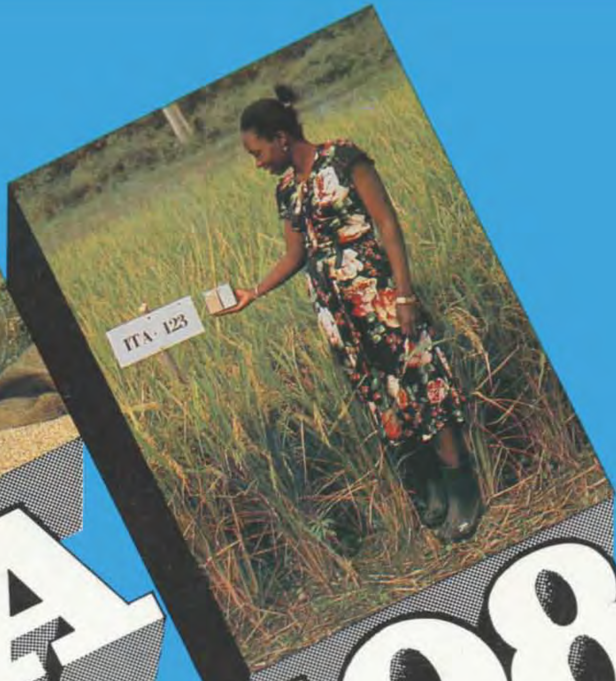
# IITA 1980

## research highlights





International Institute of Tropical Agriculture

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# Facts about IITA

The International Institute of Tropical Agriculture (IITA) —one of the major links in a world-wide network of agricultural research and training centers—was established as an autonomous, non-profit corporation on July 27, 1967. The Federal Republic of Nigeria alloted 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.

The 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 1980 was provided by the Canadian International Development Agency (CIDA), Overseas Development Ministry of the United Kingdom (ODM), U.S. Agency for International Development (USAID), World Bank, International Fund for Agricultural Development (IFAD), Ford Foundation, International Development Research Centre (IDRC), and the governments of Australia, Belgium, 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 program.

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).

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# PREFACE

*This Institute now appears to have reached the stage where its research material and techniques can make a significant contribution toward the solution of the food problems of the humid and subhumid tropics, especially those of the African region. A solid research base has been laid by IITA and its dedicated scientists over the past decade which is a necessary step in the process of determining sound and practical soil and crop management components of efficient food production systems.*

*Without sufficient knowledge of the relevant ecosystems and the real life situations of farmers in Africa, the Institute's preliminary results from no-till farming, plant breeding for insect and disease control, and low-cost input "packages" of technology could not have been obtained.*

*The time has come for IITA to further increase its efforts to test esearch results in various countries and assist in speeding up the ansfer of technology to more national programs that in turn can each their farmers. Moreover, we intend to strengthen our nkages with national and international programs, universities, nd other research institutes. Recent actions have been taken to acomplish this. For example, we have established a new Office of Inernational Programs to give additional impetus to this important ooperative phase of our work. Also, closer links are being forged vith the Institut de Recherches Agronomiques Tropicales (IRAT) imilar to those with our sister institutions (CIMMYT and IRRI) who have placed liaison scientists with us at Ibadan. And we will continue to strengthen our network of contacts and collaborations with African universities and research institutions and with those in the developed countries who have scientific personnel and sophisticated equipment not available to us but necessary for certain basic research.*

*We have prepared this publication as testimony to various accomplishments during 1980. It records some of the highlights of IITA's research during that period but by no means all of it. If you wish to obtain more complete information, it can be found in the Institute's 1980 Annual Report which is available to you upon request.*

***E. H. Hartmans***
***Director General***

# Contents

# Potentials and Limitations of No-Till Farming

Traditional, small-scale farming with the bush fallow system and large-scale modern farming in tropical Africa face the same basic and serious problem: how to maintain the productivity of the fragile tropical soil for sustained and stable food production. Technology adapted from other regions that disregards soil and climatic constraints can create serious problems associated with maintenance of soil productivity.

IITA scientists, therefore, have been making a major effort to improve traditional systems and develop alternative systems that would contribute toward a solution of problems of continuous crop production. Among them is no-till farming with appropriate agronomic "packages" for different soils, agro-ecological environments, and cropping systems.

The merits of no-till farming lie in: (1) soil and water conservation; (2) reduction in capital inputs and land area for installing and maintaining the conventional soil conservation measures; (3) savings in time required for seedbed preparation; and (4) a drastic reduction in damage to the environment and the natural resource base caused by soil erosion. The savings in energy, as often believed, are questionable because herbicides–an essential component of the no-till "package"–are petro-based and comprise a large proportion of the energy consumed. Crop yields with the no-till system may be equivalent to those with conventional methods during the initial stages of development. Subsequently, when under conventional tillage the soil becomes degraded by erosion, the no-till system usually sustains higher yields. This "soil conserving system," however, is not applicable for all soils and crops. But these conclusions can be drawn from ITTA research and relevant literature concerning the appropriate tillage methods required for soils from various agro-ecological zones with different moisture regimes:

**Humid and subhumid regions.** No-till farming with periodic fallowing should be applicable for coarse-textured


*Soil profile from a bush fallow plot (left) shows a porous surface horizon with worm casts. The one on the right, which has been under continuous cultivation, shows compaction and little worm activity.*

soils for production of row crops (maize, cowpea, soybean, pigeon pea) and some root crops (cassava). Since soil erosion by water and the susceptibility of these soils to drought are serious problems, the no-till system can be successfully applied for management of these soils. For soils high in silt with crusting and capping problems of the surface soil, periodic physical manipulation may be necessary. For heavy textured soils, water logging and impeded surface drainage are major limitations. Unless appropriate measures are taken for draining the surface soil, tillage methods are of secondary importance. The no-till system will be harmful unless drainage conditions are improved.

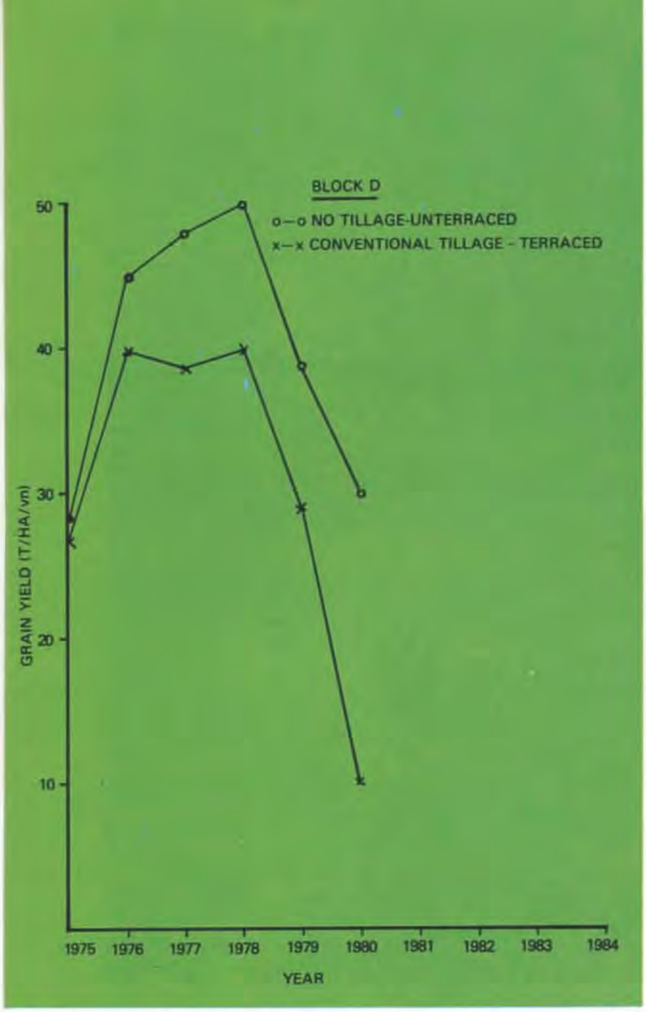
A successful no-tillage technology "package" for maize production has been developed for Alfisols for land newly cleared from secondary forest fallow (5 years or more) and with slopes up to 12% in the transitional forest zone. This "package" is best applied on large-scale land development schemes, but a number of different packages are possible on farms of different sizes (20 ha, 50 ha, 100 ha). Generally large farms are recommended from a management point of view because additional tractors per farm increase the flexibility of operations during peak periods.

Under upland conditions, effective erosion control can be achieved with a no-tillage system if cropping sequences and combinations are adopted that will permit about 4 t/ha of residue at the surface during the first four weeks of crop establishment. Data in Figure 1 show that for six consecutive years consistently higher yields of maize were obtained from unplowed plots. Soil erosion from plowed plots resulted in a poor crop stand, fertilizer imbalance, impeded root growth, and reduced yield. However, mechanized operations for seeding and harvesting can cause soil compaction below plow depth in the plowed system and in the surface layer of untilled land. The degree and severity of this compaction depend on soil texture, number and type of field operations, the soil moisture regime during the periods of seeding and harvesting, and the effective depth of rooting.

Manual operations of seeding and harvesting—the practice on small-scale farms—do not cause such compaction. Experiments conducted at IITA involving 22 consecutively-grown crops of maize with the no-till system indicate no symptoms of soil compaction in the surface or subsurface horizon. On the other hand, reduction in maize yield after eight consecutive crops of no-till maize with mechanized operations can be attributed to severe compaction and acidification in the surface horizons (Figure 1). Under these conditions, periodic chiselling, fallowing with deep-rooted tree crops and perennials to recycle soil nutrients, or occasional plowing at the end of the rainy season may be desirable to overcome the adverse effects of soil compaction.

Although most of the information on soil fertility for crop production in the tropics is concerned mainly with tilled systems, limited data show the great importance of soil fertility (particulary nitrogen) for the success of the no-till system. On low N-status soil, higher yields were obtained with tilled maize, but on fertile soil with adequate fertilization no-tilled maize gave equal or higher yields (Figure 2).

*A poor stand of maize on a field that has been continuously plowed for six years. It suffers from soil erosion, compaction, and a decline in nutrient status.*



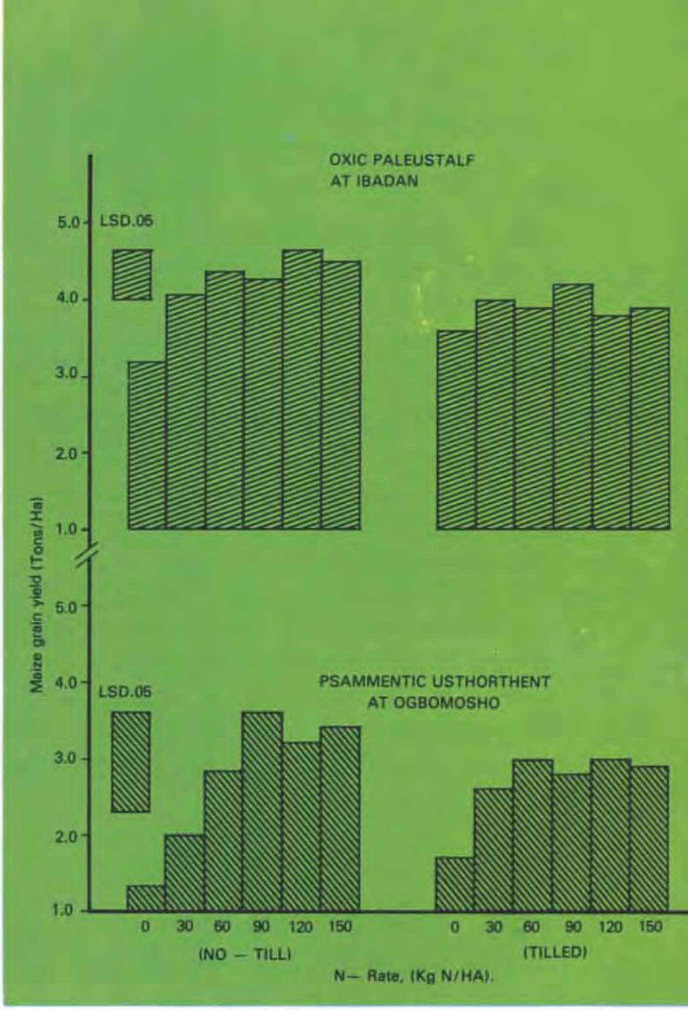




*FIGURE 1. (Above)*
***Maize grain yield (two crops per year) as affected by tillage methods.***

*FIGURE 2. (Right)*
***Effect of tillage systems and nitrogen (N) rates on the yield of maize.***

For upland crops, adequate weed control is an important factor for successful implementation of the no-till system. With continuous cultivation and the use of appropriate herbicides, there is generally a shift in weed population. *Brachiaria* and other grass species dominate in plowed plots but rhizomatus weeds *(Imperata cylindrica)* and bush regrowth are dominant in untilled land. However, the "package" for adequate weed control will differ for different soils and crops.

The advantages of no-till farming for rice cultivation in lowland soils include savings in time and energy and easier double cropping. Equivalent yields of rice can be obtained from untilled plots for four to six consecutive crops (Figure 3). After this, however, no-tillage can have adverse effects on crop yield, and periodic plowing (both wet and dry) becomes necessary to overcome them. Frequency of plowing depends on soil texture and the moisture regime during the dry season.

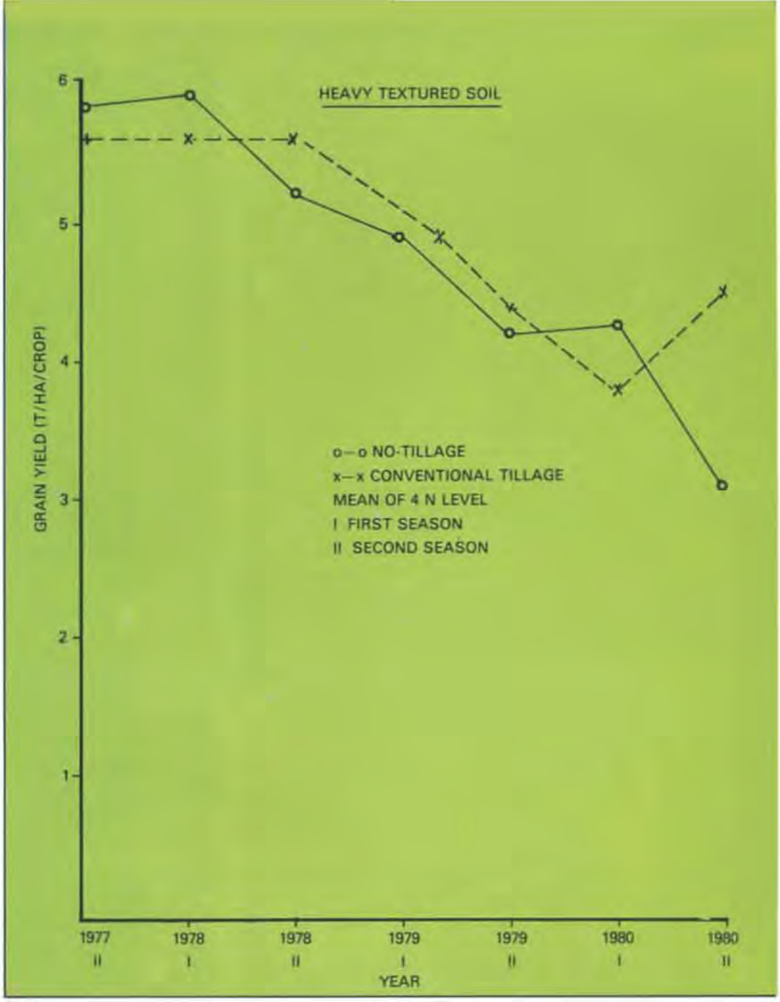



*FIGURE 3.*
*Rice grain yield as affected by tillage methods. (Humid region.)*

**Semi-arid regions.** Depending on the soil texture and land use, soils of this region suffer from wind and water erosion and frequent drought. Soils with a coarse-textured surface horizon can be cultivated by the no-till method with periodic (every two or three years) chiselling required to loosen the compacted soil surface. For soils high in silt and fine sand fraction, rough plowing at the end of the rainy season may be necessary to prevent wind and water erosion and loosen the compacted soil. Heavy-textured soils, such as Vertisoils, respond favorably to a permanent and graded ridge/furrow system that directs the water run-off into a storage tank to be used for supplementary irrigation. This, however, does not imply that mulch farming techniques are not useful for these areas, but the availability of crop residue mulch, in view of its alternate uses, could be a serious limitation.

**Arid regions.** Wind erosion is serious in the arid regions, and soils predominant in fine sand and silt fraction are more susceptible to wind erosion than coarse-or heavy-textured soils. Crop yield depends on the availability of water reserves and their conservation in the root zone. Dry farming techniques, water harvesting, and use of wind breaks are appropriate methods of soil management.

No single tillage method can be universally applicable for a range of soils and crops of the tropics. The objective is to optimize the use of the limiting resource and conserve the natural resource base. The potential and use of no-till farming can be extended to other soils and ecological regions with suitable modifications in the agronomic "package" for that environment. Even if the mechanical tillage operations cannot be completely eliminated, either the number of operations required for seedbed preparation can be reduced or the mechanical tillage can be limited to a portion of the field (row zone) rather than covering the entire land surface.

# Influence of Cassava on Soil Structure

Cassava, produced on 6 million hectares in tropical Africa which constitutes 40% of the world output, is grown under diverse soil and agro-ecological regions. It is generally the last crop in the rotation prior to returning the land to bush fallow. Although the highest yields are obtained through proper management and in soils that promote development of tuberous roots, cassava can still produce decent yields even under the most adverse soil conditions where other crops may not. This can be attributed partly to its deep root system.

Cassava roots can penetrate soils of relatively high bulk density. No significant differences were observed in root density of cassava grown on sandy loam soil with a bulk density range of 1.4 to 1.8 $g/cm^3$ (Figure 4). Development of tuberous roots within a few centimeters of the surface layer and a complete ground cover over 6 to 12 months can have beneficial effects on physical properties of the soil surface. Compaction and crusting of the surface layer caused by impacting raindrops, as commonly observed in open-row crops, become minimized in cassava due to the protective effects of its canopy structure. While soil beneath the tubers may be

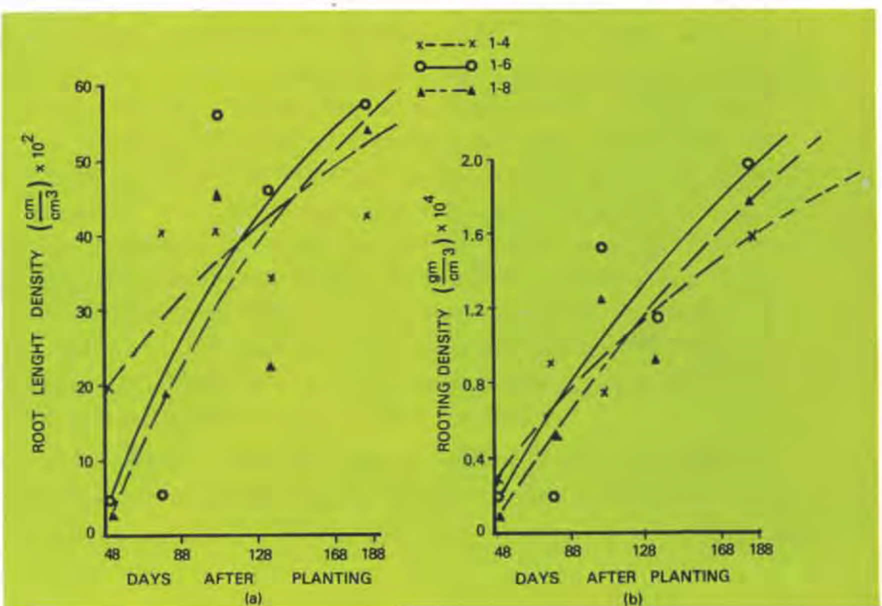



*FIGURE 4.*
***Effect of soil bulk density on the density of cassava feeder roots.***

*Because of its canopy structure, cassava causes relatively less soil degradation than open-row grain crops.*

compacted by their development, they can have a loosening effect on the layers above. Also, due to its canopy structure and protective effects against impacting raindrops, cassava when well established causes relatively less soil degradation than open-row grain crops.

Data of soil bulk density and penetrometer resistance of the surface layer under maize and cassava (Table 1) indicate severe compaction of the surface layer under maize but not under cassava. Loosening of the surface layer under cassava results in high water intake and relatively low runoff and erosion. Under favorable soil density and moisture regimes, root penetration may exceed 2 m depth, even within a short span of three months.

Under equivalent soil moisture stress, cassava leaves can maintain higher leaf-water potential than maize or even sweet potato. With no rain for about 10 weeks, leaf-water potential

***TABLE 1.***
***Effects of cassava and maize on soil physical properties.***

| Soil Property | Cassava | Maize |
|---|---|---|
| Penetrometer resistance ($kg/cm^2$) | 0.67 | 1.84 |
| Hydraulic conductivity (cm/hr) | 269 | 29 |
| Bulk density ($g/cm^3$) | 1.37 | 1.37 |

*Loosening of the surface soil layer by cassava results in high water intake and relatively low runoff and erosion.*

of cassava was observed to be -6 to -8 atmosphere compared with - 10 to -12 for sweet potato. The mechanisms responsible for maintenance of high leaf-water potential throughout the growth of cassava during a prolonged dry season are not well understood: However, the presence of latex and the leaves' stomatal behavior and surface characteristics may be responsible for this adaptability. These characteristics will be investigated further.

# Nitrogen, Stakes, and Firewood from *Leucaena*

Population pressure and other factors in many parts of the tropics have shortened fallow periods so much that small farmers find it difficult to effectively restore soil productivity or produce stakes, firewood, and other essentials usually harvested from bush fallow. To help alleviate this problem, investigations have been initiated to develop efficient alternatives to bush fallow. One of these alternatives — "alley cropping" — was described in the 1979 issue of "Research Highlights." Another alternative for farmers accustomed to open field cropping or conventional stakings is a *Leucaena* "cut and carry method" now being investigated.

Using a 1/2 ha plot in which *Leucaena leucocephala* was once used for in-situ yam vine support, the potential leaf N and stake yield were evaluated. *Leucaena* was spaced 150 cm x 50 cm and cut back to about 15 cm at the end of the dry season following the yam harvest. Free regeneration was allowed with both seedlings and shoots which contributed to a thick regrowth with approximately 149,000 upright stems/ha. During the early dry season of the following year (1980), the plot was selectively harvested. Stems having a diameter over 2.0 cm at 100 cm above ground were cut. The data (Table 1) show that 13,330 stems per ha or 9.0% of the stems in the field were judged to be suitable for supporting yam vines. To harvest the leaves, the stems were leaned against a horizontal bar. The leaves which withered and fell

*Thinning a Leucaena forest lot (below) provides stakes and firewood. Dried Leucaena leaves are collected (below right) to be put on the soil to improve its nitrogen content, and then the stems will be used as stakes and firewood.*

*TABLE 2.*
*Production from a Leucaena forest lot.*

| Item | Quantity |
|---|---|
| Stem population density | 149,000/ha |
| Stem harvested | 13,330/ha |
| % of total stand | 9% |
| average length | 620 cm |
| average diameter at 100 cm | 2.9 cm |
| Leaf yield from harvested stem (dry weight) | 2,240 kg/ha |
| Leaf N content | 4.2% |
| Leaf N yield | 94 kg/ha |
| Labor for cutting + setting to dry | 64 man days/ha |

from the stems after about seven days were collected on canvas or plastic sheets. The leaves from the harvested stems yielded 2,240 kg/ha of dry matter with a nitrogen content of approximately 4.2%. This gave a nitrogen yield of 94.0 kg/ha. The harvested stems represent a fraction of the total biomas and therefore only a fraction of the total leaf nitrogen yield. Farmers interested in higher nitrogen yield may harvest the entire crop of *Leucaena*. Although many of the stems may not make good stakes, unsuitable ones could be used as firewood.

The labor data (Table 2) represent the man-hour/ha required for cutting and setting the stems to obtain dried leaves. The figure is high and indicates the difficulties involved in removing stems with leaves and branches attached. The figure could be much lower relative to yields in a clear felling situation.

The benefit of nitrogen from leaves could be significant in developing countries where the shortage of foreign exchange limits the quantity of fertilizer purchased or where a poor infrastructure prevents efficient distribution and use. The stakes and firewood could be important in those areas where a shortened bush fallow period has already limited these supplies. A supply of stakes available from nearby managed lots could increase yam production in areas where a shortage of stakes has been adversely affecting production. Moreover, the used stakes make good firewood.

Cocoyam, a component of a larger yam-based farming system, may have a promising future. In an IITA survey, farmers reported that they are increasing their production.

## Promising Value of Cocoyam

In a 1980 survey, IITA economists of the Farming Systems Program found that farmers in Western and Eastern Nigeria are increasing their cocoyam production and that the crop may have a more promising future. Nigeria is the world's largest producer of the crop with 40% of total production. (FAO reports.) It is the second most important root crop in Cameroon, Ghana, and Gabon.

Forty percent of the 66 farmers in 10 different villages in the Nigerian survey sample grew cocoyam (*Colocasia esulenta* and *Xanthosoma sagittifolium)* as a cash crop, selling at least half of their yearly production. Planting dates varied from March/April to April/May and seemed to depend on the planting and harvest dates for yam. As such, the cocoyam

*TABLE 3.*
***Labor utilization (man days/ha) for maize, cassava, and cocoyam by activity.***

| | Maize | Cassava | Cocoyam |
|---|---|---|---|
| | | Man days/ha | |
| Land preparation | 24 | 40 | 36 |
| Planting | 10 | 13 | 14 |
| Weeding* | 25 | 45 | 38 |
| Harvesting | 16 | 70 | 60 |
| Total | 75 | 168 | 148 |

** Generally two weedings for cocoyam.*

farming system is a component of a larger yam-based farming system. This was further confirmed by the intercropping and rotation patterns reported. Mixed cropping with maize was the general mixture, although a yam-cocoyam-maize association was very common. Farmers also intercropped cocoyam with tree crops — kola and citrus, for example.

All varieties were cultivated on well-drained, fertile, upland soils. The choice of variety was largely dependent on the method of food preparation. Qualities such as "hard" vs. "soft" and "scratchy" vs. "sweet" were important. From the point of view of taste, yam (white or yellow) was preferred, but cocoyam had preference over maize or cassava. Pounding was the most common form of food preparation.

Labor utilization for cocoyam was estimated to be 148 man-days per hectare and less labor-intensive than cassava (Table 3). The most common storage areas were a shady place in the field, huts or barns, houses, and pits.

# Hybrid Maize for Africa

Some countries in Africa have a program of genetic improvement in maize based on hybrids, and hybrid maize is extensively grown in Kenyan and Tanzanian highlands and on commercial as well as small-scale farms in Zambia. In West Africa, Senegal and Ivory Coast have developed hybrids which have established a good performance, but the state of the seed industry has restricted their large-scale popularization.

Over the past two years, IITA has had a very modest program to explore the prospects for hybrid maize, initially through top crosses (line x variety cross) which have obvious advantages in seed production over other types of hybrids. In the program of top crosses,a base location likeITTA does not develop the hybrids *per se* but only inbred lines (mainly $S_3$ and $S_4$) with specific attributes of adaptation, such as resistance to diseases and insects and combining ability. The lines so developed can be used by national programs either to develop synthetics and composites, or they can use the lines as male parents in the top cross seed production plots wherein the female parent will be the locally adapted variety (Figure 5). The detasseling will be limited to the local variety.

*Top cross (left) vs a composite maize variety. Research shows an impressive yield gain in the top crosses over the parent populations.*

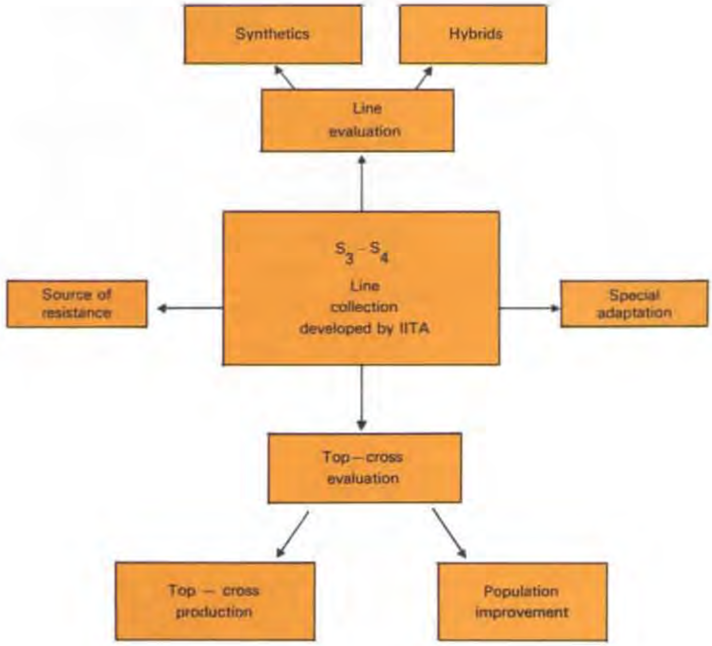



*FIGURE 5.*
***How the IITA maize line collection may be used by national programs.***

Seed production in the male parent will be concurrent to the top cross seed production. Since the lines are not advance generation "inbreds," they have reasonable vigor. The top cross seed will produce a crop of greater unformity than the composites and is expected to be more vigorous and productive. In general, the seed production technology is simpler, although the farmer will have to change seed each year as with regular hybrids.

IITA looks upon the top crosses as an intermediate stage in the development of the hybrid program and visualizes the prospects for its exploitation in mostly large-scale organized commercial farms. The questions relevant to the development of the top crosses are:

(1) Magnitude of heterosis obtainable in crosses between the local populations and the $S_3$ - $S_4$ lines.
(2) Relative yield potential of the top crosses with the best available composites in a given situation.
(3) Dominance of traits controlling specific adaptational attributes–resistance to streak, borer, ear-rot, stalk-rot.
(4) Yield disparity from the best available hybrids.

*Yields harvested from three replications of the same top cross (right). compared with the original $TZE_3$ composite variety (left)*

Research so far indicates an impressive yield gain in the top crosses over the parent populations (Figure 6). The potential for further improvement exists, since not enough effort has gone into the production of inbred lines.

When the line employed in top crosses has resistance to maize streak virus, and the parent variety is sensitive, the $F_1$ (top cross derived commercial crop) is intermediate in reaction to maize streak virus. When exposed to an epidemic of MSV, an average of 20 $F_1$ crosses yielded 2,600 kg/ha compared with the original 20 sensitive composites which yielded 125 kg/ ha. A similar opportunity may exist for other stresses where the trait is genetically dominant.

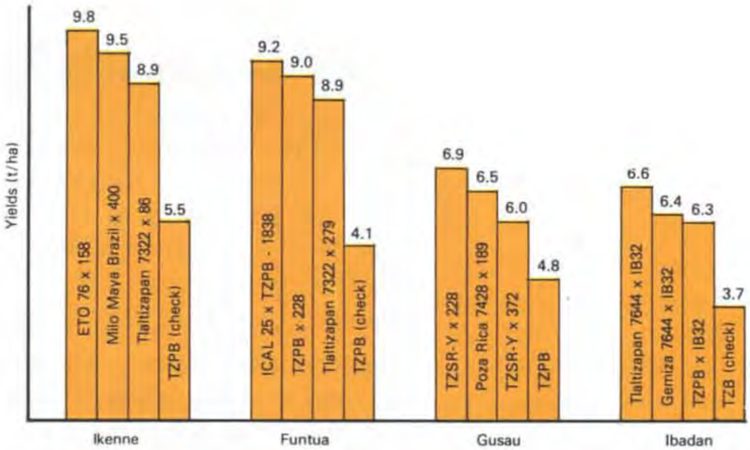
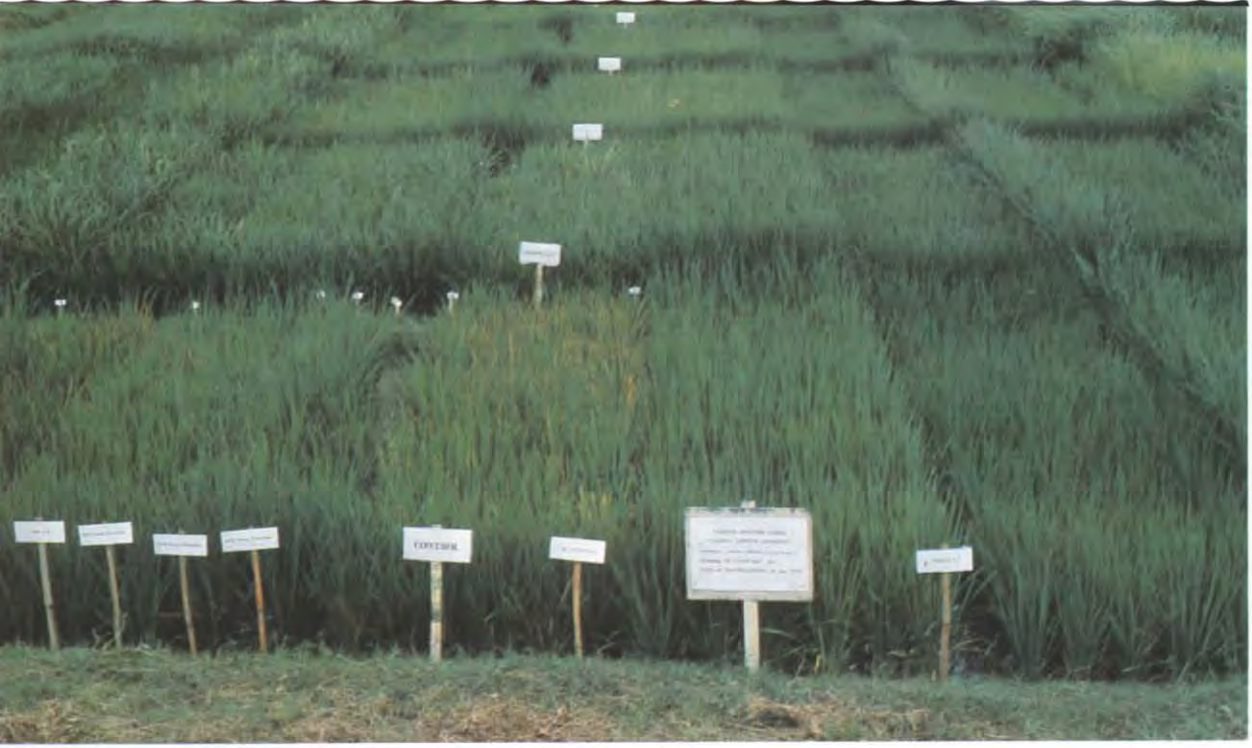



*FIGURE 6.*
*Yields of new, promising top crosses (hybrids) in four locations in Nigeria, 1980. (Medium-maturing maize.)*



*Large numbers of cultivars being evaluated in improved swamps show a high production potential in Africa.*

# Semi-Dwarf Swamp Rices

Flooding regulation, irrigation, and/or drainage facilities are necessary to make swamp rice productive. Semi-dwarf (IR 8) plant type for improved swamps with good water control and intermediate (IR 5) plant type for swamps with fluctuating water depths (not exceeding about 30 cm standing water) have generally been found to be suitable.

Several such types are available from various breeding programs in Asia, South America, and elsewhere. They are being evaluated for either direct introduction or for use as parents in developing material tolerant to the prevailing stresses in Africa, such as blast, Rice Yellow Mottle Virus (RYMV), and tolerance to iron toxicity. Therefore, efforts at IITA are directed toward solving these problems.

The screening for general performance and adaptation of fixed lines is being done through multilocational tests in Nigeria in cooperation with the National Cereals Research Institute (Ibadan). Screening and selection for blast resistance, RYMV tolerance, and grain type is done from the early generations by ITTA.

The screening for iron toxicity tolerance is being accomplished through cooperation with the Central

Agricultural Experiment Station (CAES) and West African Rice Development Association (WARDA) at Suakoko, Liberia. In addition, the international testing is being accomplished through the testing programs of WARDA in West Africa and through the International Rice Research Institute (IRRI) world-wide.

In tests in various locations, TOx 514-16-101-1-1, TOM 1-3, and BG 6850 were the three highest yielding, semi-dwarf rice varieties for improved swamps. These cultivars have now been designated as ITA 121, ITA 123, and ITA 212, respectively.

ITA 121 (Moroberekan/SE 363G, Ikong Pao) was initially selected in upland environments up to the $F_3$ stage and then selected under low nutrient (N, P and K) irrigated paddies where it was superior to all the 120 other lines tested. It is tolerant to Fe-toxicity. Further, it has exhibited good performance in well-managed paddies and was among the top three ranking cultivars yielding 7.0 t/ha or more.

ITTA 123 is a semi-dwarf mutant of OS 6 — the most prominent tall, upland variety in Nigeria. Although this line has thick and deep roots similar to OS 6, it is moderately susceptible to panicle discoloration under upland stress conditions. However, under irrigated paddies it has performed well in comparison with other varieties in various tests conducted in Nigeria. In addition to having high yield potential, the grains of ITA 123, which are long, slender, and translucent, are preferred grain types by urban consumers in the region. In IITA's high rainfall substation (Onne,

*ITA 123 with long, slender, and translucent rice grains and ITA 212 with blast resistance were found to be high yielding.*


Nigeria) under rainfed upland conditions, this line was moderately resistant to blast, but several other semi-dwarf mutants of OS 6 died because of severe leaf blast.

ITA 212 (BG 90-2[4] / Tetep) was selected from 250 $F_4$ lines obtained from Centro Internacional de Agricultura Tropical (CIAT), Colombia. BG 90-2, which has been one of the highest yielding improved swamp rice varieties in West Africa, needed improvement, especially in blast resistance and grain translucency. Tetep was used as a donor for these two traits and ITA 212 was selected retaining the superior yield potential of BG 90-2. Selection for blast resistance was done in Ibadan through a horizontal blast resistance screening methodology developed at IITA. In a large seed multiplication plot at Ibadan, it yielded 5.8 t/ha.

These varieties were evaluated throughout the nation in the 1980 Nigerian zonal trials organized by the National Cereals Research Institute (NCRI), Moor Plantation, Ibadan. Their performance in five locations is presented in Table 4. All three varieties are now included in the Nigerian Green Revolution Program.

*TABLE 4.*
*Performance of ITA 121, ITA 123, ITA 212, and some recommended varieties in Nigeria*.*

| Cultivar | GRAIN YIELD (t/ha) | | | | | | Range in growth duration (days) |
|---|---|---|---|---|---|---|---|
| | Edozhigi | Badeggi | Abakaliki | Bende | Ogoja | Mean | |
| ITA 121 | 3.3 | 5.8 | 7.5 | 5.1 | 6.7 | 5.7 | 121-133 |
| ITA 123 | 3.7 | 5.5 | 5.6 | 4.3 | 6.9 | 5.2 | 117-129 |
| ITA 212 | 4.4 | 5.7 | 6.9 | 6.1 | 6.5 | 5.9 | 120-128 |
| IR 30 | 2.7 | 5.2 | 4.6 | 2.4 | 4.6 | 3.9 | 107-120 |
| TOs 103 | 2.7 | 5.1 | 5.0 | 2.9 | 4.0 | 3.9 | 110-120 |
| BG 90-2 | 3.9 | 5.2 | 6.4 | 3.6 | 7.8 | 5.4 | 117-138 |
| FARO 15 | 3.1 | 4.9 | 5.6 | 2.6 | 8.5 | 4.9 | 140-154 |

* *National Cereals Research Institute Zonal Trials, 1980*

*An intermediate-statured cultivar—TOx 86-1-3-1 —which has deep and thick roots was superior to OS 6 under drought conditions.*

# Selection and Breeding for Drought Resistance in Rice

Most upland soils in African regions where rice is traditionally grown have a low water-holding capacity. This, coupled with the relatively shallow rooting habit of rice, limits the soil volume that the plants can exploit for moisture. They suffer from moisture stress due to breaks as short as one week during the rainy season. Therefore, extensive root development is one of the significant characteristics for drought resistance.

Intensive research to understand the drought resistant mechanisms and to breed drought resistant rice varieties have been a primary focus for upland rice improvement in various national programs and at the International Rice Research Institute (IRRI), Institut de Recherches Agronomiques Tropicales (IRAT), and IITA.

Aware that the traditional *O. sativa* cultivars for West Africa are among the highly drought resistant varieties, IITA scientists evaluated their morphological characters and noted that they have a large proportion of long, thick roots which enable them to absorb soil moisture from deeper soil horizons and thus suffer less from drought. Experiments at the Institute demonstrated the advantage of root thickness over high stomatal resistance among the rice varieties studied.

Response of five rice cultivars (BG90-2, IR-442-2-58, IR 2035-120-3, IR 2071-586-5-6-3, and TOx 504-13-14-1) to water stress at the flowering stage was studied in pot culture. Various traits related to drought resistance were measured. The latter two cultivars maintained higher leaf water potential and had lower stomatal densities but lower stomatal resistance compared with the control up to seven days after stress (Table 5). Stomatal lengths were not significantly different. Also, differences in stomatal resistance between varieties disappeared nine days after stress. However, differences between varieties for their ability to maintain high leaf water potential persisted.

| Cultivar | Leaf water potential | | Stomatal resistance | | Stomatal density | |
|---|---|---|---|---|---|---|
| | Stressed | Control | Upper | Lower | Upper Face | Lower Face |
| IR 442-2-58 | - 15.7 | - 9.2 | 4.0 | 7.8 | 210 | 259 |
| IR 2035-120-3 | - 12.0 | - 7.8 | 2.1 | 2.7 | 231 | 257 |
| IR 2071-586-5-6-3 | - 13.5 | - 11.8 | 1.5 | 1.9 | 155 | 206 |
| TOx 504-14-14-1 | - 9.3 | - 8.0 | 2.0 | 1.9 | 153 | 176 |
| BG 90-2 | - 13.8 | - 8.8 | 2.4 | 2.5 | 206 | 261 |
| LSD (0.05) | 4.3 | | 4.11. | | 38.9 | |

*TABLE 5.*
***Leaf water potential (bars) and stomatal resistance (5 $cm^{-1}$) in the morning, seven days after stress and stomatal densities (No. $mm^{-2}$) of five rice cultivars.***

In other experiments where 36 cultivars were screened under four moisture treatments, the grain yield differences could not be explained on the basis of leaf water potential alone. Ratio of root (up to 20 cm) to total shoot weight were different among the cultivars but showed no clear relationship with water potential measurements. But generally the cultivars which were higher yielding under drought conditions had thicker roots. In a separate study under upland conditions, the percentage of root dry weight over total dry weight was actually lower (10 to 15%) for upland varieties such as Moroberekan, LAC 23 and 63-83 which are known to possess drought avoidance mechanism compared with improved lowland types (14 to 24%). On the other hand, all the upland types had much thicker roots (2.1-3.3 score) while the improved lowland types had generally thin roots (5.7 - 8.0 score). This suggests the importance of root type or thickness for the uplands rather than root density *per se*. Recent studies at IRRI confirm that root thickness is associated with drought resistance.

IITA scientists have focused their attention on combining the thick-rooted character from the traditional upland types with lodging resistance and high yield potential from the semi-dwarfs to develop improved semi-dwarf upland cultivars. Semi-dwarfs for the uplands should differ from the

***Thick rice roots rather than root mass is associated with drought resistance. IITA scientists found that it is possible to select for root thickness and short stature at the rice seedling stage (upper right).***

typical IR 8 type for the lowlands in order to adapt to "upland stresses." Among other things, they should have thick and deep roots, lower leaves droopy to suppress weed growth, upper leaves erect to efficiently use solar radiation, and well exerted panicles with good grain filling.

Although selecting for short stature at seedling stage has been practiced by most breeders, the possibility of selecting for thick and deeper roots at this stage has not been explored in the past. However, evaluation by IITA scientists in 1980 of an $F_2$ population of TOx 936 (IR 1529-430-3/Iguape Cateto-a semi-dwarf x tall cross) indicates that this may be possible.

The fitness of seedling stage selection of root thickness in short-statured plants was as high as 95%. Also, the correlation between plant height and root thickness was not significant. Plant height and root thickness behaved as independent characters. This means that it should be possible to combine the thick-rooted character of the traditional, tall upland varieties with a short-statured character of the improved, high-yield potential semi-dwarfs. Furthermore, these two desirable traits can be recognized at the seedling stage.

Seedling stage selection for plant height and root characters will increase the probability of developing superior semi-dwarfs for uplands because it is simple.

*Rearing leaf hoppers in cages for artificial infestation of maize streak virus.*

# TZSR—Streak Resistant Maize

Maize streak virus is the major production constraint in Africa in the lowlands and mid-altitude growing conditions. IITA research (c.f. IITA Research Highlights for 1978) led to the identification of two populations–TZSR(W) and TZSR (Y) – which held up their resistance under many conditions. But there was room for further yield improvement. Taking advantage of the hybridizations between TZSR and the well adapted improved varieties, the genetic base of TZSR populations was further broadened and the populations so developed have been redesignated as TZSR-Y-1 and TZSR-W-1 (Figure 7).

***TABLE 6.***
***Grain yield (t/ha) of new streak resistant maize varieties — TZSR-W-1 and TZSR-Y-1— at four locations in Nigeria, 1980.***

| | | Ikenne | | | | |
|---|---|---|---|---|---|---|
| | | 1st | 2nd | | | Avg. |
| Variety | Ibadan | Seasons | | Mokwa | Funtua | yield |
| TZSR-W-1 | 4.4 | 6.2 | 3.3 | 5.2 | | 5.0 |
| TZSR-Y-1 | 4.7 | 7.6 | 4.1 | 5.7 | | 5.6 |
| TZPB (check) | 4.5 | 6.4 | 3.3 | 5.6 | 5.8 | 5.2 |
| TZB (check) | 4.5 | 5.7 | 3.6 | 6.3 | 6.5 | 5.5 |
| 5% LSD | 1.2 | 1.6 | 1.0 | 1.8 | 1.8 | 1.5 |
| C.V. (%) | 21.2 | 15.9 | 22.6 | 21.3 | 23.2 | 21.2 |

***TABLE 7.***
***Reported grain yield (t/ha) of streak resistant maize varieties in two countries.***

| | Cameroon | | | Nigeria |
|---|---|---|---|---|
| | Lowland | Lowland | Highland | NAFPP pre-minikit |
| Variety | West | East | | trials** |
| TZSR-W-1 | 6.5 | 6.0 | 3.4 | 2.8* |
| TZSR-Y-1 | — | — | — | 5.5 |
| TZPB | 7.0 | 5.2 | 3.5 | 4.7 |
| TZB | 7.0 | 6.1 | 2.8 | 4.9 |
| Local | 6.3 | 1.6 | 3.9 | 3.1 |

* *Old TZSR-W*
***Average yield of several locations.*

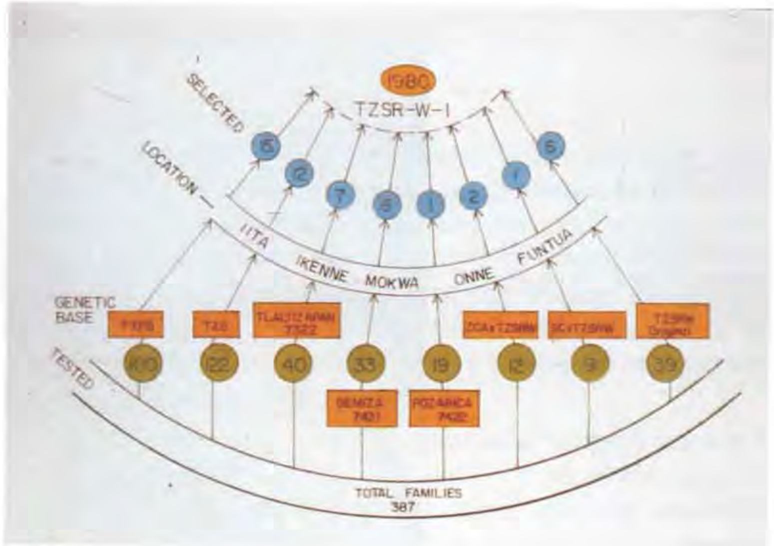



*FIGURE 7.*
*Genetic makeup of the 50 selected TZSR-W-1 families.*

Extensive multilocational testing of the newly constituted populations confirmed their yield potential to be comparable to the widely adapted and accepted (in Nigeria) streak-sensitive populations (TZB and TZPB) named earlier by IITA (Table 6). Similar good performance has been reported from Cameroon (Table 7).

IITA has always been concerned about determining the validity of resistance over a wide range of environments in Africa. At various stages in the development of resistant materials, international testing has been undertaken to be sure that the resistance holds up against the existing variation in the virus. The data from such tests conducted in several West African countries and in Zaire and Tanzania have clearly indicated that the IB-32 and La Revolution-based MSV resistance holds up in many locations in Africa. The most dramatic display was in the MSV epidemic of 1979 in Sao Tome where the susceptible populations stood up to the epidemic and gave decent yields.

Satisfied with the wide relevance of streak resistant material and recognizing the scope for genetic advance in the reconstituted TZSR populations, scientists tested over 700 half-sib families in different environments within Nigeria.


*Drying TZSR-W-1 for the Nigerian Green Revolution Program.*

Fifty families from each population have been selected for a new cycle of selection. This program will be further expanded in 1981 to include testing of full-sib families in six African countries to develop experimental varieties with specific adaptation. Simultaneously, the TZSR-W-1 and TZSR-Y-1 are being popularized in the Nigerian Green Revolution Program.

In addition, two other types of streak resistant populations are being developed. Half-sib families of early maturing (90-95 days) white and yellow populations are being tested in five locations in Nigeria, and the best families will be recombined during the dry season of 1981 for international testing during 1982. Streak resistant populations adapted to the mid-altitude ecology (700-1200 m) will also be available for international testing in 1982 for East and Central Africa.

The CIMMYT International Testing Program has identified several experimental varieties with proven performance in one or more African countries. Their major weakness is susceptibility to MSV. Ten of these varieties are employed for conversion to streak resistance by the back-cross method. Also, CIMMYT has relocated the base populations of La Posta (population 43) at IITA with major emphasis on incorporating streak resistance.

# Virus Research

Virus diseases have a disastrous effect on crop yields and threaten the food producing potential of Africa and other parts of the world. A basic key for methods of control is the identification of the viruses, their characterization or description, and final diagnosis of the diseases observed in the field. Mixed or complex infections can occur, and in that case they have to be separated before biological and physico-chemical properties can be studied.

IITA virologists provide a specialized support service to the Institute's plant pathologists and breeders working on the improvement of cereals, grain legumes, and root and tuber crops. They survey these crops for possible virus diseases, identify and characterize the viruses, develop indexing techniques, determine the rate of seed transmission to make sure that virus-free seeds are distributed for multilocational testing, provide representative and pure virus isolates for resistance screening, develop resistance screening techniques, and assist in resistance screening and virus indexing where required.

*Early symptoms of maize mottle virus infection (below). IITA scientists found a large reservoir of viruses on the Island of Sao Tome, and the 40 hectare field on the right is evidence of that. The non-resistant local variety here shows severe stunting due primarily to viruses.*

During 1980,research on the sweet potato virus disease involved further clarification of the two-component nature of the disease. It could be confirmed that both components are necessary to produce the disease symptoms, and it was found that the plants cannot be readily indexed by means of serological techniques if only one component is present. A simple and reliable virus indexing method was developed involving approach grafting to a purposely selected highly-susceptible sweet potato seedling clone. In a preliminary survey, it was found that symptomless plants among otherwise diseased sweet potato clones in the field can have either the aphid-transmitted or the whitefly-transmitted component or neither one.

Maize mottle/chlorotic stunt, like maize streak virus transmitted by the leafhopper vector, *Cicadulina triangula,* is largely overlooked as a virus disease, probably because the symptoms strongly resemble nutrient deficiencies. Close monitoring of this disease, both under greenhouse and field conditions, showed that even in IITA's improved maize populations severe chlorosis and stunted growth may occur in varying degrees of severity. But these varieties, like local maize varieties, are far less susceptible than any introduced exotic variety. During a 1980 survey in Northern Nigeria in the middle of the growing season, maize mottle/chlorotic stunt infections were seen throughout the area, and the disease may present a potential constraint to production.

In a search for possible wild grasses or other alternate hosts, it was found that sorghum plants in farmers' fields adjacent to a large-scale maize production area (Mokwa, Nigeria) were affected by a serious and epidemic disease. From artificial inoculations of sorghum in greenhouse experiments, further evidence was obtained that this disease was possibly caused by maize mottle/chlorotic stunt virus. A severe chlorosis, followed by leaf tip necrosis, developed in sorghum seedlings two to three weeks after inoculation. However, symptoms were completely transient in the sense that new growth did not develop any further chlorosis/necrosis. However, in the late chronic phase, in the sorghum variety tested, the same disease syndrome developed as that observed in sorghum in the field.

*Plants are examined in an insect-proof screenhouse for virus symptoms.*

It is not impossible that large scale introduction of a relatively new crop like maize into areas traditionally growing millet and sorghum may result in dramatic shifts in the ecology of the maize mottle/chlorotic stunt disease in the future.

A set of 13 maize varieties and breeding lines was tested for resistance to an isolate of maize dwarf mosaic virus (MDMV) obtained from maize at IITA. Some of these materials have useful resistances to other virus diseases, including MSV, maize rough dwarf virus (MRDV), and MDMV types from other places in the world (Table 8). One finding from this experiment was that the MSV-resistant TZSR (white population), which is also resistant to maize mottle/chlorotic stunt and maize stripe virus, only developed comparatively mild symptoms in about half of the plants inoculated. Therefore, it can also be considered moderately

*TABLE 8.*
***Reaction of a selection of virus resistant and other maize materials to infection with maize dwarf mosaic virus (MDMV).***

| Variety or line tested | Other resistances | Symptoms expression with MDMV | |
|---|---|---|---|
| | | Incidence rate(1) | Severity rating(2) |
| B 73 | | 8/8 | 3 - 4 |
| B 37 | | 2/8 | 2 |
| B 68 MT | MDMV, MMV-1 | 0/9 | 1 |
| MO 17 | | 5/5 | 4 - 5 |
| IB 32 (S3) x 14 | MSV | 4/12 | 2 - 4 |
| IB 32 (S3) - 8 | MSV | 1/2 | 3 |
| OH 43 UT | | 7/8 | 4 |
| H 95 | MRDV | 10/10 | 5 |
| TZB | | 0/6 | 1 |
| TZPB | | 4/13 | 1 - 3 |
| TZ SR — White | MSV | 6/15 | 2 |
| IB 32 x La Revolution | MSV | 11/18 | 2 - 3 |
| B14 AHt | MDMV, MMV-1 | 0/2 | 1 |

*(1) Number of plants developing symptoms/number of plants tested.*
*(2) Severity rating 1—5: no symptoms - very severe symptoms.*
*MDMV — Maize dwarf mosaic virus. MRDV — Maize rough dwarf virus.*
*MMV-1 — Maize mosaic virus. MSV — Maize streak virus.*

TABLE 9.
*Resistance of TZSR (white) and TZSR (yellow) to maize mottle as compared with TZPB and Sao Tomean local variety (1980).*

| Variety | % Plants infected with maize mottle |
|---|---|
| TZSR (white) | 13.3 |
| TZSR (yellow) | 18.0 |
| TZPB | 66.5 |
| Local variety | 34.0 |

resistant to MDMV. This maize variety combines high levels of resistance to four different virus diseases of regional or continental importance in Africa and on neighboring islands.

IITA scientists found that a large reservoir of these viruses affect maize production on the Island of Sao Tome and that the TZSR lines developed at IITA have performed very well under those conditions. (Table 9). Maize yields of the TZSR lines were approximately double the local Sao Tomean variety (6,369 vs. 3,443 kg/ha and several times higher than other improved but disease-susceptible cultivars.

A very sensitive serological technique–Enzyme-linked Immunosorbent Ássay (ELISA)– has been successfully applied to detect not only maize streak virus but also cowpea mottle, cowpea yellow mosaic, and rice mottle viruses. IITA scientists are in the process of producing antisera against several other viruses occurring in food crops in West Africa.

Progress made so far and the research underway are summarized in Table 10.

*A scientist uses an ultracentrifuge to concentrate virus particles, and then they are purified for electron microscope examination, characterization, and antiserum production.*

*TABLE 10.*

## *Progress made so far in the Virology Unit.*

| Disease | Virus isolated | Vector | Etiology | Antiserum produced | Indexing methods Serology | Indexing methods Test plants |
|---|---|---|---|---|---|---|
| Cassava mosaic | Doublet ? | Whitefly | ± | — | — | — |
| Sweet potato virus disease (a) Aphid-transmitted component | Filamentous | Aphid | + | + | + | + |
| (b) Whitefly-transmitted component | Unknown | Whitefly | ± | — | — | + |
| Yam mosaic | Filamentous | Aphid | + | — | — | + |
| Dasheen mosaic in cocoyam | Filamentous | Aphid | + | — | — | + |
| Maize streak | Doublet | Leafhopper | + | + | + | + |
| Maize dwarf mosaic | Filamentous | Aphid | + | + | + | + |
| Maize stripe/hoja blanca | Uknown | Planthopper | — | — | — | + |
| Maize mottle/chlorotic stunt | Unknow | Leafhopper | — | — | — | + |
| Rice yellow mottle | Spherical | Beetle | + | + | + | + |
| Cowpea yellow mosaic | Spherical | Beetle | + | + | + | + |
| Cowpea mottle | Spherical | Beetle | + | + | + | + |
| Cowpea aphid-borne mosaic | Filamentous | Aphid | + | — | — | + |
| Cowpea golden mosaic | Unknown | Whitefly | — | — | — | + |
| Cowpea cucumovirus | Spherical | Aphid | + | — | — | + |
| Cowpea mild mottle | Flexuons rod | Unknown | + | + | + | + |
| Lima bean golden mosaic | Unknown | Whitefly | — | — | — | + |
| Lima bean green mottle (Cowpea aphid-borne mosaic) | Filamentous | Aphid | + | — | — | + |
| Lima bean cucumovirus | Spherical | Aphid | + | — | — | + |
| Lima bean latent virus (Cowpea mild mottle virus) | Flexuous rod | Unknown | | | + | + |
| Soybean virus disease from Abuja area | Spherical | Unknown | + | + | + | + |
| Soybean Carlavirus (Cowpea mild mottle virus) | Flexuous rod | Unknown | + | + | + | + |
| Soybean mosaic | Filamentous | Aphid | + | | — | + |

***Plus sign completed; minus sign not completed.***


*The first of several steps in the production of virus-free plants involves disection of meristem tips (above). Virus-free clonal material in the culture room (above right).*

## Virus-Free Clonal Material in Tissue Culture

During 1980, the Tissue Culture Laboratory produced virus-free clonal material of improved cultivars of cassava and sweet potato and continued to work on the establishment and maintenance of a germplasm collection of sweet potato clones *in vitro*.

The production of virus-free clones has become essential for the international exchange of clonal material because it is the only way to safely exchange such material without introducing new disease into non-affected areas. Two major steps are involved in production: (1) the meristem tip culture and (2) indexing for virus.

Plantlets of 54 clones of sweet potato have been obtained from meristem tip culture. From these 54 clones, 20 are elite varieties developed at IITA, and they have been tested for virus freedom. In addition, plantlets of 10 clones of cassava have been produced by meristem tip culture and 8 of them are improved clones produced at IITA. They also have been tested for virus freedom.

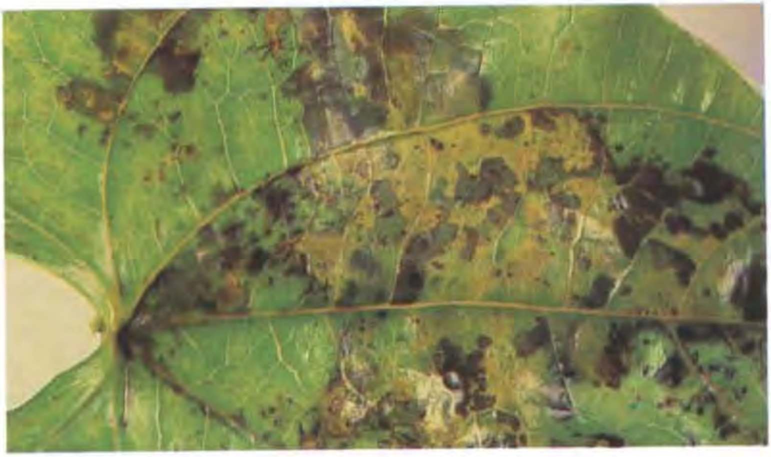
During the year, 17 countries in Africa and Asia requested clonal material of improved varieties of cassava and sweet potato. A system of international distribution was developed, and, because of the close and effective collaboration between the Quarantine Station of Moor Plantation at Ibadan and IITA, the material will be sent to these and other countries in 1981. Plants obtained through meristem tip culture are indexed for virus freedom at IITA. Those that appear to be virus-free are then inspected and tested by the Quarantine Officer. If the material is confirmed virus free, phytosanitary certificates are issued according to information on the import permit sent to IITA by the requesting country.

The virus-free material is then multiplied in tissue culture form and shipped to the requesting country together with the import permit, phytosanitary certificate, and a manual with recommendations for handling of the material upon receipt and its transfer from the culture tube to the soil. The tissue culture material is hand-carried whenever possible.

The *in vitro* germplasm collection of sweet potato now totals more than 300 clones and will be increased in 1981. It has been possible to keep some clones for up to 19 months without transfer to a fresh culture medium. Fourteen clones of water yam *(Dioscorea alata* L*)* are also maintained in tissue culture form.


*Virus-free material in tissue culture form being prepared for shipment to requesting countries.*

*Water soaking tests of water yam leaves showed these characteristic necrotic lesions and epidermal blackening to be similar or identical with D. alata anthracnose and "scorch."*



## Anthracnose and "Scorch" in Yam

Laboratory tests during 1980 indicate that fungi or bacteria may not play as significant a role as generally believed in causing a serious disease problem in water yam *(Dioscorea alata* L.*)* and that physiological stresses as yet unidentified may be much more important. *D.alata* anthracnose and "scorch" cause a generalized necrosis of leaves and vines which results in heavy yield losses.

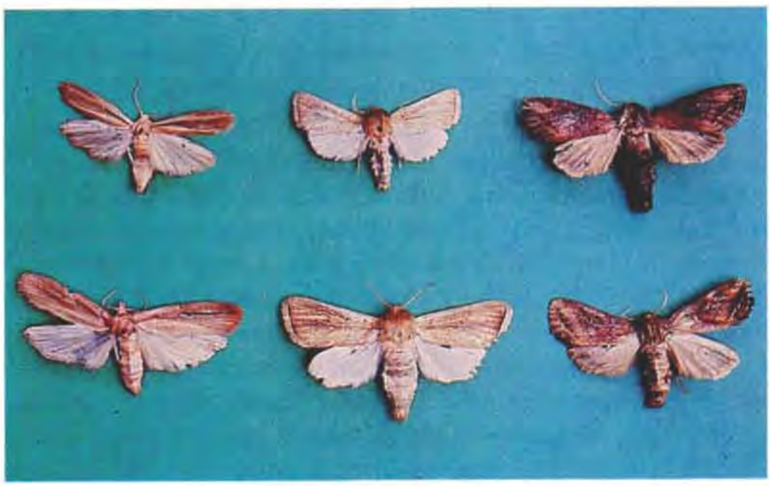
Scientists conducted soaking tests with water yam leaves from greenhouse and field plants at various stages of growth. Leaves from eight different clones were subjected to different soaking treatments. Characteristic necrotic lesions and epidermal blacking, which are similar to or identical with *D. alata* anthracnose and "scorch" in Nigeria, were consistently induced by soaking leaves in ordinary tap water. Benonyl and Streptomicyn sulphate added to tap water did not reduce the incidence of these symptoms.

Additional investigations are underway to clarify the role of physiological stresses in the etiology of this disease so screening methods for resistance may be more reliably developed.

# Distribution of Maize Stemborers in Nigeria

Results of a two-year IITA study (1979-80) in different regions of Nigeria have revealed a definite pattern in the distribution of the three major stemborers of maize. The country can be divided into three "stemborer ecological areas"—Southeastern area of *Sesamia calamistis*, Western area of *Eldana saccharina*, and Northern area of *Busseola fusca*. The study also reinforces existing evidence and validates the practiced IITA strategy that the testing, selection, and demonstration of breeding material should not take place at a single location but a number of sites representative of the major ecological zones in which the crop is grown.

*Sesamia calamistis* — a moist area oriented species — is abundant in the Southeast where it ranks as the most destructive pest of maize. Stemborer populations in the Umudike area (Southeast) consist almost exclusively (92%) of *Sesamia calamistis*. The humid environment of the region is best suited for the development of this species. The stemborer attack is most serious during the second season (July-November). Therefore, farmers do not grow maize in this season.



***Three species of male (top) and female maize stemborers found in different ecological areas of Nigeria. Left to right:*** *Eldana saccharina, Sesamia calamistis,* ***and*** *Busseola fusca.*

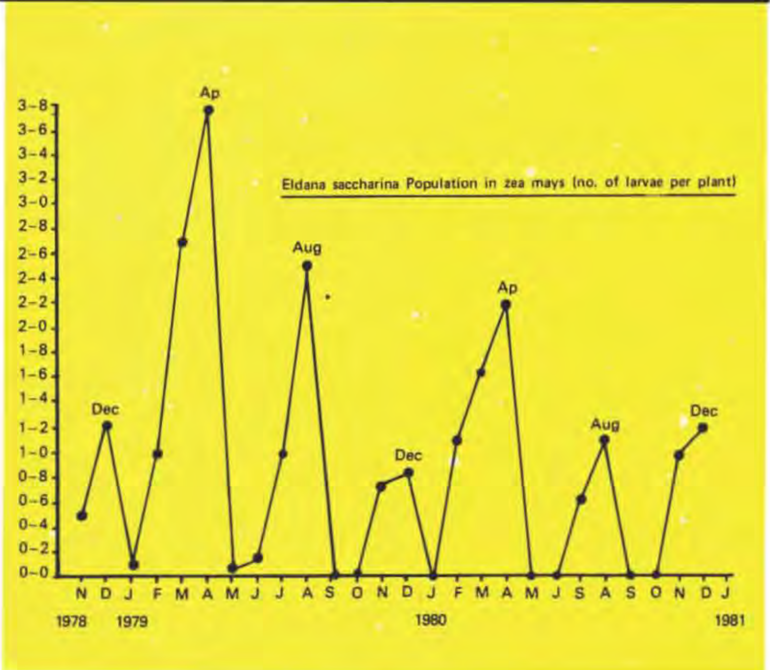



***FIGURE 8.***
***The population of the** Eldana saccharina **larvae coincides with the harvest-post harvest period of maize in Western Nigeria.***

*Eldana saccharina,* a dry area oriented species, has spread from the North to the West where it has become a major pest of maize. The species prefers maize to sorghum but can thrive almost equally well on both. Peaks of *Eldana* population coincide with the harvest-post-harvest period of maize in the West (Figure 8). Where the crop residues of the preceding crops are left, as in no-till farming, *Eldana* has been observed to build up a high pest load.

*Busseola fusca* is a major pest in sorghum in the North. It thrives on this crop and also feeds readily on maize. Therefore, with the intensification and spread of maize cultivation in the savanna, it may also become an important pest for maize in the savanna. In Western Nigeria, *Busseola* populations do not normally build up to high levels comparable to the northern savanna. When *Busseola* populations from the West were reared on maize and sorghum stems, they showed a distinct "preference" for maize. The Western population of *Busseola* which was forced-fed on sorghum throughout the larval period has clearly shown evidence of prolonged larval phase, mortality, uneven sex ratio, and sterility while that fed continuously on maize was normal (Table 11). Similarly, the northern *Busseola* fed on maize for more than one life cycle results in sterile offspring. But the reciprocal sex attraction between the western and northern *Busseola* populations is normal. Artificial matings between these two forms of *Busseola* result in hybrid sterility. The hybrids produce only a limited number of unfertilized eggs.

*TABLE 11.*
***Effects of sorghum and maize on the development of two populations of Busseola and their $F_1$ hybrids.***

| | Northern population fed on: | | | Western population fed on: | | $F_1$ hybrid fed on: |
|---|---|---|---|---|---|---|
| | Sorghum | Maize $F_1$ | Maize $F_2$ | Sorghum | Maize | Sorghum |
| Larval period (days) | 37 | 25 | 27 | 58 | 28 | 35 |
| Larval mortality % | 58 | 60 | 77 | 87 | 56 | 83 |
| Pupal period (days) | 14 | 14 | 15 | 12 | 14 | 15 |
| Pupal mortality % | 8 | 3 | 8 | 25 | 4 | 10 |
| Pupal weight (mg) | 126 | 195 | 199 | 128 | 200 | 149 |
| Sex (% females) | 52 | 17 | 17 | 33 | 53 | 40 |
| Fecundity (no. eggs/female) | 108 | 281 | 0 | 0 | 396 | 0 |
| Adult longevity (days) | 3.3 | 4.5 | 4.0 | 3.0 | 7.0 | 5.1 |

Although the northern and western forms of *Busseola* have been described under one species–*B. "fusca"*–the host preference and hybrid sterility strongly indicate that they are genetically isolated and should be further investigated to verify their taxonomic status.

It is interesting to speculate on the plant protection opportunity the above stated isolating mechanism can provide. Is it possible to reduce the population of northern *Busseola* by a massive release of males from the western *Busseola* in the savanna?

IITA research on resistance breeding has thus far been limited to *Sesamia* and utilizing the heavy natural infestation during the second season at Umudike. The selected families of the "borer resistant" population showed a damage score of 3.56 against the susceptible checks with 4.85 in the severity scale of 1 to 5 where the most susceptible is scored at 5. There is justifiable optimism for resistance breeding against *Sesamia,* but the genetic advance will be speeded up by artificial infestation. Artificial diets have been developed and a pilot rearing laboratory has been set up.

*In order of preference, the destructive cassava mealybug feeds on the stem near the growing point, on petioles, and on leaves.*

# Cassava Mealybug—Biological Control

Soon after it had first been discovered in Zaire in 1973, the cassava mealybug started developing and spreading out quickly into countries around the Gulf of Guinea and even farther west into Senegal. Now it is threatening cassava production in areas toward the east.

Cassava mealybug specimens collected in Africa were used for the description of the new species, *Phenacoccus manihoti* (MAT-FERR), in 1977. Morphological similarities with the North American *Phenacoccus* spp. lead to the designation of the Americas as its area of origin. At the time of the description of the new species, a mealybug collected on cassava in northern Brazil had also been identified as being *P. manihoti.*

As a result of IITA's investigation into the origin of *P. Manihoti,* it has been possible to clear the taxonomic status of the mealybug occuring on cassava in the northern part of South America. This mealybug, first identified as *P. manihoti,* has been described by Drs. Williams and Cox (1981), CIE, London, as *Phenacoccus herreni.* This clarification is significant since efficient parasitoids are usually very

*FIGURE 9.*
*Since 1973, the cassava mealybug has spread quickly from Zaire to other African countries.*

specific and therefore have to be collected from *P. manihoti* in the area of origin of this species. (Somewhere in the Americas between 30° latitude South).

This insect pest has caused large economic losses and food shortages and is now a recurrent problem in several Central and West African countries. Yield losses may be as high as 60% of the roots and 100% of the leaves. These high losses are due mainly to the adverse effect of saliva toxin injected into the plant during the feeding process which depresses the plant's growth.

*P. manihoti* has a life cycle from egg to reproductive adult of 24 days at 26°C and is strictly parthenogetic. The average fertility in the laboratory is 440 eggs per female, with a maximum of 750. The life span of an adult is about 26 days. The mealybug feeds generally (in order of preference) on the stem near the growing point, on petioles, and on leaves. The dispersal of the crawlers and the egg masses occurs passively with the wind. Man also helps to spread mealybugs by moving infested planting material.

The population dynamics of the cassava mealybug follows a seasonal pattern. During the dry season the population builds up very rapidly to reach a self-destructing level. At this point, which generally occurs before the onset of the rainy season, the population will break down because of lack of food, overcrowding, and entomopathogens. The survivors will eventually resettle on the newly produced shoots at the beginning of the rainy season and maintain themselves in small colonies throughout the cassava fields until the next dry season.

The biological control approach to solve the cassava mealybug problem has been advocated by IITA for several reasons. Cassava is grown by small landholders in Africa in widely dispersed plots, and access to many of these plots is difficult. Also the crop is in continuous cultivation throughout the year. Therefore, it acts as an excellent host for insects since the plant, in several stages of growth, may be present in any one area. Furthermore, most growers cannot obtain the required chemicals and equipment or do not have the money to buy them. Also, mealybug resistance to chemicals is known to build up rapidly, and secondary pest outbreaks may be induced. Another reason it is difficult to take a chemical control approach: cassava leaves are used as a leafy vegetable in many African countries.

IITA's research team is currently working on the bionomics of the cassava mealybug and of the presently available natural enemies. Adequate knowledge of the ecology, biology, and behavior of the insect pest, as well as its interaction with the host plant, are a "must" if a biological control program is to be carried out successfully. Efficient methods for mass-culturing of mealybugs and natural enemies and for releasing of the latter are being developed. Studies of the cassava agro-ecosystem are underway, as well as investigations of the arthopod fauna of areas surrounding cassava fields. Emphasis is given to the live table studies of the cassava mealybug since it is very important to know exactly the population dynamics and the factors regulating it to assess the impact of the released natural enemies.

Scientists at IITA are collaborating closely with the Commonwealth Institute of Biological Control (CIBC) whose entomologists have already found a predator, *P. Herreni.* The predator, a coccinellid of the genus *Hyperaspis,* is being cultured successfully, and the first experimental releases have already been made in Nigeria by IITA. The development of the released predator population and its impact on the pest population are now carefully followed with the life table method.

*A cassava crop in Senegal wiped out by the mealybug.*

*A close-up of mealybugs feeding on a cassava leaf and an adult predator (spotted insect) feeding on the mealybugs.*

*The first experimental releases of a mealybug predator have been made by IITA in cassava fields in Nigeria.*

*Breeding for resistance is the most promising method of control of cassava green spider mite. The diseased plant (left) is non-resistant to this insect pest, the one next to it resistant.*

## Role of Trichome in Resistance to Cassava Green Spider Mite

Resistance against the destructive cassava green spider mite, *(Mononychellus tanajoa),* has been discovered in IITA germplasm and seedling material. Both the germplasm and the 1980 cassava seedling nursery were evaluated for resistance. Researchers screened 149 previously selected cassava seedlings based on a scoring system ranging from 1 to 5 (1 = resistant, 5 = susceptible) and selected a total of 18 seedlings which showed high to moderate levels of resistance.

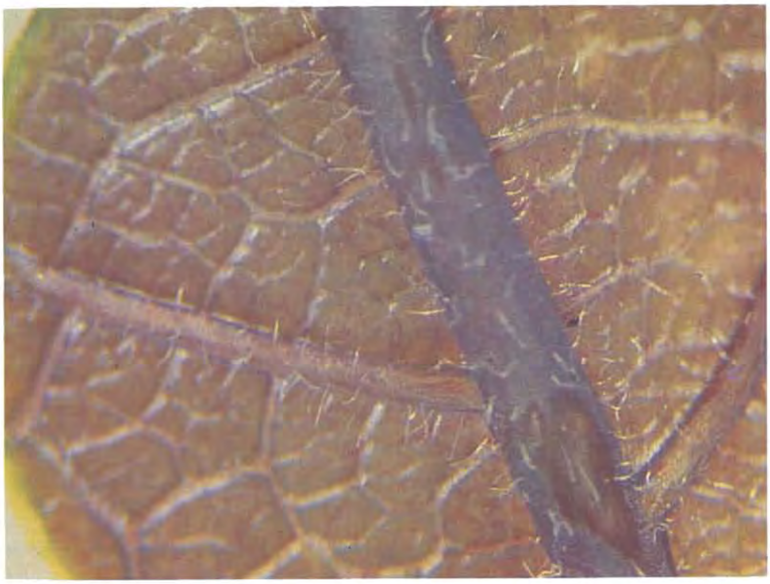
All cassava material selected as resistant showed varying degrees of pubescence on the young leaves while highly susceptible plants had fewer or no hairs. Subsequent hair counts per $mm^2$ gave evidence that hair density may be a factor for resistance. Table 12 shows the results on susceptible, intermediate, and resistant clones.

The cassava green spider mite (CGM), introduced to the African continent about 10 years ago, can reduce yields up to 40%, especially on late-planted cassava. The mite attacks the shoot area of the plant and causes severe chlorosis and reduction of leaf area during the dry season. For African farming conditions, breeding for resistance is the most promising control method because no additional inputs are necessary.

*TABLE 12.*
***Pubescence density (no. of hairs/mm$^2$) on the first 15 cassava leaves of susceptible, intermediate, and resistant clones in relation to green spider mite resistance.***

| Leaf position* | Suscept-ible | Inter-mediate | Resistant |
|---|---|---|---|
| 1 | 6.95 | 10.45 | 15.00 |
| 2 | 1.95 | 7.40 | 7.90 |
| 3 | 1.80 | 4.90 | 4.85 |
| 4 | 1.05 | 5.55 | 5.00 |
| 5 | 0.30 | 4.60 | 6.75 |
| 7 | 0.15 | 5.60 | 4.60 |
| 9 | 0.85 | 4.55 | 2.50 |
| 11 | 0.10 | 4.15 | 2.45 |
| 13 | 0.10 | 3.70 | 1.70 |
| 15 | 0.04 | 3.05 | 3.15 |

* *From top to lower leaves.*



***The density of pubescence shown here on the mid-rib of a cassava leaf may be a factor for resistance to the green spider mite.***

# Cowpea Podborer—Population Dynamics and Mating Behavior

Major emphasis has been put on the identification of insect resistant cowpea cultivars as a means of reducing the risks of growing the crop in the tropics. One of the most important pests is the legume podborer, *Maruca testulalis,* which can wipe out the crop if not controlled, and field damage ranging from 20% to 70% is not unusual.

Previous research identified TVu 946 as resistant to *Maruca,* and work in 1980 confirmed this. The cultivar showed the lowest larval populations in the terminal buds, stems, flower buds, and flowers. In addition, since fewer pods were infested, there was less damage to seed (Table 13), and the build up in population was slower than on a typically susceptible cultivar such as VITA 3 (Figure 10).

The seeds of TVu 946, however, are very small, dark pigmented, and speckled – a type generally unacceptable to consumers. (They prefer a large white or tan cowpea with a wrinkled seed coat.) The objective is to combine the *Maruca* resistance of TVu 946 with superior consumer-preferred seed and plant characteristics which permit higher yields.

In 1980, all breeding material in which TVu 946 had been used as a parent were tested for resistance to *Maruca.* One such cross–TVx 3890-010F – has been identified and appears to possess high yield potential combined with moderate podborer resistance (Table 13).

*TABLE 13.*
***Indeces of resistance of cowpeas to** M. Testulalis.*

| Cultivar | Plant resist. index (PRI) | | |
|---|---|---|---|
| | I | II | III |
| Resistant parent TVu 946 | 1.4 | 1.7 | 1.5 |
| Resistant progeny TVx 3890 - 01F | 9.4 | 11.2 | 8.1 |
| Suscept. check TVu 1190 (VITA 3) | 45.7 | 36.2 | 30.1 |

*PRI: I Based on stem, flower, and pod measurement.*
*II Based on flower and pod measurements only.*
*III Based on flower, pod, and seed damage measurements.*

***Cowpea pods touching leaves and showing* Maruca *damage. The circled flower (right above) shows the insect's entry/exit point. When larvae feed on the ovary of the flower, there is no pod production.***

Studies of the variation in a field population of *Maruca*, which attacks both the vegetative and reproductive parts of the cowpea crop, show that the attack starts around 21 days after planting (DAP). Terminal shoots and other parts of the stem are the main focus of damage at this early stage.

Eggs are laid on the terminal shoots and young, partially-opened leaves. When the larvae hatch, they feed on the terminal shoots and later bore into the young succulent stems. This constitutes the early generation of the borer population. From the terminal shoots, larvae migrate to flower buds and flowers, and the peak infestation is usually seen around 42-49 DAP. Counts indicate that there are more eggs on the flower

*TABLE 14. Distribution of eggs on different parts of the cowpea plant.*

| Repli-cations | Flower buds | Flowers | Abscission scars | Peduncle | Terminal shoots | Pod | Total No. |
|---|---|---|---|---|---|---|---|
| I | 18.4 | 28.9 | 21.6 | 42.2 | 5.8 | 1.1 | 190 |
| II | 24.8 | 38.8 | 30.9 | 3.6 | 1.9 | 0.0 | 165 |
| III | 13.6 | 25.4 | 32.2 | 28.8 | 0.0 | 0.0 | 59 |
| Mean | 18.9 | 31.0 | 28.2 | 18.9 | 2.6 | 0.4 | 138 |
| ± SE | 3.3 | 4.05 | 3.4 | 7.8 | 1.72 | 0.4 | 40.4 |

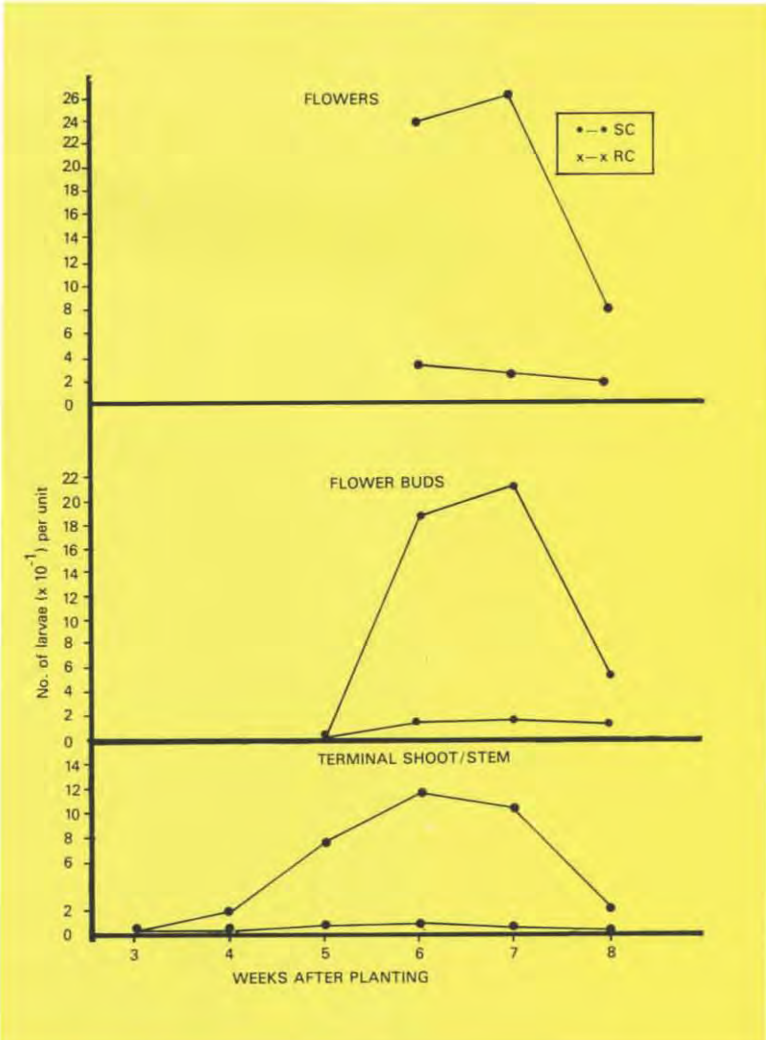
buds and flowers than on other plant parts (Table 14), a fact that may be related to proximity of larval food sources.

There are usually fewer larvae on pods than on floral parts. Damage to pods is normally a result of migration of larvae from the floral parts. It appears that larvae do not generally migrate during the first two instars–the stage at which they are most vulnerable. A generation cycle takes between 22 and 25 days. It is therefore theoretically possible to have up to four generations of the insect during one crop season. However, as generations overlap, scientists can only estimate the number of generations in the course of a crop season.

The population of adults in the field during the day seems to be affected by the type of plant canopy. Cowpea cultivars with dense canopies (VITA 3, for example) usually harbor a large adult population. This cultivar often shows high larval infestation (Figure 10), perhaps because of the high "resident" adult population. On cultivars with a thin, open canopy (TVu 946, for example), few adults, if any, are seen during the day. Research is underway to determine the influence of natural enemies on the population of the podborer.

Part of the research effort is devoted to development of methods to artificially infest the breeding material and so make selection more reliable. Work is in progress to develop techniques for mass rearing on the synthetic diet. A suitable diet has already been developed which is comparable to the natural diet, but moths did not mate in the confines of insect-rearing facilities at IITA. Several factors may be responsible

*FIGURE 10.*
*Differences in M. Testulalis larval population build up/reduction between a susceptible cultivar SC (= VITA 3) and a resistant one RC (= TVu 946). Second season 1979.*



for this, and some of the probable ones have been identified. Noise and other forms of disturbance, food, and cage size and form may be important.

In actively flying insects, flight patterns and mating are often intimately associated with each other. Normal mating does not happen if such flight patterns are denied. When *Maruca* is released, it tends to fly vertically rather than horizontally. The on-going studies show that female longevity ranges from 9 to13 days (average 12) in tall, round cages (30 x 90 cm), whereas longevity was only 5-8 days (average 7) in small, square, wire-mesh cages (30 x 30 x 30 cm). Increased longevity will ensure better oviposition. In the tall cage, 82% of the females mated, and 86% of these had empty ovaries when they died. In comparison, in the small cage 76% mated of which 46% were after oviposition. Therefore, the tall cage proved to be twice as effective as the short one. These studies on mating were carried out at IITA during the dry season months and should be considered preliminary.

*Cage size and form, food, and other factors affect the mating habits of* Maruca *in captivity. Vertical flight patterns, possible in a cage such as this, proved to be important.*

*Aphids on a cowpea seedling in Upper Volta.*

# Resistance to Cowpea Aphid

The aphid, *Aphis craccivora,* is a pest of significant importance on cowpeas, and it has been observed to cause serious damage in fields in West Africa. Research was initiated at IITA in1979 to identify cowpea cultivars resistant to this pest, and several lines were identified in 1980 as resistant. When aphid populations were compared from the different regions in Nigeria, presence of an additional biotype was observed. Based on the host reaction, they were identified as biotype A and B.

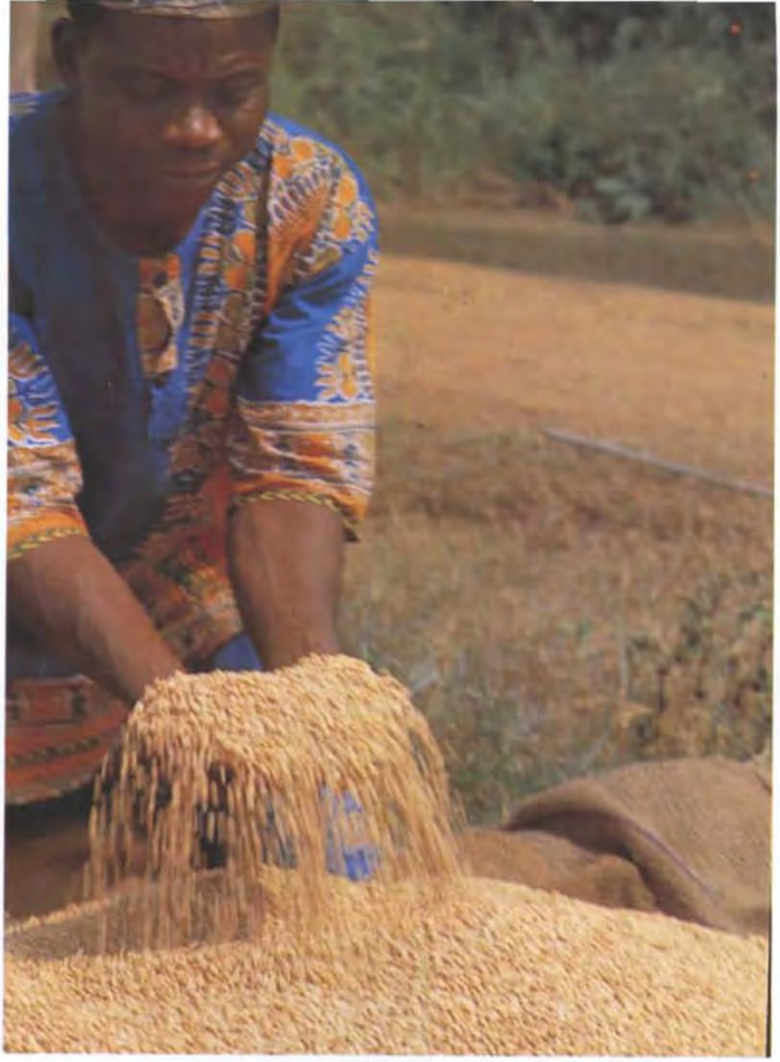
*Aphid damage in a cowpea field.*

When these lines were tested in Upper Volta (Kamboinse) under the Semi-Arid Food Grain Research and Development Project (SAFGRAD), the differential reaction of the lines shown in Table 15 indicated the presence of a third biotype designated as biotype K. During 1980, cowpea cultivars resistant to all three biotypes were identified — TVu 36, TVu 2896, and TVu 3000 (Table 15). The resistance is now being incorporated in the breeding lines. The high level of resistance is associated with antibiosis as no aphid colonies could survive on the resistant lines either in Nigeria or in Upper Volta.

***TABLE 15.***
***Reaction of cowpea cultivars to the different cowpea aphid biotypes. The three cultivars in the color band are resistant to all three biotypes.***

| Cultivars | Biotype | | |
|---|---|---|---|
| | A | B | K |
| VITA-7 (KN-1) | S | S | S |
| TVu 76 | S | S | S |
| TVu 36 | R | R | R |
| TVu 2896 | R | R | R |
| TVu 3000 | R | R | R |
| TVu 310 | R | R | MR |
| TVu 1037 | R | S | R |
| VITA-4 | R | S | MR |
| TVu 410 | R | S | MR |
| TVu 119 | R | R | S |
| TVu 2962 | R | R | S |
| TVu 107 | R | S | S |
| TVu 207 | R | S | S |
| TVu 109 | S | MR | MR |
| TVu 1889 | S | R | S |
| TVu 1893 | S | R | S |

*A & B = Biotypes from Nigeria. K = Biotype from Upper Volta.*
*S = Susceptible, MR = Moderately resistant, R = Resistant.*



*High-yielding, thrips-resistant TVx 3236 seed is being distributed for multiplication in West African countries.*

# TVx 3236—A Thrips Resistant Cowpea

Flower thrips, *Megalurothrips sjostedti,* may cause severe losses ranging from 30 to 100% of a cowpea crop in Africa. Research was initiated at IITA with the principal objective to develop cowpea cultivars resistant to flower thrips and with acceptable seed quality and superior yield.

Resistance to flower thrips from TVu 1509, a cultivar identified as moderately resistant to thrips, has been successfully incorporated in Ife Brown — a locally improved variety developed at the University of Ife. Ife Brown, widely

TABLE 16.
*Effect of thrips on yield of cowpea.*

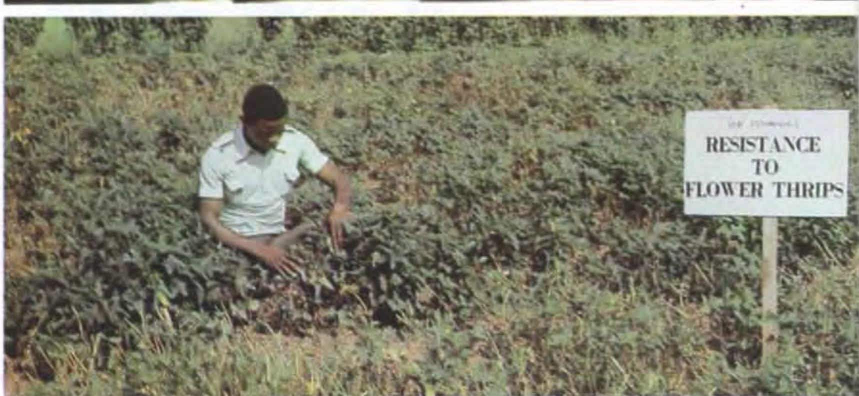
| | Thrips/flower | | Yield kg/ha | |
|---|---|---|---|---|
| | No insecticide | Insecticide | No Insecticide | Insecticide |
| TVx 3236 | 5.7 | 0.3 | 1000 | 1120 |
| TVu 1509 | 7.3 | 0.2 | 790 | 850 |
| Ife Brown | 8.4 | 0.5 | 150 | 930 |

adapted with good seed quality, is susceptible to flower thrips. TVu 1509 was crossed with Ife Brown and a single selection identified as TVx 3236 combines resistance to flower thrips with good yield potential and seed quality.

The resistance in TVu 1509 and TVx 3236 may be due to antibiosis which reduces the thrips population compared with Ife Brown (Figure 11).

The grain yield of TVx 3236 was compared with its parent lines, with and without insecticide. Thrips in the unsprayed plots caused a large reduction in the yield of Ife Brown. The loss of yield from TVx 3236 and TVu 1509 was much smaller (Figure 12 and Table 16). Furthermore, TVx 3236 had superior yields at test locations in Nigeria, Upper Volta, Senegal, Tanzania, and Togo.

*Adult thrips on cowpea flower.*




*TVu 1509 in the field—thrips resistant parent of TVx 3236.*

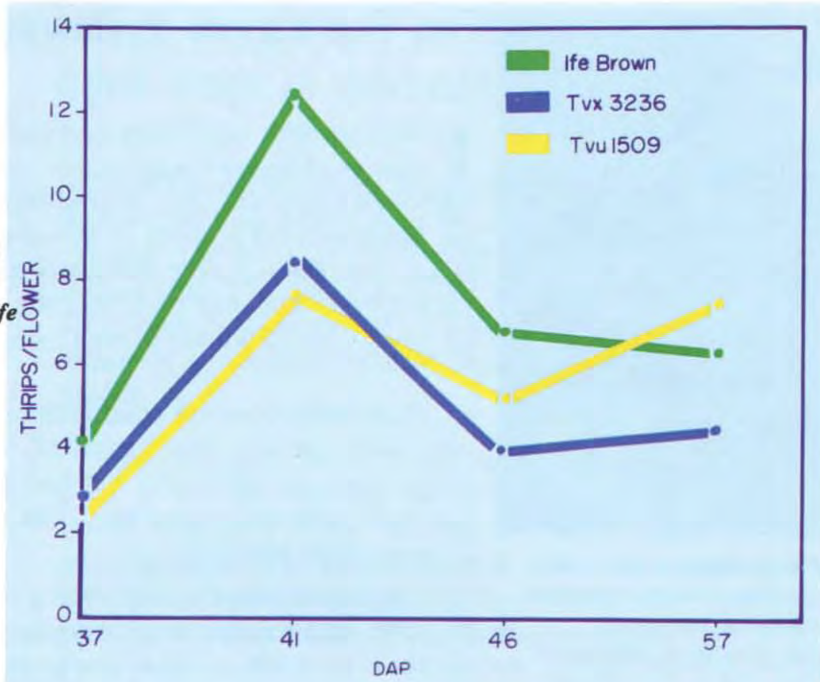



*FIGURE . Comparative thrips population during plant growth stage on TVu 1509, TVx 3236, and Ife Brown cowpeas.*

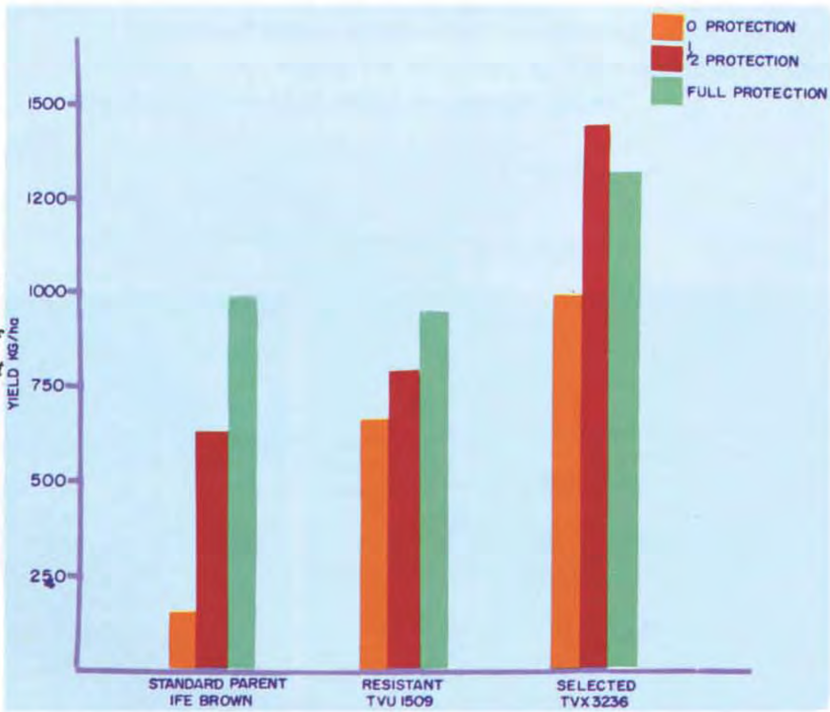



*FIGURE 12. Comparative yields of TVu 1509, TVx 3236, and Ife Brown cowpeas under levels of insecticide protection against thrips.*

*Pod-resistant cowpea lines are being crossed with those known to have seed resistance to cowpea weevil.*

# Pod Resistance to Cowpea Weevil

Five lines with significant pod resistance to cowpea weevil *(Callosobruchus maculatus)* have been identified. Although there was very little difference in the oviposition egg hatch and the number of larvae penetrating the pods between these lines and the Ife Brown and Vita 5 standards, larval survival, damaged seed, and the number of exit holes in the pods were strikingly lower (Table 17).

These reductions are attributed to pod wall characteristics that have not yet been identified, but a chemical may be responsible. As the newly hatched larvae bore through the pod wall, they may ingest sufficient amounts of the chemical to cause high mortality.

The pod-resistant lines are being crossed with those known to have seed resistance to cowpea weevil. Research efforts continue to combine these characteristics with shatter-proof pods so that massive seed storage losses can be substantially reduced or even eliminated.

***Table 17.*** ***Oviposition, development, and survival of cowpea storage weevil on lines that possess pod resistance compared with susceptible lines.***

| | Eggs | | Larvae | | Seed | |
|---|---|---|---|---|---|---|
| | Av. No. per pod | % hatch | No. penetrating pod wall | % survival | % damage | Exit holes per pod |
| Ife Brown (Standard) | 26.1 | 93.91 | 24.4 | 55.73 | 65.92 | 10.4 |
| Vita 5 (Standard) | 35.0 | 91.96 | 31.8 | 28.67 | 55.85 | 3.8 |
| TVx 3356-04F | 17.6 | 93.71 | 15.0 | 3.51 | 4.97 | .4 |
| TVx 3336-04E | 35.9 | 86.99 | 24.7 | 2.34 | 4.56 | .1 |
| 7R-0189-D | 23.9 | 86.69 | 18.9 | 4.76 | 6.58 | .7 |
| TVx 3385-027D | 27.5 | 89.28 | 21.3 | 4.67 | 5.90 | .2 |
| Vita 4 | 33.5 | 90.48 | 24.7 | 1.62 | 2.54 | .4 |
| F. Value | NS | NS | NS | 21** | 30** | 21** |
| LSD | — | — | — | 16 | 19 | 3 |

# "Trap Cropping" for Control of Stink Bugs in Soybeans

Even though soybeans are a relatively new crop to Africa, pod sucking insects have became a serious pest in some regions. The most common ones are stink bugs, including *Nezara* spp., *Piezodous guildinii,* and *Aspavia armigera.* All are known to cause serious yield losses, and the only available means of controlling them at the present time is with insecticides.

The biology of stink bugs, especially *Nezara* spp., has been extensively studied because of their importance in Brazil, southern United States, and other major soybean growing areas. The insects have a wide host range, and a reservoir population is maintained on many wild leguminous plants and other weeds. They normally migrate into a soybean field in relatively small numbers, but the population rapidly increases as eggs are deposited on the crop. If the initial migratory population can be controlled, multiplication within the crop would be minimal, and the population may not reach levels that cause economic losses.

*Under "trap cropping," stink bugs (below) are attracted to the cowpeas for food as the main soybean crop does not have pods. Only the cowpeas are sprayed to kill the "trapped" insects. Right below, early-maturing soybeans planted on the edges of the main crop effectively "trapped" stink bugs.*

In 1980, IITA scientists studied a technique called "trap cropping." It is based upon directing the initial invasion of adult stink bugs to a preferred food source. Since the insects are concentrated on the food source, they are effectively "trapped," and the population can be controlled by applying insecticides *only* on the "trap crops."

Research conducted on a large government farm in Nigeria clearly illustrated the effectiveness of "trap cropping." Early-maturing soybeans or cowpeas planted on the edges of the soybean field attracted the stink bugs as the main soybean crop did not have pods. The "traps" were sprayed to control the invading population before it was allowed to multiply. The insect population in the main soybean crop was reduced by 50-80% due to "trap cropping" (Table 18).

The stink bug population never exceeded the economic threshold level in the soybean and cowpea "trap" treatments. Damage to pods was significantly reduced through the use of "traps" and this was reflected in the yield (Table 19). In the unsprayed plot, stink bugs reduced yields by 85%. In contrast, equal yields of soybean were obtained in the continuously sprayed plot and the treatment where "traps" were used.

The principal advantage of "trap cropping" is more effective and economical use of insecticides. Since the "trap" occupies only 10-20% of the total crop, the area requiring insecticide application is reduced by 80-90%. For example, a

***TABLE 18.***
***Adult stink bug populations on soybeans grown under various methods of insect management.***

| Management method | Insecticide applied | No.of adult stink bugs/2m row Days after planting 77 | 91 |
|---|---|---|---|
| Soybean monocrop | None | 4.1 (0.3) | 7.4 (0.9) |
| Soybean monocrop | Sprayed throughout pod development | 0 (0) | 0 (0) |
| Soybean "trap" | Only "trap" sprayed | 1.8 (0.3) | 3.8 (0.6) |
| Cowpea "'trap" | Only cowpea sprayed | 0.8 (0.2) | 0.8 (0.2) |

*Values are means followed by standard error of mean in parenthesis.*

***TABLE 19.***
***Pod damage at physiological maturity and yield of soybeans grown under various methods of insect management.***

| Management method | Insecticide applied | % of pods without seeds | Yield kg/ha | % yield loss due to insects |
|---|---|---|---|---|
| Soybean monocrop | None | 75.0 (6.0) | 255 (45) | 85 |
| Soybean monocrop | Sprayed throughout pod development | 4.6 (1.0) | 1688 (97) | 0 |
| Soybean "trap" | Only "trap" sprayed | 3.7 (0.5) | 1545 (55) | 8.5 |
| Cowpea "trap" | Only "trap" sprayed | 6.0 (1.0) | 1679 (53) | 0.5 |

*Values are means followed by standard error of mean in parenthesis.*

minimum of two to three applications of an insecticide is normally required to maintain the population below the economic threshold level of 4 insects/2 m row. This amounts to 4-6 liters of chemical per hectare per growing season (assuming 2.0 lts/ha is the recommended rate).

If "trap cropping" is practiced, only 10-20% of the field is sprayed. Assuming three applications, this amounts to only 0.6-1.2 lts of chemical. Furthermore, the cost of applying the chemical is reduced by 80-90% because less area is treated. Since the insects are concentrated on the "trap," insecticidal control is more effective (less insects escape) and environmentally acceptable. By concentrating the target insects on the "trap," the beneficial insects such as predators are not killed on the main crop of soybean.

By growing cowpeas on the edges of the soybean field, a farmer could essentially control the insects in the soybeans free of charge. This system produced yields of 1,564 kg/ha of cowpeas and 1,679 kg/ha of soybean—and only the cowpeas were sprayed. The main snag in the application of this technique may be the need to protect cowpeas not only against pod bugs but also against earlier flower pests, thus extending the number of sprays needed.

# Inoculants for Soybeans in Tropical Soils

One approach to develop soybean varieties for tropical environments is to combine the ability of soybean varieties from southeast Asia that nodulate freely with the improved, high-yielding soybeans from the United States or elsewhere that do not nodulate readily with rhizobia in African soils (IITA Research Highlights 1979). An alternative is to provide an inoculum of the rhizobia strains that the high-yielding, introduced soybeans will use. The effect of doing so is shown in Table 20. The yields of soybeans at widely different locations were substantially increased by the introduction of inoculant of suitable strain of rhizobia. They were comparable to or larger than those obtained with the addition of 90 kg/ha of nitrogen as fertilizer.

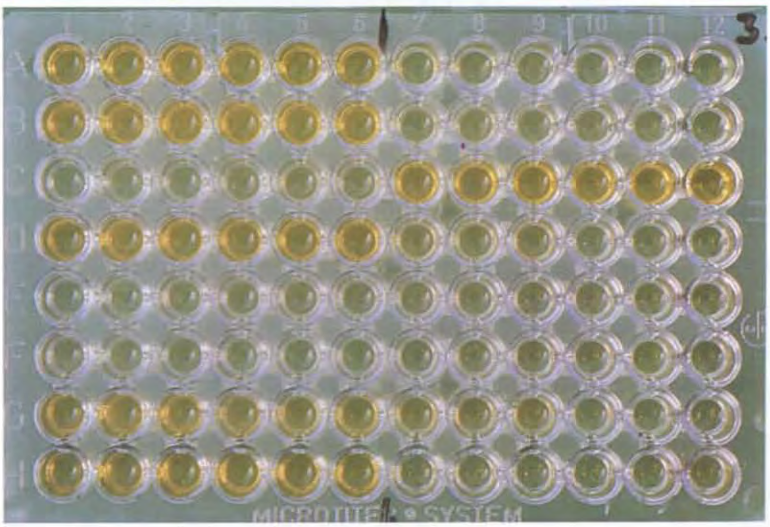
For small African farms, the use of an inoculant would be difficult and expensive. Also, it is important to know how long the introduced inoculum will survive and remain effective. To provide an answer, uninoculated soybean seed was sown in 1980 at IITA in plots that had been inoculated and had grown soybeans two years earlier. Without inoculant or fertilizer, the yields of two American varieties—Bossier and TGm 294—were similar in the two years (Table 21). Addition of nitrogen fertilizer or inoculum substantially increased their yield. The inoculant that had been introduced two years earlier was almost, but not quite, as effective as freshly

***TABLE 20.***
***Effect of inoculant and fertilizer nitrogen on the yield of soybean variety Bossier at seven locations in Africa.***

| Country | No. of locations | Seed yield t/ha: Control uninoculated | Inoculated* (strain IRJ 2111) | Nitrogen fertilizer (90kg/ha) |
|---|---|---|---|---|
| Nigeria | 2 | 1.51 | 2.22 | 1.99 |
| Ivory Coast | 1 | 2.69 | 2.62 | 3.44 |
| Kenya | 3 | 1.74 | 2.34 | 1.94 |
| Senegal | 1 | 0.71 | 1.14 | 2.22 |
| Mean | | 1.66 | 2.17 | 2.40 |

* *Mean of four different inoculants.*

*Scientists freeze dry and seal Rhizobium cultures under vacuum in this machine. The product is a raw material for the nitrogen fixation program.*



*An innovative serological technique for identification of rhizobia in the nodules of soybeans and cowpeas. The yellow color shows a positive reaction.*

*TABLE 21.*
***Effect of inoculant in year of application and two years later on yield of two varieties of soybean.***

| Treatment | Seed yield t/ha | | | |
|---|---|---|---|---|
| | Bossier | | TGm 294 | |
| | Year 1 | Year 3 | Year 1 | Year 3 |
| Uninoculated | 1.6 | 1.5 | 1.1 | 1.7 |
| N fertilizer 150 kg/ha | 2.7 | 2.3 | 2.7 | 2.2 |
| Inoculation: year 1 | 3.0 | 2.5 | 2.8 | 2.3 |
| Inoculation: year 3 | — | 3.0 | — | 2.9 |

introduced inoculum. The ELISA test (a sensitive serological technique used to identify strains of rhizobia) showed that more than 90% of the nodules on these two varieties were formed by the inoculant introduced in 1978. Scientists concluded that the introduced strain survived and was competitive with indigenous rhizobia.

On an acid soil (pH 4.4) the initial response of Bossier to the addition of inoculum was large and all the nodules were formed by the introduced strain. A year later, however, there was no difference between the yield on these plots and uninoculated plots, although about 65% of the nodules were formed by the strain of rhizobia introduced a year before. It seems, therefore, that some introduced strains do not survive well in acid soils.

To select strains that may do well in acid soils, large numbers have been grown on artificial, acid media in the laboratory. Of 84 strains tested in this manner, 21 strains, including most of those isolated from tropical soils, were found to be tolerant to acid conditions. There seemed to be no relation between tolerance on the media and the pH of the soil from which the strain had been collected. It remains to be seen whether strains tolerant to acidity in an artificial medium are tolerant and can survive in acid soils.

To strengthen research efforts to find ways of maximizing nitrogen fixation in crops, the United Nations Development Program (UNDP) has provided financial support to IITA, and the Institute has subcontracted several areas of investigation to Boyce Thompson Institute for Plant Research, Cornell University, and the University of Western Australia.

# List of Personnel

## ADMINISTRATION

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O.O.Ogundipe, M.D., medical officer.
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F.O. Ogunyemi, A.C.A., accountant.
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M. Price, Ph.D., agronomist, Tanzania.
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A.S.R. Juo, Ph.D., soil chemist.
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T. Kaufman, Ph.D., entomologist.
H.C. Knipscheer, Ph.D., agricultural economist.
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* *Left during the year.*

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