint survey in 1983 by IITA and the West African Rice Development Association (WARDA) revealed that the disease had appeared in alarming proportions in farmers' fields in Niger and to a lesser extent in parts of Upper Volta and the deepwater polders of Mali.

In Upper Volta and Mali, wild rice (*Oryza longistaminata*) harbored the virus, indicating that it may represent an original natural host of RYMV. This finding adds a new dimension to the epidemiology of the disease.

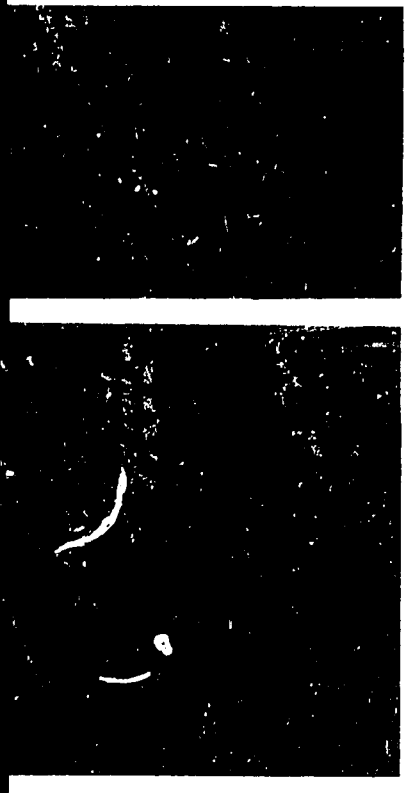
Realizing the potential threat of this disease, IITA initiated research in 1978 on aspects of detection, survey, and screening for resistance. (See *Research Highlights* for 1978 and 1981.) Several African upland varieties have been reported to be tolerant to the disease by earlier workers, and during 1982 carefully controlled screening trials by repeated inoculation and serological assay confirmed the superior tolerance of varieties such as Moroberekan and Lac 23.

During 1982 and 1983, the major emphasis has been on breeding for resistance to rice yellow mottle virus, as well as on a

TABLE 14.
Number of lines selected for tolerance to rice yellow mottle virus (RYMV) disease (1983).

Cross	No. of F_4 lines grown	No. selected for tolerance and plant type
TOM 1-9/Moroberekan	29	15
6850/Moroberekan	31	18

irus Disease



(Top photo). A semi-dwarf rice variety resistant to yellow mottle disease (background) compared with a susceptible popularly grown variety (yellowed plants in the foreground).

(Lower photo). Thirty-three rice progenies are being studied in a screenhouse for resistance to RYMV disease and for acceptable plant type for lowland production.

more intensive search for resistance among lowland varieties. Crosses were made between Moroberekan and high yielding dwarfs. The F_2 and F_3 populations were artificially inoculated and several promising F_3 families are being retested for plant type as well as resistance (Table 14). A backcrossing program to incorporate the resistance into the high yielding lowland varieties and studies on the genetics of resistance are also underway.

In the meantime, a few lowland dwarf varieties have been identified that are also highly tolerant to RYMV, and these are being confirmed for their tolerance. Some of these will soon be used in hybridization since crosses between RYMV-tolerant lowland varieties and high yielding semi-dwarf but susceptible varieties are likely to yield pedigree lines with tolerance and high yield in a shorter time. The crosses between tolerant upland and semi-dwarf lowland varieties will need repeated backcrosses. Therefore, this work is more time consuming. The final objective, however, is to develop superior high yielding RYMV-tolerant lowland varieties to be used in RYMV endemic areas in Africa.

Rice Varieties Resistant to the Storage Moth *Sitotroga cerealella*

Reducing storage losses caused by insects is an important goal in Africa's drive toward rice self-sufficiency, and the least expensive way is through varietal resistance.

In screening tests of 33 rice varieties of diverse origin during 1983, two of IITA's varieties – ITA 233 (lowland variety) and ITA 135 (upland variety) – had the highest level of resistance to the storage moth *Sitotroga cerealella* in short-term (one-month) storage.

Also, ITA 233 consistently showed a high level of resistance to moth damage when evaluated along with other rice varieties in a longer term (four-month) storage screening test. It suffered only 4.5% damage compared with 65.4% for the most susceptible variety, IRAT 110 (Figure 21).

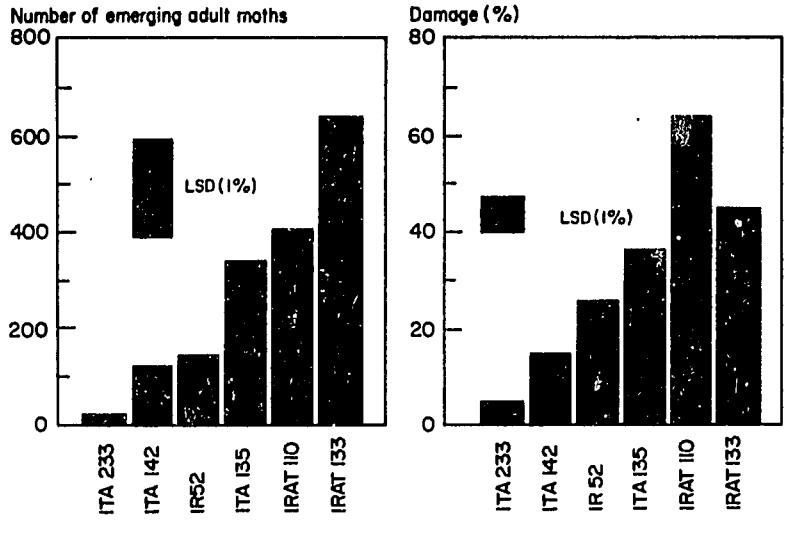
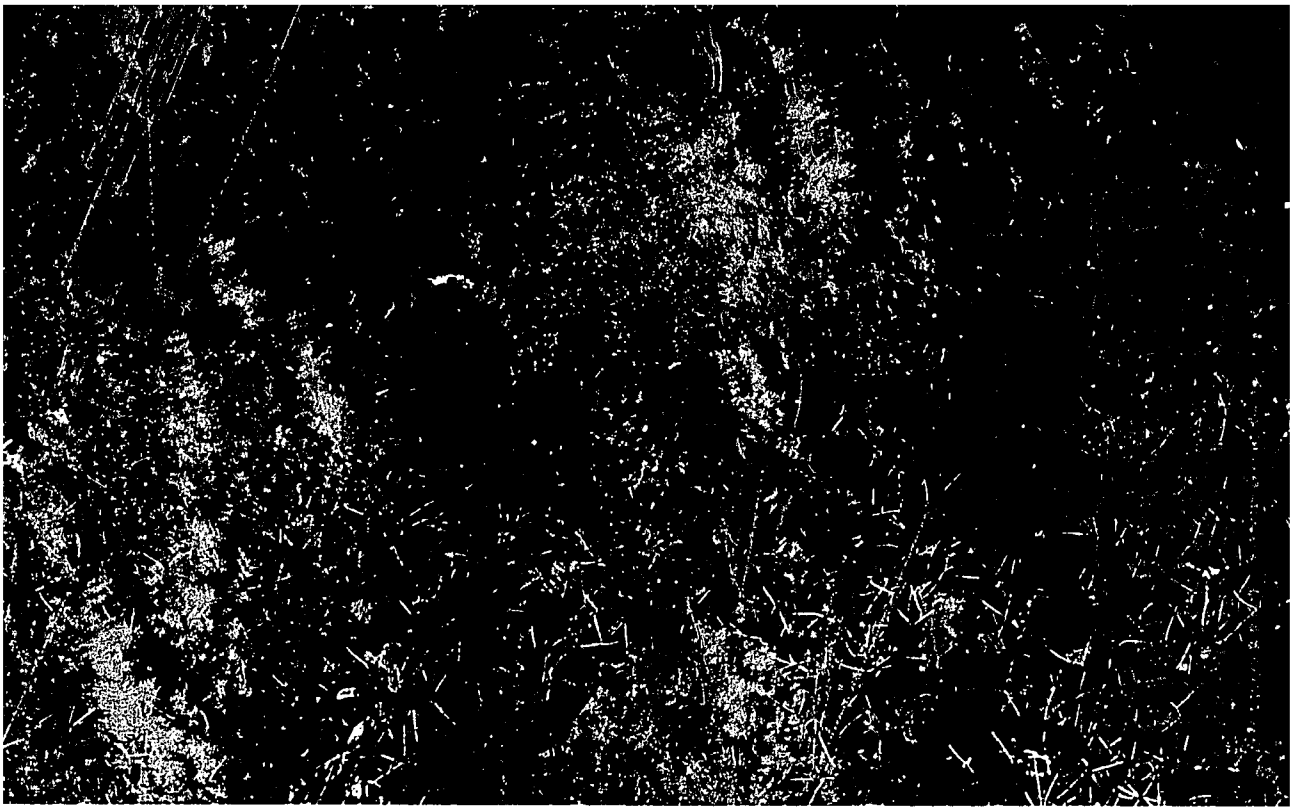


FIGURE 21.
Comparison of moth populations and damage on six rice varieties stored for four months.

The larva of the storage moth** Sitotroga cerealella **feeds on the rice grain inside the husk, eating from 50 to 70% of the kernel. Then the adult moth emerges from an exit hole in the husk.

Resistance was found to be related to a physical property of the husk – husk tightness. Rice varieties with a high proportion of grains with open husks were more susceptible than those with a low proportion. Open husks gave the larva easy access to the kernels. However, the number of insects emerging from each variety was not directly proportional to the amount of grains with open husks. This suggests that some other unidentified factors may also influence the development of the insect in some rice varieties with a large proportion of open husks. Therefore, resistance through other mechanisms (such as antibiosis) is being investigated using milled rice.



IITA's newest cowpea line – IT 82D-716 – during the first season of 1983 in an experimental field at Ibadan, Nigeria. It combines resistance to eight diseases and two major insect pests – thrips and bruchids.

New Cowpea Line with Multiple Attributes

Most promising of the new high yielding cowpea lines developed at IITA is IT 82D-716 which combines resistance to eight principal diseases and two major insect pests, plus improved plant type, medium maturity, and good seed quality. It was developed from a cross involving TVx 6332 (a bruchid resistant line) and TVx 3236 (a thrip resistant line).

Yield potential of IT 82D-716 is similar to TVx 3236 – one of the highest yielding varieties which is becoming popular in Nigeria and other West African countries. The newest line, however, differs in disease and insect resistance characteristics.

While TVx 3236 is susceptible to cowpea yellow mosaic, cowpea aphid borne mosaic, and cercospora leaf spot, IT 82D-716 is resistant to all three diseases. Both varieties are resistant to thrips, but the newest line is also resistant to bruchids (Table 15).

Resistance to thrips in both lines is similar, and they are much superior to the susceptible lines (Table 16). This level of resistance to thrips is reflected in the performance of these lines, especially under minimum insecticide protection (Table 17). The performance of IT 82D-716 and TVx 3236 was much superior with two sprays compared with the susceptible variety IT 81D-1137.

Bruchid resistance in IT 82D-716 is as good as that of the original bruchid resistant parent TVu 2027 (Table 18), but TVx 3236 and Ife Brown (a local improved variety) are highly susceptible to bruchids. Seed characteristics of IT 82D-716 and

TABLE 15. Performance of IT 82D-716 compared with cowpea variety TVx 3236 in three locations in Nigeria (1983).

	Grain yield (kg/ha)			Reaction to diseases*									
Variety	IITA	Mokwa	Samaru	CYMV	CAbMV	Anth.	BB1	BB	BP	WB	CC	Thrips	Bruchids
IT 82D-716	**1404**	**1670**	**1148**	**MR**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
TVx 3236	1412	1994	1169	S	S	R	R	R	R	R	S	R	S
CV	18	15	14										
LSD (5%)	322	946	253										

**CYMV = yellow mosaic virus; CAbMV = aphid borne mosaic virus; Anth = anthracnose; BB1 = Brown blotch; BB = bacterial blight; BP = bacterial pustule; WB = web blight; CC = cercospora leaf spot. R = resistant; MR = moderately resistant; S = susceptible.*

TABLE 16. Mean scores for thrips damage in IT 82D-716 compared with other cowpea varieties

Variety	No. of thrips per raceme	Thrips damage score*
IT 82D-716	**2.7**	**3.0**
TVx 3236	2.0	2.5
IT 81D-1137	3.8	5.0
IT 82E-60	9.5	5.0
CV	33.7	11.7
LSD	2.9	1.01

**1 = No damage; 5 = completely damaged.*

During the second season of 1983, the newest IITA cowpea line (IT 82D-716) produced high yields in a humid area at Onne in Southern Nigeria.

TVx 3236 are similar, except that the seed of the newest line is a little larger. Also, the plant type is more erect.

Because of its multiple disease and insect resistance, cultivation of IT 82D-716 should ensure greater yield stability in the field and minimize losses in storage caused by bruchids. Many farmers in Africa, Asia, and South America are compelled to dispose of their cowpea crop soon after harvest because of the substantial damage caused by bruchids (*Callosobruchus maculatus*) in storage. This not only reduces an important protein source for their families but forces them to sell at a time when market prices are usually the lowest of the year.

TABLE 17.
Yields* of IT 82D-716 compared with other cowpea varieties under insecticide protection.

Variety	5 sprays (kg/ha)	2 sprays (kg/ha)
IT 82D-716	**1665**	**1251**
TVx 3236	1530	1395
IT 81D-1137	1296	891

** Yield estimates are from unreplicated plots of 125 m².*

TABLE 18.
Mean adult bruchid emergence in IT 82D-716 compared with other cowpea varieties.

Variety	Mean adult emergence (%)
IT 82D-716	**39.0**
TVu 2027	37.9
TVx 3236	91.4
Ife Brown	98.4
CV	16.8
LSD (5%)	10.3

International Trials – Global Links for Rapid Development of Cowpeas

Within the international network of agricultural research centers, IITA has been assigned worldwide responsibility to develop improved genetic materials of cowpeas for use by national programs, and its systematic research has led to the development of many disease and insect resistant varieties combining high yield potential, good plant type, and early maturity with acceptable seed quality.

Distribution of these new, improved breeding lines of cowpeas is accomplished through Cowpea International Trials (CIT) formulated each year. IITA includes only those lines which have proved superior in its multilocation trials in various ecological zones within Nigeria – humid forest, derived savanna, guinea savanna, sudan savanna, and sahel.

FIGURE 22.
Worldwide distribution of improved cowpea breeding lines from IITA (1983).

Cowpea International Trials are conducted by scientists of national programs.

In 1983, three Cowpea International Trials were distributed to approximately 150 collaborators in 51 countries in many parts of the world: 28 countries in Africa, 11 in Asia, and 12 in Central, South, and North America (Figure 22). CIT-1 included extra-early-maturing varieties, CIT-2 medium-maturing varieties, and CIT-3 bruchid resistant varieties.

The international trials are conducted by the scientists of national programs, and copies of their data are sent to IITA for analysis. The results at individual locations, as well as the combined results for all locations, are then made available to collaborators. The most promising lines selected from these trials are further evaluated by the national scientists in agronomic and on-farm trials, and the best lines are either directly released for planting by farmers or used as parents in breeding programs.

This annual cycle of developing and distributing new, improved cowpea lines to various national programs has resulted in a global network of cowpea researchers and led to rapid development of cowpeas in many countries. Several varieties of IITA-bred cowpeas have been released in Brazil, Venezuela, Nicaragua, Guatemala, South Yemen, Togo, Upper Volta, Nigeria, Tanzania, and Guyana. At the present time, selected varieties are being multiplied in Zambia, Zimbabwe, and Botswana for release to farmers.

Damage Thresholds for Pod Borers and Pod Sucking Bugs on Cowpeas

Cowpea flowers are checked to determine the extent of larval infestation and/or damage by Maruca testulalis. This is one step in studies to determine damage threshold levels.

Although the pod borer's common name may indicate it feeds only on the pods of cowpeas, it causes the most serious damage at the flowering stage. Control measures are most critical then because few pods are likely to be formed if larval infestation and/or damage in flowers by *Maruca testulalis* is high. Yield reduction could be enormous.

A study was conducted during the second cropping season in 1983 at Ibadan, Nigeria to determine the level of flower damage/infestation at which significant yield reduction takes place. Pre-determined damage threshold levels were set at 0, 20, 40, 60, 80 and 100% flower damage/infestation. Plots were large (170 m^2) and unreplicated, but sub-plots were staked out from which samples of 100 flowers were taken and examined on location once a week over a three-week period for larval infestation or larval feeding damage. If the pre-determined damage/infestation level in any given plot was exceeded, a spray of Decis was applied the same day. Grain yield was taken at full maturity.

Theoretically, the damage/infestation level beyond which grain yield is significantly different from the sprayed control would be considered the damage level at which control measures should be initiated. This is the action threshold (ATh) for the borer on that particular cowpea variety. (ATh is not a static measure and may vary with season, location, and cowpea variety.)

Results shown in Figure 23 indicate that most treatments required at least one spray to maintain the damage/infestation within the pre-set level. Yield data on Table 19 indicate that up to an action threshold of 40% there was no significant yield reduction from the control which was sprayed weekly. However, two insecticide applications were necessary to maintain this level.

Even at an action threshold of 60%, yield reduction was not very high, but prudence and good judgement would dictate that 40% is a more realistic ATh since this minimizes the risks of miscalculation. Farmers can be trained to make this sort of damage evaluation. The only requirements are the recognition of the insect and the damage it causes, plus a good pair of eyes.

The pod sucking bug (*Clavigralla tomentosicollis*) causes serious damage to young, developing cowpea pods. In some years, population levels of these insects have been recorded at 50 bugs/2 m-row. To realistically tackle this problem, scientists need to determine the population levels that can be tolerated by the plants at the crucial growth stages without heavy losses in yield.

A study was conducted in 1983 at IITA, in collaboration with an entomologist at the University of Ibadan, using caged plants of Ife Brown variety cowpea infested with adults of *C. tomentosicollis*. Infestation levels were set at 0, 2, 4, 6, 9, 16, and 32 pairs at two different times of infestation – at the onset of

FIGURE 23.
Population fluctuation of pod borer (M. testulalis) larvae with respect to different levels of pre-set action thresholds (ATh – broken lines) for cowpea flower damage/infestation. (Numbers on the bars indicate insecticide sprays; ATh = 0 and ATh = 100 represent weekly sprayed and unsprayed controls, respectively.)

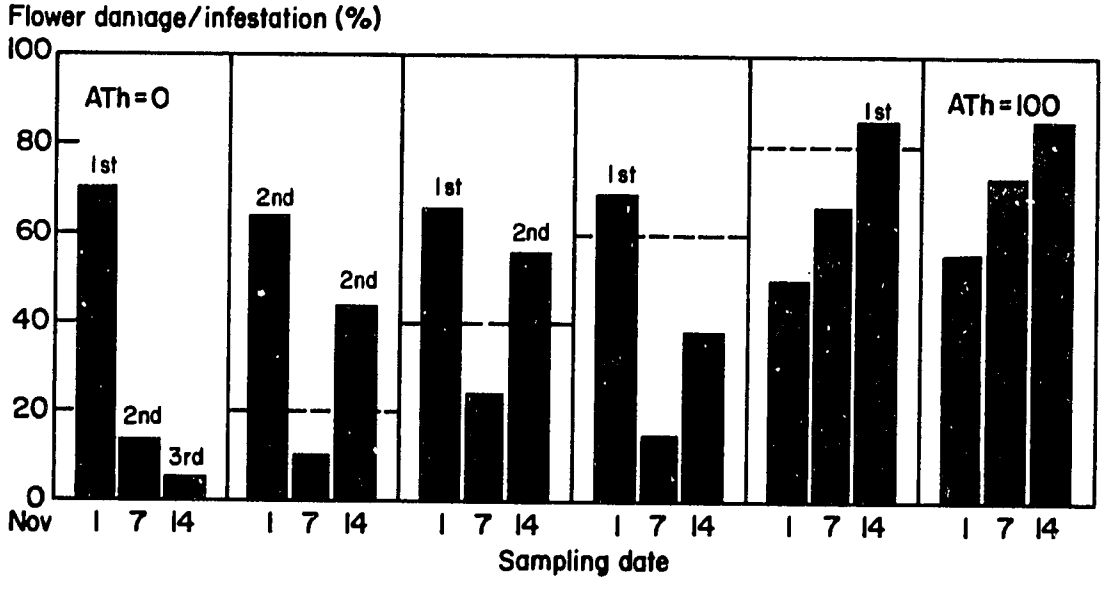


TABLE 19.
Grain yield obtained from different levels of flower damage/ infestation of cowpea variety TVx 3236 by the pod borer (M. testulalis).

Damage levels (%)	Yield (kg/ha)
0	[illegible] (±[illegible])
20	[illegible] (±[illegible])
40	[illegible] (±[illegible])
60	872.2 (±24.9)
80	801.2 (±31.5)
100	442.6 (±17.6)
Mean	695.1
SE	[illegible]
LSD (5%)	148.9

flowering and at podding. Different yield components, damage levels, and yield were monitored during the study.

No differences in flower production and abortion were recorded at either time of infestation, but there was a measurable increase in pod production and pod abortion as the level of infestation increased. The highest level of pod abortion was recorded for treatments with 16 and 32 pairs ($p < 0.01$) with a significant correlation ($r = 0.85^*$) when infestation was done at flowering. Pod production and abortion were lower with infestation at the podding stage. This suggests that an early attack of *C. tomentosicollis* is likely to cause greater damage than if the attack occurs much later.

Damage to seeds increased with a corresponding increase in infestation with over 50% damage occuring at an infestation level of four pairs/cage. Damage was generally lower when infestation was done at the onset of flowering, possibly because pods did not set seed before they were damaged and aborted (Tabl 20).

Yield was drastically reduced at both times of infestation. At two pairs/cage this reduction was significantly different from the uninfested control. No yield was recorded at the highest infestation level when infestation was done at the onset of flowering.

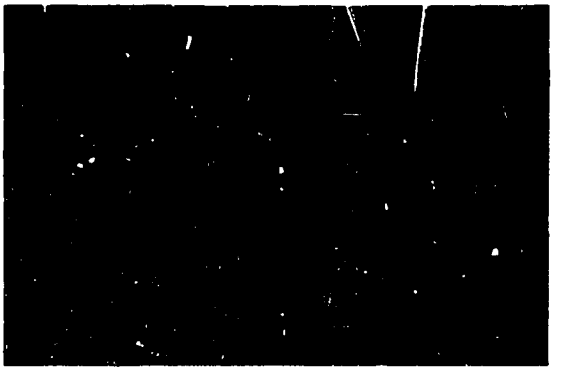
This study shows that infestation of pod bugs up to and above two pairs/10 plants (or two bugs/meter of row) would be considered the action threshold at which control measures become necessary. When scientists consider the population pressure generally observed on cowpea fields (20 bugs/2 r -row), they realize the pressing need to develop a good pest management strategy for pod bug control. If chemicals were the sole control measure, the action threshold of two bugs/meter of row would require sprays at least every five days.

Work is underway to identify resistant cowpea cultivars which could be used in concert with chemical, cultural, and biological control measures to suppress pod bug populations and reduce the need for frequent insecticide applications.

TABLE 20.
Yield and yield reduction caused by the pod sucking bug (C. tomentosicollis) caged with cowpeas at onset of flowering and at mid-pod fill (IITA, 1983).

Treatments (Pairs of bugs)	Infestation at the onset of flowering		Infestation at mid-pod fill	
	Yield (kg)	Percent reduction	Yield (kg)	Percent reduction
0	965.54 a	0	908.85 a	0
1	1003.31 a	-3.91	839.34 ab	13.83
2	620.67 b	35.71	704.28 b	22.26
4	302.65 c	68.65	358.72 c	82.95
8	141.04 d	85.39	249.72 cd	74.20
16	0 e	100	46.52 d	95.21

Figures followed by the same letter are not significantly different at p = 0.05 (DMRT).



Above, aphid resistant and susceptible cowpea progenies used in studies on the nature of inheritance of insect resistance.

Right, thrip resistant and susceptible cowpea progenies used in genetic studies.

Using Results of Studies on Inheritance of Insect Resistance in Cowpea Breeding

During 1982/83, IITA scientists conducted systematic genetic studies on the nature of inheritance of resistance to aphids, thrips, and bruchids. The results are used in developing a suitable strategy for their cowpea breeding program, and they believe the information will be helpful also to scientists in national programs who have initiated breeding programs for insect resistance in cowpeas.

The F_1, F_2, F_3, and backcross populations involving resistant and susceptible parents for each of the three insects were evaluated along with parental lines. In each case the inheritance of resistance was rather simple and the effects of individual genes were large and easily discernible. The data indicated that resistance to aphids is a dominant trait and monogenically inherited as evident by 3 resistant to 1 susceptible ratio in F_2 population and 1 resistant to 1 susceptible ratio in the backcross population (Table 21).

On the other hand, resistance to bruchids and thrips was a recessive trait and digenically inherited. This was evident from

Bruchid resistant and susceptible cowpeas.

15 susceptible to 1 resistant ratio observed in F_2 progenies for bruchids and F_3 progeny rows for thrips (Tables 22 and 23). Backcross data supported the F_2/F_3 segregation patterns for both characters. The size of population in backcross, as well as in a regular hybridization program, largely depends on the number of gene pairs involved in controlling the resistant character.

TABLE 21.
Genetic segragation for aphid resistance in F_2 populations of different cowpea crosses.

Cross	No. of F_2 plants		X^2
	Resistant	Susceptible	(9:1)
TVx 3236 × TVu 36	91	29	.01
TVx 3236 × TVu 3000	221	79	.28
IT 82E-60 × TVu 3000	188	67	.22
TVx 3236 × TVu 801	172	66	.95

TABLE 22.
Genetic segregation for bruchid resistance in F_2 populations of different cowpea crosses.

Cross	No. of F_2 plants		X^2
	Resistant	Susceptible	(1:15)
TVu 2027 × TKx 133-16D-2	7	102	.05
TVu 2027 × Cross 1-6E-2	6	154	1.44

TABLE 23.
Genetic segregation for flower thrips resistance in F_3 populations of different cowpea crosses.

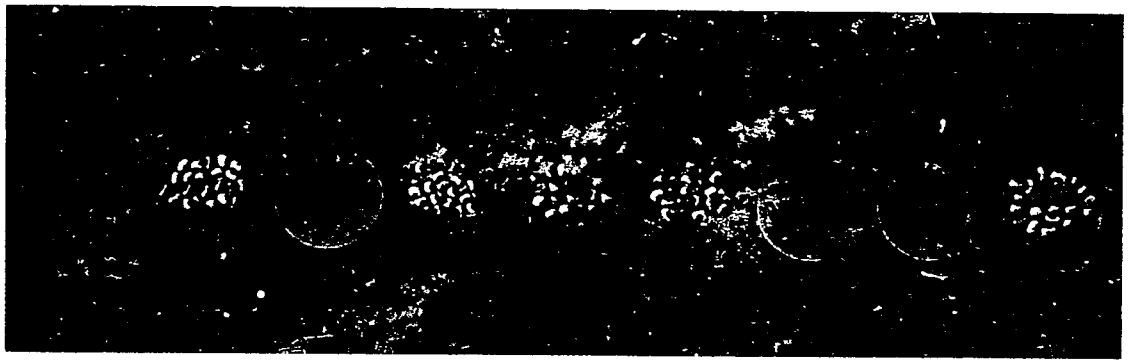
Population	No. of F_3 progeny rows		X^2
	Resistant	Susceptible/ segregating	(1:15)
TVx 3236 × TVu 36	12	178	0.001
TVx 3236 × IT 82E-60	20	279	0.098

Elite Cowpea Varieties Rate High in Analyses of Protein and Amino Acids

Several IITA cowpea varieties and new breeding lines were analyzed by the University of Manitoba (Canada) scientists during 1983, and the results show that incorporating high yielding and disease and insect resistance characteristics was not at the expense of the quantity or quality of the protein content. Furthermore, their amino acids rating was considerably higher than the FAO provisional pattern with the exception of methionine.

The Canadian scientists performed the analyses for eight of the essential amino acids. Table 24 shows the amino acids profile of IITA-developed varieties and lines compared with the FAO provisional pattern and the protein content which ranged from 19.8 to 24.4%.

Cowpeas are the major source of protein in the daily diets of millions of people throughout the tropics, and they are consumed in association with basic starchy staples such as cassava, yam, cereals, and plantains. Therefore, one of the major objectives of the cowpea improvement program at IITA is to develop high yielding and widely adapted varieties with improved levels of protein. Analyses such as those made in 1983 help to ensure that newly developed varieties and advanced breeding lines distributed to national programs in many parts of the world will continue to have a high protein content and other valuable characteristics.



IITA-developed cowpea varieties and breeding lines that rated high in amino acid and protein content analyses.

	Improved cowpea lines										
	Released			Medium maturity				Early maturity			
	VITA										
	– 3	– 5	– 7	TVx-3236	TVx-4659 -03E	IT 82D – 716	IT 82D – 889	IT 82E – 32	IT 82E – 60	FAO rate	A.A. value compared to FAO
Amino acid											
Isoleucine	4.8	4.7	4.6	4.9	4.9	4.8	4.7	4.8	4.6	4.2	Sufficient
Leucine	8.8	8.8	8.6	8.8	8.8	8.7	8.7	8.8	8.4	4.8	Sufficient
Lysine	7.8	7.7	7.5	7.8	7.6	7.6	7.6	7.6	7.4	4.2	Sufficient
Phenylalanine	6.5	6.5	6.4	6.4	6.5	6.4	6.5	6.4	6.1	2.8	Sufficient
Tyrosine	3.3	3.2	3.3	3.3	3.4	3.4	3.5	3.3	3.3	2.8	Sufficient
Methionine	1.4	1.5	1.3	1.5	1.4	1.5	1.5	1.4	1.4	2.2	Deficient
Threonine	4.2	4.1	4.0	4.3	4.2	4.2	4.1	4.1	4.0	2.8	Sufficient
Valine	5.9	6.5	5.7	6.0	6.0	5.8	5.8	5.9	5.6	4.2	Sufficient
Total a.a.	42.7	43.0	41.4	43.0	42.8	42.4	42.4	42.3	40.8	28.0	Sufficient
Protein (%)	**21.8**	**23.0**	**23.0**	**19.8**	**23.1**	**22.2**	**23.1**	**24.4**	**23.8**		

*"As is" moisture basis for cowpea genotypes.

TABLE 24. Amino acid and protein analyses of improved IITA cowpea lines.

Predicting Acceptability of Food Crop Varieties by City and Rural Consumers

The final test for new crop varieties is actual use by consumers, and their preferences affect the direction scientists take to develop new varieties.

In a 1983 survey planned and conducted by IITA and the University of Ibadan, residents in 177 households in Ilorin city and four villages in Kwara State, Nigeria were asked in personal interviews about their preferences for 10 characteristics of cowpeas for five different uses: boiled cowpea-maize mixture (adalu), bean cake (akara), boiled beans (ewa), cowpea soup (gbegiri) and steamed bean pudding (moi-moi). Each person interviewed was asked to indicate his/her preference for the different cowpea characteristics on a zero to 100 scale for each use.

Computers were used for quick data processing, and the calculated index values gave the weevil-free quality the most important rank for all five uses, followed by swelling ability

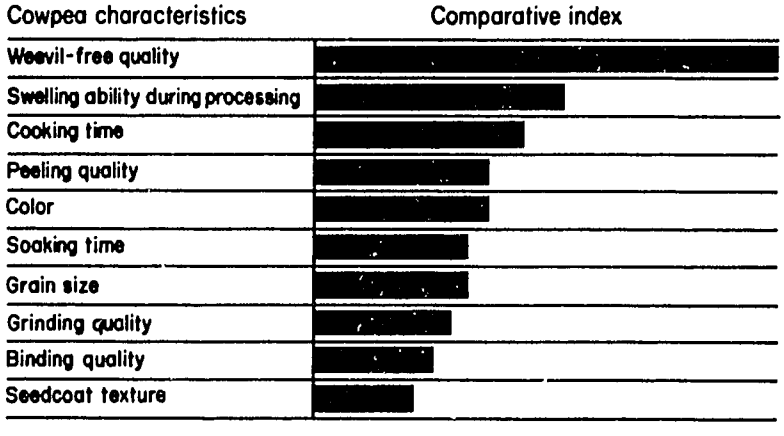


FIGURE 24. Cowpea characteristics and their relative importance as ranked by city and rural consumers in Kwara State, Nigeria (1983).

A village woman prepares "akara" – a popular food made from cowpeas. Both rural and city consumers rated weevil-free quality, swelling ability, soaking time, and binding quality as the most important characteristics of cowpeas for making this product.

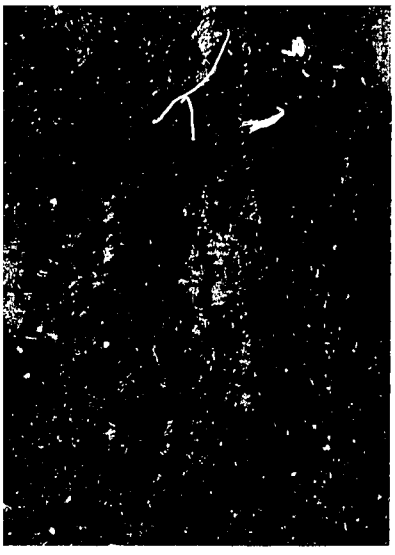
during processing, cooking time, peeling quality, color, soaking time, grain size, grinding quality, binding quality, and seed texture (Table 25 and Figure 24).

By introducing a second rating for the most important characteristic for each food dish, it was found that the visual aspects — color, size, and no weevils — were decisive mainly for boiled beans (cowpeas). For the other food dishes, however, processing aspects were important: swelling ability and cooking time for the cowpea-maize mixture; binding quality and seedcoat texture for bean cake; peeling quality and soaking time for steamed bean cake; and grinding quality for cowpea soup (Table 25).

This cooperative research work with the University of Ibadan will be continued to provide additional data to help predict consumer acceptability for a range of new varieties of various crops in different production and consumption areas. The researchers plan to further simplify data collection and calculation procedures and speed up the feedback to scientists who can use the information when they plan the strategies for their plant breeding programs.

TABLE 25. Index value for characteristics of cowpeas for five food uses in Kwara State, Nigeria. (Index range from 0 to 100.)

Characteristics	Cowpea-maize mixture "adalu"	Bean cake "akara"	Boiled beans "ewa"	Cowpea soup "gbegiri"	Steamed bean cake "moi-moi"	Average all uses
Weevil-free quality	**25**	**20**	**29**	**25**	**21**	**24**
Swelling ability during processing	18	14	15	9	11	13
Cooking time	15	7	13	12	8	11
Peeling quality	3	9	3	14	18	9
Color	10	9	12	6	8	9
Soaking time	5	10	5	9	11	8
Grain size	10	5	11	7	5	8
Grinding quality	3	8	3	11	8	7
Binding quality	5	10	5	3	6	6
Seedcoat texture	4	8	4	6	5	5



Soybean lines that nodulate with rhizobia indigenous in African soils and incorporate good seed longevity, desirable agronomic characteristics, and high yield potential have been identified by IITA scientists from 1983 multilocational trials.

Soybean Lines for the Lowland Tropics

Two major constraints to soybean production in the tropics are the inability of most lines to form nodules necessary for symbiotic nitrogen fixation and rapid loss of seed viability in storage in a warm, humid environment. IITA scientists have found several lines that nodulated with rhizobia indigenous in African soils. These lines are called "promiscuous nodulators" because of their characteristics of forming symbiotic relationships indiscriminately with diverse rhizobia strains. This is important because most developing countries lack inoculant industries and extension systems to distribute inoculants to small farmers. Promiscuous lines can yield well without inoculation.

Other lines in the germplasm collection were found to maintain their germinating power even when stored under ambient conditions in the humid tropics. However, lines with either of these characteristics were unacceptable, almost without exception, because of other traits such as lodging, shattering, susceptibility to diseases, and low yield potential. In 1978, a breeding program was initiated to incorporate promiscuous nodulation and good seed longevity into lines with good agronomic characters and high yield potential. Such soybean lines have been identified from 1983 multilocational trials and are available for testing by national programs.

One of these promising lines – TGx 536-02D – is a backcross between Bossier (released in the U.S.) and the recurrent parent TGm 737p (a line from Indonesia). The cross was planned to incorporate good soybean yield potential, stem strength, and pustule and shattering resistance from Bossier with superior seed longevity and promiscuous nodulation of TGm 737p. (The latter is otherwise agronomically unacceptable.)

The line originated as a bulk selection from a population grown in the 1982/1983 dry season at Ibadan and was tested

during 1983 at four sites in Nigeria (Table 26). It incorporates both a good level of pustule resistance and resistance to shattering. The level of promiscuous nodulation is nearly as good as the promiscuous parent, and it can be grown without inoculant on many tropical soils.

Soybean yields from TGx 536-02D at Mokwa and Ilorin in the southern Guinea savanna and at Ibadan in the forest region averaged over 2 t/ha. Average yield was 1.6 t/ha at Zaria in the northern Guinea savanna where rainfall was severely limited in 1983. This line has yellow seeds which weigh about 14g/100 seeds. Days of maturity ranged from 105–114 in Nigeria and height from 76 cm under relatively high fertility conditions to 51 cm where soil fertility was low. A possible drawback is a tendency to lodge under high soil fertility.

Another line – TGx 306-036C – has been tested in IITA trials since 1981 and in Nigerian cooperative and international trials since 1982. It is a cross between Jupiter, a high yielding cultivar from Florida, and Malayan, a cultivar introduced to Nigeria in the early 1900s. The latter is highly promiscuous and has acceptable seed longevity but low yield potential. This line (Table 26) has yielded consistently well in trials in Nigeria, and a trial conducted in 1983 indicates that it maintained a high yield with and without fertilizer in both sandy and clay soils. It has a maturity similar to Malayan (125–135 days), resists lodging and shattering, and should give good, stable yields in lowland tropical

TABLE 26. Performance of promising soybean breeding lines (TGx 536-02D and TGx 306-036C) in multilocation trials for mean seed yield, disease reaction, and some agronomic traits compared with check cultivars.

	Yield (kg/ha)	Nodulation[1]	Seed storage[2]	Pustule[3]	Shattering resistance	Lodging	Maturity (days)
TGx 536-02D	**1972**	**fair**	**good**	**R**	**good**	**fair**	**108**
TGx 306-036C	1894	v. good	fair	MR	good	good	128
Bossier (check)	1615	poor	v. poor	R	good	good	105
Malayan (check)[4]	1306	v. good	good	S	fair	poor	137

[1] *Nodulation with indigenous rhizobia.* [2] *Relative seed longevity.* [3] *Reaction to bacterial pustule: R = resistant, S = susceptible, MR = moderately resistant.* [4] *Local variety grown in Nigeria; parental source of promiscuous nodulation.*

regions with long growing seasons. Seed is yellow and weighs about 14g/100 seeds.

IITA has identified breeding lines with reasonable yield potential and improved plant type that have levels of seed storability similar to the donor parents. They are useful parental materials for breeders who want to incorporate superior seed longevity into high-yielding backgrounds (Table 27).

TABLE 27.
Soybean breeding lines proposed for use as improved parental material for superior seed longevity as compared to high-yielding parent with poor seed longevity (Bossier) and previous donor parent with good seed longevity (TGm 737^P).

	Emergence[1] (%)	Pustule[2]	Lodging resistance	Shattering resistance	Seed size[3] (g)	Seed color	Maturity[4]
TGx 342-356D	**66**	**MR**	**fair**	**poor**	**16**	**black**	**110**
TGx 536-01D	**66**	**S**	**fair**	**excellent**	**13**	**black**	**106**
TGx 709-01E	**66**	**MR**	**fair**	**poor**	**15**	**yellow**	**112**
Bossier (Check)	15	R	good	good	19	yellow	108
TGm 737^P (Check)	68	S	poor	poor	8	black	99

[1] *Seedling emergence following accelerated ageing (6 weeks at 40°C and 75% R.H.); data represent the means averaged over three trials, each trial having four replications.* [2] *Reaction to bacterial pustule; R = resistant; MR = moderately resistant; S = susceptible.* [3] *100 seed weight.* [4] *Days to harvest at 7°N latitude.*

Secondary and Micronutrient Requirements of Soybeans in the Savannas

Agroclimatic zones with the greatest potential for soybean production in West Africa are the Guinea savannas, but only limited work has been done on the secondary and micronutrient requirements of the crop in these regions of Nigeria. Trials were conducted at two sites in Benue State to determine these requirements, as well as for phosphorus (P) and potassium (K). Secondary and micronutrients were applied to the soil in a slurry consisting of Mg, S, Zn, B, Cu, Mn, and Mo, and phosphorus as triple superphosphate and potassium as muriate of potash.

At Yandev, Nigeria, with a long history of fertilization with N, P, and K, response to phosphorus was small and linear (Figure 25). Application of secondary and micronutrients increased yields by 500 kg/ha – a 50% increase without P. At Mkar, where little fertilizer had been applied previously, response to P was very large (Figure 26). Application of 50 kgP/ha alone or with K

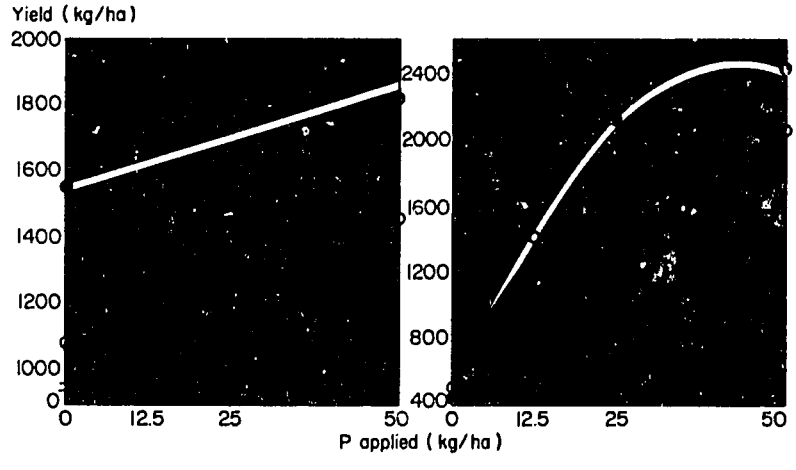


FIGURE 25 (left). Yields of M 351 soybeans with and without secondary and micronutrients at four levels of phosphorus application at Yandev, Nigeria.

FIGURE 26 (right). Yields of M 351 soybeans with and without secondary and micronutrients at four levels of phosphorus application at Mkar, Nigeria.

tripled yields. An additional 400 kg/ha yield increase was obtained by the addition of secondary and micronutrients at the two highest rates of P application.

Response to secondary and micronutrients at these two sites is consistent with that obtained previously at three other southern Guinea savanna sites (Figure 27). In each case, the secondary and micronutrients significantly increased yield when applied with high levels of P. The decrease in yield of the soybean variety Hernon-237 at Mokwa when P was applied alone (Figure 27) suggests that some minor element was already in limited supply in the soil and that P fertilization induced deficiency in the plant. Application of secondary and micronutrients counterbalanced the detrimental P effects.

The consistent response of soybeans to secondary and micronutrients at five separate locations suggest that deficiencies

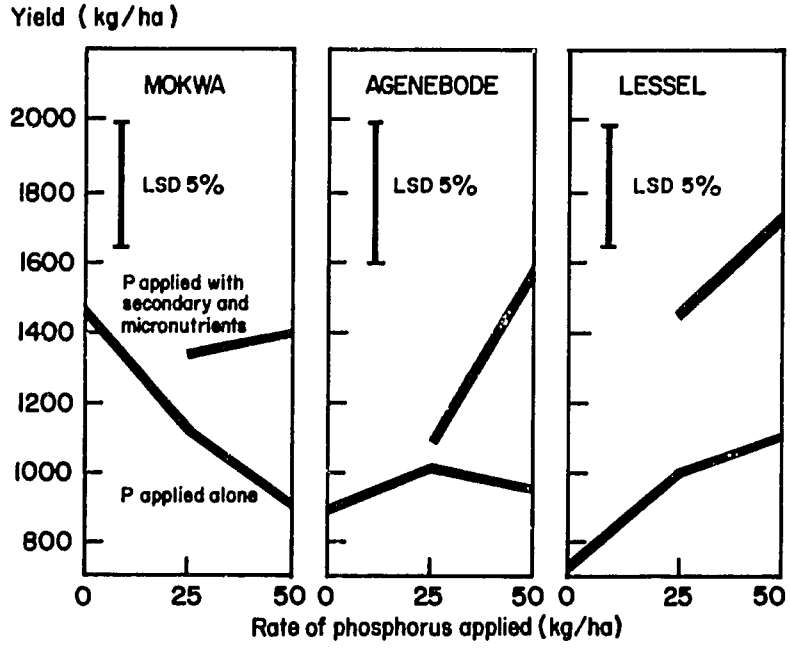
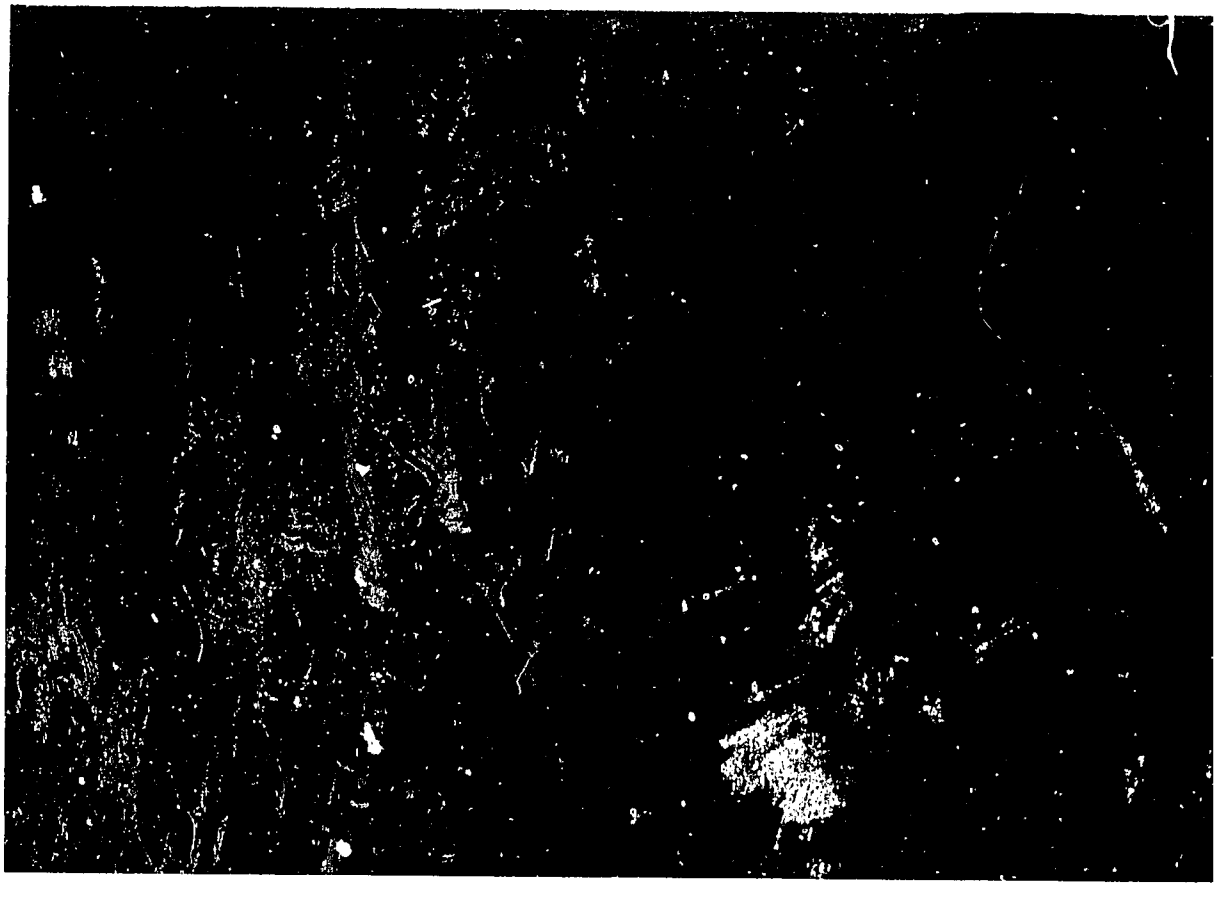
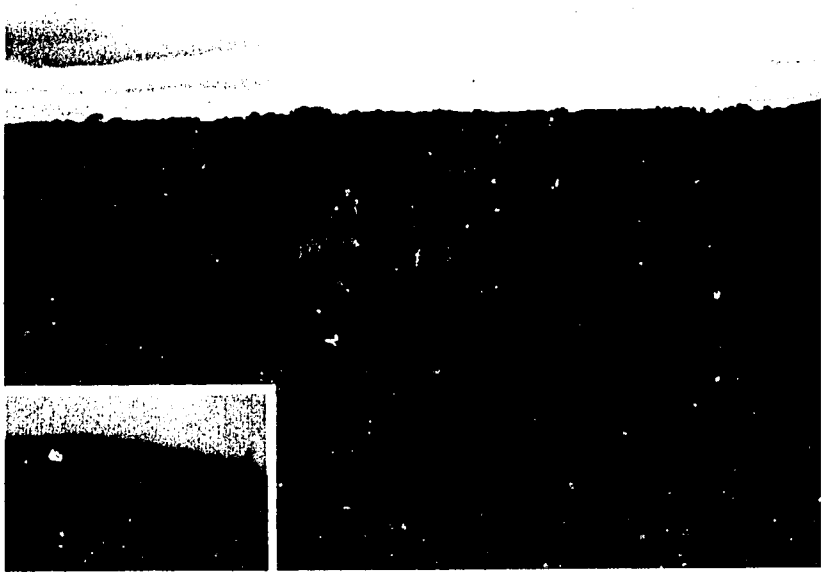


FIGURE 27.
Yields of Hernon-237 soybeans with and without secondary and micronutrients at three levels of phosphorus application at three locations in the southern Guinea savanna of Nigeria.

in nutrients other than N, P, and K may be widespread in the southern Guinea savanna. Under high management with adequate rates of P fertilizer, it may be necessary to fertilize with one or more secondary or micronutrients to obtain high soybean yields on these soils.

A soybean field which has the necessary secondary and micronutrients and other fertilizer requirements for high production (Mokwa, Nigeria).





Apoanagyrus lopezi – ***the natural enemy of the mealybug – was released on this 3,000 hectare cassava farm near Abeokuta in Western Nigeria. The inset photo shows the mealybug and the parasitic wasp which was originally found in South America.***

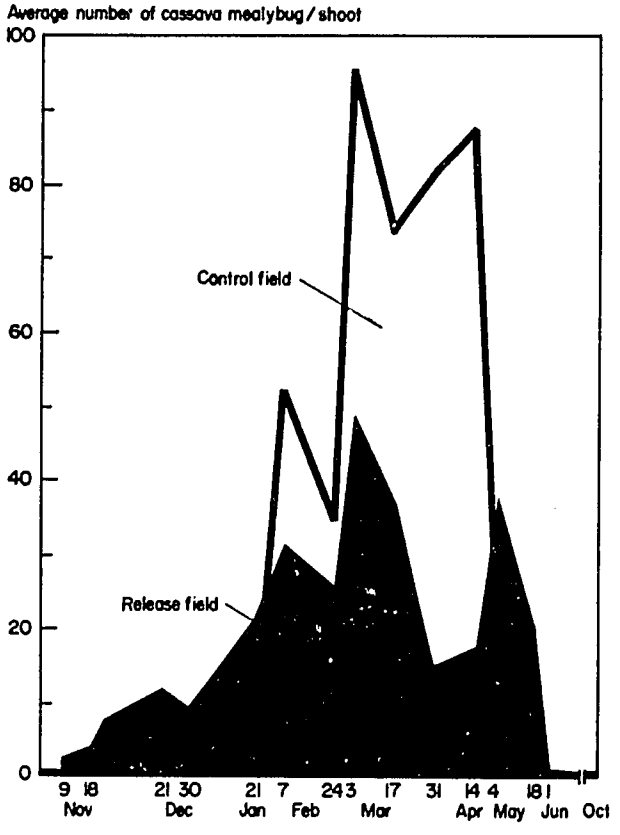
Results of Natural Enemy Releases Against the Cassava Mealybug

Marked progress in biological control work against the destructive cassava mealybug has been recorded in Nigeria during the past three years. The release of one of its natural enemies, *Apoanagyrus lopezi*, in IITA experimental fields at Ibadan in 1981 and in a 3,000 hectare cassava farm at Abeokuta in late 1982 resulted in much lower mealybug populations (Figure 28).

Then in March 1983, a large-scale survey showed that *A. lopezi* had spread from the big farm to most cassava fields sampled within a 100 km radius and was sporadically encountered up a distance of 173 km from the release site at the farm (Figure 29). This parasitic wasp (found originally in South America) spread throughout Ogun and Ondo states and reached Lagos and Kwara states, covering an area extending from the rain forest into the Guinea savanna.

As in the previous year at IITA, the wasp survived the rainy season, and in the following dry season was found in almost all infested fields within its previous distribution. Moreover, by

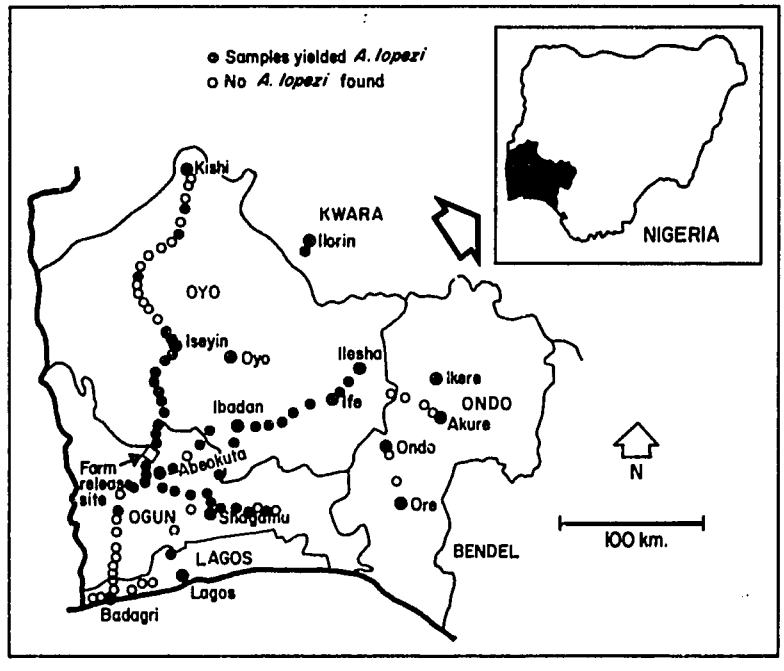
FIGURE 28.
Impact of release of** A. lopezi **– a natural enemy of the mealybug – at a large cassava farm near Abeokuta, Nigeria.



December 1983 it had spread all through Ondo state and beyond Benin City in Bendel state.

The cassava mealybug has been attacked also by numerous indigenous predators which previous to the entry of the mealybug (*Phenacoccus manihoti*) into Africa in 1973 fed on other closely related mealybugs. Most important among these indigenous predators were several species of lady beetles (*Coleoptera Coccinellidae*). In addition, an indigenous green lacewing and a dusty wing (both *Neuroptera*), two predacious bugs (*Heteroptera*), and a cecidomyiid midge larva (*Diptera*) preyed on the cassava mealybug.

FIGURE 29.
A. lopezi spread as far as 173 km from the release site on a farm near Abeokuta, Nigeria.



Moreover, five chalcidoid species indigenous to Africa were found as hyperparasites on *A. lopezi*. Before the establishment of *A. lopezi*, they parasitized wasps attacking other mealybugs. In the release area, these unwelcome hyperparasites destroyed an average of 50% of all *A. lopezi* larvae. Despite this reduction, observations indicated that the wasp was responsible for a greater reduction in mealybug populations in the release fields compared with the control fields. The reduction cannot be attributed to indigenous predators since both types of fields harbored the same density of indigenous predators.

A. lopezi is credited also with the reduction in the size and incidence of cassava bunch-tops caused by mealybugs at the release site compared with the situation in outlying fields spread in all directions (Figure 30). The severity of bunch-top symptoms increased with the distance from the release site because the wasp reached these fields later.

A specific parasitoid of the cassava mealybug, *A. lopezi* was found in South America through concerted efforts of the International Center for Tropical Agriculture (CIAT) in Colombia, the Commonwealth Institute of Biological Control (CIBC) in England, and the Empresa Brasileira de Pesquisa Agropecuaria (EMBRAPA) in Brazil under IITA's leadership. Before being introduced into Nigeria, natural enemies such as *A. lopezi* are quarantined in the CIBC laboratory in London and inspected on arrival in Nigeria by the local quarantine authorities in accordance with the rules set up by the OAU Inter-Africa Phytosanitary Council.

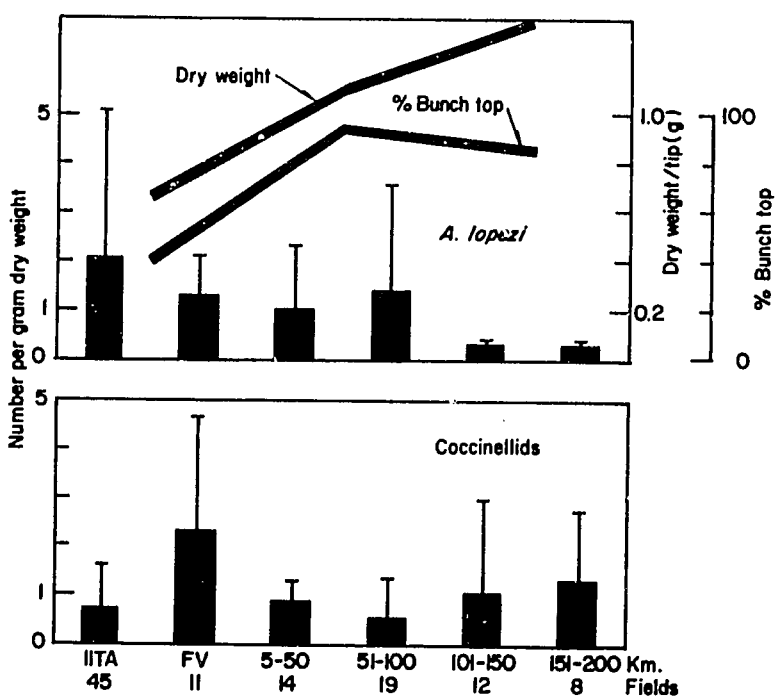


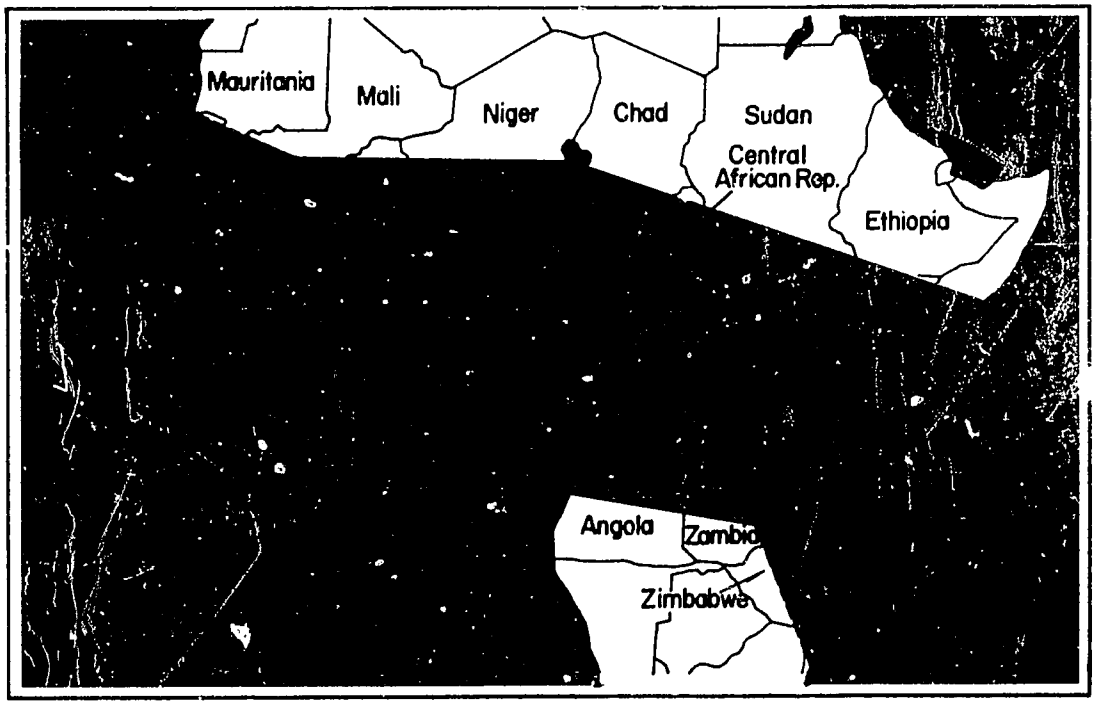
FIGURE 30.
Numbers of A. lopezi and coccinellids per gram dry weight of cassava tips in relation to the distance from the release site near Abeokuta, Nigeria, together with the mean dry weight per tip and mean percent bunch tops in the fields. (IITA = improved varieties; FV = farmers' varieties; median, lower, and upper quantiles are indicated.)

Progress Report: Cassava Pest Management and a Special

Because of the current scourge of cassava mealybug (CM) and green spider mite (CGM) which have decimated yields over 60% of the cassava growing areas of Africa with estimated losses amounting to about two billion dollars (U.S.) annually, IITA has launched a two-pronged attack on these cassava pests. (Figure 31 shows the spread of cassava mealybugs in Africa south of the Sahara.)

Some success has been reported on both fronts. First, there is the conventional breeding program in which sources of resistance to the two pests have been identified and are being incorporated

FIGURE 31. ***Spread of cassava mealybug (*** *Phenacoccus manihoti* ***) in Africa south of the Sahara over a 10-year period (1973–83).***



into improved cassava breeding lines. Also, attempts are directed toward using both cultivated and other *Manihot* species in the development of higher levels of resistance.

Secondly, a biological control approach introduces host-specific natural enemies from the pests' area of origin in South America as a means of effectively reducing pest populations to tolerable levels which exist on that continent. Based on the progress made so far, an emergency biological control program is in the initial stages of development and testing before launching it on a large scale.

Most promising natural enemy against the mealybug in field tests in Nigeria so far is the parasitoid wasp, *A. lopezi*. (See pages 92–95.) A green spider mite predator is now undergoing preliminary testing.

The Africa-wide Biological Control Project of Cassava Mealybug and Green Spider Mites developed by IITA with the assistance of international and national organization, is designed to achieve a reasonably rapid and significant reduction in populations of CM and CGM over the next few years through the release of millions of their natural enemies (predators and parasitoids) at ground level and from aircraft. Twenty countries in West, Central and East Africa have requested trial releases of natural enemies, indicating a high degree of confidence in the need for biological control of cassava pests.

Plans have been drawn for a centrally located mass production insectary to provide the supply of the natural enemies. Several options for mass production systems have been investigated by IITA. Preliminary specifications for a tunnel insect production system have provided for a capacity for production of up to 15 million beneficial insects and/or mites per day on 5,000 cassava plants. A smaller unit is shown in Figure 32.

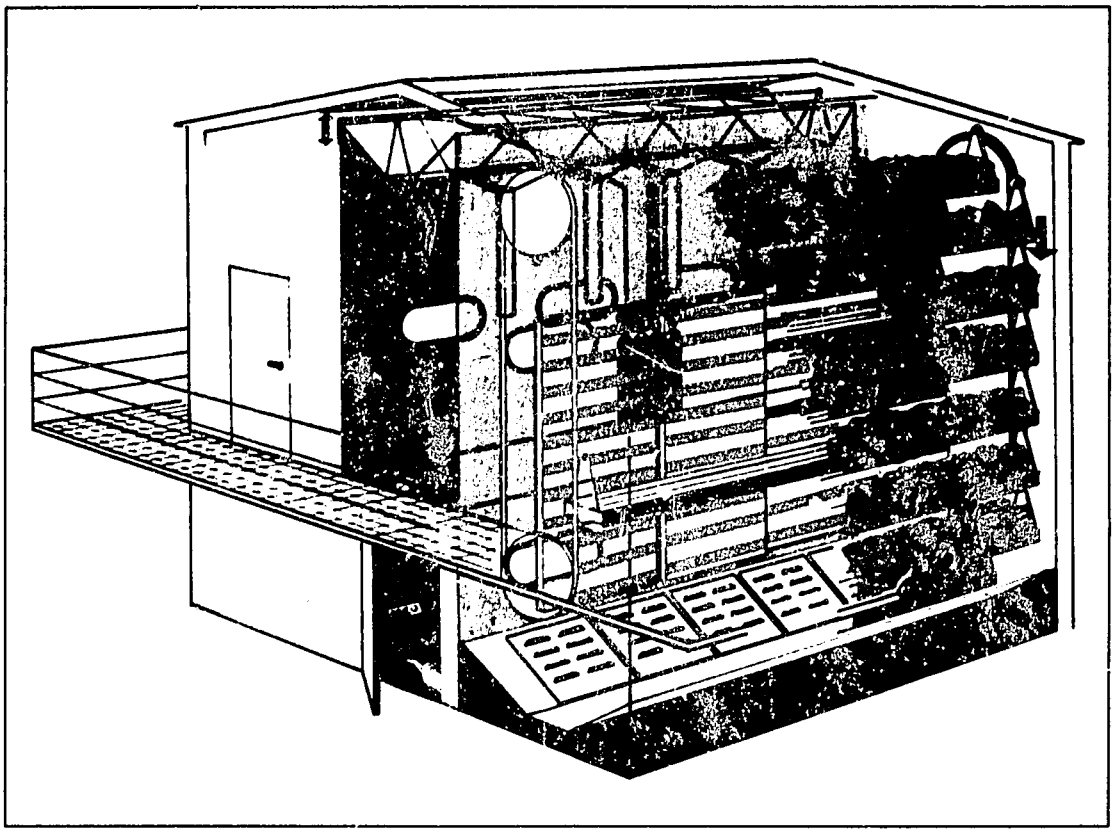


FIGURE 32.
One of the design options for a plant and insect rearing unit. Either one or several such units could be used for mass rearing of natural enemies of the mealybug and green spider mite.

As these insects and mites emerge from the tunnel system, they would be transferred to a packaging room with facilities that automatically package up to four species in the same release unit. (Figure 33 shows the model currently under construction.) Up to 1,500 natural enemies, depending on the species, can be put into small plastic capsules which, in turn, are placed in cassettes. The loaded cassettes (each with 361 capsules) are kept in specially designed containers with their own cooling system and later transferred into the aircraft.

Aerial release of the natural enemies is expected to be of benefit not only to farmers along major roads (where ground releases are easy to make) but also the farmers in remote areas.

During the development period of the aerial insect release

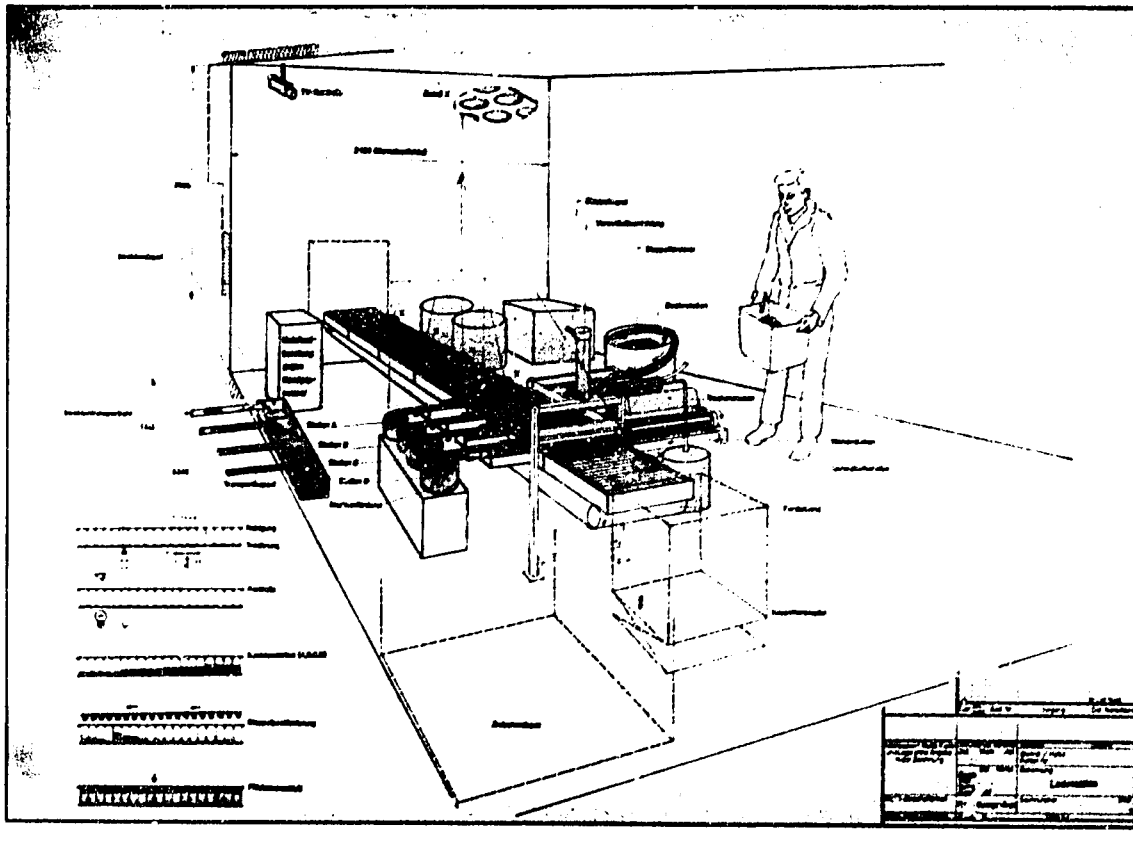


FIGURE 33.
Model of a packaging room with automatic facilities to package up to four species of natural enemies of the cassava mealybug and green spider mite in the same release unit.

system, engineers conducted intensive wind tunnel testing in Austria where the equipment was designed and built. The equipment (Figure 34) was installed in a twin turboprop airplane, and tests were scheduled to start in February 1984 in three different ecological zones in Nigeria where cassava is grown. These tests will last for several months. The plane will fly over cassava fields at a speed of 250 to 330 km/hr and release about one capsule per second. The wind tunnel tests showed that accelerations and the air currents did not harm the insects.

For the feasibility study, the International Fund for Agricultural Development (IFAD) provided $780,000 and the German Agency for Technical Cooperation (GTZ) $250,000. In addition, $3.7 million has been allocated to IITA for the Africa-

During the development period of the automatic insect release system, intensive wind tunnel testing took place in Austria where the system was designed and built.

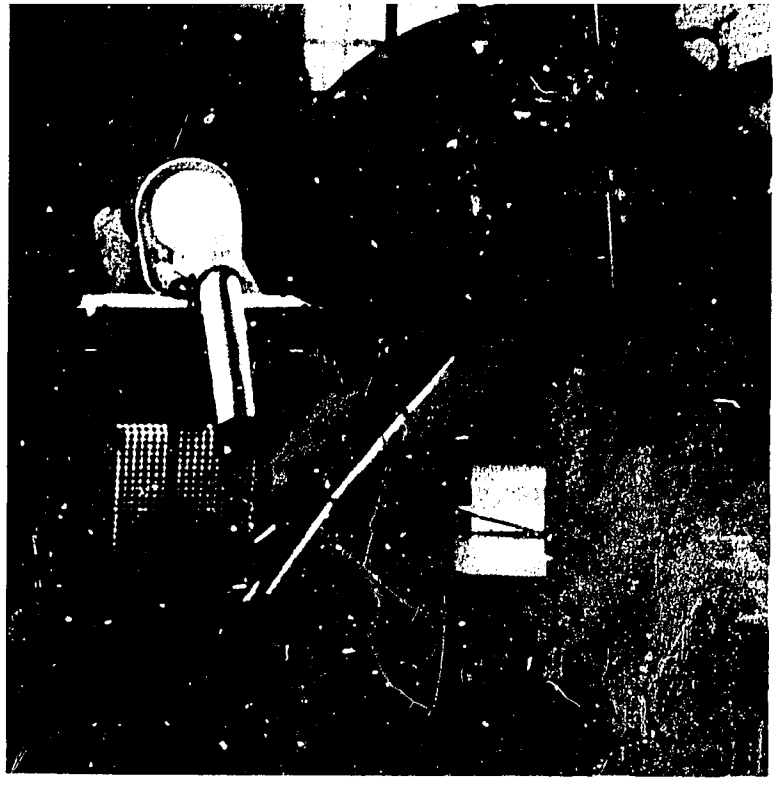
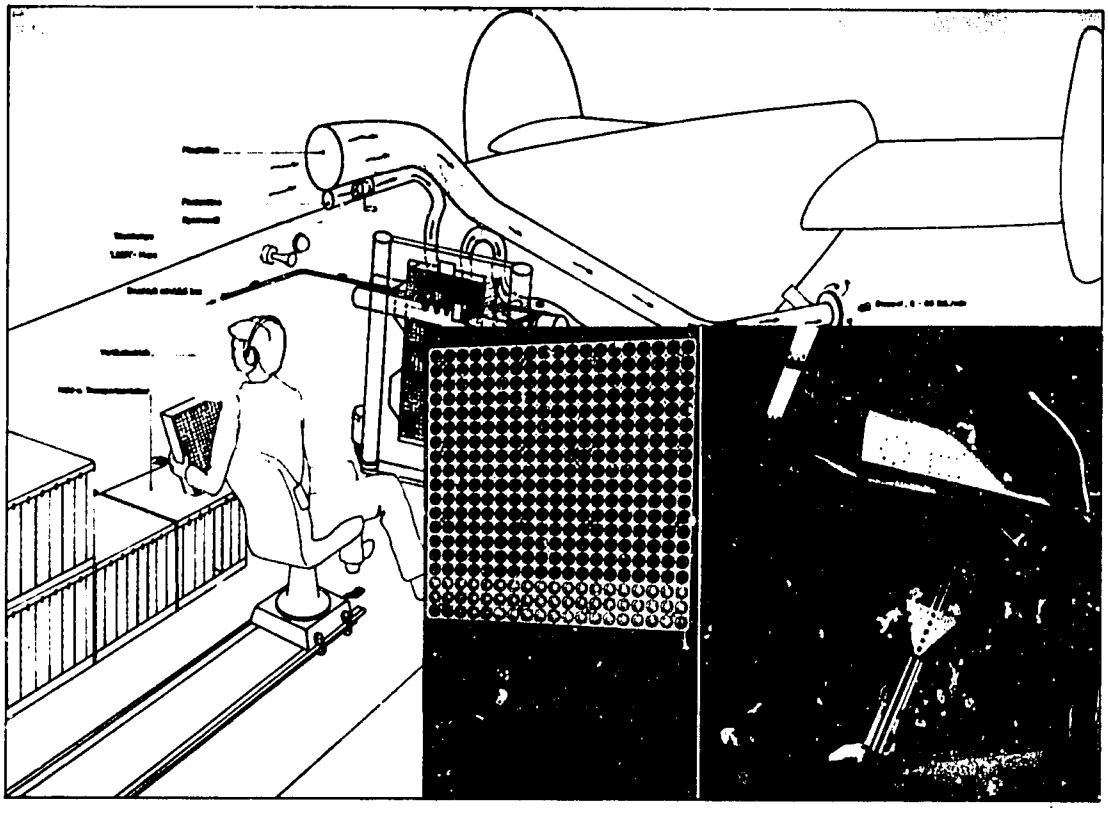


FIGURE 34.
Sketch and photo of the automatic insect release system inside the airplane which has the capacity to release one capsule per second onto cassava fields below. The photo on the left shows a close-up of one of the cassettes which has 361 small plastic capsules. Each one can be filled with up to 1,500 natural enemies.



wide Project for Biological Control of Cassava Pests – $2 million for 1983/86 from the Swiss Directorate for Cooperation and Development and Humanitarian Aid, $1.425 million for 1983/84 from Austrian Technical Cooperation (BKAWIKORD), and $250,000 for 1984 from GTZ. An estimated total of $30 million may be required eventually for the two phases of the planned five-year project.

Although the total amount of funding for the project has not yet been obtained, IITA has decided to step up the pace of research and development of the new technologies to be ready for the Africa-wide project. Also, efforts to find more natural enemies in Latin America have been increased in anticipation that the project will receive the needed financial support.

The project itself is to be established under the auspices of the Organization for African Unity/Scientific, Technical and Research Commission (OAU/STRC). It has two complementary components – a research program, continuing as a responsibility of IITA, and an operations component to handle the control campaign. The latter will be the responsibility of a Board of Operations, including representatives of OAU/STRC, donors, participating countries, Food and Agriculture

The automatic aerial insect release system is being tested for six months in three areas in Nigeria. This photo shows a test run of the specially equipped aircraft over cassava fields at IITA; 20 African countries have requested trial releases of natural enemies of the mealybug and green spider mite.

Organization, IITA, and others. A committee of experts will be appointed to advise the Board on technical matters.

Research and operations will be closely linked to insure a steady flow of the latest results of research into the control campaign and a feedback of observations from the campaign to research. The OAU/STRC Inter-African Phytosanitary Council will play a major role in informing governments and the public about the problems of cassava mealybug and green spider mites, as well as in standardizing the procedures of the campaign.

Yam microsett cuts (upper photo) ready to be put into trays for sprouting and sprouted microsetts ready for planting (lower photo).

A System to Increase Seed Yam Production

Although yam as a crop has a great potential and the tubers are in high demand, production is declining in many areas because of increasing costs and low yields. A major cause can be attributed to the availability, cost, and quality of seed yams. They are expensive and often unavailable to small farmers. Moreover, those that farmers can get may be of poor quality. A significant contribution to increased yam production would be a system that could provide plenty of clean, healthy seed yams at a reasonable cost.

Seed yam – a small-sized tuber weighing from 200 to 1000 gm – can generally survive long storage periods (3–4 months) under ambient storage conditions with minimum loss. Many environmental factors can affect the performance of yam setts (cut pieces) in the soil after planting, but, when whole seed yams are planted, they perform reliably over a wide range of conditions.

The traditional system of seed yam production usually results in a low multiplication ratio, substantial labor input, and high costs. Scientists at IITA have succeeded in improving a seed yam production system originally developed by the National Root Crops Research Institute at Umudike, Nigeria. In the new system, seed yams are produced under plastic (polyethylene) mulch. This has resulted in an increased net return and up to a 10-fold increase in the multiplication ratio over the traditional method.

The technique is simple, easy to adopt, and capitalizes on the fact that yam tubers produce sprouts from almost any place on the yam surface. It involves the following series of processes:

- Clean, healthy yams or "mother seed yams" are selected at the ripe physiological age – immediately after overcoming tuber

dormancy of one to two months. (The term,"mother seed yam," is used here to describe a seed yam cut into pieces and used to produce more seed yams.)

- The tuber is cut across to produce several cylindrical pieces, and each piece is again cut longitudinally so that many pieces are obtained from each tuber or "mother seed yam." Each piece, called a "minisett," weighs between 20 and 50 gm. Smaller pieces than these weighing between 5 and 10 gm (named "microsetts") can also be cut. Each piece needs to have an outer layer - the "skin" or periderm.

- Freshly cut surfaces are dusted with wood ash, a suitable fungicide, or a mixture of both. Then the minisetts, with cut surfaces up, are put under light shade to avoid direct sunlight and to "heal" the cuts. This takes two or three days and helps to reduce losses of minisetts and microsetts through rotting when they are planted later in nursery beds.

- Minisetts are laid in rows side by side on nursery beds with the cut surfaces up. They are then covered with about a 2 cm layer of sand or sawdust. Light shade is provided and a small amount of water applied regularly. The minisetts sprout in two to three weeks in the moist sand or sawdust. Microsetts are pre-sprouted in polystrene trays in a sawdust medium.

- Ridges are made 1 m apart in the field and covered with polyethylene (plastic) mulch before the pre-sprouted minisetts and microsetts are transplanted. The mulch covers the ridge and the furrow and is held in place with soil. Holes just big enough to allow the planting of the pre-sprouted minisett or microsett in the ridge are cut through the plastic. (Plant spacing 50 cm or less.)

This new system has given early and improved plant establishment which often results in increased yield and improved crop uniformity. The mulch eliminates weeding and staking and reduces leaf disease problems. Moreover, it conserves soil moisture, especially during the dry season, and the plant growth period is prolonged which should contribute to high yield.

The number of "mother seed yams" used to produce seed yams by the minisett and microsett methods are from two to 10 times less than with the conventional method and the amount of money needed to purchase the "mother seed yams" is also correspondingly less (Table 28).

A Nigerian illustration emphasizes the potential of the minisett and microsett systems of seed yam production. They reduce drastically the initial quantity of "mother seed yams" needed to produce enough planting material for a given unit area. Nigeria produces about 15 to 20 million tons of yams a year, and of this quantity an estimated 20% is used as planting material in the traditional system where seed yams are usually not available. This means that 4 million tons of the annual production are used as planting material on 1.5 million hectares.

If minisetts of 50 gm weights were used, only 750,000 tons of yams instead of 4 million would be needed to produce seed yams to plant the 1.5 million hectares or about 20% of the quantity used by the traditional system. With the microsetts, only 150,000 tons of yam would be needed. Thus, the amount of yams which could be saved for food by these two systems is enormous.

With the improved methods, the multiplication rate of seed yam can be increased by two to 10 times at the end of the first

TABLE 28. Quantities and cost of "mother seed yams" needed to produce enough seed yams for one hectare by different production systems.

Seed yam production system	No. of pieces cut from one "mother seed yam"	No. of "mother seed yams" needed to produce seed yams for 1 ha*	Cost of "mother seed yams" at $0.60 (U.S.)
Conventional	**5**	$\frac{10,000}{5} = 2000$	**$1200**
Improved			
Minisett	10	$\frac{10,000}{10} = 1000$	600
Microsett	50	$\frac{10,000}{50} = 200$	120

**Number of seed yams required to plant 1 ha = 10,000.*

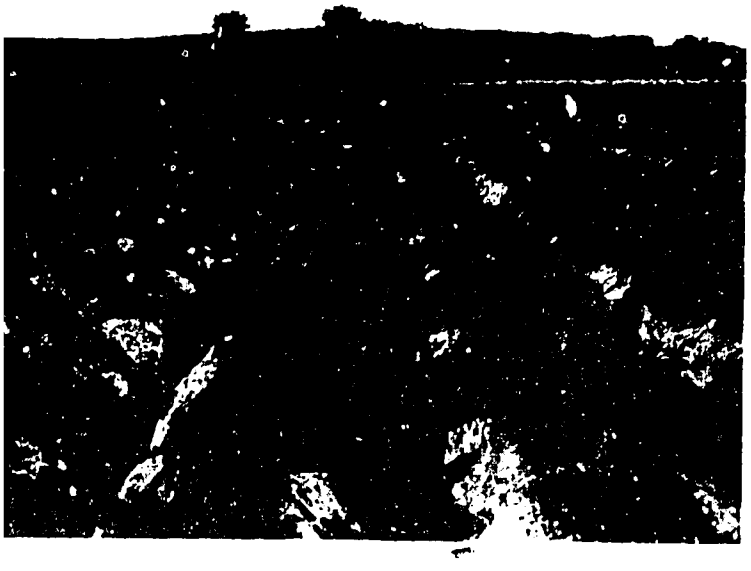
production year when compared with the conventional system. In subsequent years, however, the multiplication rates are even higher – increasing in geometric proportions (Table 29).

Moreover, physiologically healthier seed yams are produced. Under the traditional system, yams planted in February/March are usually harvested in October/November. They remain in storage from harvest until about March when they are planted – a four to five-month storage period before planting. By then, most of the yams may have sprouted. If they are not planted soon after sprouting (or soon after tuber dormancy) vine growth suffers, resulting in physiologically weak tubers which produce small tubers when they are planted later in the field. With the improved seed yam production system, minisetts or microsetts are transplanted in June and harvested in December. The seed yams are stored from harvest until they are planted in March for producing ware yams. This is an appropriate three-month storage which helps to ensure physiologically healthy seed yams that give better ware yam yields than the traditional method.

TABLE 29.
Rate of multiplication of seed yams using different production systems.

	Number of seed yams at the beginning of successive years						
Production system	1st	2nd	3rd	4th	5th	6th	7th
Conventional*	1	5	25	125	625	3,125	15,625
Improved:							
Minisett**	1	10	100	1,000	10,000	100,000	
Microsett***	1	50	2,500	125,000	625,000		

Formula to describe rate of increase:
**Conventional = 5^{x-1}, x being # years (i.e. planting seasons covered).*
***Minisett = 10^{x-1}*
****Microsett = 50^{x-1}*



Minisetts (D. rotundata; white yam) planted under plastic mulch (above); harvest of seed yams from the same field (right).

Improving Rapid Multiplication of Cassa

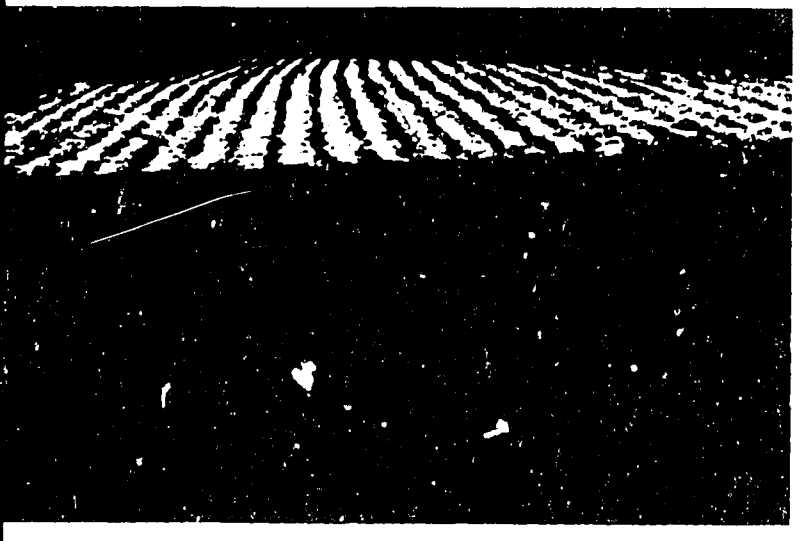
After an improved cassava variety is released, enough planting material should be made available to farmers in the shortest possible time. Because cassava is vegetatively propagated by stem cuttings, efficient agro-techniques have been developed to rapidly increase the number of cuttings which can be obtained from a plant.

Usually one-node and two-node cuttings from hardwood stem portions, semi-mature stem cuttings (above the hardwood stem), and tip-shoots of the stems are rooted in nursery beds or in black polythene bags filled with soil. Plants which develop from these methods are either planted directly in the field or shoots are taken from them for further rooting in the bags or in beds. This cycle is repeated a few times so that as many shoots as possible are obtained from each initial multiplication planting material.

This system has been used extensively, but one of its disadvantages has been serious weed problems. Pre-sprouted cuttings transplanted in the field are small and do not form a closed canopy in time to suppress weeds. Therefore, it is not easy to maintain large hectarages planted with the pre-sprouted one-node, two-node, and tip-shoot cuttings, even though herbicides and hand-hoeing may be used to control the weeds. Another problem has often been poor plant establishment because of erratic rainfall and inadequate soil moisture retention following field transplanting.

Use of the plastic mulch at transplanting has improved this system and allows more land to be put under cassava multiplication with greater success. Plastic mulch ensures good plant establishment and vigorous plant growth, especially at the initial stages. It requires only limited or no weeding. Without plastic mulch, three or more weedings may be necessary before the canopy closes and more may be needed later.

lanting Material with Plastic Mulch



Contrast between two cassava fields (above) planted with pre-sprouted cuttings for multiplication purposes; 95% germination in the plastic covered field but only about 70% in the field with no plastic mulch (foreground). Right, young cassava cuttings taken from the plastic covered field.

The limited weeding advantage achieved with the plastic mulch encourages the planting of large hectarages to cassava multiplication with small pre-sprouted planting material. Also, this system reduces soil erosion and provides better soil moisture conservation. Preliminary observations indicate that there may be less cassava mealybug and green spider mite infection, probably because of a better soil moisture regime. Plastic mulch is low cost, easy to use, and economical in Nigeria and other countries where labor is expensive.

The rapid multiplication system used at IITA involves the following procedures:

- Cut hardwood or semi-mature cassava stems into four or five node cuttings.
- Pre-sprout the cuttings by planting them in hollow segments or polystyrene trays filled with soil and water them at regular intervals. These trays are light and more than 120 cuttings can be pre-sprouted in each 66 × 33 cm tray. With the use of these trays, several thousand cuttings can be pre-sprouted at one multiplication center and transported to other places where

facilities for pre-sprouting may not be adequate. About four weeks after rooting and hardening of the plants, the cuttings are ready to be transplanted in the field.

- Prepare the field for transplanting. Spray the field with a herbicide to kill vegetation. Then two or three days later, spread out the plastic mulch flat on the soil, holding it to the ground with soil on the edges. A slight overlapping of plastic avoids gaps between two adjacent rows and discourages weed growth. (Plowing, harrowing, and ridging are not necessary.)
- Irrigate before laying the plastic in the dry season and irrigate at intervals to ensure good plant establishment. Lay the plastic and transplant in the normal growing season to take advantage of the rains.
- Use a pointed stick or sharp pointed metal tool to punch small holes through the plastic and insert the pre-sprouted stem cuttings.

If correct procedures are followed, stems can be cut from field plants at a height of about 20 to 25 cm from the ground six to seven months after transplanting and supplied to farmers to produce storage roots. Several stems sprout from the ratoon left in the field. Herbicide and fertilizer are applied to the ratooned plots, and another set of stems are cut again about six months later. At IITA, as many as three ratoons have been taken from rapid multiplication plants.

Controlling the Sweet Potato Weevil

Sweet potatoes are grown extensively throughout the tropics, and consumers in some countries depend on the tubers as a staple food and use the leaves, high in protein and vitamins, as a preferred vegetable. But one of the most serious problems of the crop in Africa is the damage to leaves, vines, and tubers caused by three species of sweet potato weevil. *Cylas formicarius* is mainly distributed over East Africa while *C. puncticollis* and *C. brunneus* occur in West and Central Africa.

Previous research has shown the value of integrated pest management, improved cultural methods, and resistant varieties. Early planting and harvesting allow the plants to escape attack. Re-ridging about 30 days after planting places the tubers deeper and out of the reach of weevils. They cannot bore through the soil to get to the tubers, relying on cracks in the soil to reach them. Foliar insecticide sprays and soil insecticides (granular) have been useful.

Also, a number of high yielding, good quality clones have been developed that show resistance to the weevils, and they have been multiplied and distributed to farmers in Nigeria and to several national programs in and outside Africa. Materials have also been distributed in tissue culture form and as seeds to national programs.

A principal problem still remaining is weevil damage to tubers in storage. The developmental period of the weevil from egg to adult is about 21 days, and a female lays more than 300 eggs during its life span of about 80 days. Therefore, even if sweet potato tubers go into storage with a low weevil population, several adults will emerge within a few weeks and cause serious damage.

Tests have shown that various pre-storage and storage

measures will prevent development of weevils, including the following:

- Select storage tubers which have not been damaged by weevils or during harvesting and cure them in the open tropical weather for about three days after harvest. Then store these tubers in underground pits. If the pits are constructed in the right way and lined with dry mulching material, the tubers can be kept in good condition for about three months. Low underground temperatures (20–23°C) extend the developmental period of the weevil, with high mortality occurring at about 20°C. Also, the weevils are not active in underground storage and most of them die after eight days.

- Immerse infested tubers in tap water for about 24 hours. This will kill all stages of the weevil. Tubers are then laid in the open to dry the wet surfaces before storage.

- Use high temperatures to get rid of the weevils before storage. When the weevils were buried at different soil depths, all the insects within the first 5 cm depth died after three days. (Afternoon temperatures reached 42°C)

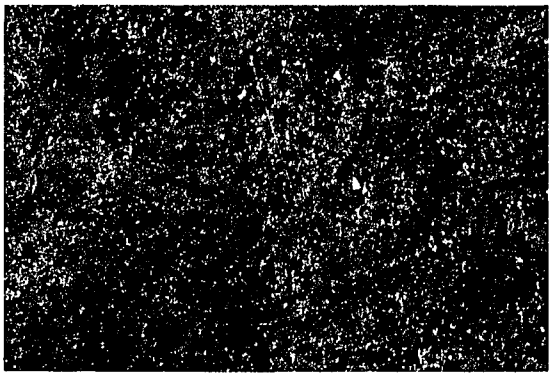
TABLE 30.
Influence of curing sweet potato tubers in polyethylene bags under shade and in open air on percent survival of different stages of the weevil *(Cylas puncticollis)*.*

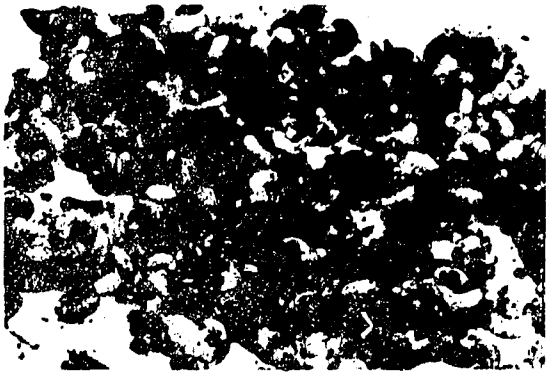
Duration of curing (hr)	Adults		Pupae		Larvae	
	Open air	Shade	Open air	Shade	Open air	Shade
24	26.0	33.8	11.4	67.6	32.4	92.6
48	12.8	37.9	10.5	32.4	18.5	65.2
72	0.0	39.3	19.6	45.7	6.4	37.2
96	2.3	28.8	11.9	46.2	2.4	36.6

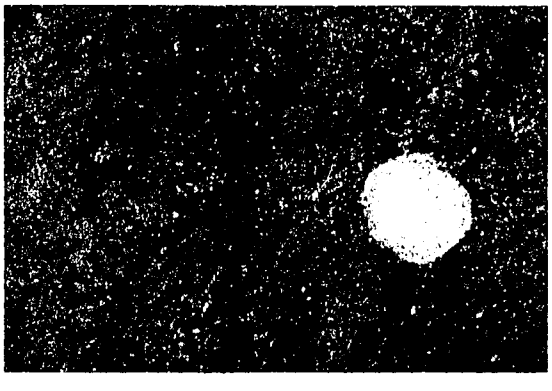
**Each result has been averaged over four replications.*

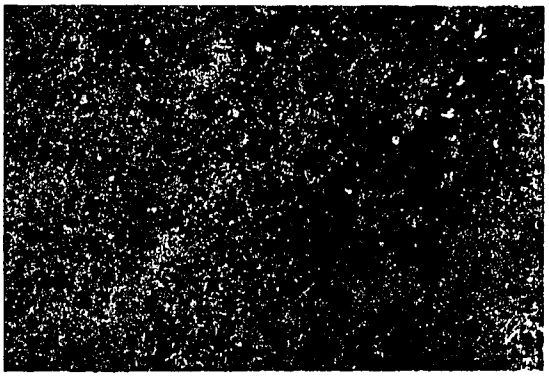
An experiment to study the survival of weevil-infested tubers inside polyethylene bags filled with different amounts of pounded fresh cassava leaves and infested tubers packed alone in the bags showed no advantage of one method over the other. The main factor was the temperature within the bags. Also, putting the bags in the open air had a significant effect on weevil survival compared with placement under shade (Table 30). After three days the tubers should be kept in underground storage because the polyethylene bag treatment does not completely kill all stages of the weevils.

Top left, a weevil lays eggs inside the sweet potato tuber, and they will hatch within 21 days. Top right, close-up of dead sweet potato weevil larvae. Lower left, weevil-infested sweet potatoes compared with no weevil damage. Lower right, underground storage for sweet potatoes. The tubers at the side had been stored in this underground storage for three months.









Update on Cooperative Country and Regiona

Beginning with the first formal cooperative research projects in 1973 between IITA and two African countries (Liberia and Tanzania) involving the outposting of some of its scientists, the Institute has continued to foster close linkages with national and regional programs. The guiding principle underlying these "outreach" activities is to strengthen the national research capabilities so that developing countries can

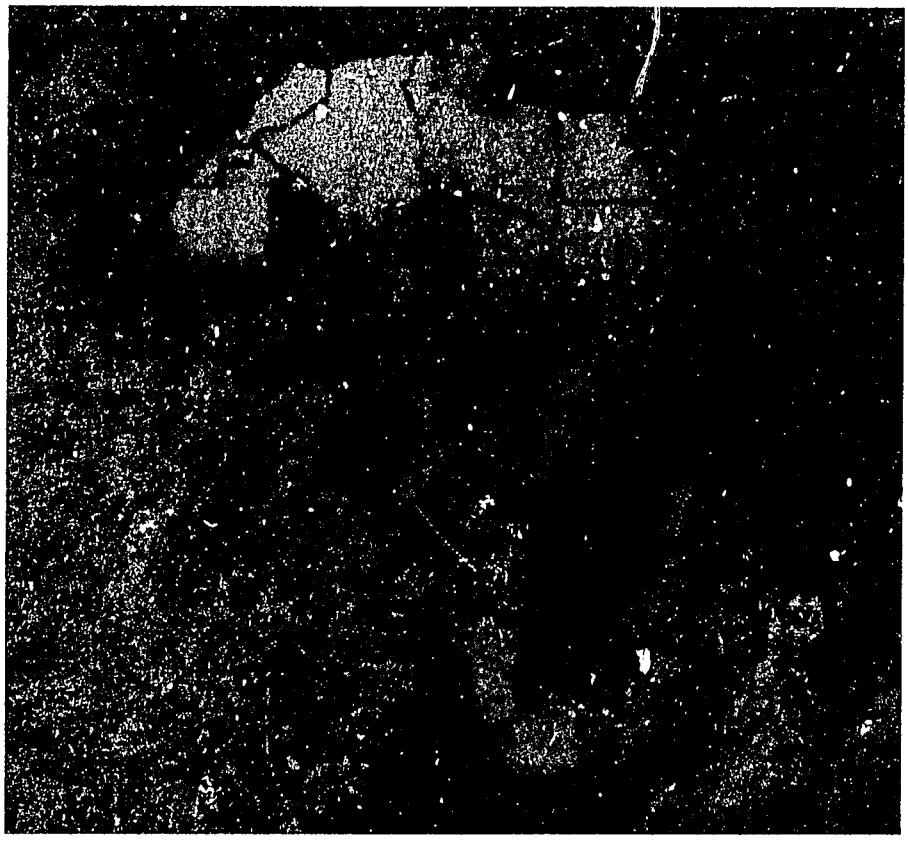


FIGURE 35.
IITA has collaborated with 31 national agricultural research programs in Africa over the past 10 years (1973–83).

Research Projects in Africa

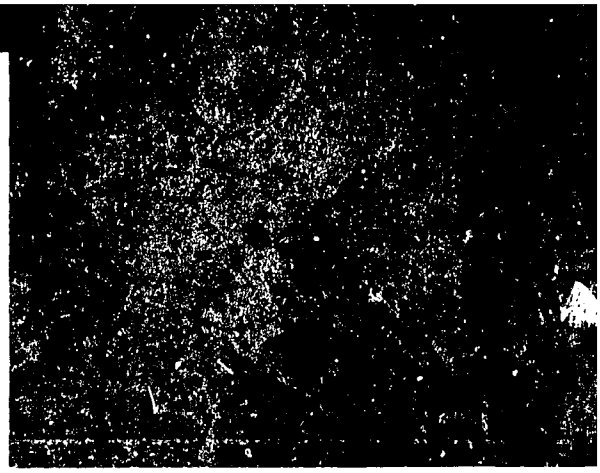
solve their own pressing food production problems. Some of the results of research on various food crops under these cooperative projects have been reported in previous editions of *Research Highlights* and in this current issue.

Thirty-one national agricultural research programs in Africa have collaborated with IITA over the years (Figure 35). Some of these have involved outposting of IITA scientists and others only participation in multilocational testing programs. Certain projects are phased out because they reach a logical state for the national scientists to assume complete responsibility (i.e. Cameroon root crops improvement program), others because their financial support has terminated. New ones have been established (Table 31), the latest being a cassava and sweet potato improvement program and an applied food crops research and training program in Rwanda. They started operations in 1983 in cooperation with the Rwanda Ministry of Agriculture and financially supported by the International Development Research Centre (IDRC) of Canada and the World Bank.

In addition to carefully selecting national programs for cooperative projects, the Institute's International Programs Unit is reassessing the need and desirability to further strengthen relationships through regional programs. One of the most successful of these is the Semi-Arid Food Grain Research and Development (SAFGRAD) project with headquarters in Upper Volta in which an IITA maize and cowpea scientific team has participated since 1978. This project was organized and developed through cooperation of the Scientific, Technical and Research Commission of the Organization of African Unity (OAU/STRC) and several international agencies and 25 countries in the semi-arid tropics of Africa that stretch across the southern edge of the Sahara Desert and down through the center of the continent.

TABLE 31.
A listing of 14 cooperative programs between IITA and African countries over the past 10 years (1973-1983).

Cooperative project title	Location	Date established	Date of termination
Tanzania Food Crops Research	Tanzania	November 1973	March 1983
Liberia Rice Research	Liberia	December 1973	March 1979
Assistance to the Rokupr (Sierra Leone) Rice Research Station	Sierra Leone	March 1974	December 1980
Programme National Manioc (PRONAM)	Zaire	May 1974	May 1984
Cameroon National Root Crops Improvement Program (CNRCIP)	Cameroon	March 1977	September 1983
Food Legume (Upper Volta)	Upper Volta	June 1977	June 1985
Nigerian Accelerated Food Production Program (NAFPP)	Nigeria	July 1977	May 1981
Semi-Arid Food Grain Development Project (SAFGRAD)	Upper Volta	March 1978	March 1985
Sao Tomé Crops Diversification Project	Sao Tomé y Principe	May 1978	September 1983
Zone d'Action Prioritaires Intégrée de l'Est (ZAPI-EST)	Cameroon	May 1978	June 1983
MIDAS Small Farm Systems Research	Ghana	June 1979	March 1983
National Cereals Research & Extension (NCRE)	Cameroon	January 1981	January 1985
Applied Food Crops Research & Training	Rwanda	December 1982	December 1987
Rwanda Root Crops	Rwanda	January 1983	January 1985



During the past five years, IITA has outposted a maize and cowpea scientific team in Upper Volta to participate in the regional SAFGRAD program. New IITA high yielding and disease resistant varieties of both crops have been adopted by farmers in the region.

A shortage of well trained persons ranks as one of the most serious handicaps to agricultural development in Africa. Therefore, training is an integral part of the Institute's efforts to strengthen national programs. See 1982 *Research Highlights*.

Because of the need to maintain a strong "core" research program that will not be diluted by too many "outreach" projects involving outposting of scientists and the back-up necessary at the Institute's research headquarters, the number has been kept deliberately low in spite of increasing requests from several nations. Currently, seven projects of this type are in operation in four countries—Cameroon, Rwanda, Upper Volta, and Zaire. IITA's principal focus remains the generation of new technology through research rather than technical cooperation *per se*.

The following specific criteria for choosing cooperative projects have been established by IITA:

- The Institute must be invited by the host country. This is not merely a procedural requirement but a means to ensure the host country's commitment to the project and its willingness to channel resources to the project during its tenure and for the follow-up after the termination of the project.
- Designers of the project must include activities directly related to the Institute's ongoing "core" research program so that it gains as well as gives by this cooperation.
- Responsibility to finance the project and for mobilization of other inputs must be clearly identified.
- The opportunity should exist for the program to eventually serve a regional focus. When the problem to be solved is widespread, it is expected that neighboring countries can benefit from the progress made.

As part of the activities to establish the newest cooperative project in Rwanda, interested parties look over the beginning of construction of a field laboratory and seed storage facility at the Research Station in Karama.

Training in the field, laboratories, and classrooms get major attention in the Institute's efforts to strengthen national programs.

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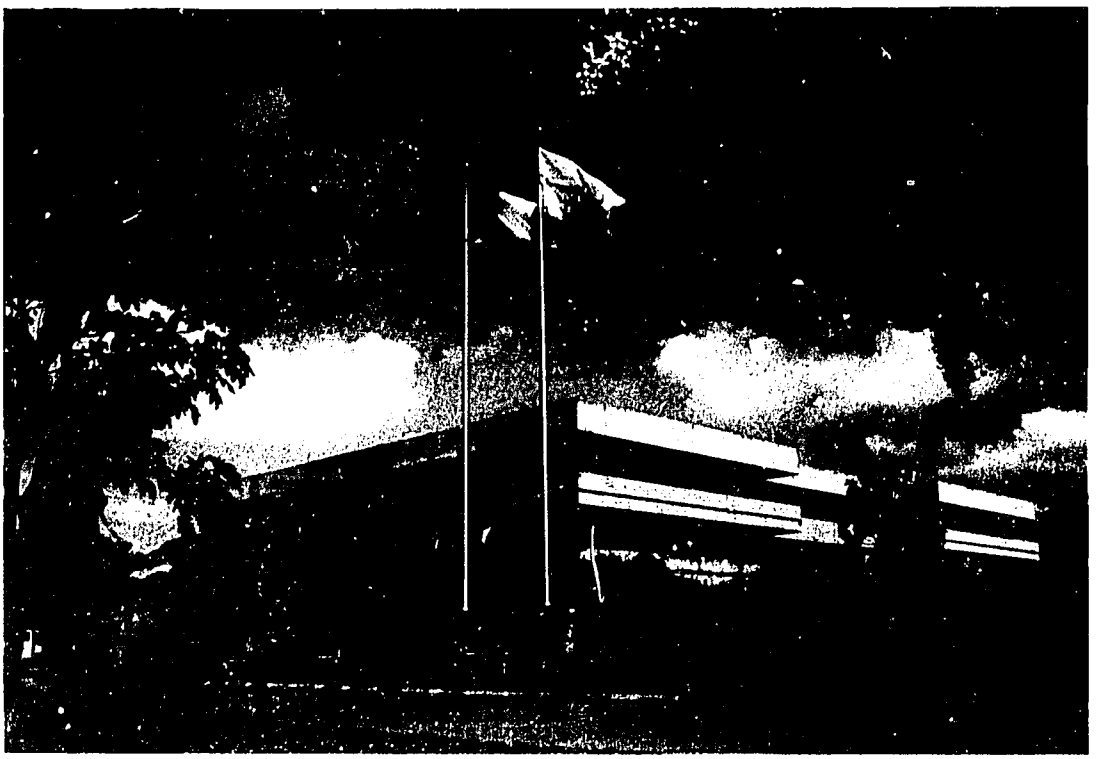

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