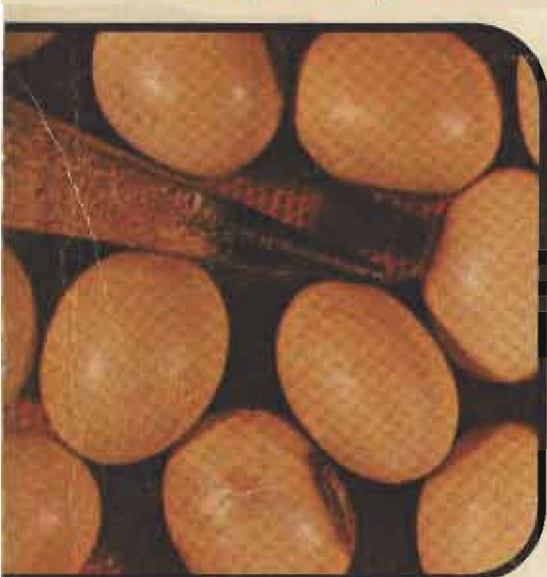
international institute of tropical agriculture



1979 annual report

COVER PHOTOS *(clockwise)*

1. *Cassava clone TMS 30572 produced an average yield at IITA of 37.2 t/ha.*
2. *TOX 718, an improved upland rice variety, was bred from OS6 x variety 6383.*
3. *The mandate region of IITA includes the lowland humid tropics, an area of the tropics below 1,000 m where precipitation exceeds evaporation for five months or more each year (roughly areas with more than 1,200 mm of rain per annum).*
4. *Elite lines of soybean are developed to combine seed viability in storage, promiscuity and good agronomic characters.*

1979 ANNUAL REPORT of the INTERNATIONAL INSTITUTE OF TROPICAL AGRICULTURE

ABOUT IITA

The International Institute of Tropical Agriculture (IITA) was established on July 27, 1967, as an autonomous, non-profit corporation by a decree of the Federal Military Goverment of Nigeria. It formally organized at the first meeting of the Board of Trustees in Ibadan during July 1968.

Federal Republic of Nigeria provided 1,000 hectares of land for the IITA site and the Ford Foundation the initial capital for buildings and development. Support for research and day-to-day operations in 1979 came from the Ford Foundation, the Canadian International Development Agency (CIDA), the Overseas Development Ministry of the United Kingdom (ODM), the U.S. Agency for International Development (USAID), the World Bank, the International Fund for Agricultural Development (IFAD), and the Governments of Australia, Belgium, Japan, The Netherlands, Nigeria, Norway, and the Federal Republic of Germany.

The Institute is governed by an international Board of Trustees.

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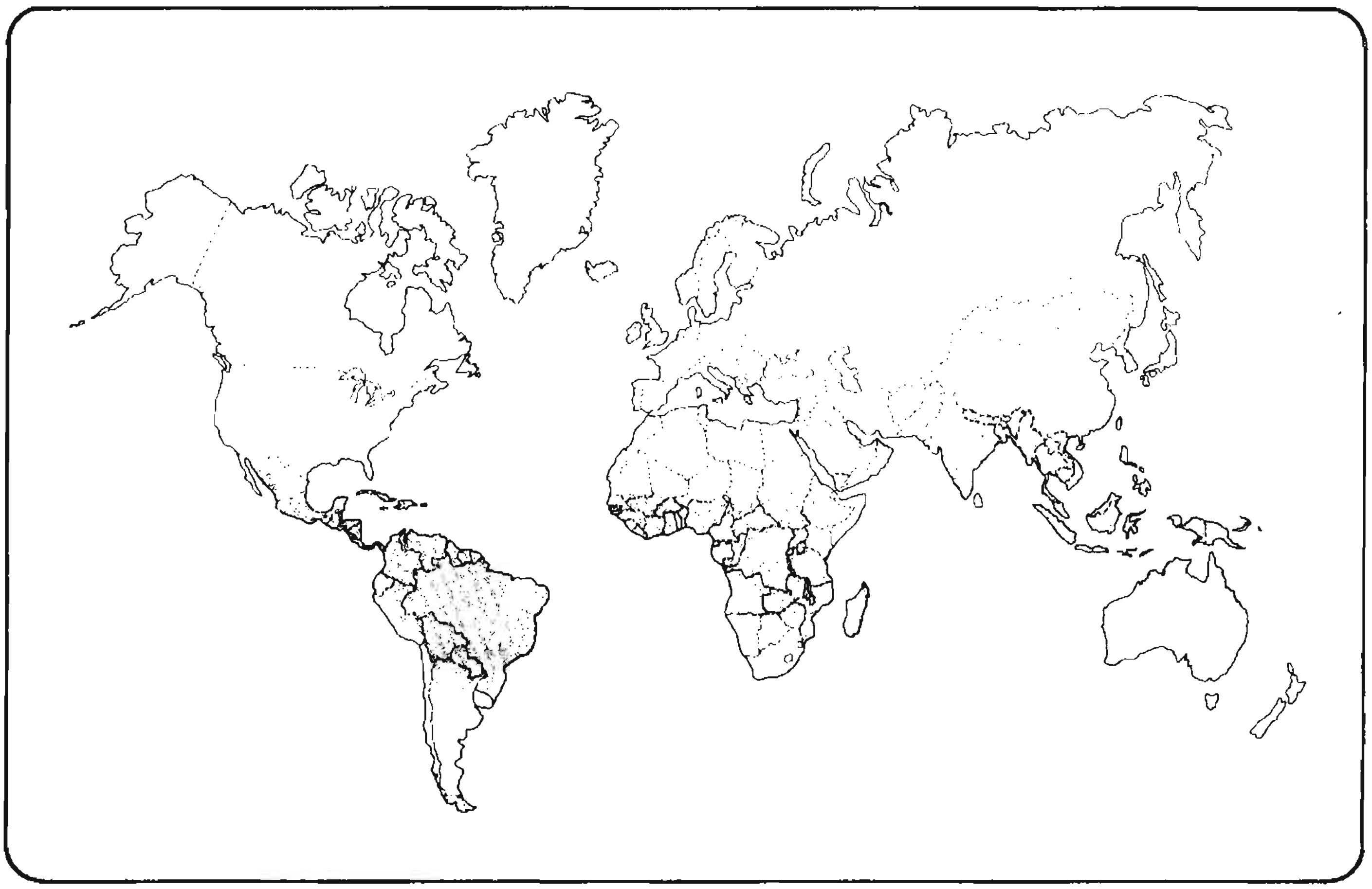


Although the major focus of IITA's work is in Africa, its problem-oriented research activities are directed at the solution of biological and management problems which constrain production at the farm level in the humid and subhumid tropics of the world.

FOREWORD

While the central location for the research of the International Institute of Tropical Agriculture is at its headquarters site at Ibadan, Nigeria, it extends its research to many different countries through formal cooperative programs, scientist-to-scientist contacts, and its international testing program. The major focus of IITA's work is in Africa, but its concern is not limited to that continent alone. The problem-oriented research activities are directed at the resolution of biological and management problems which constrain production at the farm level in the humid and subhumid tropics.

This Annual Report is a compendium of the research results for the year and is structured on the basis of the program organization of the Institute. It is limited to reporting the most important findings and eliminates some details which active researchers in related work may wish to have. Additional information can be obtained by addressing a request to the appropriate program leader or scientist listed in the back of this publication.

The key issue in the Farming Systems Program continues to be the replacement of shifting cultivation and related bush fallow by a permanent, stable, and profitable agriculture while not impairing the long-term productivity of the fragile and often infertile soils of the tropics. Within the same program, research and development on farm tools and small-scale machinery has the objective to improve labor productivity in this area where there is little available power on farms. The research on agricultural hydrology, which tests and evaluates different methods of clearing tropical forests and subsequent soil management practices for their effects on soil erosion and crop production, has relevance for many countries seeking to open new lands for expansion of crop production. The recent work on "alley-cropping," wherein the bush fallow of traditional agriculture is replaced by selected shrubs row-planted and intercropped, appears to offer good economic return while maintaining soil productivity and minimizing soil erosion.

Within the Consultative Group for International Agricultural Research (CGIAR) system, IITA has a worldwide responsibility for the improvement of cowpeas, sweet potatoes, and yams. In cowpeas, the main production constraint is the field damage to the crop from insects. The strategy of IITA's crop improvement program is to maximize genetic resistance through the use of a wide germplasm base that seeks to identify natural resistance which can be incorporated into the improved lines. Considerable progress has been made in breeding for resistance to leaf hoppers, aphids, thrips, pod borers, and bruchid. The Institute is also engaged in a small but very important activity in soybeans to develop lines which have good seed quality and that can modulate with indigenous rhizobia.

Progress continues in both yam (Dioscorea sp.) and cocoyam (Colocasia and Xanthosoma) in breeding for disease resistance and improved quality. Sweet potato lines of good quality and high production, developed by IITA, are now being utilized in many different countries in Africa. Two major insect pests on cassava in Africa—green spider mite and cassava mealybug—are receiving considerable attention in seeking genetic resistance, as well as possible control through biological means.

Excellent progress has also been made in identifying streak virus resistant cereal materials and incorporating this resistance into high yielding improved lines. In rice, the breeding objectives to obtain blast resistance, yellow mottle virus resistance, drought resistance, intermediate stature, and highly acceptable grain quality made considerable headway in 1979.

The Institute will be pleased to share its research results and improved breeding materials with interested national programs and will welcome the opportunity to continue to cooperate with developing countries in training programs for research scientists.

William K. Gamble
Director General

FARMING SYSTEMS PROGRAM

Introduction

The Farming Systems Program emphasizes research to develop methods of land use and crop management suited to the humid and subhumid tropics that will enable more sustained production of food crops and the most efficient use of the farmer's natural resources of land, weather and adapted crops. The program places particular emphasis on incorporating into its research efforts the improved planting materials of cassava, yam, sweet potato, cocoyam, tropical legumes, maize and rice which emerge from IITA's three crop improvement programs.

Priorities of the program involve the dominant agricultural typologies. These regions are characterized for research purposes in terms of land types, cropping systems and dominant bio-technical limitations as shown in the IITA Annual Report 1977. IITA (3° 45′ E, 7° 29′ N) at Ibadan, Nigeria, is representative of a region with high-base status soils, and the Onne substation (7° 01′ E, 4° 43′ N) near Port Harcourt, Nigeria with low-base status soils of the tropics.

The vast majority of food crops produced in the Institute's mandate region, except for intensive rice production on hydromorphic soils, are grown today, as in the past centuries, by subsistence farmers who cultivate areas seldom larger than three hectares and often much less. But, today, unlike past centuries, population densities are high and rapidly increasing.

When population density remains low, farmers cultivate intermittently on a shifting cultivation or natural fallow rotation basis, normally with longer periods of fallow than cultivation. With today's high and rapidly increasing population densities, heavy demands are placed on the limited resources, and fallow periods are drastically shortened. Consequently, soil fertility and production decline. Productivity is falling because of reduced resources committed to food production.

For better focusing of the research priorities in the program, a conference was convened at IITA in 1979 to review the climatic and soil resources and constraints in relation to the production of maize, upland rice, cassava and cowpea in West Africa. Several areas for more baseline data gathering were identified in soil-water-plant relationships and soil and crop management.

In land management, work continues in developing and testing of land development and soil management methods for the low- and high-base upland and hydromorphic soils. More emphasis was given to better quantification and delineation of specific soil and land conditions that are suitable for no-till systems. Intensive studies are also being conducted in fertility, weed and pest management problems in no-till systems under various soil and ecological conditions. Testing of the no-till system is presently being undertaken in collaboration with several African and Asian national institutions.

As part of the program effort for better soil preservation, hydrology and watershed studies were carried out at IITA to find better ways of clearing and post-clearing land management. In support of this project and also for exchange of information, a conference on watershed management and land development for the tropics was organized in 1979 at IITA.

To provide for a better understanding of nutrient management in the strongly weathered soils of the high-rainfed tropics, greater emphasis was given to the interaction, retention and nutrient losses in these soils.

As a transition from the shifting cultivation or bush fallow system to continuous cultivation, the concept of alley cropping is being tested with good results. Results indicate a potential for developing a stable, low-input, productive system of continuous cultivation with a small tree or shrub component, which recycles nutrients (N with leguminous trees or shrubs), provides mulch and supports twining crops. The suitability of several indigeneous trees or shrubs to be used in this system is presently being studied. An agro-forestry survey is also being carried out to further assess the role of trees or shrubs in traditional farming systems.

Weed control continues to be an important constraint for farmers in their crop production programs. The weed scientist is following 3 lines of study that can be adopted by farmers with differing resources and production systems. The first is the use of herbicides in connection with no-till and as a supplemental factor in weed control with conventional-till in both mixed cropping and monoculture systems. The second is the use of live mulch in the system with low-growing plants (legumes or grasses), which suppress the weeds but allow the food crop plants to grow and produce. The third area of study is weed control through shading. Variation in plant population results in differing degrees of plant canopy.

The development and improvement of agricultural tools and implements relevant to peasant agriculture with particular attention to tropical Africa has been quite successful, and a number of these tools and implements are under commercial production and distribution. Full-scale testing and adaptation will be carried out in several African countries in addition to a continuation of developmental work at IITA. In collaboration with the Government of Sri Lanka and with special project funding, development work and testing of tools and equipment for utilization with farming systems in the upland areas will be carried out in that country. Work in agro-economics continues in identifying production constraints, factors affecting adoption of new varieties or techniques, market feasibility and the potential viability of selected farming systems.

Environmental management

Research in environmental management focuses on the effects of climatic and soil factors on crop production.

In agro-climatology, work continued on weather data gathering and analysis as well as on the evaluation of crop water requirements and on changes in aerial environments, resulting from deforestation and their related effects on crop production. Investigations on the physics of soil erosion continued. Laboratory procedures are being tested for better estimation of soil erodibility. Other studies were also carried out in soil physics on the effect of crop residue mulches and tillage methods on physical soil properties and crop performance with continuous cropping, the effect of hydro-thermal regime on performance of maize and the assessment of some of the mechanisms of drought tolerance of rice.

Soil chemistry and fertility research continued on the fertility management problems of the upland soils from the subhumid and humid regions and the hydromorphic soils for continuous cropping under various crop and soil management systems. The interaction, retention, movement and losses of plant nutrients, especially in the strongly weathered Ultisols, were studied for better nutrient management on these soils. A soil fertility capability classification is being worked out for the soils of Central and West Africa.

Other research was to quantify specific soils and land conditions that are suitable for conventional- and no-till systems and assess the importance of the role of legumes in rotation and organized fallow systems in soil fertility maintenance under low-input agricultural systems.

Also, methods of forest or bush clearing and subsequent land development were studied. An area of 59 hectares was cleared at IITA toward the end of 1978 as the Hydrology and Watershed Management Project. It is designed to investigate the impact of alternative methods of land clearing and subsequent soil management on crop production and the hydrological, chemical and biotic properties of the soil.

General weather conditions

The weather in 1979 at IITA was uncharacteristically wet and generally warmer than usual. Higher insolation prevailed for most of the year, particularly early in the second season; evaporative demand was, by contrast, below average. A summary of key variables is presented in Table 1.

Rainfall and evaporation. January and February were practically dry with a cumulative rainfall of only 3.6 mm (Fig. 1). The rains became consistent relatively early, mid-March, providing good conditions for an early start of the first season. Total rainfall for the month was, however, below average (26 percent) because of the dry conditions in the first half. Thus, in spite of the favorable water balance in the last two weeks of March, the cumulative rainfall for the first quarter of the year was no more than 17 percent of the total evaporative demand of 472.2 mm.

April was wetter than average by 38 percent, but the rainfall was not well distributed (Fig. 2). There were only seven rainfall incidences, two of which yielded 77 percent of the total 178.1 mm for the month (Table 1). These

Table 1. Summary of climatic data (IITA, 1979).

Months	Total rain-fall (MM)	Total evapo-ration (MM)	Solar radia-tion G_m-cal/ cm^2/day	Temperature (°C)			Relative humidity (%)		
				Min	Mean	Max	Min	Mean	Max
Jan.	0	120.84	375.43	22.8	27.8	32.5	42	70	98
Feb.	3.6	170.26	470.72	23.9	29.4	34.9	32	65	97
March	76.5	181.10*	480.19	23.4	28.5	33.7	42	69	96
April	178.1	146.97*	493.04	23.7	28.0	32.3	53	75	97
May	205.4	139.70*	465.83	22.8	26.6	30.4	61	79	97
June	133.8	98.30	392.47	23.0	26.1	29.1	66	82	97
July	290.6	100.20*	398.39	22.6	25.5	28.5	67	82	97
Aug.	184.8	94.96*	371.61	22.7	25.4	28.0	68	83	97
Sept.	259.4	111.10*	411.84	22.0	25.4	28.6	65	81	97
Oct.	156.4	112.13*	424.12	22.6	26.3	29.8	61	79	96
Nov.	18.1	101.71	414.12	23.2	26.8	30.4	57	77	96
Dec.	0	109.60*	405.49	20.3	29.7	31.1	41	69	97

Values adjusted for days with missing data.

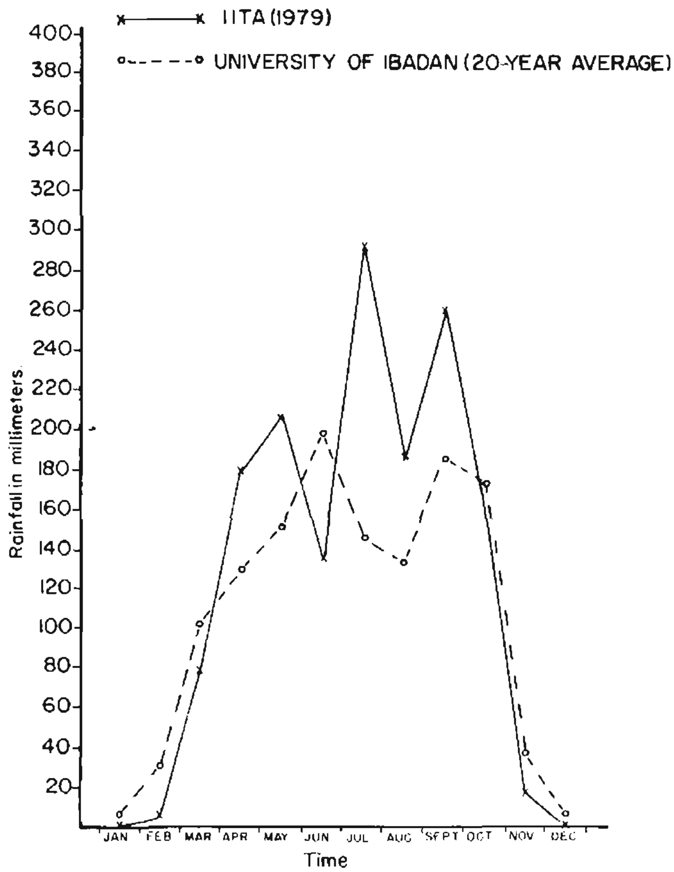


Fig. 1. Mean monthly rainfall.

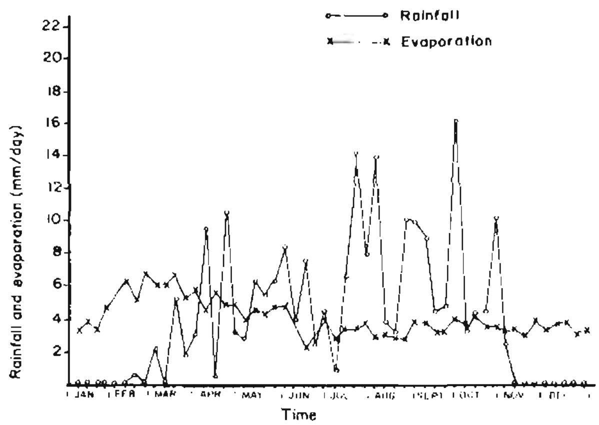


Fig. 2. Weekly mean rainfall and evaporation (IITA, 1979).

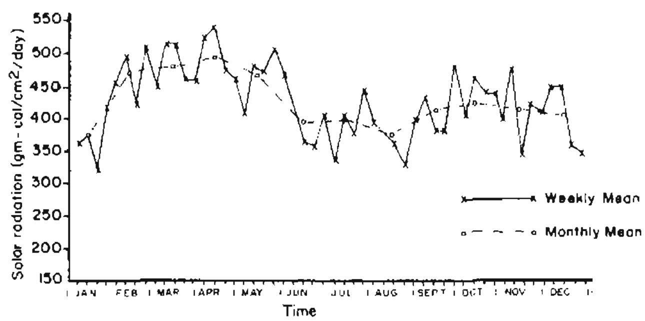


Fig. 3. Weekly and monthly mean solar radiation (IITA, 1979).

rains with peak intensities of 122 mm/h and 152 mm/h, respectively, were highly erosive. April 5-21 was essentially rainless and early sown crops at different stages of development were clearly subjected to moisture stress.

May was also wetter than average by 36 percent, and the rainfall was well distributed. No rainless period was longer than two days. The excessive rainfall still represented only 61 percent of the corresponding pan evaporation.

In June, there was a decrease in precipitation similar to 1978, which resulted in a drastic change in the normal rainfall pattern (Fig. 1.). Although the monthly total was -2 percent below average, it was, however, well distributed throughout the month. In conjunction with a 21 percent decrease in evaporative demand, this minimized the adverse soil moisture conditions that might have been again generated. There was, therefore, no significant stress on crops, particularly cereals that were at a rather sensitive stage of growth.

There was a reversal in the rainfall pattern in July. Another wet cycle set in and lasted until September. Departures in the monthly totals were +100 percent, +63 percent and +39 percent for July, August and September, respectively. Pan evaporation showed small increases, ranging from +3 percent in July to +8 percent in August and September. The period was the wettest for the year and proved very detrimental to the maturing and harvesting of the first-season crops, which delayed second-season planting.

The rains were again below normal in October-December. The cumulative total for these months was below the multi-annual average (1953-70). The last quarter, October-December, was also marked by relatively low evaporative demands, the largest departure being -23 percent in November. The total amount for the year was 1,486.9 mm. On the whole, the second season ended earlier with the last significant rain on November 4.

Sky conditions and solar radiation. A marked decrease in the frequency and intensity of fog, mist, and haze was observed in January and February. Broken to scattered clouds dominated the late morning and afternoon skies; a higher level of insolation consequently prevailed (Fig. 3), reaching 5 percent above average in January and 11 percent in February.

Early March saw a return to hazier skies. Cloudiness increased by mid-month as the rains set in but remained variable through the rest of the period. Above average global radiation was again received; the departure, this time, fell back to +6 percent. Similar conditions prevailed in April and May, each with a 5 percent increase in isolation compared to their respective multi-annual average (1972-76). Insolation was intense during the April dry spell when daily values averaged 513g-cal cm^{-2} day^{-1}.

Global radiation declined rapidly under cloudy but variable skies in June (Fig. 3). The lowest value observed in the month was 152.5 gm-cal cm^{-2} on 30 June, compared to a high of 542.1 gm-cal cm^{-2} on June 2. The monthly mean fell below average (−5 percent) for the first time in the year.

With the exception of November, which showed another negative departure (−2 percent), the radiation regime in the second half of the year was significantly higher than 'normal' with the departure in values ranging from a minimum of +7 percent in October to a maximum of +15 percent in September. The overall mean value for the year was 425.3 g-cal cm^{-2} day^{-1} or 6 percent higher than the corresponding 5-year average (1972-76.)

Temperature and relative humidity. Daytime temperatures were in most cases near normal or slightly below normal with the exception of May, November and December when the mean maxima were distinctly cooler by 1.1°C, 1.6°C and 1.2°C, respectively, (Fig. 4). The daily minima, on the other hand, were much warmer than normal. The highest mean departure in this case reached +2.7°C in January and the lowest, except for December with no change, was +0.8°C.

Paralleled with the higher mean temperatures, mean relative humidities were also above average (Fig. 5). January was particularly noteworthy; the mean value of 70 percent for the month was 9 percent higher than the 20-year average (1953-73). July-September were normal. The higher relative humidity contributed to higher night-time temperatures.

Dew/light precipitation. Contribution to the water budget in the form of dew and deposition of fine droplets from fog and mist totaled 18.4 mm. This compares with an approximate value of 11.0 mm in 1977 and 14.6 mm in 1978. The monthly amount ranged from 0.92 mm in March to 2.68 mm in December.

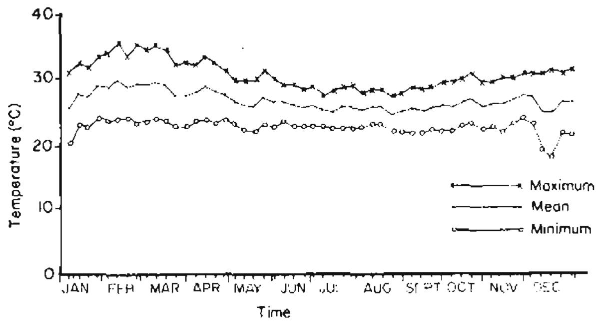


Fig. 4. Weekly mean maximum, minimum and mean temperatures (IITA, 1979).

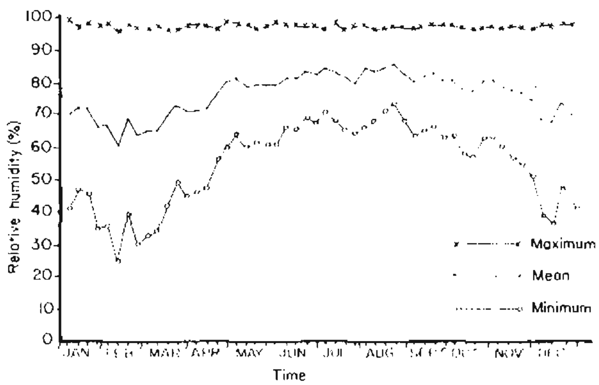


Fig. 5. Weekly mean maximum, mininum and mean relative humidity (IITA, 1979).

Light transmission in crop canopies

Light transmission studies continued in 1979 with the objective of identifying cropping patterns and densities compatible with efficient utilization of insolation, which was previously shown to be limiting. Light transmission through the crop canopies was measured at ground level, using 970-mm tube solarimeters connected to a Grant recorder.

The following general conclusions can be drawn from the results of this investigation:

1. At medium- and high-plant populations (27,000/30,000 plants/ha and 54,000 plants/ha), changing the planting pattern by either increasing intra- or inter-row spacing and keeping the population constant by increasing the number of plants/stand increased light transmitted to ground level by 4-7 percent.
2. Changing the plant population from 54,000 to 27,000 plants/ha by reducing the number of plants/stand without changing the planting pattern increased light transmitted by 13 percent.
3. Changing the plant population as in the preceding case through an increase in intra-row spacing from 25 to 50 cm increased light transmission by 16 percent. By leaving the intra-row spacing, there was a transmission increase of 22 percent.

Thus, the full benefit of increased incident light on a low-growing intercrop through a decrease in plant population is achieved through simultaneous modifications of inter-row spacing. The difference in gain between changing intra-row spacing or the number of plants/stand is marginal. Higher gains in intra- and inter-row modifications were indicated in 1978 results at 160 cm × 25 cm and 80 cm × 50 cm spacings than in 1979 results at 150 cm × 25 cm and 75 cm × 50 cm spacings. This suggests that more light reaches the inter-row spaces of TZB, a tall maize variety used in the studies, when the distance between rows reaches beyond some minimum value and reduces the population density below some limiting value.

Rainfall erosivity and soil erodibility

Climatic erosivity. Kinetic energy and momentum of natural rains were determined in 1979 by a Distromet Transducer and found to be highly correlated with sand splash. Kinetic energy of as much as 67 $Jm^{-2}mm^{-1}$ of rain was observed. Rainstorms with energy loads of less than 100 Jm^{-2} and momentum of less than 30 $Jm^{-3}s^{-1}$ were found to be nonerosive.

Erodibility of some soils from Nigeria. Research was initiated on the erodibility of 20 surface soils from Nigeria, using soil samples and a laboratory rainfall simulator (Table 2). The soils have a wide range of textures, structures and contents; erodibility ranges from 0.004-40.4 cm/hr.

Figures 6-8 show the effects of kinetic energy from rainfall on runoff, infiltration, soil loss and other parameters of *Oxic paleustalf*, Egbeda soil. These observations were made with the laboratory rainfall simulator. Figures 7 and 8 show the detachability and sediment transportability characteristics of the soils.

Erodibility of some soils from Zaire. From the physical characteristics of a range of soil groups from Zaire, Mollisols, Oxisols, Vertisols, Inceptisols and Ultisols, soil erodibility was estimated. Consistent with observations on similar soils elsewhere, the erodibility of a majority of

Table 2. Equilibrium infiltration rate of some Nigerian soils.

Location	Soil type	Infiltration rate (cm/ hr ⁻¹)	Equilibrium time (minutes)
Ngala*	Vertisol (Depression)		
	Ngala series	0.004	1440
	Salfir series	0.02	1440
Kadawa*	Inceptisol	1.1	240
Little Gombi	Ulfisol	1.2	95
Samaru**	Alfisol	4.3	205
Benin City NIFOR***	Alfisol	4.4	360
Tam (Bio Farm)	Vertisol	5.0	140
Bauchi	Alfisol	13.4	105
Gamawa	Inceptisol	25.7	90
Gombe Tumu Station	Ultisol	32.5	91
Lafia	Alfisol	39.9	68
Ryom	Alfisol	40.4	74

*Information given by Lake Chad Development Basin Authority.

**Information given by Institute of Agricultural Research, Samaru.

***Information given by Nigerian Institute for Oil Palm Research.

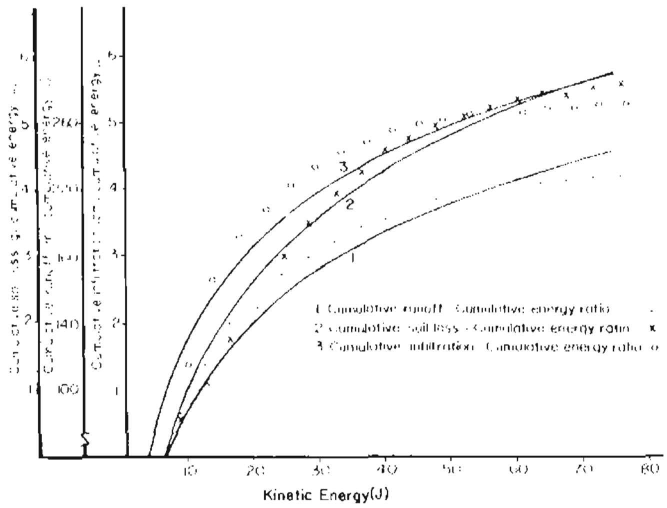


Fig. 6. Effect of kinetic energy of the rain received on runoff, soil loss and infiltration.

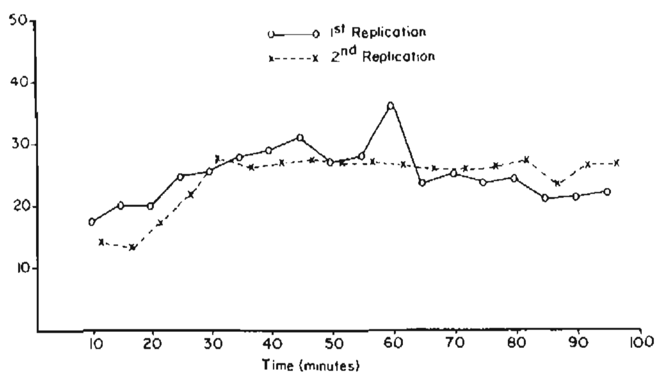


Fig. 7. The "Detachability Index" expressed as soil loss/ runoff relationship at different times during the simulated rain.

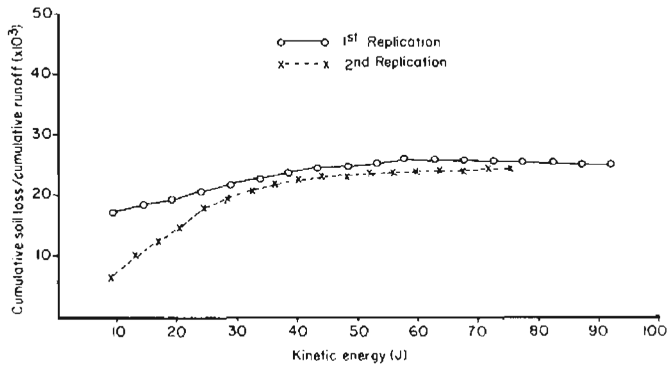


Fig. 8. The "Transportability Index" expressed as cumulative soil loss/cumulative runoff as a function of the kinetic energy.

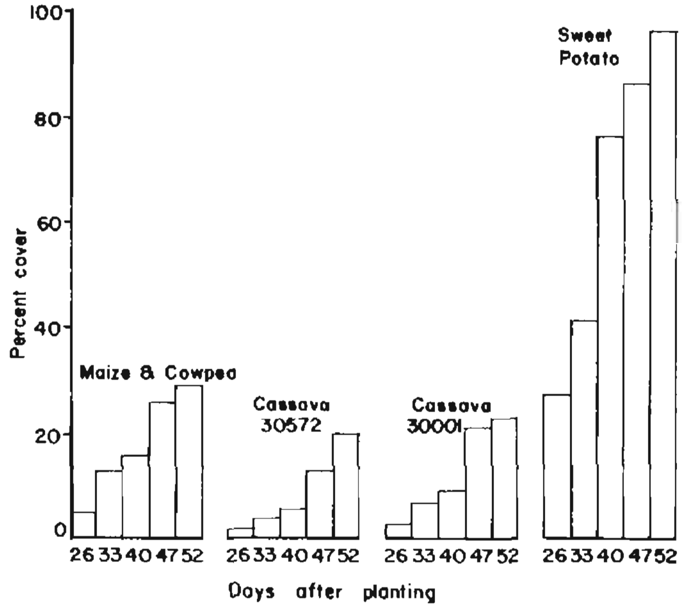


Fig. 9. Percent of ground covered by the canopies of different crops during the period Sept. 8-Nov. 6, 1979.

these soils is low and is generally less than 0.15 t/acre/ foot-ton. Based on the soil erodibility and climatic erosivity, a map is being made of the potential erosion hazard in different regions of Zaire.

Soil loss in relation to canopy cover. The development of the canopy cover of sweet potato, cassava and maize with cowpea at different growth stages is shown in Figure 9. There are measurable differences in canopy development of these crops. Because of the slow rate of canopy development, cassava cover gave the lowest soil loss. The mean soil loss was maximum under variety 30572 (3.8 t/ha/season) and minimum under variety 30001 (2.4 t/ha/season). Variety 30572 has less ground cover at all growth stages than variety 30001. Sweet potatoes provide early effective ground cover while a maize/cowpea intercrop also offers good protection against the impact of raindrops.

Effects of crop residue mulches on yam

Yam grown in filled-in lysimeters with five different soil profiles yielded significantly more with crop residue mulch (Table 3). Along with crop yield, root growth was also observed against the glass windows. Root distribution and total root activity was generally proportional to the yield and overall crop performance.

Effects of tillage methods

Continuous cultivation of Egbeda soil since 1970 by no-till with mulch and conventional-till with mulch incorporated with plowing and harrowing indicated significant differences in soil physical properties, including the mean weight diameter, bulk density, penetrometer resistance and hydraulic conductivity.

Effects on soil properties under maize showed that the mean weight diameter of the surface soil in the no-till plots was 3.60 mm compared to 2.61 mm in the conventional-till plots. Similarly, the bulk density of the no-till plots was generally lower than the conventional-till plots up to a 30-cm depth and 12 weeks after seeding (Fig. 10)

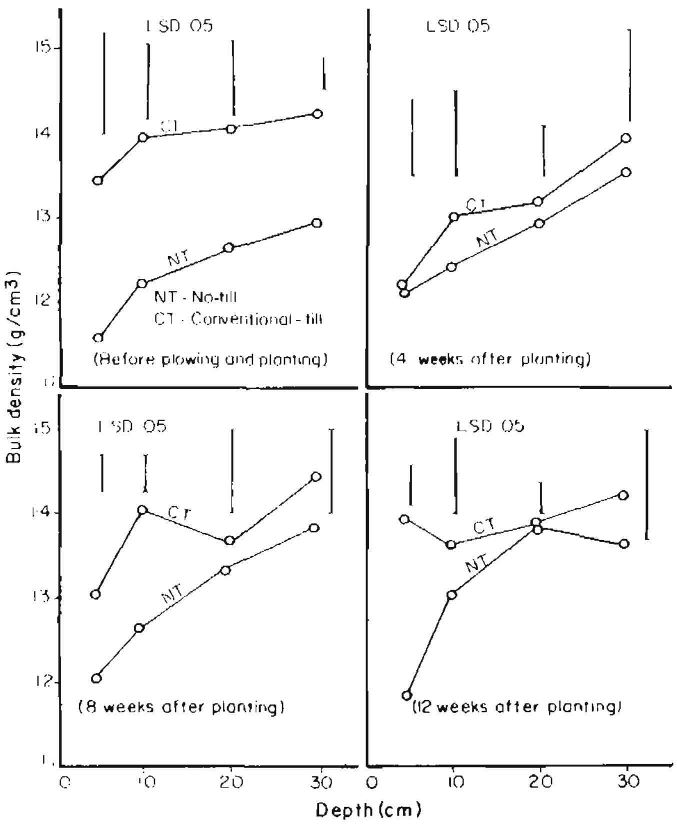


Fig. 10. Effects of tillage method on soil bulk density.

The penetrometer resistance and the saturated hydraulic conductivity were also favorable on no-till plots compared with conventional-till plots. Investigations on root growth of maize, cowpea and soybean indicated that the surface layer had significantly more root density in no-till plots than conventional-till plots. However, more roots penetrated deeper layers in the conventional-till plots.

Soil-plant-water relations

Maize

Effect of soil moisture was shown to be more detrimental to maize at its grain filling stage than at any other stage (Fig. 11).

Moisture stress applied at both floral initiation and grain filling stage produced the lowest yields. Reduction of the grain yield of maize subject to moisture stress at both floral initiation and grain filling stages was more than 60 percent compared with 40 and 50 percent for plants that suffered moisture stress at floral inititiation or grain filling stage, respectively.

Effects of soil-temperature regime. Studies conducted in growth cabinets indicated that soil temperature of 40°C had a significant adverse effect on maize growth, development and nutrient uptake (Table 4). Dry matter partitioning between the roots and shoots was also markedly affected by root temperature. Shoots were affected significantly more at a 40°C root temperature than lower temperature. This implies that at higher root temperatures relatively more dry matter is accumulated in the shoot than root. Consistent with the observation reported earlier, supraoptimal root temperatures can cause significant yield reductions in maize and other crops.

Rice

The water requirement of rice was studied to determine the total water demand by the crop under the prevailing climatic conditions and the pattern of consumption throughout the growing season. The upland rice variety OS 6 was used, and moisture consumption was measured by means of drainage lysimeters. The crop was planted and thinned to a density of 22 hills/m^2. The first planting was in October 1978, with the crop maturing in the 1978-79 dry season.

Average moisture consumption was stable near 3 mm/day on both Iwo and Alagba soil series during the first 4 weeks of growth (Table 5 and Fig. 12). It increased sharply to 4.8 mm/day and 4.0 mm/day on the Iwo and

Table 3. Yam tuber characteristics as affected by mulching and soil type in the rhizotron.

	Egbeda surface soil		Egbeda profile		Alagba profile		Onne profile		Apomu profile	
	Mulched	Un-mulched	Mulched	Un-mulched	Mulched	Un-mulched	Mulched	Un-mulched	Mulched	Un-mulched
Fresh Wt (kg)	4.6	3.4	7.7	6.9	3.3	2.5	3.9	2.2	4.1	2.9
Shape*	3.5	3	4.7	4.3	2.5	2.5	3.3	2.5	4	4
Texture*	1.5	1.8	1.4	1.2	2.5	2.2	1.5	1.6	1.2	1.4
Hairiness	1	1.3	1	1	1.4	1.4	1	1	1	1
Length (cm)	39.5	33.5	46.3	48	35.5	34	30.6	23	40	33.5
Ave. diameter	10.8	9.6	11.4	12.7	10.0	9.7	8.8	8.4	9.8	9.3

Scores are based on 'Recommendations for establishment, cultivation and evaluation of root crop test materials' published by IITA.

Alagba soils, respectively, and fluctuated around these values up to 16 weeks when it peaked at 6.19 mm/day and 5.11 mm/day, respectively. It declined continuously to near 3-4 mm/day at maturity.

The cumulative maximum evapotranspiration amounted to 622 mm and 538 mm on the Iwo and Alagba soils, respectively, giving a mean seasonal value of 4.44 mm/day for the former and 3.89 mm/day for the latter. But, the water use efficiency on the 2 soils remained, however, comparable at 148.9 (Iwo) and 148.0 (Alagba) kg/ha-cm with respect to total dry matter. But, again, 67.6 kg/ha-cm was produced by the Iwo soil compared to 60.9 kg/ha-cm by the Alagba soil.

The maximum evapotranspiration to pan evaporation ratio (ETm/Eo) showed a predictable trend (Fig. 13). On the Iwo and Alagba soils, the mean values of ETm/Eo increased from 0.75 and 0.70 to 1.40 and 1.15, respectively, and then decreased smoothly to absolute minimas of 0.68 and 0.52, respectively. The mean over the season was 0.98 (Iwo) and 0.85 (Alagba).

A second experiment with the crop growing and maturing in the 1979 first and second season showed a lower level of moisture consumption as expected from the prevailing lower evaporative demands. Average maximum evapotranspiration on the Iwo soil fell to 3.38 mm/day. The ETm/Eo was 1.03 and consistent with earlier results.

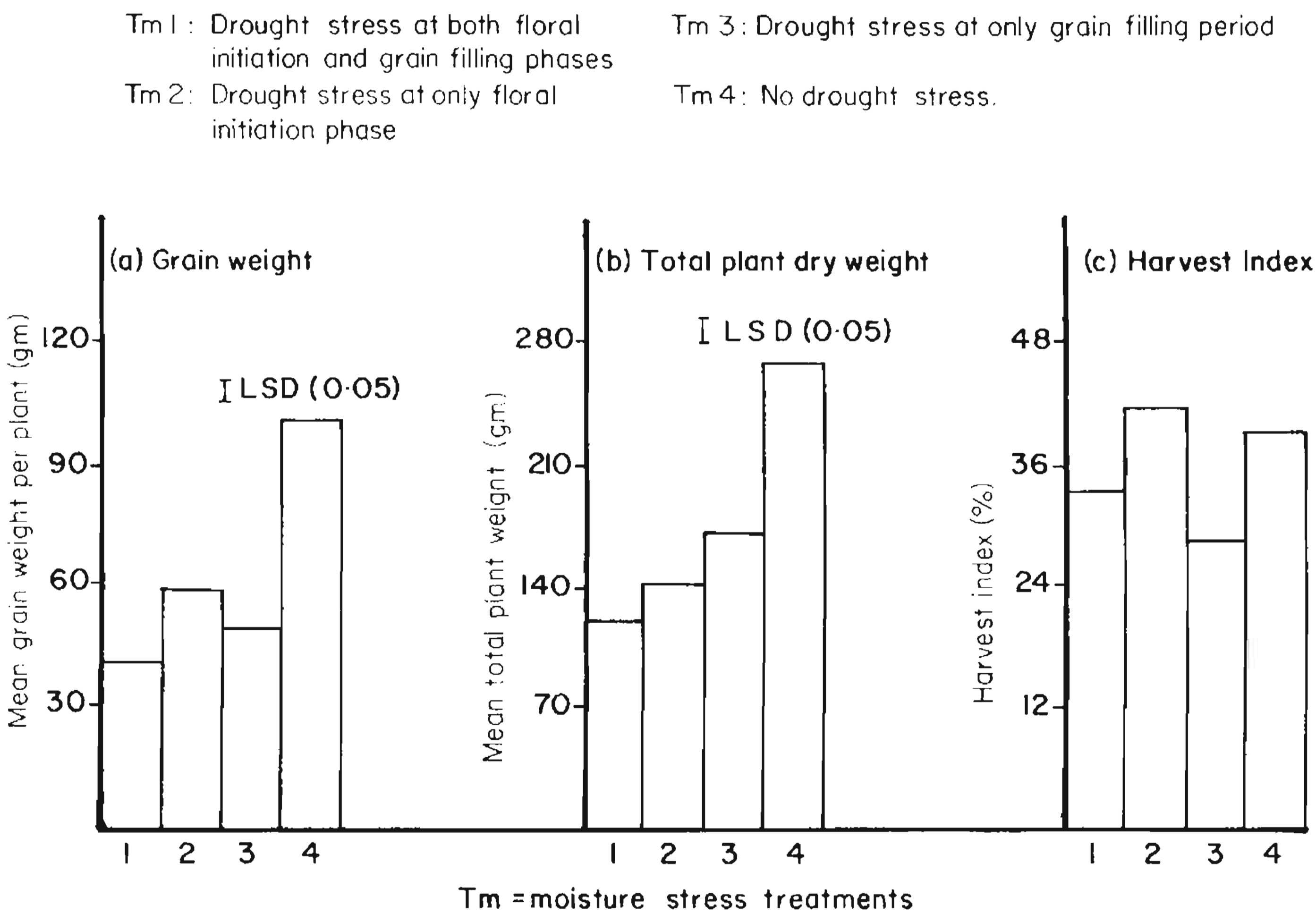


Fig. 11. Effect of moisture stress on the grain yield and related yield components of maize.

Table 4. Effect of root zone temperature on seedling growth and development of maize measured 14 days after seedling.

Growth parameter investigated	40°C Root-zone temperature	30-35°C Root-zone temperature	LSD (.01)
1. Shoot height (cm)	10.7	20.7	8.3
2. Shoot dry weight (g/plant)	0.73	2.81	0.25
3. Root dry weight (g/plant)	0.15	0.83	0.15
4. Shoot/root ratio	4.7	3.4	0.03
5. Rate of shoot growth (cm/day)	0.8	1.5	—
6. Rate of dry matter accumulation (g/day)	0.063	0.260	—
7. Number of leaves at harvest	4	6	—

Results from the Alagba soil lysimeter were evidently affected by observed anomalies in crop growth, resulting in complete replacement of the stand with plants from a guard area. The mean water used by the crop over the whole season was 2.68 mm/day, giving a relatively low ETm/Eo of 0.81.

Effects of soil-moisture regime. Greenhouse, lysimetric and field investigations on rice indicated that leaf-water potential is an integrated response of soil moisture regime, evaporative demand of the atmosphere and plant characteristics, including leaf area and surface properties and root growth and development. There were significant varietal differences in the leaf-diffusive resistance and the leaf-water potential as affected by the soil moisture regime regulated in a field lysimetric experiment (Table 6).

A summary of the effects of soil moisture regime on plant-water status of contrasting varieties is shown in Table 7. As expected, water uptake increased linearly with an increase in leaf-water potential within certain limits (Eq. 1). Similarly, leaf-water potential increased with an increase in the leaf-diffusive resistance (Eq. 2). The relative rate of plant elongation decreased with an increase in water stress (Eq. 3). Grain yield decreased linearly with an increase in water uptake deficit at the reproductive stage of growth (Eq. 4).

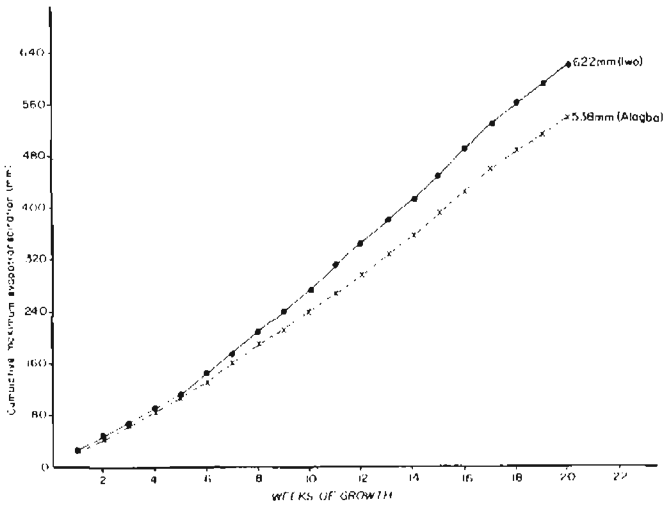


Fig. 12. Cumulative maximum evapotranspiration in rice variety OS6.

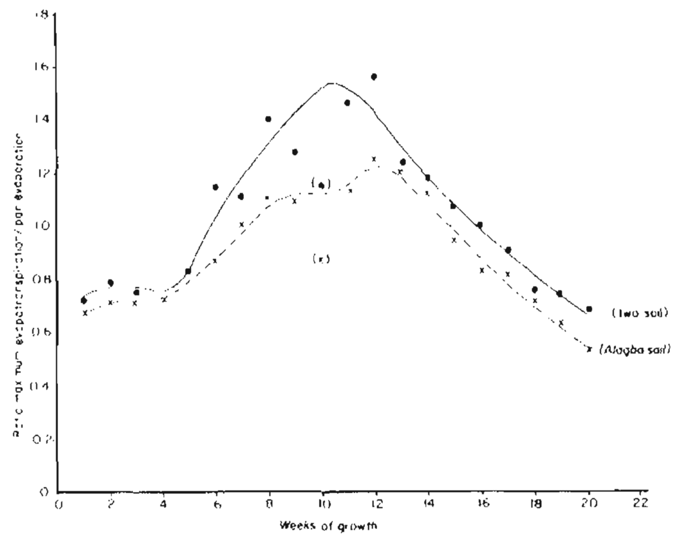


Fig. 13. Ratio of weekly mean maximum evapotranspiration in rice to Class A pan evaporation.

Table 5. Weekly mean values of solar radiation, Ra; saturation vapor pressure deficit, Ae; wind speed at 2 m, V; pan evaporation, Eo; and maximum evapotranspiration, ETm.

	VARIABLES					
Period (1978-79)	Ra (calm ^{2} day ^{1})	Ae (Mb)	V (Kmph)	Eo (mm)	ETm-Iwo (mm)	ETm-Alagba (mm)
20/10—26/10	443.3	6.96	4.0	4.48	3.28	3.05
27/10—21/11	460.2	5.98	3.5	4.06	3.19	2.94
3/11— 9/11	411.4	6.84	3.0	4.06	3.08	2.89
10/11—16/11	493.7	8.95	2.4	3.93	2.88	2.85
17/11—23/11	496.1	10.36	2.9	4.21	3.45	3.47
24/11—30/11	447.7	10.02	2.9	3.98	4.55	3.47
1/12— 7/12	445.3	10.65	3.4	4.11	4.55	4.11
8/12—14/12	396.9	9.30	2.9	3.69	5.16	4.02
15/12—21/12	377.5	8.19	2.9	3.24	4.10	3.54
22/12—28/12	416.3	11.09	4.3	4.27	4.89	3.40
29/12— 4/1	392.1	10.20	9.3	3.70	5.42	4.13
5/1 —11/1	355.8	6.06	3.2	3.21	5.02	3.98
12/1 —18/1	346.1	9.71	3.7	3.75	4.64	4.49
19/1 —25/1	367.9	12.10	3.4	3.96	4.65	4.23
26/1 — 1/2	445.3	13.86	4.8	5.74	5.40	4.77
2/2 — 8/2	493.7	15.17	5.1	6.15	6.14	5.11
9/2 —15/2	469.5	14.77	5.1	5.86	5.35	4.56
16/2 —22/2	452.6	13.20	4.8	5.87	4.41	4.20
23/2 — 1/3	474.4	14.84	5.0	6.28	4.55	3.91
1/3 — 8/3	486.5	13.62	4.6	6.14	4.19	3.23

$Eq.\ 1.\ LWP = 0.4 + 0.9\,(WU) \quad a < WU < b \qquad r = 0.93$
where LWP = Increase in leaf-water potential, and
WU = Increase in water uptake

$Eq.\ 2.\ LWP = 0.5 + 0.6\,(DR) \quad a' < DR < b' \qquad r = 0.59$
where LWP = Increase in leaf-water potential, and
Dr = Increase in leaf-diffusive resistance

$Eq.\ 3.\ ER = 1.77 - 0.8\,(RS) \quad a'' < RS < b'' \qquad r = 0.76$
where ER = Plant elongation rate, and
RS = Relative stress

$Eq.\ 4.\ PDY = 7.0 + 0.88\,(WD) \quad c < WD < d \qquad r = 0.77$
where PDY = Percent decrease in grain yield, and
WD = Water uptake deficit

Whereas, the relative grain yield decreased linearly with an increase in the leaf-diffusive resistance, it increased with an increase in the water uptake (Fig. 14). Similarly, the relative grain yield increased with an increase in the root density both at a 24-cm depth and in the whole profile (Fig. 15).

Limits of plant-water availability

The permanent wilting point of maize, cowpea and soybean was identical in an Alfisol and ranged from 2 to 8 percent in volumetric moisture content (Fig. 16). However, the moisture content at the permanent wilting point was generally more in conventional-till than no-till plots, probably due to mixing the clayey sub-soil by plowing. Moreover, the greenhouse experiments under controlled conditions indicated that the volumetric moisture content at the permanent wilting point varied among soils, and there were differences in maize and cowpeas (Table 8).

The field capacity, soil moisture suction at equilibrium after free drainage had ceased, was observed to correspond with soil-water suction, ranging from 10 to 50 millibars. This range of field capacity was generally lower than expected. These observations on the upper and lower limits of available water were also related to the root system development under different tillage systems (Table 9).

Table 6. Varietal differences in leaf-water status of rice cultivars under different soil moisture regimes.

	Leaf diffusive resistance (sec. cm $^{-1}$)			Leaf Water Potential (bars)		
Variety	Flooded	No flooding	LSD (.05)	Flooded	No flooding	LSD (.05)
63-83	7.9	13.8	5.4	13.9	16.00	3.9
IB-43	9.3	13.1	3.2	13.0	15.4	3.6
OS 6	7.9	18.2	3.8	14.5	15.8	1.7
IB 6	7.2	13.8	0.3	12.8	13.5	4.0
IRI529-680-3	10.2	30.6	3.5	13.8	19.0	5.0
C22	10.6	19.7	1.9	13.4	17.5	4.1
IRAT 13	8.0	11.5	5.1	13.4	14.1	3.8
TOS 4688	9.5	18.8	6.5	12.6	14.1	0.7
IZT 4688	12.5	35.0	1.4	—	—	—
SE 302 6	10.2	21.0	5.5	13.2	18.5	4.8
IET 1444	—	—	—	13.1	17.9	4.8

Table 7. Relative effects of evaporative demand and soil moisture stress (0.03 cm) on three rice varieties.

	Characteristics			Regression			
			Unstressed	F (ψ t) Stressed		ψ F (ψs) Stressed	
Varieties	Root system	Leaf diffusive resistance		Simple regression	Partial regression	Simple regression	Partial regresson
IB 6	deep, dense	low	4.03**	3.73*	3.72*	1.35 (n.s5%)	0.76*
IRI529-680-3	deep, not dense	high	2.06**	1.23	1.87*	1.37*	1.72
EIT 1444	shallow, very low density	very high	1.65*	1.19	1.29*	1.54**	1.59**

	COEFF. OF DETERMINATION						
		ψL Vs ψ t			ψL Vs ψs		
	Unstressed	Stressed			Stressed		
Varieties		Simple regression	Partial regression	Multiple (ψ t and ψs) regression	Simple regression	Partial regression	Multiple (ψ t + ψs) regression
IB 6	0.93	0.70	0.70	0.98	0.07	0.07	0.98
IR 1529-680-3	0.53	0.18	0.71	0.83	0.43	0.80	0.83
IET 1444	0.84	0.17	0.61	0.67	0.47	0.77	0.67

Fertility management problems

Alfisols and Entisols

Trials were initiated at IITA in 1972 on *Oxic paleustalf*, Egbeda soil, and *Psammentic usthorthent*, Apomu soil, to determine the long-term nutrient responses and soil property exchanges under continuous cropping with and without fertilizer application. A maize and sweet potato annual cropping cycle was used intially. In 1976, cowpeas replaced sweet potato during the second season. This was to evaluate the cowpea for its N contribution.

Maize yields were high in 1979 as in previous years with fertilizer used at both locations (Table 10). On Egbeda soil, despite years of intensive cropping, significant responses to N and P were observed. Confirming 1972-78 results, 80 kh N/ha and 30 kg P/ha for continuous maize and cowpea cropping appears to be quite adequate for the Egbeda soil. Without Mg on the Apomu soil, the yield of maize was lower; thus, the application of Mg as well

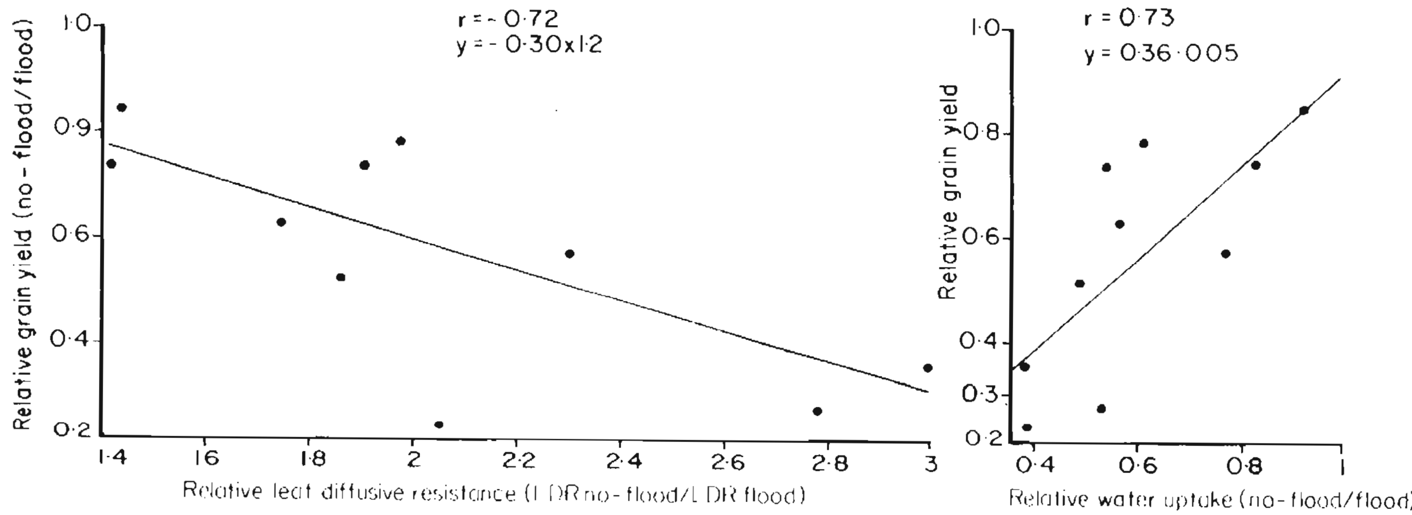


Fig. 14. Rice grain yield in relation to leaf diffusive resistance and water uptake.

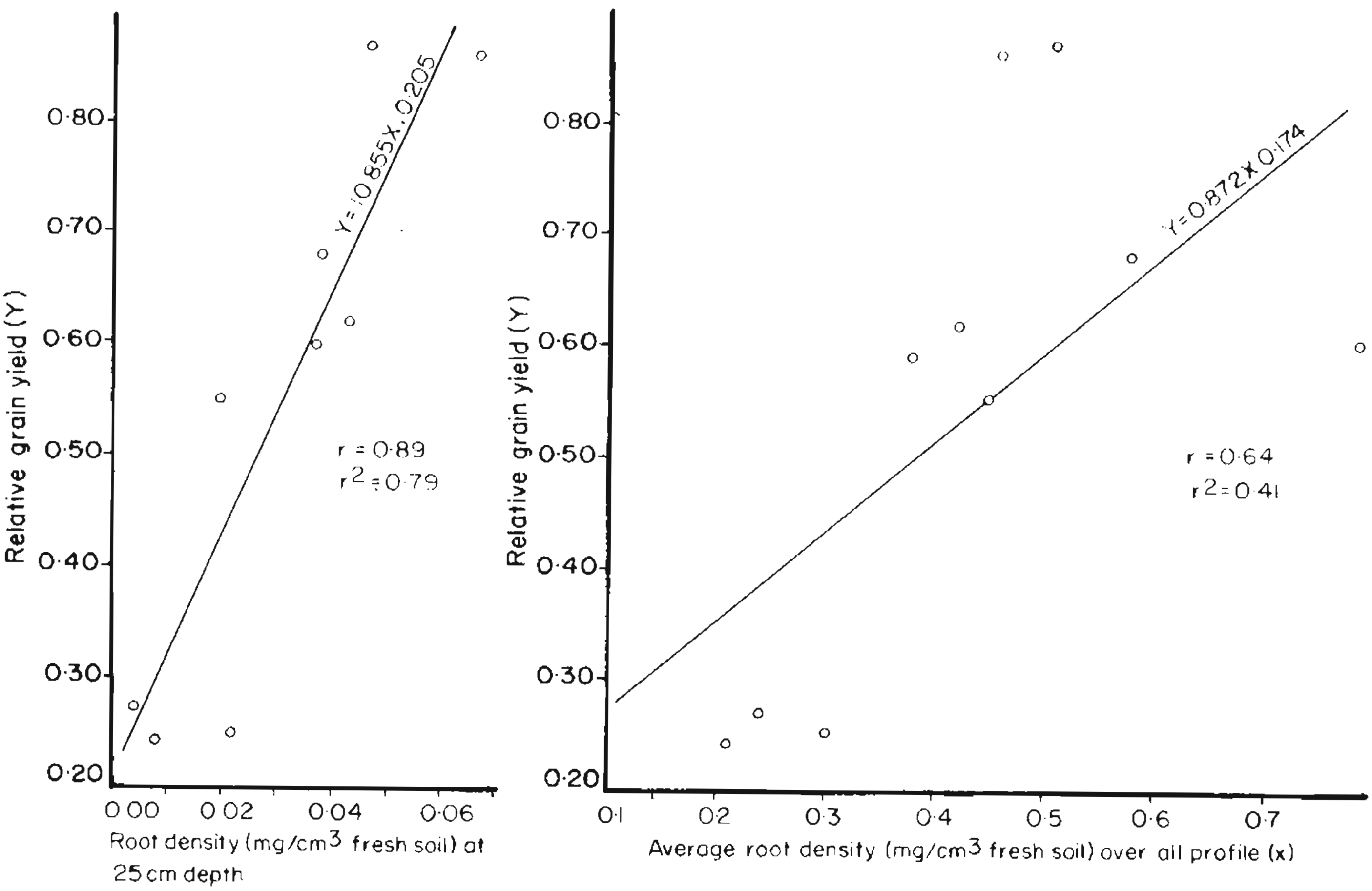


Fig. 15. Rice grain yield as related to root density.

as N, P and K appears to be necessary for continuous cropping on the Apomu soil.

Due to the favorable rainfall conditions during the second season, excessive vegetative growth of the cowpea was observed at both locations. This resulted in delay and less pod production, particularly in the higher fertility plots. This also explains the lack of fertilizer response

Table 8. Volumetric moisture content of maize and cowpea at the permanent wilting point as an average of three depths by horizon and as an average of the wetter layer per horizon.

		Maize		Cowpea	
Series	Depth	Mean	SE	Mean	SE
Iwo	0-15	9.88	0.57	6.00	0.43
Ekiti	0-16	5.91	0.43	3.48	0.19
Apomu	0-16	3.86	0.48	3.06	0.46
Adio	0-10	4.19	0.21	3.23	0.44
Alagba	0-13	5.49	0.73	3.45	0.40
Owode	0-15	7.40	0.49	6.46	0.56
Iwo	0-15	11.48	0.23	6.78	0.03
Ekiti	0-16	7.45	0.68	3.90	0.10
Apomu	0-16	4.08	0.49	3.15	0.16
Adio	0-10	4.52	0.30	3.78	0.68
Alagba	0-13	6.86	1.23	4.80	0.84
Owode	0-15	8.33	0.58	6.80	0.80

Table 10. First season grain yield, maize variety TZPB, and second season grain yield, cowpea variety VITA-4, as affected by fertilizer application.

	Egbeda soil (Oxic paleustalf)		Apomu soil (Psammentic usthorthent)	
Treatment	Maize	Cowpea	Maize	Cowpea
	Kg/ha			
N P K S Mg				
0 0 0 0 0	3345	976	826	946
0 2 1 1 1	4749	1097	1420	793
1 2 1 1 1	5842	1230	3608	819
2 2 1 1 1	5843	1100	5219	748
2 0 1 1 1	2671	954	3004	951
2 1 1 1 1	5091	1391	4322	853
2 2 0 1 1	5608	1080	4039	890
2 2 2 1 1	5669	1276	4639	923
2 2 1 0 1	5733	1298	4861	917
2 2 1 1 0	5667	1137	4572	903
0 0 0 0 0*	2994	867	973	914
2 2 1 1 1*	5386	1129	4381	925
LSD (.05)	942	272	999	241

**Maize crop residue removed. The O level - none. Fertilizer rate N_1 - 80 kg N/ha; N_2 - 160 kg N/ha for Egbeda soil; N_1 - 100 kg N/ha; N_2 - 200 kg N/ha for Apomu soil; P_1 - 30 kg P/ha; P_2 - 60 kg P/ha; K_1 kg K/ha; K_2 80 kg K/ha; S_1 - 15 kg S/ha; Mg - 11 kg/ha*

Table 9. Changes in soil suction (millibars) as a function of time and depth in conventional- and no-till.

	Accumulated hours after irrigation													
	24		48		72		96		120		168		192	
	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE
No-till														
0-7	17	8	18	8	17	8	17	8	17	8	17	8	-	-
7-14	7	7	8	8	10	10	10	10	10	10	10	10	-	-
14-21	17	17	8	8	17	17	17	17	17	17	17	17	-	-
21-28	28	17	57	30	47	26	47	26	47	26	47	26	-	-
Conventional-till														
0-7	0	0	0	0	15	12	-	-	15	12	35	35	35	35
7-14	0	0	0	0	45	45	-	-	50	50	45	45	45	45
14-21	0	0	13	13	13	13	-	-	13	13	13	13	13	13
21-28	0	0	0	0	0	0	-	-	0	0	0	0	0	0

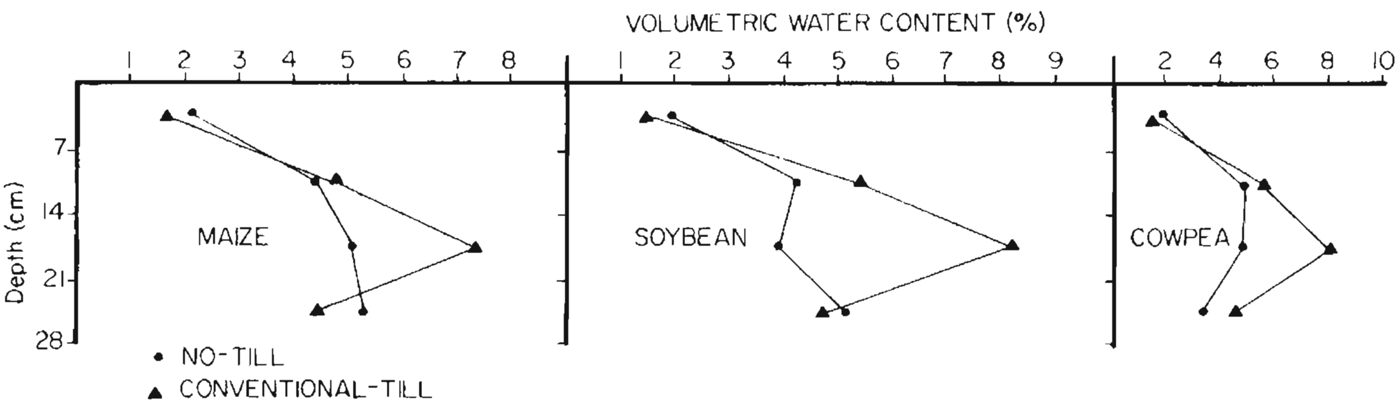


Fig. 16. Effects of tillage systems on the volumetric soil-water content.

of the cowpea crop. Removal of the maize crop residue had little or no effect on maize and cowpea yields.

Nitrogen × Tillage interaction. Investigations to determine the N responses of maize grown with and without tillage were conducted at 3 locations in Nigeria. A trial of Ikenne with Egbeda soil was a continuation of a 1978 trial. Trials at Oyo and Ogbomosho with Apomu soil were located at an Agro-Service and Farm Settlement site, respectively. Plots were mainly under low shrub and mixed grass fallow. Tillage consisted only of discing.

At Ikenne, which is the second year of cropping after *Eupatorium* fallow, maize variety TZE responded significantly to lower N rates only in the second-season crop (Table 11).

In line with the 1978 results on this relatively fertile soil, which also has a lower bulk density (1.31-1.37 g/cc), no differences were observed in maize yields due to tillage treatments. On the other hand, the less fertile soil at Oyo and Ogbomosho, which also has a higher bulk density (1.44-1.48 g/cc), had significantly higher maize yields with tillage. Higher yields due to tillage were more pronounced at lower N rates. Maize yields at both locations leveled off more at lower N rates with conventional-till than no-till conditions, indicating higher N application is needed with no-till maize (Fig. 17).

Nitrogen response of maize alley cropped with *Leucaena leucocephala*. Results showed that maize that is alley cropped with *Leucaena* (spaced 4 m apart) benefits from N when the tops of the *Leucaena* are trimmed (Table 12). "Reasonable" yields were observed with alley cropped maize without N application grown on a low-fertility Apomu soil. For obtaining maximum yields, only low N rates were required.

Although large quantities of N were produced in the trimmings of *Leucaena* tops (Table 13), only low quantities of the N was utilized by the maize.

This may be attributed to three factors:

1. The *Leucaena* was trimmed to reduce shading when the growth stage of the maize did not benefit from additional N.
2. The tops of *Leucaena* were used as mulch and were ineffective (Table 14).
3. The leaves of *Leucaena* decomposed quickly when applied to the soil (Fig. 18).

Table 11. Effect of tillage and N rates on grain yield of maize varieties TZPB and TZE grown in the forest and derived savanna zones of Nigeria in 1979.

Tillage Treatment	N rate kg/ha	Maize Grain Yield kg/ha — Ikenne (*Oxic paleustalf*) First season	Ikenne (*Oxic paleustalf*) Second* season	Oyo (*Psammentic usthortent*) First Season	Ogbomosho (*Psammentic usthorthent*) First Season
Conventional till	0	3799	936	761	1627
	30	3827	1463	1185	1984
	60	4045	1532	2175	3507
	90	4020	1503	2553	4036
	120	3779	1306	3229	4804
	150	4053	1412	3233	4952
Mean		3922	1367	2189	3488
No-till	0	3628	921	403	756
	30	3946	1537	706	1066
	60	3606	1415	1178	2297
	90	3900	1850	2076	3181
	120	4088	1943	2567	3304
	150	4153	1795	2680	4652
Mean		3867	1577	1602	2543
LSD (.05)					
Tillage means		374	168	129	535
Between N rates:					
	Within tillage	377	301	247	678
	Between tillage	497	589	583	800

*Variety TZE.

Table 12. Effect of N rates on grain yield of maize alley cropped with** Leucaena leucocephala **on Apomu soil.

	N Rate (kg N/ha) 0	60	120*	180*	
	Grain yield (kg/ha)				LSD (.05)
First season 1979**	2090	3130	3537	3686	357
Second season 1979***	1602	2227	2425	2481	415
Total yield	3692	5357	5902	6167	

*Two third of N applied to first season crop.
**Variety TZPB.
***Variety TZE.

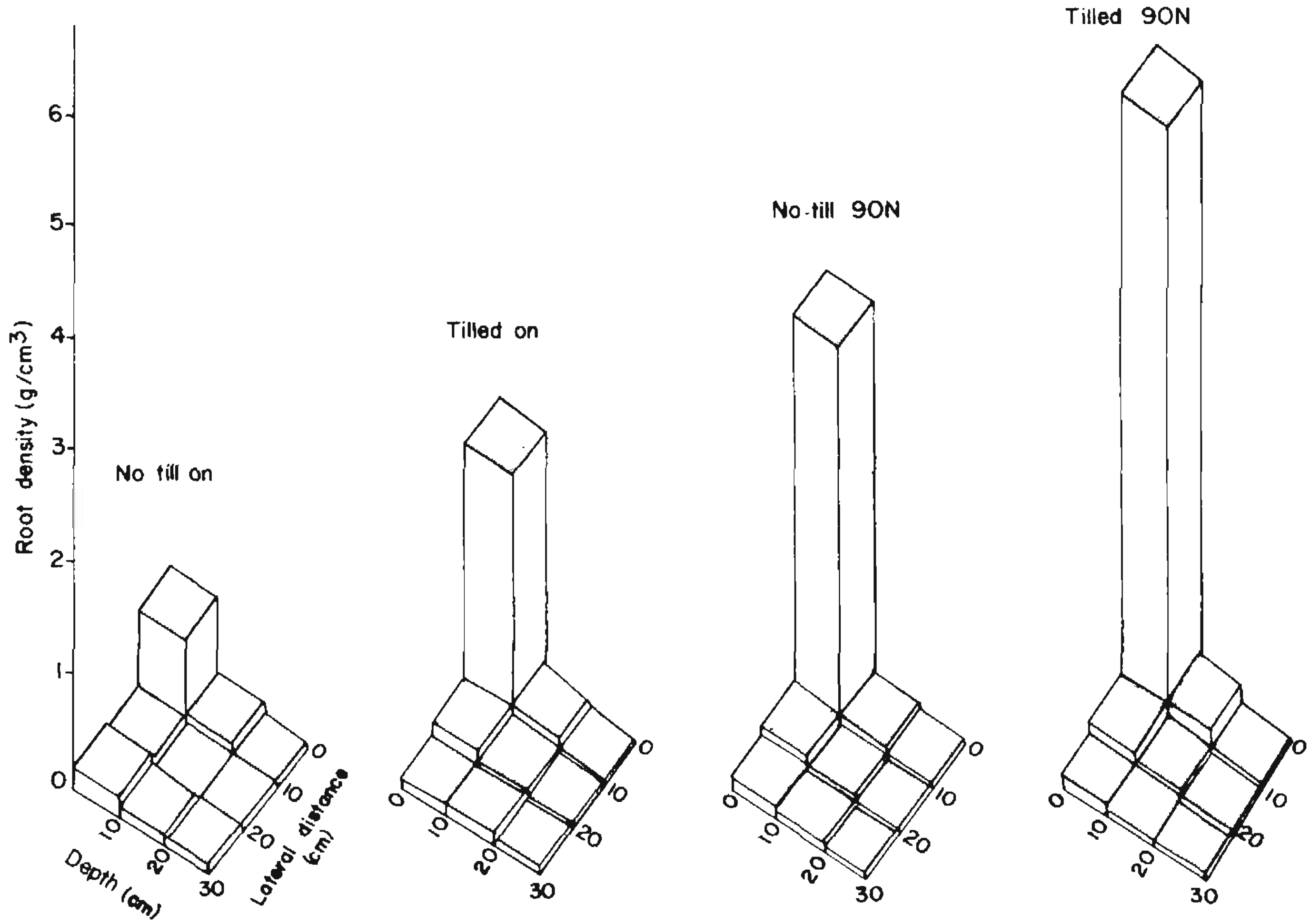


Fig. 17. Effect of tillage and N application on the root distribution in maize variety TZE.

Leaves of shrub legumes as nutrient source. An inexpensive nutrient source is among the most important considerations in the development of a low-input, low-energy cropping system. Many plant species, especially the nitrogen fixing legumes, are alternatives to inorganic fertilizers. Many of these rapidly growing species produce through their leaves large quantities of nutrients, especially N.

The potential nutrient contribution of 4 regime species was evaluated in a cropping system. The species, *Cajanus cajan, Glyricidia sepium, Leucaena leucocephala* and *Tephrosia candida*, were all established from seeds and grown in combination with maize and cassava. The legumes were spaced 200 cm × 50 cm × 50 cm. After one year, maize was planted by no-till between the legumes. The leaves and small branches were then cut and spread over the area planted to maize. Leaf and grain yield and potential nutrient contribution are shown in Table 15.

C. cajan had the highest leaf yield and significantly higher N and P levels while *G. sepium* had the lowest leaf yield and significantly lower N and P levels. Maize yield was highest under *C. cajan*, but this was only significantly different from *T. candida* (Table 15).

Though N levels might not have been the major factor responsible for maize yield, the potential for significant N contribution from legume leaves exists. Full utilization

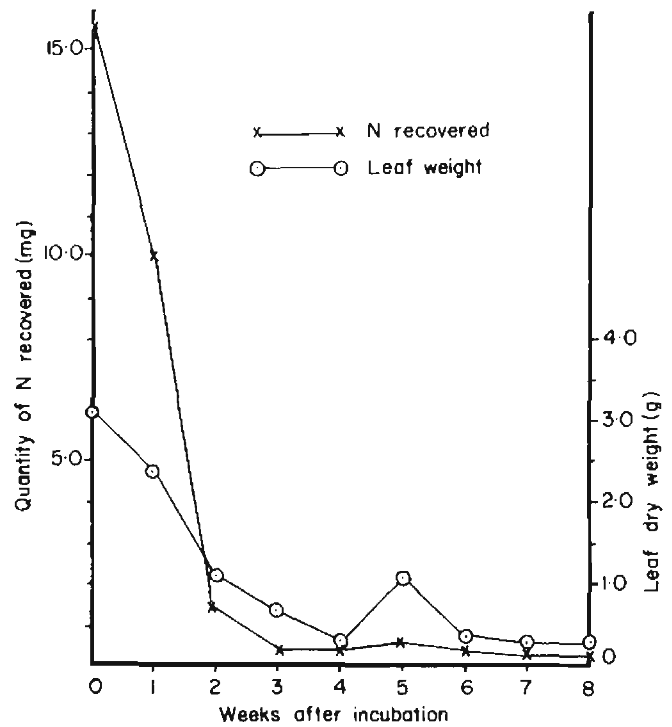


Fig. 18. Dry matter and Nitrogen recovery from** Leucaena **leaves during soil incubation.

Table 13. ***Dry matter and nitrogen yield of*** *Leucaena leucocephala* ***tops alley cropped with maize on Apomu soil. Nitrogen applied to associated maize crop.***

	N rate (kg N/ha)			
	0	60	120	180
First season (3 cuttings)*				
Dry matter yield (kg/ha)	3201	3508	3778	4748
N mean (%)	3.44	3.42	3.73	3.62
N yield (kg/ha)	95.7	107.7	125.9	153.8
Second season (2 cuttings)*				
Dry matter yield (kg/ha)	3043	2744	2747	3201
N mean (%)	3.81	3.37	3.62	3.29
N yield (kg/ha)	111.2	89.6	93.2	104.1

First season trimming April-June; and second season trimming, September-October.
Leucaena *row trimmed to height of 150cm.*

Table 14. ***Effect of rates and methods of application of*** *Leucaena leucocephala* ***tops and N rates on grain yield of maize variety TZPB grown on Apomu soil.***

N rate kg N/ha	*Leucaena* top added fresh weight tons/ha	Mulch	Incor- porated	Mean
		Grain yield kg/ha		
0 N	0	1740	1283	1511
	5	2013	2313	2163
	10	1855	3213	2534
50 N	0	2218	2093	2155
	5	2300	3035	2668
	10	2338	2578	2458
100 N	0	3138	3315	3226
	5	3028	3453	3240
	10	3023	3068	3045
Mean		2406	2706	
LSD (.05)				
Application method:				
Leucaena top		689		
Treatment:				
Within application method		1002		
Between application method		1146		

of this potential may not be achievable from leaves placed on the soil surface. Vocalization may be responsible for the loss of a high proportion of N. The efficiency of N utilization could be increased by incorporating leaves, but the accompanying increased hazard of soil erosion is a major deterrent to this modification. Leaf alone is an unlikely source for all nutrients. Other nutrient sources may have to supplement the leaf supplied nutrients.

Investigation on method of application of *Leucaena* tops. Results of this trial confirmed 1978 results (Table 14): *Leucaena* tops are more effective as a N source when they are incorporated into the soil. Maximum maize yields can be obtained with 10 t fresh *Leucaena* tops/ha, 50 kg N and 5 t fresh *Leucaena* tops/ha or 100 kg N/ha.

Nitrogen response of maize grown in rotation with grain legumes. This rotation trial is a continuation of a 1978 trial on an Egbeda soil. Higher maize yields were realized with the inclusion of grain legumes in the rotation, particularly without N or 45 kg N/ha treatments (Table 16). The first-season maize crop showed the same trend as in 1978 trials. Maize yield was highest with maize and cowpea and lowest with maize and maize. Maize and soybean were between these. The second-season maize crop showed no such trend partly due to late planting and drought effect.

Effect of N × S on maize/cassava intercropping. The effect of N and S applications on maize and cassava intercropping was studied at Ogbomosho. Results showed significant effects of N and S applications on the maize yield (Table 17). N and S interaction was not significant. The cassava crop also showed good growth responses to additions of N and S.

Acidification of Alfisols under continuous cultivation. The soil acidification plot on Egbeda soil at IITA has been continued for its fourth year. The plot, 20 subplots, was

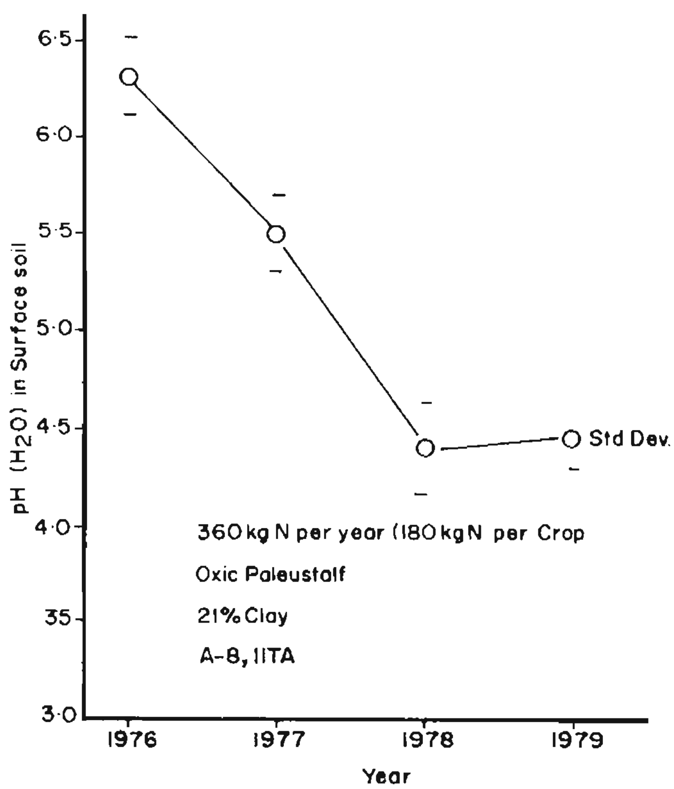


Fig. 19. Change in soil pH due to heavy nitrogen (N) fertilization (Ammonium sulfate) at IITA.

Table 15. Leaf yield and leaf nutrient content of shrub legumes spaced 200 cm x 50 cm.

	Leaf dry wt kg/ha	N kg/ha	N (%)	P kg/ha	P (%)	K kg/ha	K (%)	Maize yield kg/ha
Cajanus cajan	4100	151	3.6	9	0.2	68	1.6	3173.4
Tephrosia candida	3067	118	3.8	7	0.2	49	1.5	1912.2
Leucaena leucocephala	2467	105	4.2	4	0.2	51	2.0	2601.6
Glyricidia sepium	2300	84	3.7	4	0.2	55	2.5	2587.6
Control	-	-	-	-	-	-	-	2030.3
LSD (0.05)		19		2		8		
COV (%)		8		13		7		

Table 16. Effect of N rates and rotation on grain yield of maize variety TZPB grown on Egbeda soil.

Treatment N Rate kg N/ha	Maize-Maize FS*	Maize-Maize SS**	Maize-Maize Total	Maize-Soybean FS	Maize-Soybean SS	Maize-Soybean Total	Maize-Cowpea FS	Maize-Cowpea SS	Maize-Cowpea Total
					kg/ha				
0	812	826	1638	1045	1222	2267	1732	1046	2778
45	2556	1947	4503	3015	2710	5725	3044	2127	5171
90	3289	2648	5937	3427	2448	5875	3351	2318	5669
Mean	2219	1807		2496	2126		2709	1830	

LSD (.05) Between rotation means; FS 348; SS 280
Between fertilizer means within rotation; FS 489; SS 385
Between fertilizer means between rotation; FS 529; SS 421

*FS = First season maize grain yield following previous year second season maize, soybean or cowpea crops.
**SS = Second season maize grain yield following first season maize, soybean or cowpea crops.

Table 17. Effect of N and S application on grain and stover yields of maize variety TZPB intercropped with cassava grown at Ogbomosho.

S Rate kg S/ha	Grain yield (kg/ha) N Rate (kg N/ha) 30	60	90	Mean	Stover yield (kg/ha) 30	60	90	Mean
0	2104	2470	2870	2558	2710	3879	4111	3567
10	2287	3116	3683	3028	2970	4168	4930	4023
20	2470	3094	3970	3177	3709	4541	5465	4572
Mean	2287	2970	3507		2227	4196	4835	

LSD (.05) Grain yield 635; Stover yield 981
LSD (.01) Grain yield 860; Stover yield 1330

planted with two crops of maize (TZPB) each year. Each crop received high rates of N (180 kg N/ha as ammonium sulfate) and moderate rates of P and K (30 kg and 40 kg/ha, respectively).

Yield decline, due to soil acidification and possible manganese (mn) toxicity and magnesium (mg) deficiency, was reported earlier. Soil analysis taken each year prior to the first-season fertilizer application gave the following significant results:

1. Soil pH declined from its initial value of 6.3 to 4.4 in 1978 but stabilized to 4.5 in 1979 (Fig. 19).
2. Exchangeable Mg, Ca and K in the surface soil also declined with time (Fig. 20). The rate of decline follows the order of Mg, Ca and K, which is in agreement with the exchange selectivity sequence of these three cations found in the kaolinitic Alfisols and Ultisols. Such decline may be caused by a variety of factors such as the decrease in cation exchange capacity caused by the lowering of soil pH. The rapid decline of exchangeable Mg in soil under continuous cultivation with heavy-to-moderate NH_4^+ and K^+ fertilizers suggests that the use of

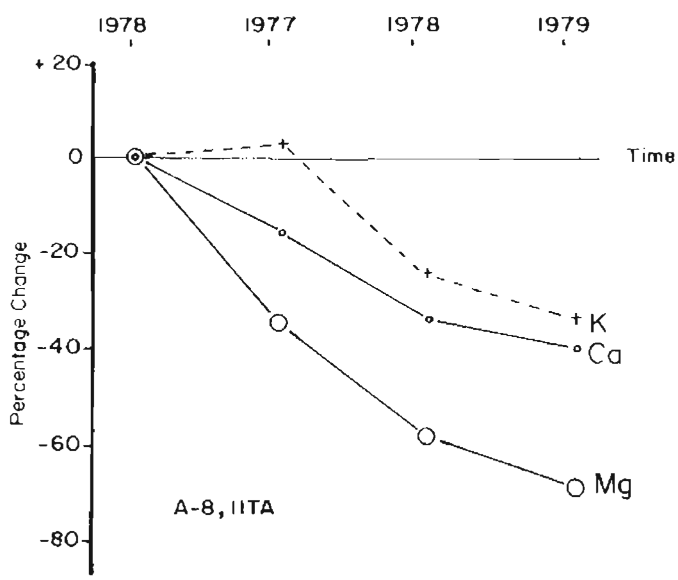


Fig. 20. Decline in exchangeable C, Mg, and K in surface soil (Oxic paleustalf) due to cropping and soil acidification at IITA.

Mg fertilizers may be required when exchangeable Mg has reached a critically low level for a specific crop.

Mineralization of soil organic matter after small-scale forest clearing. *To study the contribution of soil organic* matter to soil fertility and crop growth after small-scale forest clearing, an area of 0.25 ha under 15-year-old secondary forest was manually cleared. Soybean (TGm 294) was planted as the first crop. Maize will be planted as the second crop. To minimize the disturbance of the surface soil, no-till is used. The soybean was innoculated with *Rhizobium;* fertilizer is not used.

Changes in soil properties after each cropping will be *monitored with special emphasis on the mineralization* and availability of soil organic P, N, and S.

Fertility management problems of Ultisols

Nutrient leaching in Ultisols. *Laboratory leaching stud-*ies, using undisturbed Ultisol profiles from the Onne substation with a depth of 100 cm and diameter of 12 cm, showed the differential movement ot Ca and K ions, which were applied in the form of Ca $(NO_3)2$ and KNO_3 to the bare soil surface. The differential movement of Ca and K is closely related to the exchange selectivity of these two cations in the Onne soil; whereas, the downward movement of the Ca ion in the predominantly Ca-A1 system may be predicted by the Walter's equation of chromatographic transport (IITA Annual Report, 1978).

Analysis of the leachate after the application of 242 cm of water (equivalent to the annual rainfall at Onne) through a rainfall simulator showed that the nitrate anions applied to the *bare soil surface as a mixture of Ca* $(NO_3)_2$ and KNO_3 were completely recovered in the leachate (Table 18). The predominant cation leached with nitrate is $A1^{3+}$ (60 percent of total cations in meq), which is followed by CA^{2+} (26 percent) and Mg^{2+} (11 percent). About 65 percent of the Ca applied as calcium nitrate was retained in the profile.

Table 18. Leaching of Ca $(NO_3)_2$ and KNO_3 in Onne soil profile** (Typic paleudult)* ***under bare surface after 242 cm of water applied through a rainfall simulator.

Ions	In (meq)	Out (meq)	Retained (meq)
		Cations	
Ca^{++}	22.6	8.0	14.6 (65%)
$A1^{3+}$	-	18.8	-
Mg^{++}	-	3.3	-
Na^{+}	-	0.8	-
K^{+}	5.6	0.2	5.4 (96%)
Total	28.2	31.1	20.0
		Anions	
NO_3	28.2	28.3	-
Cl^{-}	-	0.6	-
Total	28.2	28.9	-

There were few K^+ ions found in the leachate. Of the 5.6 meq of K^+ applied as KNO_3, 96 percent was retained in the profile. The soil strongly retained K against leaching in this acidic and predominantly A1 saturated Ultisol profile. Moreover, soil analysis showed that nearly all the retained K was in the exchangeable form. Mineralization of nitrate in the undisturbed moist soil column (pH 4.5) during the 72-day leaching period was negligible as indicated by the balance of nitrate data (Table 19).

Table 19. Leaching of KNO_3 and Mg $(NO_3)2$ in Onne soil profile limed to pH 5.6 with Ca $(OH)_2$ under bare surface after 242 cm of water.

Ions	In (meq)	Out (meq)	Retained (meq)
		Cations	
Ca^{++}	22.6	4.3	18.3 (82%)
Al^{3+}	-	14.8	-
Mg^{++}	18.0	7.8	10.2 (56%)
Na^{+}	-	0.2	-
K^{+}	9.0	1.5	7.5 (83%)
Total	49.6	28.6	36.0
		Anions	
NO_3	27.0	25.7	-
Cl	-	0.5	-
Total	27.0	26.2	-

'Lime applied to 0 5 cm layer.

The column leaching experiments also examined the effect of liming on the mode of leaching and retention of Ca, Mg, K and nitrate in the Onne profile. Lime, $Ca(OH)_2$, was added to the surface 0-5 cm layer to *raise the pH* of this layer to 5.6. Nitrate was added as a mixture of $Mg(NO_3)_2$ and KNO_3 while the $Ca(OH)_2$ was the only source of Ca applied. Results of leachate composition again showed the near complete recovery of nitrate after 2,420mm of water (Table 19).

The amounts of the cationic species in the leachate were in the order of $A1^{3+}$ Mg^{++} Ca^{++} K^{+}. Ca ions in the surface 5 cm layer of the profile were apparently held by the *organic exchange sites. Of the 22.6 meq Ca applied as* $Ca(OH)_2$, 82 percent was retained in the profile.

To further detect the nitrate (KNO_3) movement within the undisturbed soil profile, water was added on the basis of pore volume of the profile of the unsaturated soil (a 45 cm column length was used in this experiment). An example of this experiment is shown in Figure 21. After a 0.4-pore volume of water was added at a tension provided by a 150 cm head, the vertical distributions of nitrate, pH and exchangeable K clearly showed that nitrate moves rapidly with water along with $A1^{3+}$ (or $A1(OH)^{+}$ and H^{+}) ions as indicated by the corresponding pH profile. Potassium (K) moves differentially with nitrate because of the preferential adsorption of K^{+} at the *exchange sites.*

From the laboratory investigations, these conclusions can be drawn:

1. Nitrate moves readily in this acid, kaolinitic Ultisol. The leachate is strongly acidic because of the presence of $A1^{3+}$ ions. This poses a serious question about whether roots of common plants and crop species would be capable to explore the sub-soil nitrate if it coexists with $A1^{3+}$ ion in the soil solution.
2. Potassium, when applied in small or moderate amount, is preferentially absorbed by the soil in exchangeable form against leaching losses. Cal-

cium, when applied in adequate amounts as lime, neutralizes the exchange acidity (A1 + H) and is held preferentially on the organic exchange sites in the surface layer. Magnesium ions are more readily lost through leaching than Ca and K ions. Thus, Mg deficiency in crops could be easily induced by inadequate and imbalanced fertilization under such soil and climatic conditions.

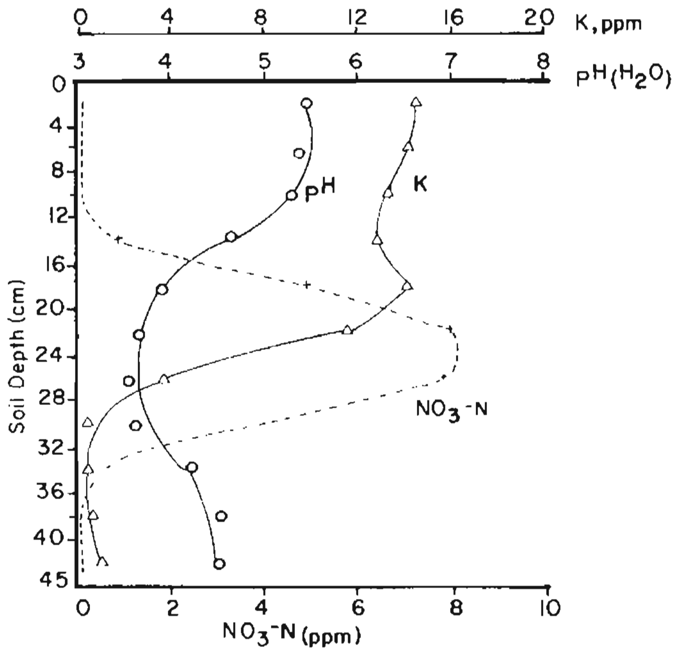


Fig. 21. Vertical distribution of NO_3-N, PH and K in undisturbed soil column after 0.4 pore volume of water was added under unsaturated flow. 22.4 meq of KNO_3 were added to the surface.

Large tension drained lysimeters. The cutting and lifting of six monolith lysimeters at the Onne substation were completed during the early part of 1979 with technical assistance from the Letcombe Laboratory, U.K. The lysimeters will enable monitoring of leaching losses of nutrient NO^-_3, K^+, Ca^{2+}, Mg^{2+}, Mg^{2+} under different cropping sequences and fertilization schemes.

Long-term liming trial on Ultisol at Onne — maize and cowpea. Plots were established in 1976 with five rates of lime (0, ½, 1, 2, 4 t/ha as $Ca(OH)_2$) at the Onne substation to study the response of IITA maize and cowpea cultivars to liming and soil A1 levels, monitor the persistence and downward movement of applied Ca (lime) and other nutrient cations and anions under high-rainfall conditions (i.e. K^+, Mg^{2+}, NO_3^-). Lime had not been added since the experiment began in 1976. Maize (TZPB) was planted in the first season and cowpea (VITA-1 and VITA-4) in the second season with adequate fertilization of N, P, K, Mg, S, Zn and Mo. Except for initial land preparation (plow and harrow) and incorporation of lime into the surface soil, no-till has been practiced and crop residues were returned as surface mulch.

With adequate and balanced fertilization, lime had no significant effects on the growth and yield of maize initially in 1976. In 1979, significant yield response to initial lime rates was observed. The plots received lower rates of lime because of increased exchange A1 saturation (Fig. 22). The plots that received 1 and 2 t lime/ha main-

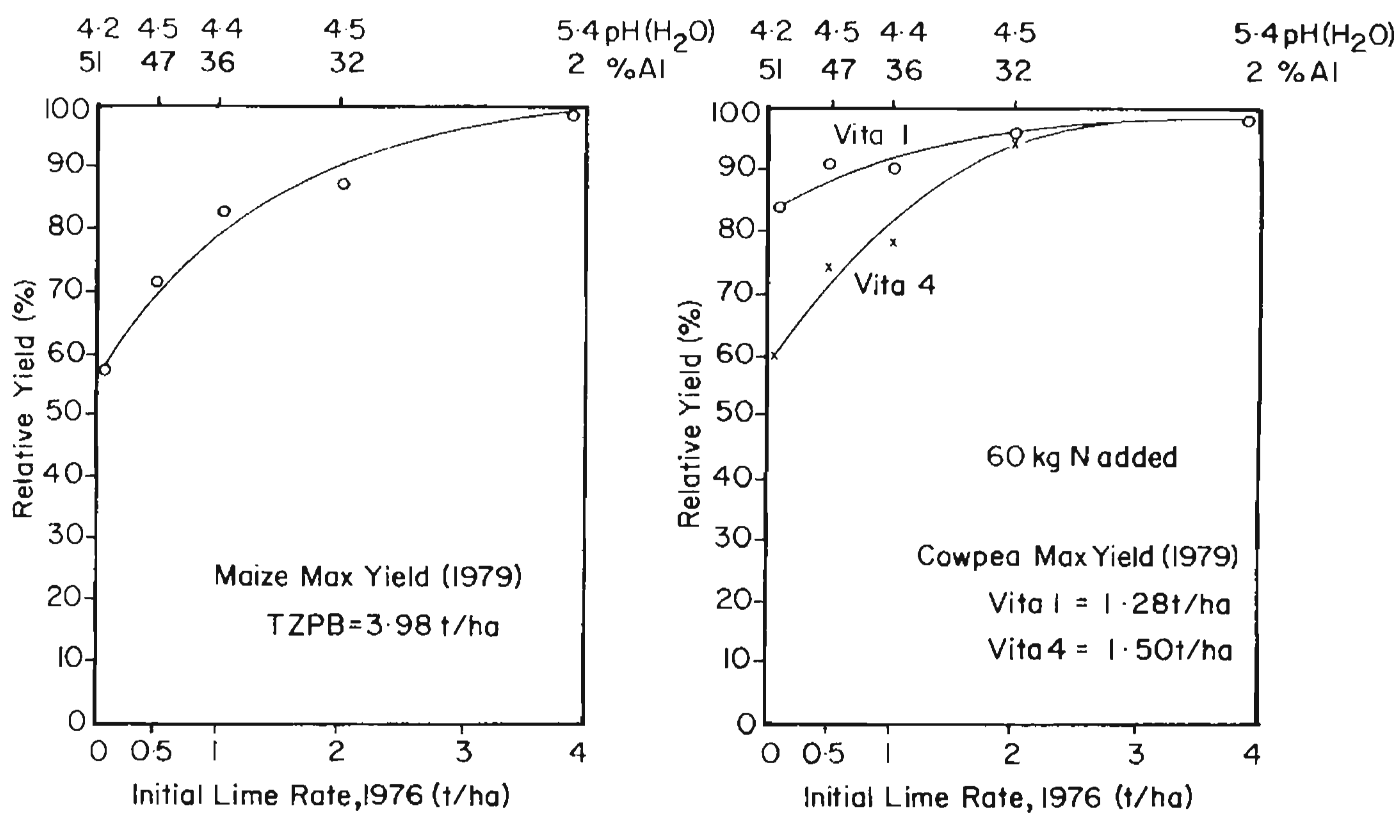


Fig. 22. Relative grain yield (12 percent moisture) of maize variety TZPB and two cultivars of cowpeas, VITA 1 and VITA 4, as affected by percent A1 saturation three years after liming.

tained approximately 80 and 90 percent of maximum yield, respectively, 3 years after liming. The exchangeable A1 and pH (H_2O) of the surface soils taken before planting in March, 1979, are also given in Figure. 22. These data suggest that the exchangeable A1 saturation *is a more indicative criterion than soil pH for estimating* the level of soil acidity as well as lime requirement for specific crops grown in acid soils with "low activity clays."

For the cowpea crop in the second season, results showed that high exchangeable A1 saturation and/or low soil Ca level in the check plots significantly affected nodulation, N-fixation, growth and grain yield of cowpea varieties VITA-1 and VITA-4. To minimize cowpea nitrogen stress due to poor nodulation, 60 kg of N/ha (urea) was applied to all treatments in 1979 along with other nutrient elements (P, K, Mg, S, Zn, Mo). In the presence of nitrogen fertilizer, both varieties grown in all treatments were green and healthy. There was little visual difference between the no-lime and lime plots observed about 45 days after planting. However, in spite of the normal vegetative growth, yield data showed significant differential responses to soil A1 and/or Ca levels (Fig. 22). VITA-1 is more tolerant to A1 toxicity than VITA-4 although both varieties show considerable tolerance to high A1 saturation and low soil pH and soil exchangeable Ca.

Thus, the maize and cowpea varieties tested showed tolerance to high soil acidity and relatively low exchangeable Ca levels when other nutrients (N, P, K, Mg, S, Zn, Mo) are adequately supplied. In order to maintain stable and near maximum yield, an exchangeable A1 saturation *level of* 35 percent lower may be required for both maize (TZPB) and cowpea (VITA-1 and VITA-4). Maize yield (3.98 t/ha first-season crop) may be partly attributed to the three split applications of nitrogen (total rate of 150 kg/ha), and better insect control and bird scaring. Despite the insect and disease pressure at the Onne substation, cowpea yield may be high if sown in mid-October as a late rainy season crop (IITA Annual Reports 1977 and 1978).

Changes in soil pH, A1 and Ca levels in surface soils with time have been reported previously (IITA Annual Reports, 1976, 1977 and 1978). During 1979, detail core samplings were made in all plots prior to planting maize in the first-season. Soil samples were taken at 15-cm intervals up to a 90 cm depth, and 30 random cores were taken from each plot. Results of soil analysis reveal two important changes in soil chemical properties after three years of continuous cropping.

First, there is considerable downward movement of applied Ca (Table 20). At a lime rate of 2 t/ha, approximately 45 percent of the applied Ca moved beyond the 15 cm surface layer after three years but were entirely redistributed within the 0-90 cm depth of the profile. These data confirm the laboratory profile leaching studies, which showed that nitrate leached predominantly with A1 ions in this acid Ultisol. The slower movement of Ca beyond the 90 cm depth may be also attributed to the split application of N fertilizer and returning crop residue as surface mulch. A lime rate of 2 t/ha was required to raise the surface soil to pH (H_20) near 5.5 initially in 1976. The same limed surface soil after 3 years gave a pH (H_20) value of 4.5.

Second, there is a significant change in soil property because of the buildup of soil exchangeable K (Table 21). The surface soil received 300 kg K/ha/annum (150 kg K/crop) for 3 years. The present levels of soil exchangeable K (0.20 to 0.30 meq/100 g) in the surface layer are considered adequate for most crops grown in these coarse-textured soils. The increase in soil exchangeable K with time under field conditions again confirms the results obtained from previous studies of column leaching and ion exchange selectivity.

Effect of fallow and crop residue management on fertility of acid Ultisol at Onne. Trials were established in 1978 at the Onne substation to provide a better understanding of the importance of the traditional practice of burning the fallow residues during land preparation, particularly on acid soils. Burning of the fallow added about 563 kg ash/ha. This resulted in an increase in soil pH, extractable P and cations. In turn, this helped to reduce exchangeable soil acidity in the surface soil (Table 22).

Trials were continued in 1979. Results of the second-season cowpea crop showed no differences with burning or mulching (Table 23); there were also no significant treatment effects. Results of the second-year maize crop showed slightly better yields with burning. Overall, however, there was large yield reduction in the second year maize crop without fertilizers. Highest yields were obtained with NPK, Mg, Zn and residual lime treatments.

To further study the effect of fallow burning on soil properties, the effect of ash and soil heating on the phosphate (P) sorption capacity of the soil was determined. Addition of lower ash rates resulted in P desorption while addition of higher ash rates resulted in P sorption. The effect of soil heating or P sorption is shown in Figure 23. Increased temperatures increased P sorption. This may be due to a loss of soil organic matter coating of the soil adsorbing complex or an increase in the amorphous Fe with soil heating at high temperatures, which will increase the P sorption capacity of the soil.

Effect of liming and K and Mg applications on cassava grown on acid Ultisol at Onne. The K and Mg response of two cassava varieties was studied on the Ultisol at the Onne substation. There were no differences in tuber *yields between the two varieties harvested at 13 months* after planting. No significant yield differences due to K and Mg applications were observed (Table 24). Although there was yield reduction with TMS 30211 with increased K and Mg application, TMS 30395 appears to respond to low levels of K and Mg applications.

Lime response of cassava varieties. The lime response of five cassava varieties was studied at the Onne substation (Table 25). Differences in lime response appear to exist among varieties. TMS 30395 and TMS 30211 slightly responded to liming while TMS 30555 was less affected and TMS 30572 showed a yield reduction. In general, all the TMS varieties had low yields with 4 t lime/ha. Isunikankiyan, the check, had the lowest.

Fertility management problems of hydromorphic soils

Effect of water management and N application on rice in hydromorphic soil. To determine the long-term effect of water management and N application on soil productivity and rice crop performance, a trial was carried out on a hydromorphic soil (Inceptisol). Results of five croppings are shown in Table 26. Significant response to N

Table 20. Downward movement of calcium in limed soil at the Onne substation three years after lime application.

Depth cm	Exch. Ca, meg/100g No Lime	2 t/ha
0-15	0.42	1.89
15-30	0.32	0.79
30-45	0.30	0.49
45-60	0.30	0.51
60-75	0.28	0.58
75-90	0.32	0.62

Table 21. Change in soil exchangeable K within three years under high rainfall condition (2400 mm p.a.)

Depth	Exchangeable K, meq/100g**				
		1st Yr. (1977)		3rd Yr. (1979)	
cm	Initial	L_0#	L_3	L_0	L_3
0-15	0.09	0.24	0.26	0.21	0.31
15-30	0.03	0.09	0.08	0.16	0.21
30-45	0.03	0.07	0.06	0.14	0.18
45-60	0.3	-	0.06	0.15	0.14
60-75	0.02	-	0.05	0.15	0.14

#L_0. No lime applied; L_3: 2 t $Ca(OH)_2$/ha applied in 1976.
***Total amount of 900 kg K/ha applied during three years (six cropping seasons).*

application was noticed in the fourth rice crop in both irrigation and rainfed conditions. Starting from the fourth crop, yield of rainfed rice with and without N application declined. Eighty kg N/ha may not be adequate for the rainfed bunded rice. Yield of irrigated rice declined without N application but not drastically, and it was maintained at high levels with N application.

Effect of N application and tillage. The grain yield of rice was not significantly affected by the tillage systems

Table 24. Effect of K and Mg application on tuber yield of cassava cultivars TMS 30395 and TMS 30211 grown on the Onne substation Ultisol.

Fertilizer treatment (kg/ha)		TMS 30395 Tuber yield (t/ha) Fresh	Dry	TMS 30211 Fresh	Dry
K	Mg				
0	40	13.47	5.48	16.00	5.52
30	40	14.14	5.67	13.95	4.90
60	40	17.70	6.95	13.97	4.71
120	40	11.80	4.78	13.67	4.81
120	0	13.83	5.11	13.74	5.06
120	20	16.24	6.32	17.81	6.62
Mean		14.53	5.72	14.86	5.27

LSD 0.05 variety means fresh tuber 1.45, dry tuber 1.15
between fertilizer treatments within variety fresh tuber 4.05, dry tuber 1.73
between fertilizer treatments among variety fresh tuber 3.94, dry tuber 1.91

Table 22. Effect of fallow residues burning on some soil chemical properties of the Onne substation Ultisol.

Soil	pH	Organic C (%)	Bray I-P (ppm)	NH_4OAc extactable cations (me/100 g) Ca	Mg	K	Mn	Acidity (Al^{3+} + H^+)	
			0-7.5 cm						
BBO	4.30	1.73	108	1.32	0.39	0.16	0.04	1.44	1.92
ABO	5.00	1.82	123	2.96	0.85	0.33	0.14	0.08	0.53
			7.5-15 cm						
BBO	4.30	1.19	100	0.76	0.23	0.10	-	1.50	2.01
ABO	4.40	1.09	101	0.58	0.22	0.12	0.01	0.75	1.75
			15-30 cm						
BBO	4.40	0.76	89	0.33	0.13	0.06	-	1.68	2.06
ABO	4.30	0.69	71	0.32	0.12	0.06	-	0.93	1.94

Table 23. Effect of previous fallow and crop residue management on maize and cowpea grain yields on the Onne substation Ultisol.

Treatment	First year after clearing (1978) Maize (TZPB) mulch	burn	Compea (TVx 1193-7D) mulch	burn	Second year after clearing (1979) Maize (TZPB) mulch	burn
			(kg/ha)			
Control	1740	1190	1138	1010	556	595
NPK	3412	2727	1128	1045	2190	2036
NPK Mg Zn	2878	2802	1203	1156	1682	2233
NPK Mg Zn + lime	3495	3008	1282	1223	1799	2355
Mean	2881	2431	1188	1109	1557	1805
LSD (0.05)						
between residue management means	671		160		249	
between treatments among residue management	679		271		746	

though the grain yield increased with increasing rates of N application (Fig. 24). In the 1979 first season, the rice with conventional-till responded more favorably to N application than rice with no-till.

Bench-mark soil characterization and soil fertility classification

A sizable number of selected "bench-mark" soil profiles, representing a wide range of land forms, parent materials and classifications have been characterized according to their morphological, chemical, physical and mineralogical qualities.

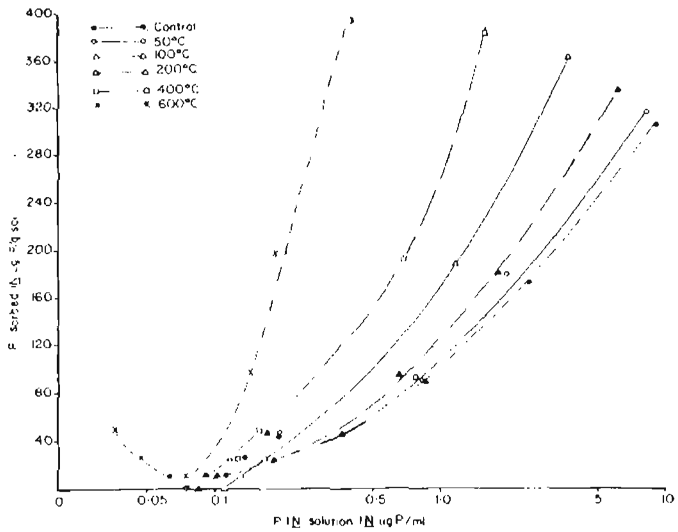


Fig. 23. The effect of heating Onne surface soil on phosphate sorption.

The sampling sites were carefully selected on the basis of published soil and land resources survey reports. Data are being compiled and summarized with the main objective of providing agricultural researchers with com-

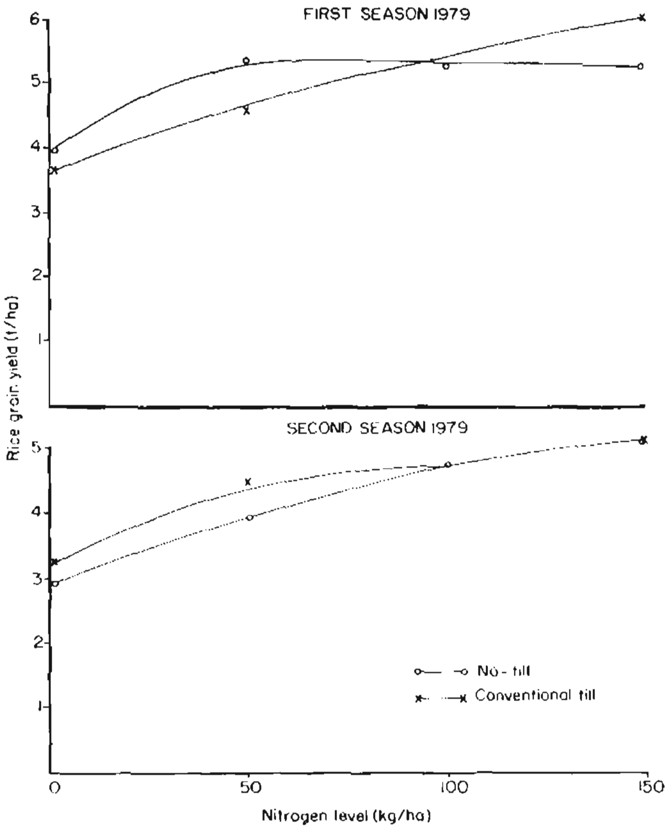


Fig. 24. Effect of N application and tillage on rice yield.

Table 25. Effect of liming on fresh tuber yield of five cassava varieties grown on the Onne substation Ultisol.

Lime rate (t/ha)	30572	30395	30211	30555	Isunikankiyan	Mean
	Variety (t/ha)					
0	31.65	15.33	32.81	31.58	4.75	23.22
0.25	28.25	20.69	42.75	30.50	9.56	26.35
0.50	29.25	25.19	39.00	27.00	6.38	25.36
1.00	28.19	29.00	30.13	32.31	4.38	24.80
2.00	25.88	21.50	31.88	28.88	4.63	22.55
4.00	21.38	23.42	35.17	21.56	4.63	21.23
Mean	28.43	22.52	35.29	28.64	5.72	

LSD 0.05 between lime rates means 1.34.
between varieties means 3.55.

LSD 0.05 between lime rates within variety 8.68.
between limes

Table 26. Effect of water management and N application on grain yield of rice variety BG 90-LL grown in hydromorphic soil at IITA at various harvest dates.

Treatments	1978 March	1978 August	1978 December	1979 May	1979 September	Mean
	(kg/ha)					
Irrigated 0N	4518	6723	4840	4215	4390	4937
Irrigated +N	4490	6778	5925	5020	4702	5383
Bunded-rainfed 0N	4618	6700	5050	2042	2005	4083
Bunded-rainfed +N*	4780	7378	6095	3553	3457	5053
LSD (0.05)	805	657	1148	855	1627	

*N rate, 80 kg N/ha applied since August, 1978.

prehensive information on the quality and limitations of major soils in tropical regions.

The concept and methodology of the FCC system (soil fertility capability) developed by the Tropical Soils Program at North Carolina State University, U.S.A., is being adopted and revised. The importance of parent materials on soil chemical and physical fertility is stressed. A simplified soil fertility capability groupings of Alfisols, Ultisols, Oxisols and associated hydromorphic soils common in West and Central Africa are given in Table 27.

The revised FCC "condition modifiers" and textural types are described as follows. Certain revisions are made on the basis of recent research data. Moreover, the NCSU/FCC system was primarily derived from soil characterization and fertility studies from Latin America with little input from Africa.

Textural types (0-20 cm and 20-50 cm).

S = Sandy, > 85 percent sand.
L - Loamy texture, < 35 percent clay.
C = Clayey texture, > 35 percent clay.
R Quartz or ironstone gravels or other hard root restricting layer present in 20-50 cm depth.

Condition modifiers (0-50 cm).

e Low effective CEC (< 4 meq/100 g of soil) between 0-50 cm depth.
h = Acidic exchangeable A1 saturation (10-45 percent), pH (H_2O) less than 5.5.
a = A1 toxic, exchangeable A1 saturation greater than 45 percent.
k = K deficient, exchangeable K less than 0.15 meq/100 g of soil, less than weatherable minerals in silt and sand fraction.
i = High P fixation, standard P requirement at 0.2 ppm in solution greater than 350 ug/g.
m = Mn toxicity, soil pH below 5.0 for soils derived from high Mn-containing parent rocks.
t = Secondary and micronutrient deficiencies (i.e. Mg, S, Zn).
w = Low available water reserve (i.e. less than 50 mm).
d = Dry, Ustic or Xeric environment, soil remains dry for more than 60 consecutive days per year within 20-60 cm depth.
r = High erosion hazard, unsuitable for large-scale food crop farming.
q Wet, or aquick soil moisture regime. The profile is saturated during most part of the growing season.
f Fe toxicity in wet-land rice.
* = Soil fertility constraints resulting from continuous cropping with moderate to high rates of chemical fertilization and inadequate soil management.

Table 27. Soil fertility capability groupings of Alfisols, Ultisols and Oxisols in West and Central Africa.

Soils (great group)	Parent materials or rocks	Land form or topography	Textural type	Condition modifiers
		I. Alfisols		
Paleustalfs Plinthustalfs	Granitic gneisses Granites Quartz-schists	Rolling to undulating	LL or LLR	e t* m* r w d
Paleustalfs	Coastal sediments Sandstones	Flat to undulating	LL	e t* w d
		II. Alfisols and oxisols		
Paleusutults Plinthustults	Coastal sediments Sandstones, shales	Undulating to rolling	LL or SL LL or SL	e h k w d r t*
Paleudults	Coastal sediments	Flat to undulating	LL or SL	e h a* k t*
Paleudults Tropudults	Granites Quartz-schists Acid gneisses	Rolling	LL, SL, LLR	e h k a* t* r
Tropohumults Tropudults Tropohumox	Basalts Diabases Amphibolites	Rolling to hilly	LC, CC	e k i h*
Haplorthox	Old alluvium	Level river terrace Small upland plateau	LL, CC	e k h a* t*
		III. Hydromorphic soils		
Aquolls Aqualfs	Colluvium or alluvium	Inland valleys	SLR, LLR, LL	q f
Aquults Aquox	Colluvium or alluvium	Inland valleys or lower river terrace	LL, LC, CC	q h f e
Aquents Aquepts	Alluvium	Inland valley and swamps; river deltas and flood plains, mangrove swamps	LL, SL, LC, LLR, SLR, CC	q, other modifiers vary widely

Agricultural hydrology and watershed management

The Hydrology and Watershed Management Project was initially cropped with maize in the 1979 first season.

Changes in meso/micro climatic factors. Changes in climatic variables on two watersheds, one forested and the other cleared, were undertaken as a study. The meso/micro climatic changes, resulting from deforestation and variously cropped surfaces, were monitored. Comparative measurements of temperature, relative humidity and rainfall components were made, using standard instruments. The results reveal significant changes in the aerial environment with changes in the surface cover through clearing and cropping.

Table 28 summarizes the repartition of incoming rainfall by the vegetative cover under the forest conditions into throughfall, stemflow and canopy interception.

From the mean throughfall figure of 73 percent, the direct reduction of rainfall impact on the soil by the forest cover amounts to only 27 percent. Considering the relative absence of erosion under the forest conditions, the protection of the soil against erosion by the forest cover must be largely through the reduction of the impact velocity of the drops reaching the forest floor as throughfall.

A linear relationship was found between gross rainfall and throughfall and stemflow, respectively (Figs. 25 and 26). The corresponding relationship between rainfall and interception appears to be exponential.

Temperature and relative humidity extremes were accentuated by the removal of the forest, the increases being larger for the maximum temperatures (up to 5.6°C) and the minimum relative humidity (Figs. 27 and 28).

Land clearing methods

After monitoring the water balance and sediment loss in the forested catchment for about 3 years, the catchment was divided into 12 subcatchments of 3-4 ha each. The effects of change in land use on sediment loss and hydrological parameters were investigated for the following treatments:

1. Forested control.
2. Traditional clearing and management — shifting cultivation.
3. Manual clearing followed by *in situ* burning — no till.
4. Manual clearing followed by *in situ* burning — terraced conventional-till.
5. Crawler tractor clearing with shear blade attachment — no-till.
6. Crawler tractor clearing with tree pusher/root rake attachments — no-till.
7. Crawler tractor clearing with tree pusher/root rake attachments — terraced conventional-till.

The manual operation was the slowest of land clearing in terms of time required and the effective stumping to pre-

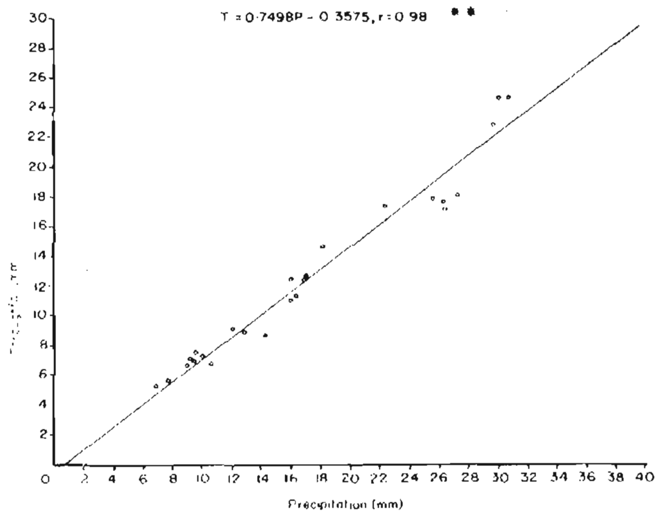


Fig. 25. Throughfall as function of precipitation in a secondary forest (IITA, 1979).

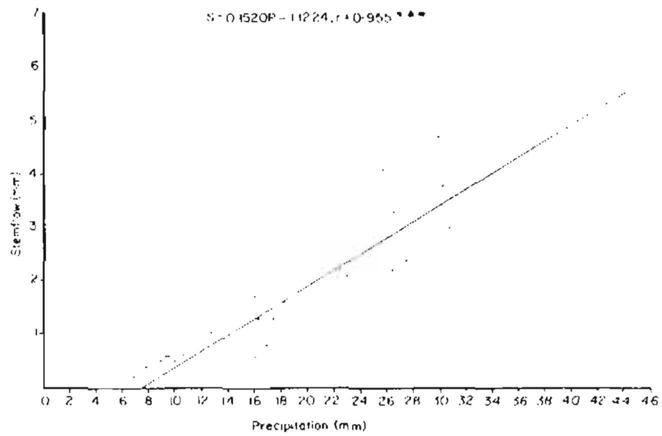
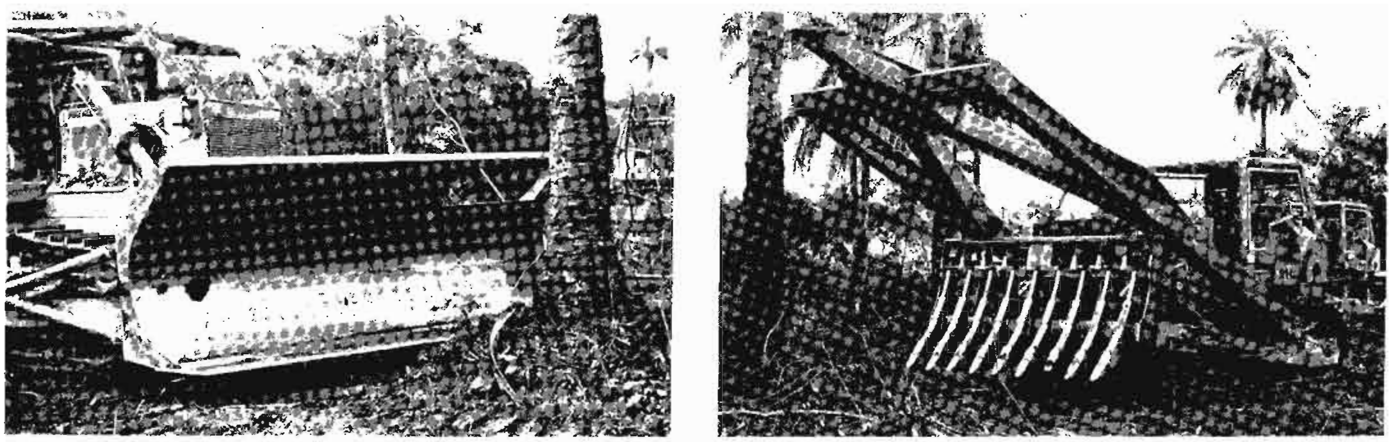


Fig. 26. Stemflow as a function of precipitation in a secondary forest (IITA, 1979).

Table 28. Rainfall and component over a forest watershed (IITA, 1979).

Variables	Period					
	May	June	July	Aug.	Sept.	Season
No of events*	5	6	7	5	7	30
Gross rainfall (P) mm	89.4	107.8	238.8	76.3	132.2	645.1
Throughfall (T) mm	68.4	85.0	170.0	50.8	98.8	473.0
Stemflow (S) mm	9.5	8.9	29.8	6.9	9.3	64.4
Interception (I) mm	11.5	13.9	39.0	18.6	24.7	107.7
T/P (%)	77	79	71	67	74	73
S/P (%)	11	8	12	9	7	10
I/P (%)	13	13	16	24	19	17

*Sampled events



In large scale land clearing experiments, the most efficient and quickest method was by crawlor tractor with a shear blade attachment (left), followed by a tree pusher/root rake attachment (right).

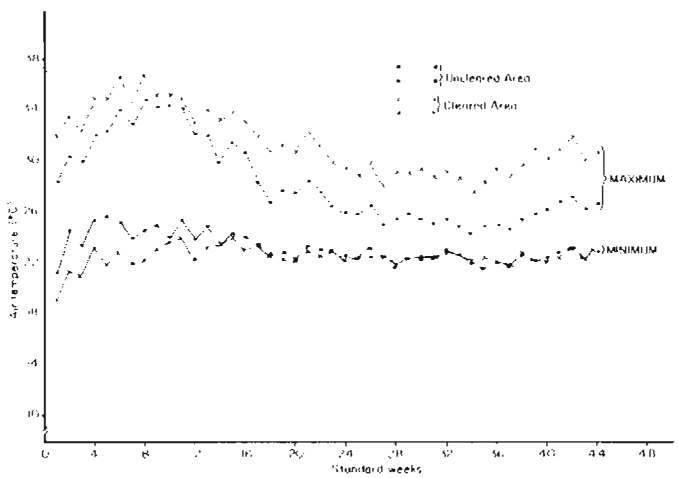


Fig. 27. Comparative weekly maximum and minimum temperature in cleared and uncleared areas (IITA, 1979).

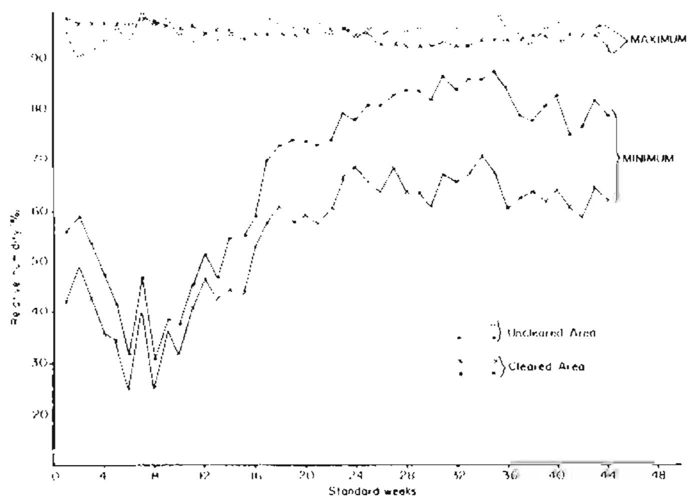


Fig. 28. Comparative maximum and minimum relative humidity in cleared and uncleared areas (IITA, 1979).

pare the land for mechanized planting and harvesting operations. It required about 180 man-days to cut and fell trees. On the contrary, the mechanized clearing with the shear blade attachments was the quickest and the most efficient method, followed by clearing with the tree pusher/root rake attachments. On the average, the shear blade cleared 1 ha in 1.9 working hours and the tree pusher/root rake in 2.7 hours. Consequently, the fuel consumption per ha was also less with the shear blade clearing (Tables 29 and 30).

Soil erosion

Methods of land clearing and soil management systems had a significant effect on water runoff and soil loss. Sediment density was related to the peak flow rate only in the conventional-till plots that were cleared with tree pusher/root rake attachments (Fig. 29). Land clearing with the root rake/tree pusher attachment resulted in a soil loss of 1,750, 7 and 4.5 times greater than with traditional, manual and shear blade clearing, respectively. The soil erosion on tree pusher cleared plots was a serious problem even with the construction of graded channel terraces. Severe gullies developed when the water

Table 29. Time required for manual clearing (man-days/ha). One working day is 8 hours.

Operation	Complete clearing (1)	Traditional clearing (2)
Underbush (3)	21 ± 5	21 ± 5
Cutting trees	96 ± 32	5 ± 1
Stumping and burning	60 ± 26	27 ± 6
Total	177 ± 9	57 ± 21

(1) Mean of 5 replications.
(2) Mean of 3 replications.
(3) Mean of 8 replications.

Table 30. Land clearing by mechanized (Fiat-Allis 21C) operations.

Clearing attachment	ha/hr	Fuel consumption (1/hr)
Shear blade	0.52 ± 0.12	40.8 ± 7.1
Tree pusher/root rake	0.37 ± 0.11	45.8 ± 9.7

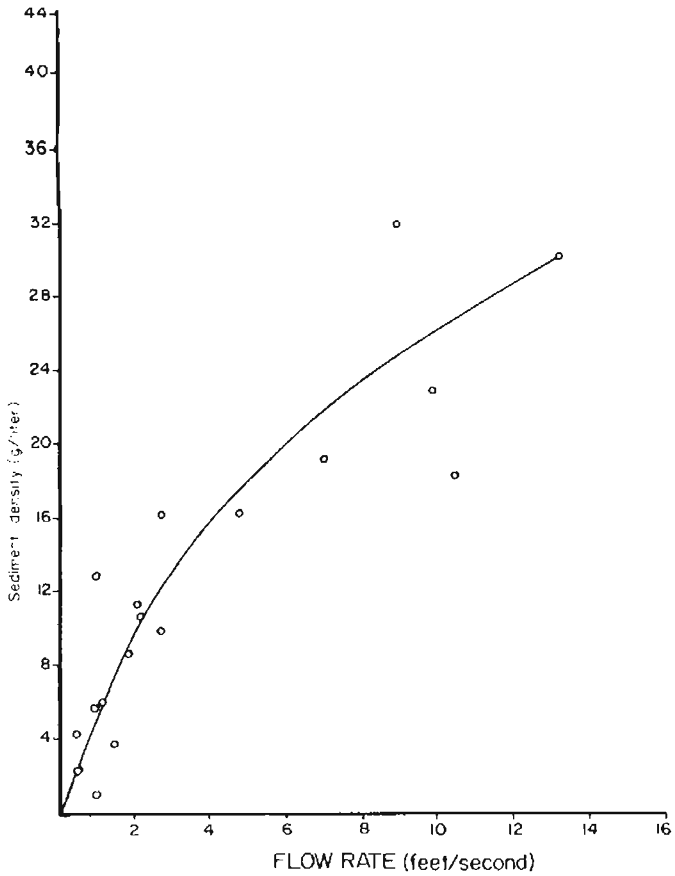


Fig. 29. The effect of peak flow rate on sediment density in water runoff.

from terrace channels drained into the main water way. Since the soil was disturbed considerably by the tree pusher clearing and the soil had scanty vegetation, no-till, following this clearing method, did not significantly decrease the erosion hazard.

Nutrient losses in water runoff

Observations on nutrient losses in runoff (Table 31) showed:

1. Losses of N and P are low.
2. Losses of K, Ca, Mg, Na, Fe and Zn are rather substantial.
3. Mechanical clearing and conventional-till systems resulted in high runoff and nutrient losses.

Low nutrient losses were observed with manual and traditional clearing followed by no-till. Concentrations of K and Na in runoff also tend to increase with increased discharge while those of Ca and Mg decreased. Concentrations of K, Ca, Mg and Na in runoff increased with time.

Nutrient status

Nutrient status of various plots from the hydrology project at time of planting is shown in Table 32. Except for P, all the plots showed adequate supply of other nutrients. The P status was more than adequate in the manual and traditionally cleared plots. They are, however, deficient in the tree pusher/root rake clearing. This was confirmed by a P deficiency observed in the maize grown in some of these treatments.

Table 31. Runoff and nutrient loss in runoff water for different land clearing and soil management treatments for the months July, August and September.*

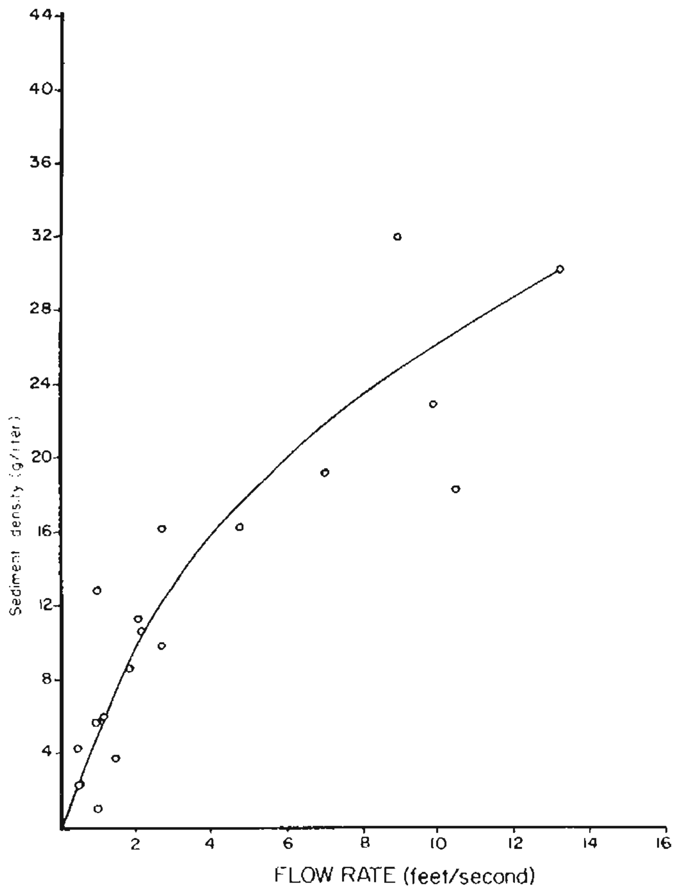
Treatments**	Runoff (mm)	NH_4-H	NO_3-N	PO_4-P	K	Ca	Mg (kg/ha)	NA	Cu***	Fe	Mn	ZN	Total
Manual-CT	23.988	0.035	0.232	0.003	2.369	1.555	0.409	4.295	tr	0.709	0.070	0.089	9.91
Manual-NT	5.310	0.027	0.039	0.003	0.958	0.374	0.094	1.052	tr	0.180	0.005	0.107	2.84
Tree pusher-CT	94.616	0.424	1.652	0.072	10.003	7.988	1.304	15.244	tr	4.299	0.354	0.584	41.87
Tree pusher-NT	66.375	0.651	0.514	0.080	6.713	3.996	1.364	6.999	tr	3.126	0.170	0.182	23.71
Bulldozer-KG blade	31.239	0.366	0.658	0.014	3.659	1.436	0.529	3.325	tr	2.109	0.260	0.170	12.56
Traditional clearing	12.75	0.095	0.138	0.0013	1.124	2.120	0.457	1.128	tr	0.127	0.041	0.094	5.33

*Data average of 2 replications, except traditional clearing, which was unreplicated.
**CT = conventional-till, NT = no-till.
***tr = trace 0.01.

Table 32. Some properties of surface and sub-soil samples from agricultural hydrology before cropping, 1979.

Treatment*	Depth (cm)	Texture sand %	silt %	clay %	pH	Organic C	Available P-Bray	Ca	Mg (meg/100 g soil)	K	Na
MC-CT	0-15	73.6	12.7	14.4	6.8	1.61	19.5	11.24	1.65	0.59	0.07
	15-30	73.6	10.8	15.5	6.4	1.05	3.9	5.70	0.83	0.25	0.05
MC-NT	0-15	74.3	13.9	11.9	6.8	1.54	12.9	10.20	1.71	0.70	0.08
	15-30	74.8	12.3	13.0	6.7	0.93	3.2	5.30	0.89	0.32	0.05
TP-CT	0-15	71.5	12.8	15.7	6.5	1.56	9.7	10.53	1.70	0.48	0.06
	15-30	71.4	11.4	17.3	6.3	1.31	7.5	8.01	1.48	0.37	0.06
TP-NT	0-15	7 .1	12.6	16.2	6.3	1.43	4.2	8.36	1.48	0.32	0.06
	15-30	69.8	11.8	18.6	6.3	1.13	2.0	6.59	1.17	0.22	0.06
KG-blade	0-15	69.2	15.5	15.4	6.2	1.72	10.2	12.86	1.99	0.58	0.07
	15-30	65.3	12.7	22.1	6.1	1.11	7.5	7.16	1.22	0.27	0.06
TC	0-15	73.1	14.4	12.5	6.6	1.55	14.0	9.81	1.68	0.60	0.07
	15-30	74.5	11.9	13.6	6.6	1.02	4.0	5.70	0.84	0.25	0.05

MC = manual clearing; TP = tree pusher; TC = traditional clearing; CT = conventional-till; NT = no-till.



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Traditional clearing	12.75	0.095	0.138	0.0013	1.124	2.120	0.457	1.128	tr	0.127	0.041	0.094	5.33

*Data average of 2 replications, except traditional clearing, which was unreplicated.

**CT - conventional-till, NT = no-till.

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	15-30	73.6	10.8	15.5	6.4	1.05	3.9	5.70	0.83	0.25	0.05
MC-NT	0-15	74.3	13.9	11.9	6.8	1.54	12.9	10.20	1.71	0.70	0.08
	15-30	74.8	12.3	13.0	6.7	0.93	3.2	5.30	0.89	0.32	0.05
TP-CT	0-15	71.5	12.8	15.7	6.5	1.56	9.7	10.53	1.70	0.48	0.06
	15-30	71.4	11.4	17.3	6.3	1.31	7.5	8.01	1.48	0.37	0.06
TP-NT	0-15	7 .1	12.6	16.2	6.3	1.43	4.2	8.36	1.48	0.32	0.06
	15-30	69.8	11.8	18.6	6.3	1.13	2.0	6.59	1.17	0.22	0.06
KG-blade	0-15	69.2	15.5	15.4	6.2	1.72	10.2	12.86	1.99	0.58	0.07
	15-30	65.3	12.7	22.1	6.1	1.11	7.5	7.16	1.22	0.27	0.06
TC	0-15	73.1	14.4	12.5	6.6	1.55	14.0	9.81	1.68	0.60	0.07
	15-30	74.5	11.9	13.6	6.6	1.02	4.0	5.70	0.84	0.25	0.05

MC = manual clearing; TP = tree pusher; TC = traditional clearing; CT = conventional-till; NT = no-till.

Maize yield

Traditional clearing produced the least maize grain yield, attributable to low plant density and the shading effect of large trees (Table 33). The plots cleared with the shear blade attachment yielded slightly higher than other treatments. Among mechanical clearing treatments, the tree pusher/root rake clearing followed by no-till produced the least yield. The soil compaction caused by heavy machinery combined with the very low P status may be responsible for this low yield on no-till plots.

The soil loss/grain yield ratio was significantly affected by methods of land clearing and tillage systems (Fig. 30). The relative soil loss/grain yield ratio from catchments cleared by the tree pusher/root rake attachments was about 100 times that from traditionally cleared plots and about 50 times that from manually cleared plots.

Table 33. Effects of methods of deforestation and tillage systems on maize grain yield (t/ha).

Land clearing treatment	Grain yield
Traditional method	0.50 a
Manual clearing—no-till	1.56 b
Manual clearing—conventional-till	1.59 b
Crawler tractor (shear blade)—no-till	1.98 b
Crawler tractor (tree pusher/root rake)—no-till	1.36 b
Crawler tractor (tree pusher/root rake)—conventional-till	1.75 b

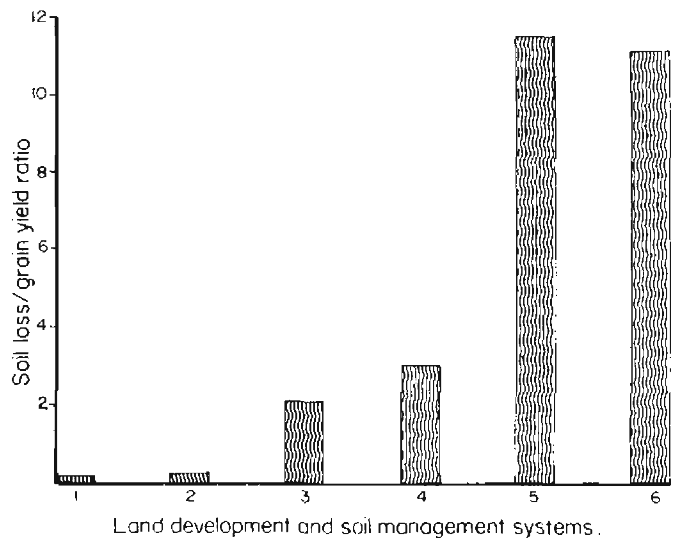


Fig. 30. Soil loss/grain yield ratio for different systems of land development and soil management.

1. *Traditional clearing and management —shifting cultivation.*
2. *Manual clearing —no-till.*
3. *Manual clearing with shear blade —no-till.*
4. *Manual clearing —conventional till.*
5. *Mechanical clearing with tree pusher/root rake —conventional till.*
6. *Mechanical clearing with tree pusher/root rake —no-till.*

Crop production

In crop production research, consolidation of previous findings into workable production systems was emphasized. Intercropping, especially maize-cassava intercropping, continued to show superiority in exploiting the environmental resources. Cover crops, tree and shrub legumes were integrated into the crop production systems in an effort to develop efficient, low-input and stable alternatives to the bush fallow system. To further assess the role of trees, particularly in traditional farming systems, an agro-forestry survey was carried out in Western Nigeria in 1979. Studies were also conducted into the problems of yield decline and apical dominance of plantain.

Investigations on identification of weed control methods in intercropping systems, in no-till systems and the role of live mulch in weed control and crop production were continued. The ecology and population dynamics of four species of stemborers were also investigated in mono- and intercropped maize and under no-till crop production systems.

Intercropping agronomy

Cowpea/cassava intercropping

Cowpea/cassava intercropping is an efficient way of integrating the high-protein cowpea into food production systems. To determine the best combinations, two cowpea populations and one cassava population were intercropped in four combinations and five planting relay times. The cassava was spaced at 100 cm × 100 cm. In combination one, cowpea was planted at 20 cm × 100 cm along the same ridge as cassava. In combination two, 2 rows of cowpea were planted on the sides of the cassava ridges, each about 30 cm from the top of the ridge. The planting times for either cowpea or cassava were 0, 7, 14, 21 and 28 days after the other crop in the same plot. Table 34 shows that earlier planted cowpea yielded more than later planted cowpea, but the differences were not significant.

Table 34. The effect of intercropping with cassava and planting time sequences on cowpea yield.

	Relay time in days					
Crop combinations	0	7	14 (kg/ha)	21	28	Mean
Casava (sole)	-	-	-	-	-	-
Cassava/1 row cowpea	653	526	862	350	462	438
Cassava/2 rows cowpea	552	615	402	364	335	454
Cassava 1 row (sole)	676	640	757	636	470	636
Cassava 2 rows (sole)	701	746	801	676	926	770
Cowpea 1 row/ cassava	470	376	204	427	304	356
Cowpea 2 rows/ cassava	725	733	825	723	748	757
Mean	629	606	574	529	502	

LSD 0.05 relay time, 803.
crop combination, 133.
means in the same combination, 326.
means in the different combinations, 851.

Table 35. The effect of intercropping with cowpea and planting time delay on cassava yield.

	Relay time in days					
	0	7	14	21	28	Mean
Crop combination			(kg/ha)			
Cassava (sole)	60900	53500	49500	41400	46200	50300
Cassava/1 row cowpea*	-	-	-	-	-	-
Cassava/2 rows cowpea	32900	25700	29000	28100	33200	29780
Cowpea 1 row	-	-	-	-	-	-
Cowpea 2 rows	-	-	-	-	-	-
Cowpea 1 row/cassava	26200	14300	8400	9600	6100	12920
Cowpea 2 rows/cassava	31700	17500	31900	24400	25600	26220
Mean	37925	17500	29700	25875	27775	

LSD 0.05 relay time, 9374.
crop combinations, 36925.
relay times in same combinations, 18749.
relay times in different combinations, 39956.
**Data not used; one main plot destroyed.*

Single-row cowpea relay planted with cassava yielded less than cowpea in other combinations or sole cowpea. Since low yields were also observed for cassava in the same treatment, the cause may be some natural variability. The sole cassava harvested at 18 months yielded more than cassava in the combinations, but the differences were not significant (Table 35).

Table 36 shows that cowpea-cassava intercropping is an efficient "land user" (land equivalent ratios (LER)). The overall results suggest that the planting of both maize and cassava should be at the same time, but there was not a clear pattern as to the number of cowpea rows. Cowpea/cassava intercropping should fit well into the second season of the bimodal rainfall pattern, especially where the season is too short for a second maize crop.

Table 36. Land equivalent ratio (LER) of cowpea/cassava intercropping at different relay planting times.

	Relay time in days				
	0	7	14	21	28
Crop combination			cm		
Cassava (sole)	-	-	-	-	-
Cassava/1 row cowpea*	-	-	-	-	-
Cassava/2 rows cowpea	1.3	1.2	1.1	1.2	1.1
Cowpea 1 row	-	-	-	-	-
Cowpea 2 rows	-	-	-	-	-
Cowpea 1 row/cassava	1.1	0.8	0.3	0.7	0.8
Cowpea 2 rows/cassava	1.6	1.3	1.7	1.7	1.4

**Data not used; one main plot destroyed.*

Maize/cassava intercropping

Using a standard interrow spacing of 100 cm, the effect of 30,000, 40,000, 50,000 and 60,000 maize/ha was tested on three maize varieties, TZE, TZPB and a local variety from Ondo State, Nigeria, intercropped along the same ridge with 10,000 cassava/ha.

The major differences observed were among maize varieties (Fig. 31). TZPB yielded significantly more than TZE, except at 60,000 maize/ha. TZPB and TZE yielded more than the local variety at all populations, but was only slightly significant at 50,000 plants/ha. This significance did not follow any definite trend and was not regarded as relevant. Differences between populations within cultivars were observed only between 40,000 and 60,000 maize/ha for TZPB.

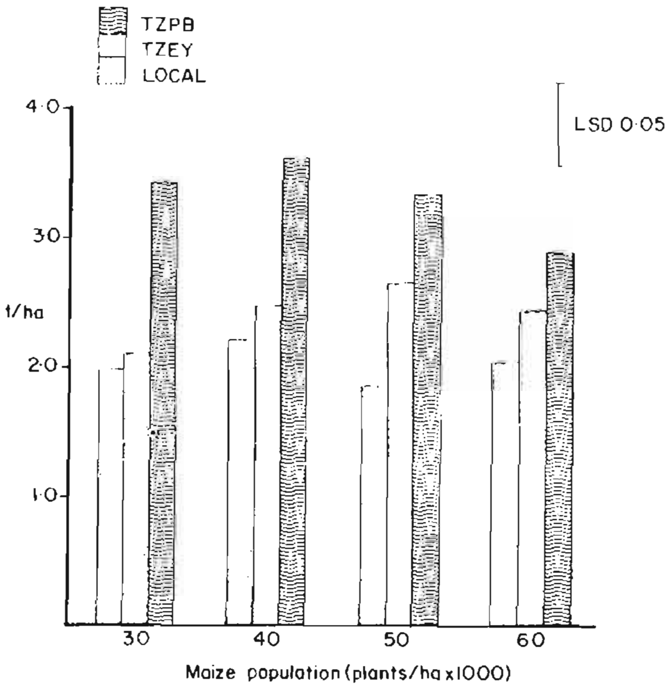


Fig. 31. The effect of maize plant density on three maize cultivars intercropped with cassava.

Figure 32 shows the effect of maize variety and density on cassava as measured by leaf area. The earlier-maturing TZE with the smaller leaf canopy and the least competitively suppressive had a significantly higher leaf area while the later-maturing TZPB with the larger leaf canopy and the most competitively suppressive had a significantly lower leaf area. The maize populations did not affect the cassava's leaf area development. Early maturity and lower-leaf density appear advantageous in maize/cassava intercropping. The results indicate that the optimum maize population for this combination and spatial arrangement lies between 40,000 and 50,000 plants/ha (Fig. 32).

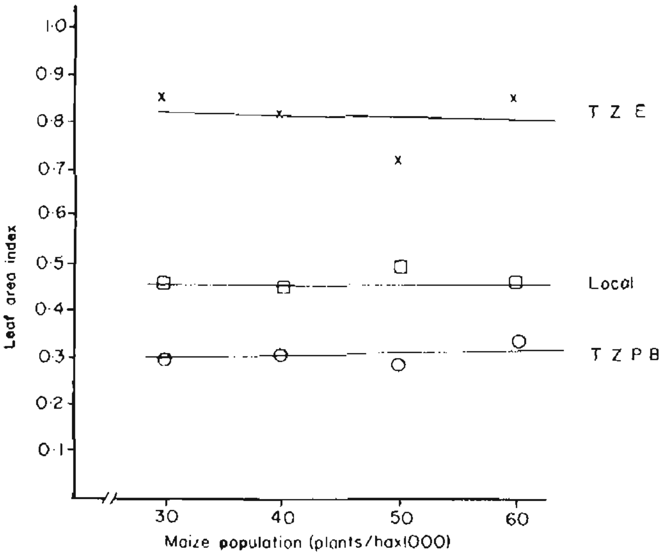


Fig. 32. Cassava leaf area index as affected by maize cultivar and population density in intercropping at maize harvest.

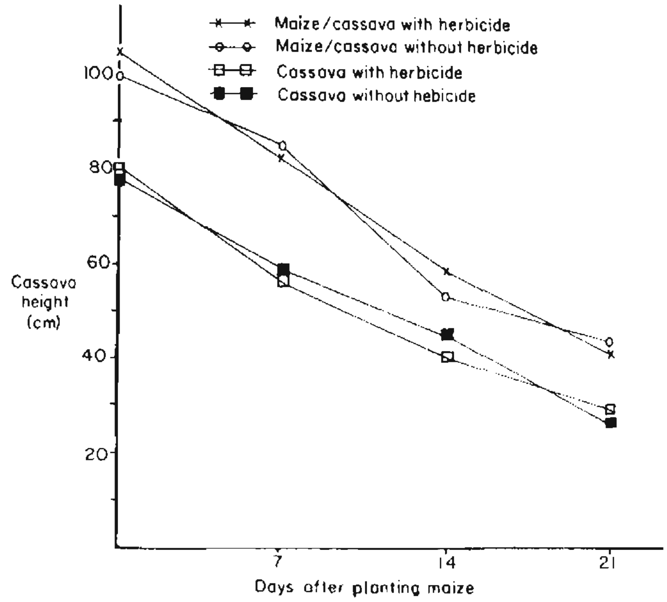


Fig. 33. Effect of relay period on cassava height in maize/cassava intercropping.

Partial mechanization. If maize/cassava intercropping efficiently uses land, it is a combination that is beneficial only to farmers who are without mechanization. It is confined to small areas manageable by hand tools. To extend the benefits of maize/cassava intercropping to large-scale production, the planting pattern must be modified to suit available machines, or new machines must be developed to meet the requirements of the crop combinations.

In this trial, maize was planted with a conventional two-row planter set to give 49,000 plants/ha at 1 m rows. Cassava was relay planted by hand 1 m apart along the same ridges as maize at 0, 7, 14 and 21 days after maize planting. The effect of the herbicide Primextra at 2.5 kg/ha a.i. applied pre-emergence at maize planting was also tested against three hoe weedings. A split-plot design was used.

The intercropping with cassava or the time of cassava planting had no significant effect on maize yield (Table 37). The herbicide treatment gave significantly lower yields than the hoe weeding. This reduction was attributed to weed regrowth and competition during the grain-filling stage. The effect of cassava planting time relative to cassava plant height at maize harvest is shown in Figure 33. The intercropped cassava was generally taller than the sole cassava. The shorter cassava from delayed plantings of 14 and 21 days prevented damage to the maize harvesting machines. This also indicated the minimum clearances for harvesting machines developed for this combination.

Maize clusters in maize/cassava intercropping. In the indigenous cropping practice of West Africa, farmers plant 5-10 maize/hill at 50-120 cm x 120-200 cm. Some farmers thin out the maize to 3 plants/hill; others do not allow *all* surviving plants to mature. The effect of the number of maize/hill on maize/cassava intercropping was tested in a trial. The maize was spaced 100 cm x 100 cm with 1, 2, 3, 4, 5, 6, 7 plants/hill for 10,000, 20,000, 30,000, 40,000, 50,000, 60,000 and 70,000 maize/ha, respectively. Cassava was spaced 100 cm × 100 cm between the maize and along the same row.

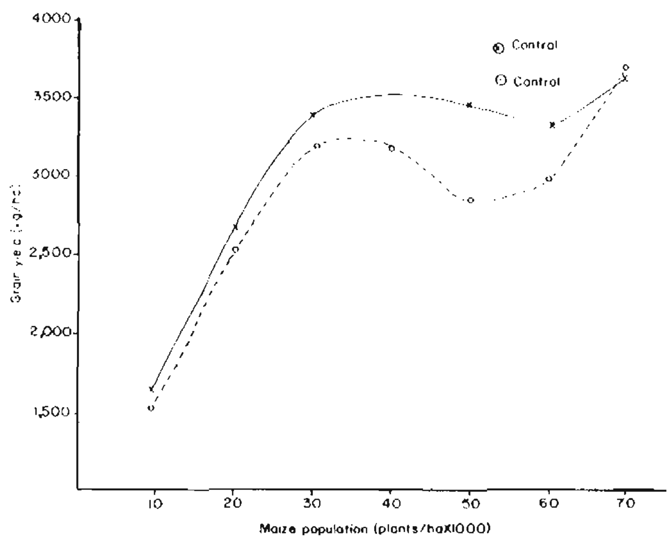


Fig. 34. The effect of maize population in maize/cassava intercropping on maize yield.

Table 37. Effect of herbicide and time of cassava relay planting on maize yield.

Cassava relay in weeks	Herbicide (kg/ha)	No herbicide (kg/ha)	Mean
Sole maize	4530	5415	4972
0	4060	5060	4559
1	3887	5101	4494
2	5059	5095	5077
3	4238	5149	4693
Mean	4355	5167	

LSD 0.05 herbicide treatment, 524.
cassava relay time, 724.
relay time same herbicide, 1024.
relay time different herbicide, 1041.

The control was sole maize at 75 cm × 25 cm for 53,333 plants/ha. This was the recommended spacing for sole maize at the localities, which were IITA and Ikenne. The *highest yield* was obtained at 70,000 maize/ha, but the differences were not significant from the controls at 30,000 and 40,000 maize/ha (Fig. 34). The yield of 3 maize/hill (30,000 maize/ha) is optimum, but thinning to 3 maize/hill may not be economical where maize grain yield is concerned. However, thinning may have value where green maize, which size is negatively correlated to plant population, is desired.

Crop combinations and sequences. Full exploitation of the resources depends on the development of efficient crop combinations and sequences. Some effective intercropping combinations such as maize/cassava and cowpea/cassava have already been identified, but these must be phased with the climatic cycle for maximum benefits. To this end, a set of combinations and sequences are being tested in various locations, including IITA and Ikenne. The combination and sequences are:

1. Maize-cassava.
2. Maize (1) (75 cm × 25 cm) — cowpea — maize (1) — maize (1).
3. Cassava-cassava.
4. Maize (2) (100 cm × 100 cm with 3 plants/hill)/cassava — maize (2)/cassava.
5. Maize (3) (100 cm × 25 cm)/cassava — maize (3)/cassava.
6. Maize (1) — cowpea/cassava — cowpea.
7. Maize (2) — maize (2) — maize — maize (2)/pigeon pea.
8. Maize/sweet potato — pigeon pea.
9. Sweet potato — pigeon pea.

The treatments maize — maize (1), maize (2), maize — cowpea and cassava were sole cropping control against which the performances of combinations could be monitored. The crop performances in IITA and Ikenne are shown in Tables 38 and 39, respectively. Yields of maize/cassava and maize-cowpea/cassava —cowpea combination were highest. The latter may be modified, the cassava may be grown through the second season of the second year or the cycle completed by maize/pigeon pea. Pigeon pea would hold the land during the dry season while contributing to its enrichment; maize — maize/pigeon pea is also attractive. Pigeon pea served mainly as a cover crop and was not harvested. The effect of locations could not be evaluated because of varietal differences.

At IITA where there is a distinct dry break between rainy season, and the second season is long enough, maize-maize/pigeon pea is attractive. The pigeon pea could provide valuable food while holding the land fallow and preventing weed colonization. Maize/cassava and maize-cowpea/cassava-cowpea or maize/pigeon pea are also attractive. In Ikenne, where the emphasis is on green maize, maize/cassava and maize-cowpea/cassava is possible provided that low pH is not a problem for maize.

Cover crops, fertilizer levels, and tillage practices on maize/cassava intercropping. The utilization of *in-situ* mulch from cover crops with no-till and inter-cropping has shown to control weeds and minimize erosion.

Using a split-split-plot design with cover crops, *Calopogonium mucunoides, Stylosanthes guianensis, Pueraria phasioloides, Centrosema pubescens* and *Psophocarpus palustris*, as the main plots, conventional no-till as subplots, and fertilizer and no-fertilizer as subplots; the performance of maize and cassava in intercropping was evaluated. The tillage plots were sprayed with glyphosate at 2.5 kg/ha a.i. to suppress the cover crops. The fertilized plots received preplanting applications of 60 kg N/ha, 60 kg P/ha and 60 kg K/ha. Maize was spaced 100 cm × 100 cm with three plants/hill; cassava was similarly spaced between the maize and along the same row. A pre-emergence herbicide was not applied; ability of the cover crop residue to suppress weeds was observed. In the conventional-till plots, weeding was necessary three weeks after planting.

Table 38. Crop yields in intercropping and sequential cropping (IITA, 1979).

Combination and Sequences	Year 1						Year 2				
	Maize		Cassava		Cowpea	Sweet Potato	Maize		Cassava	Cowpea	Sweet Potato
	1st Season	2nd Season	1st Season	2nd Season	2nd Season	1st Season	1st Season	2nd Season	1st Season	2nd Season	1st Season
Ma(1)-Ca-Cp(1)	5593	-	-	16308	-	-	-	-	-	479	-
Ma(2)-Cp(1)-Ma(2)-Ma(1)	5077	-	-	-	641	-	3459	3346	-	-	-
Ca-Ca	-	-	6294	-	-	-	-	-	(+)[2]	-	-
Ma(2)/Ca-Ma(2)/Ca	4894	-	5081	-	-	-	3413	-	(+)	-	-
Ma(3)/Ca-Ma(3)/Ca	5080	-	4969	-	-	-	3391	-	(+)	-	-
Ma(1)-Cp(3)/Ca-Cpl	5881	-	-	12270	684	-	-	-	-	708	-
Ma(1)-Ma(1)-Ma(1)-Ma(2)/Pp	5356	3570	-	-	-	-	4224	2878	-	-	-
Ma(2)/Sp-Pp-Ma(2)/Sp	5214	-	-	-	-	2409	3752	-	-	-	7281
Sp-Pp-Sp-Pp	-	-	-	-	-	19978	-	-	-	-	19032
LSD 0.05	760	-	2418	3006	343	-	474	1107	-	495	4670
COV. %	10	-	26	9	23	-	8	15	-	37	15

Ma(1) = Maize 75 cm x 25 cm; Ma(2) = Maize 100 cm x 100 cm 3 plants/hill; Ma(3) = Maize 100 cm x 25 cm; Ca = Cassava 100 cm x 100 cm; Cp(1) Cowpea 75 cm x 25 cm; Cp(2) = Cowpea 100 cm x 25 cm; Pp = Pigeon pea; Sp. = Sweet potato.

[1]Intercropping or relay intercropping; - = Sequential cropping.

[2]Crop not yet harvested.

Table 39. Crop yields in intercropping and sequential cropping (Ikenne, 1979).

	Year 1						Year 2				
	Maize		Cassava		Cowpea	Sweet Potato	Maize		Cas-sava	Cow-pea	Sweet Potato
Combination and Sequences	1st Season	2nd Season	1st Season	2nd Season	2nd Season	1st Season	1st Season	2nd Season	1st Season	2nd Season	1st Season
Ma(1)-Ca-Cb(1)	4672	-	-	12550	-	-	-	-	-	-	-
Ma(2)-Cp(1)-Ma(2)-Ma(1)	4207	-	-	-	504	-	343*	2750	-	-	-
Ca-Ca	-	-	17437	-	-	-	-	-	(-)[2]	-	-
Ma(2)/Ca-Ma(2)/Ca	4552	-	13938	-	-	-	2052	-	(-)	-	-
Ma(3)/Ca-Ma(3)/Ca	4349	-	12706	-	-	-	1680	-	(-)	-	-
Ma(1)-Cp(3)/Ca-Cpl	4939	-	-	5069	285	-	-	-	-	-	-
Ma(1)-Ma(1)-Ma1-Ma(2)Pp	5091	2768	-	-	-	-	1765	1550	-	-	-
Ma(2)/Sp-Pp-Ma(2)/Sp	4242	-	-	-	-	-	1759	-	-	-	2464
Sp-Pp-Sp-Pp	-	-	-	-	-	-	-	-	-	-	4810
LSD 0.05	450	-	3842	1588	150	-	669	1589	-	-	3209
COV. %	7	-	15	8	17	-	28	33	-	-	39

Ma(1) = Maize 75 cm x 25 cm; Ma(2) = Maize 100 cm x 100 cm 3 plants-hill; Ma(3) = Maize 100 cm x 25 cm; Ca = Cassava 100 cm x 100 cm; Cp(1) = Cowpea 75 cm x 25 cm; Cp(2) = Cowpea 100 cm x 25 cm. Pp = Pigeon pea; Sp = Sweet potato.

[1]Intercropping or relay intercropping; - = Sequential cropping.

[2]Crop not yet harvested.

**Poor stands.*

Table 40. The effect of tillage practices and fertilizer levels after cover crops on yield (kg/ha) of maize intercropped with cassava.

	Till		No-till		
Cover crop	Fertil-izer	No fertil-izer	Fertil-izer	No fertil-izer	Overall mean
Psophocarpus	5484	5201	5808	3741	5059
Centrosema	5176	4411	5648	4422	4914
Pueraria	4358	3951	4229	3764	4126
Calopogonium	4308	3091	3764	3791	3817
Stylosanthes	4008	3962	2745	2197	3228
Mean	4667	4123	4439	3583	4229
Mean	4395		4011		
SE		(28.15)			(36.84)
	Fertilizer		No fertilizer		
Mean	4553		3871		
SE		(16.32)			

Table 41. The effect of tillage practices and fertilizer levels on yields (kg/ha) of cassava intercropped with maize.

	Till		No-till		
Cover crop	Fertil-izer	No fertil-izer	Fertil-izer	No fertil-izer	Overall mean
Psophocarpus	23300	23325	24250	25313	24047
Centrosema	26275	24800	19125	18625	22206
Pueraria	31750	27700	27700	29063	20238
Calopogonium	28625	26000	31750	27700	28519
Stylosanthes	27100	29250	28813	23188	27088
Mean	27418	26215	22089	24778	24420
Mean	26817		23434		
SE			(16.29)		(±51.12)
	Fertilizer		No fertilizer		
Mean	2475		25497		
SE		(±16.32)			

In the no-till plots, weeding was necessary six weeks after planting. The weed suppression of the residue, which was far below expectation, was attributed to the relatively low density of the cover crop residue encountered at the end of the dry season or at the start of the rains.

The crop yields were good. There, differences between maize yields were not significant (Table 40) after different cover crops, but the low yield of no-till maize after *Stylosanthes* was attributed to poor germination. Tillage practice also had no significant effect. Applied fertilizer caused a small but significant yield increase. The treatments did not differ significantly in their effect on cassava, 30395, which was harvested after 18 months (Table 41).

The yields were regarded as good for the cultivars, soil and climate and suggest that maize/cassava intercropping is feasible with no-till and cover crop residue. A pre-emergence herbicide appears necessary for effective weed control when the cover crop is killed at the start of the rains.

Establishing *Pueraria phaseoloides* in maize

Pueraria phaseoloides is a leguminous cover crop that requires a fairly long time to overtake weeds and establish full cover but is very competitive with weeds. This slow growth, often regarded as a disadvantage in cover crops, is being exploited. Techniques are being developed to establish it with food crops.

Maize was planted by no-till in a plot where weed growth was killed with glyphosate at 2.0 kg/ha a.i. Primextra at 2.5 kg/ha a.i. was applied pre-emergence after maize planting. Though *P. phaseoloides* should be susceptible to Primextra, the hypothesis was that the effect of the herbicide could be neutralized or reduced if *P. phaseoloides* planting was delayed and the soil crust broken at planting. *P. phaseoloides* was, therefore, drilled between maize rows at 7, 14, 21, 27, and 35 days after maize planting.

Germination was good in all treatments. Growth was faster in the 7- and 14-day treatments where the absence of weed competition created by the herbicide action favored rapid development. Growth was slower in the other treatments where some weeds had germinated along with the cover crop. However, in all treatments, *P. phaseoloides* became the dominant non-food crop species by maize harvest. Though the cover crop had climbed the maize in the 7- and 14-day treatments and reduced the speed of hand harvesting, it had no significant effect on yield.

All treatments developed effective covers of *P. phaseoloides* within three months of maize harvest. The results indicate that *P. phaseoloides* can be affectively established in maize even when certain herbicides are used.

Alley width effect on maize and cowpea

The alley width or the inter-row spaces between the soil ameliorating trees or shrubs is an important factor in relation to the crops, the type of trees or shrubs or the equipment used in developing the leaf nutrient source or alley cropping concept. Experiments to determine suitable row widths were established with maize and cowpea at IITA.

Maize was the comparison crop during the 1979 first season. The maize was mechanically planted with 75 cm between rows and 25 cm along the row. The "fallow" plants were planted along selected maize rows to give inter-row spacings of 2.25, 3.75 and 6.74 m. The spacing along the rows was 50 cm. Each inter-row spacing was duplicated in each fallow species, which were *Tephrosia candida*, *Cajanus cajan*, *Leucaena leucocephala* and *Glyricidia sepium*. *G. Sepium* was established from cuttings; the others were from seeds.

Competition from maize retarded shrub growth, and plants were smaller than expected at the end of the maize crop. *C. cajan* grew fastest, followed by *L. leucocephala*, *T. candida* and *G. sepium*. The yields of maize (Table 42) were regarded as good. The alley width had no observable effect on maize yield. The shrub was apparently too small to affect maize growth and yield.

Cowpea was the comparision crop during the 1979 second season. The yields of cowpea (Table 42) differed markedly between both shrubs and alley widths. *C. cajan* gave the lowest yield; the well-established shrubs competed more than other shrubs. A tendency toward higher yields at the narrowest alley width of 2.25 m, except with *C. cajan*, was indicative of a kind of border effect. The poorly established shrubs were not exerting much competitive pressure on the crop. Insect control, an important aspect of cowpea production, was apparently more effective in the narrow alley. A second crop during the second season of the establishment year may be possible where shrub growth is shown and the plants are too small to compete with the crop. The same does not hold for succeeding years when shrub grows and competition with crop will be controlled by pruning.

Establishing *Leucaena leucocephala* by intercropping

Leucaena leucocephala as well as other tree and shrub type legumes are potentially useful in increasing the productivity of many food production systems in the humid tropics.

The effect of intercropping with maize and maize and cassava on the growtn of *Leucaena* was investigated. *Leucaena* spaced 200 cm × 50 cm was intercropped with maize spaced 100 cm × 100 cm with three plants/hill and maize/cassava with the maize spaced 100 cm × 100 cm and the cassava spaced 100 cm × 100 cm set between the maize hills. Figures 35 and 36 show crop performances in these combinations compared with sole maize, maize/cassava, and sole *Leucaena* in the first year. A second maize crop in the maize/*Leucaena* combination was unsuccessful; the *Leucaena* shaded the maize.

Table 43 shows that maize in maize/cassava/*Leucaena* yielded less than in the other treatments. This indicated that the joint effect of both crops adversely affected maize. But, the marked difference in cassava yields between maize/cassava and maize/cassava/*Leucaena* indicated a beneficial effect of *Leucaena*.

But, again, the differences were not significant. Sole *Leucaena* had the tallest and thickest stem at the end of the first crop year (Table 43.) The difference in plant height was significant only between sole *Leucaena* and maize/cassava/*Leucaena*. In stem thickness, sold *Leucaena* was superior to both the other treatments. The slightly shorter and thinner *Leucaena* plants, however, had no marked effect on the yields of yam for which they were cut back to approximately 200 cm, kept leaf free and used as *in-situ* support.

Retardation in *Leucaena* growth by the intercropping with maize and cassava appears of minor consequence in comparison to the benefits derived from the associated crops. The *Leucaena* from intercropping were as effective as the sole *Leucaena* plants from sole cropping, indicating that intercropping with maize and maize/cassava is a feasible recommendation for the establishment of *Leucaena* in cropping systems. The development sequences over a two-year cycle for maize/*Leucaena*, *Leucaena*/yam are diagrammed in Figure 36.

Table 42. Yields in kg/ha of maize and cowpea in alley shrubs during shrub establishment phases.

Alley width	*C. cajan*		*G. Sepium*		*L. leucocephala*		*T. candida*	
(m)	Maize	Cowpea	Maize	Cowpea	Maize	Cowpea	Maize	Cowpea
2.25	4378	250	4956	854	4867	818	4889	657
3.75	4702	249	5055	586	4906	366	4510	535
6.75	5545	256	5176	339	4500	306	4310	504

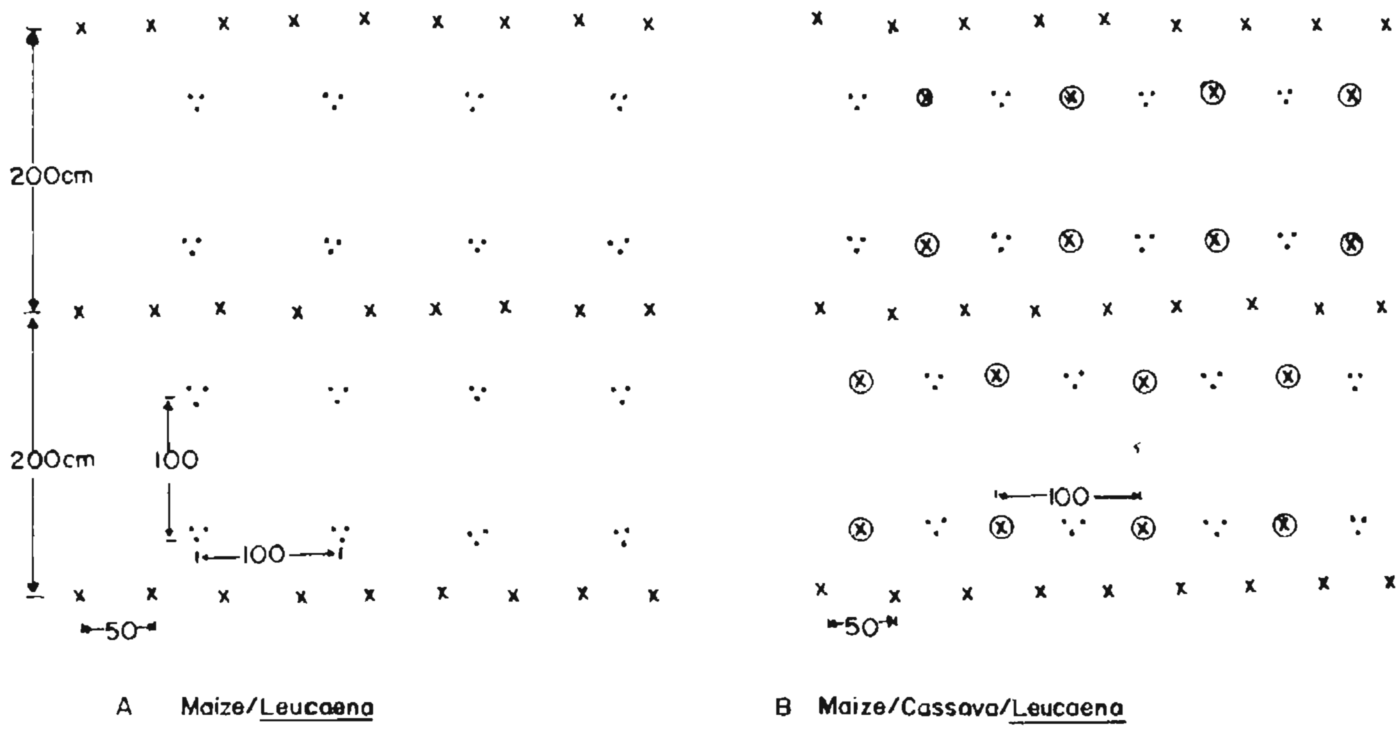


Fig. 35. Diagram of intercropping for establishment of Leucaena.

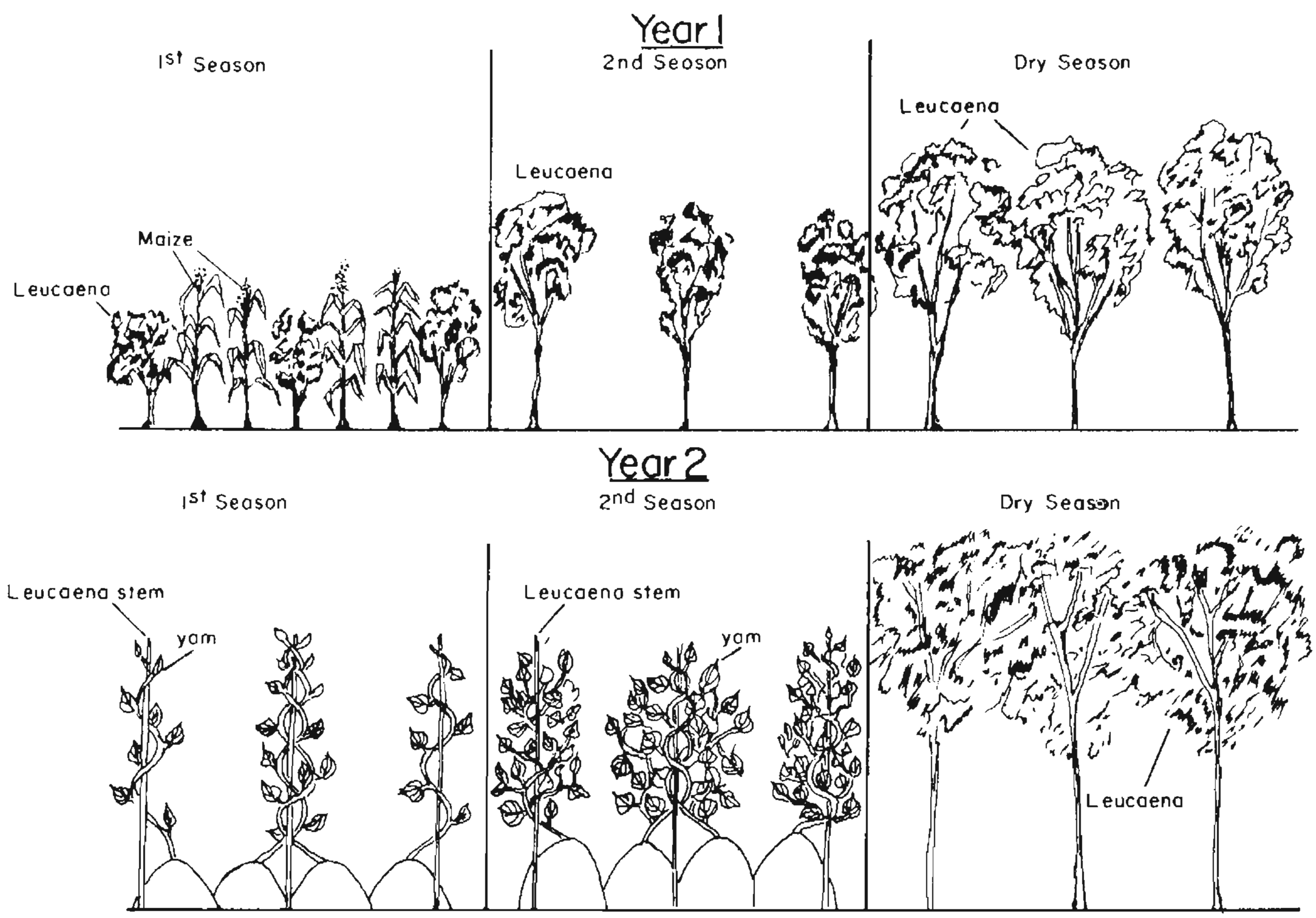


Fig. 36. Cropping sequence for establishing and utilizing *Leucaena leucocephala* ***for leaf mulch and*** *in-situ* ***yam vine support.***

Table 43. The effect of intercropping on maize, cassava and *Leucaena*.

Treatment	Maize kg/ha	Cassava kg/ha	Yam kg/ha	*Leucaena* Height (cm)	*Leucaena* Diameter (cm)
A Maize	2512	-	-	-	-
B Maize/Cassava	3058	20187	-	-	-
C Maize/*Leucaena*	2857	-	14905	375	2.72
D Maize/*Leucaena*/Cassava	1840	29229	12333	370	2.62
E *Leucaena*	-	-	13690	445	3.14
LSD (0.05)	963	20458	13906	74	0.25
CV (%)	27	36	45	12	6

Note: High CV's for maize, cassava and yam was caused by rodent damage.

Table 44. Effect of cassava population on yield of maize (TZB).

Weed control	Maize grain yield (t/ha)[1] Cassava (TMS 30395) 1 m x 1 m	Cassava (TMS 30395) 2 m x 1 m	TMS 30001 1 m x 1 m	TMS 30001 2 m x 1 m
1. Weeded at 2 WAP	1.84	1.83	1.85	2.59
2. Weeded at 2 + 5 WAP	2.28	3.01	2.54	2.30
3. Primextra 2.5 PE	2.69	2.35	3.25	2.50
4. Weedfree	2.81	3.25	3.13	3.11
5. Weedy checks	0.66	1.06	1.35	0.96
Mean	2.06	3.20	2.43	2.29
SE (D)	0.69		0.43	
LSD (0.05)	1.46		0.92	
Sole maize yield (weedfree)	3.24		3.24	

[1]Maize population = 40,000 plants/ha
LSD 0.05 for comparison of means within cassava spacing in a given cultivar.

Weed science

Weed control in mixed cropping system

To evaluate crop and weed response to varying maize and cassava populations, the following study was initiated in 1979: Two improved cassava varieties, TMS 30395 and TMS 30001, were monocropped at two populations, 10,000 and 20,000 plants/ha (1 m × 1 m and 2 m × 1 m spacing, respectively) and as components of mixtures, involving two populations of maize, 20,000 plants/ha or 40,000 plants/ha.

TMS 30395, a profusely branching cultivar, depressed maize yield more than TMS 30001, a moderately branching type (Table 44). Conversely, higher maize populations (40,000 plants/ha) depressed cassava yields more than lower maize populations (20,000 plants/ha) (Table 45).

Across all population levels, the highest food energy values were obtained when each cassava cultivar was intercropped at 10,000 plants/ha with maize at 20,000 plants/ha (Table 46). The mean weed weight was lowest at this

Table 45. Effect of maize population on yield of two cassava cultivars.

Cassava plants/ha	Weed control	F. W. Cassava tuber: Maize spacing 1 m x 0.25 m	Maize spacing 1 m x 0.5 m	Maize spacing 1 m x 0.25 m	Maize spacing 1 m x 0.5 m
10,000	1. Weeded at 2 WAP	10.8	15.29	13.56	16.78
	2. Weeded at 2 + 5 WAP	13.07	15.55	18.29	25.08
	3. Primextra 2.5 PE	13.63	23.57	16.23	34.78
	4. Weedfree	13.07	23.57	21.18	30.93
	5. Weedy check	6.27	6.83	7.71	9.32
	Mean	11.37	16.98	15.39	23.38
	SE (D)	6.18		4.39	
	LSD (0.05) with maize spacing	14.4		9.31	
5,000	1. Weeded at 2 WAP	10.31	16.50	7.59	14.12
	2. Weeded at 2 + 5 WAP	11.05	15.94	15.99	13.56
	3. Primextra 2.5 PE	11.69	19.40	13.61	20.56
	4. Weedfree	10.68	19.24	14.31	21.92
	5. Weedy check	4.49	4.02	4.42	3.09
	Mean	9.65	15.02	11.18	14.65
	SE (D)	4.11		3.87	
	LSD (0.05) within maize spacing	8.71		8.21	

mixed population level for each cultivar. At each population level, the highest food energy values (calories) were obtained in plots kept weedfree throughout the growing season either by repeated hand weeding or by application of the pre-emergence herbicide, Primextra (Table 47).

The herbicide treatment gave the lowest unit cost of weeding and the highest return on investment. This was especially true at the optimum crop combination (Table 48).

Studies also initiated earlier on weed control in maize/cassava, maize/yam, and maize/cassava/yam intercropping system were continued during 1979 at both high-rainfall (2,000 mm/year) Ultisol, and medium-rainfall (about 1300 mm/year), Alfisol, locations.

High-rainfall conditions. In the high-rainfall conditions, a number of different weed control treatments were studied, including hand-weeding, chemical weed control and biocontrol, a method of planting low-growing crops to suppress weeds. Biocontrol studies during 1979 involved the planting of "Egusi" — melon (*Citrellus lunatus* (Thunb.) Mansf.) at the beginning of the cropping season and the planting of sweet potato cuttings (c.v. TIS 2534) later in the season after the melon has been senescent.

Table 46. Effect of plant population on land equivalent ratio in maize/cassava intercrop.

Cassava	Maize	Plant/ha	Land equivalent ratio: TMS 30395	TMS 30001	Mean
2m x 1m	1m x 0.5m	25,000	1.86	1.30	1.58
1m x 1m	1m x 0.5m	30,000	1.68	1.90	1.79
2m x 1m	1m x 0.25m	45,000	1.59	1.47	1.53
1m x 1m	1m x 0.25m	50,000	1.44	1.50	1.47
		Mean	1.64	1.54	1.59
LSD (means w. cultivars) (0.05)			0.34	0.24	
LSD (means of diff. cultivars) (0.05)			0.71		

Table 47. Effect of plant population, plant type and weed control on food energy values (calories) and weed weight in maize/cassava intercrop.

Plant pop. in mixture (x 1000)	Weed control	Energy values (x 10^6 Cal) Cassava cultivars: TMS 30395	TMS 30001	Weed wt. (t/ha): TMS 30395	TMS 30001
25	1. Weeded at 2 WAP	29.23	27.08	3.61	3.05
	2. Weeded at 2 + 5 WAP	28.24	27.60	1.20	0.71
	3. Primextra 2.5 PE	32.58	35.12	1.61	2.11
	4. Weedfree	34.53	37.33	0	0
	5. Weedy	7.47	6.24	4.97	4.97
	Mean	26.41	26.61	2.28	2.17
30	1. Weeded at 2 WAP	29.38	31.79	2.74	2.53
	2. Weeded at 2 + 5 WAP	27.17	44.84	1.23	1.24
	3. Primextra 2.5 PE	39.39	59.08	1.17	1.49
	4. Weedfree	40.63	51.72	0	0
	5. Weedy	11.49	19.09	4.63	3.86
	Mean	29.61	41.05	1.93	1.80
45	1. Weeded at 2 WAP	21.89	20.58	2.31	2.64
	2. Weeded at 2 + 5 WAP	23.50	32.03	0.47	1.27
	3. Primextra 2.5 PE	27.73	29.21	1.54	0.87
	4. Weedfree	27.52	32.44	0	0
	5. Weedy	10.57	10.00	4.62	4.65
	Mean	22.24	39.80	1.79	1.89
50	1. Weeded at 2 WAP	23.38	26.81	2.51	2.19
	2. Weeded at 2 + 5 WAP	27.64	36.34	1.83	0.77
	3. Primextra 2.5 PE	29.88	39.81	1.49	1.53
	4. Weedfree	29.52	42.71	0	0
	5. Weedy	11.69	16.30	4.96	4.65
	Mean	24.23	31.59	2.79	1.83
[a]LSD (0.05)		16.84	13.00	1.56	1.34
[b]LSD (0.05)		16.52	15.85	1.46	1.27
[c]LSD (0.05)		6.86	10.87	-	-

[a]*LSD for comparison of means within each population.*
[b]*LSD for comparison of means of different population.*
[c]*LSD for comparison of means of population means.*

Table 48. Effect of weed control methods on economic return in maize/cassava intercrop.

Population (plants/ha)	Weed control method	Cost of weeding[a] (Naira)	30395	TMS 30001	TMS 30395	TMS 30001
30,000	Hoe weeding at 2 + 5 WAP	₦138.00	₦1271.83	₦2121.53	₦1133.83	₦1983.53
	Primextra	₦ 42.50[c]	₦1813.88	₦2737.19	₦1771.38	₦2694.69
50,000	Hoe weeding at 2 + 5 WAP	₦138.00	₦1406.53	₦1802.43	₦1268.53	₦1664.43
	Primextra	₦ 42.50	₦1539.53	₦1848.71	₦1497.03	₦1806.21

[a]*Two weedings in maize/cassava require 368 man-hrs/ha. Cost is based on 8 man-hrs/day @ ₦3.00/man day. ₦1.00 = U.S. $1.74.*

[b]*Net return does not include other production costs and these are identical for both weeding methods.*

[c]*Cost of herbicide plus labor. One man-day each for sprayer operator and assistant @ ₦3.00/man day.*

Table 49. Effect of weed control in maize and yam yields in selected cropping patterns in an Ultisol (Onne, 1978).

Treatment	Maize yield cropping pattern (t/ha) M[4]	M/C	M/Y	M/C/Y	X	Yam yield (F/ha) Y	M/Y	M/C/Y	Amm. of weeds (t/ha) Y	M/Y	M/C/Y
1. Weeded at 2 + 4 + 16 WAP	1.18	1.52	1.17	1.33	1.30	14.75	10.93	8.50	25.73	31.07	21.60
2. Weeded at 2 + 8 + 16 WAP	1.30	0.68	1.38	1.06	1.11	19.35	14.15	8.93	21.47	28.70	13.07
3. Weeded at 2 + 4 + 8 + 16 WAP	1.67	1.10	1.22	1.11	1.28	16.55	12.15	10.38	21.92	22.27	8.82
4. Melon Fb sweet potato cover	0.99	0.98	0.81	0.56	0.84	15.85	10.85	9.35	2.80	8.00	1.99
5. Melon Fb herbicide	1.44	0.98	0.93	1.09	1.11	14.53	9.13	12.23	20.57	29.40	10.33
6. Sweet potato cover	0.56	1.11	0.87	0.69	0.81	99.95	9.13	9.65	34.20	29.00	22.87
7. Primextra 3.0 PE[2]	1.41	1.45	0.85	0.88	1.15	10.13	9.58	7.65	35.60	27.80	21.60
8. Primextra fb. Gramuron[3]	1.04	0.84	1.09	1.09	1.02	14.53	9.78	9.30	26.13	21.86	13.33
9. Weedfree	1.59	1.20	1.35	1.80	1.49	19.70	14.15	10.43	0.00	0.00	0.00
10. Weedy	0.64	0.56	0.00	0.89	0.66	9.03	6.38	6.85	43.27	36.97	34.17
Mean	1.18	1.04	1.02	1.05		14.44	10.86	9.33	25.74	26.12	16.18
LSD (0.05)	0.61	0.52	0.50	0.60		6.08	4.46	3.71	9.08	12.38	9.64

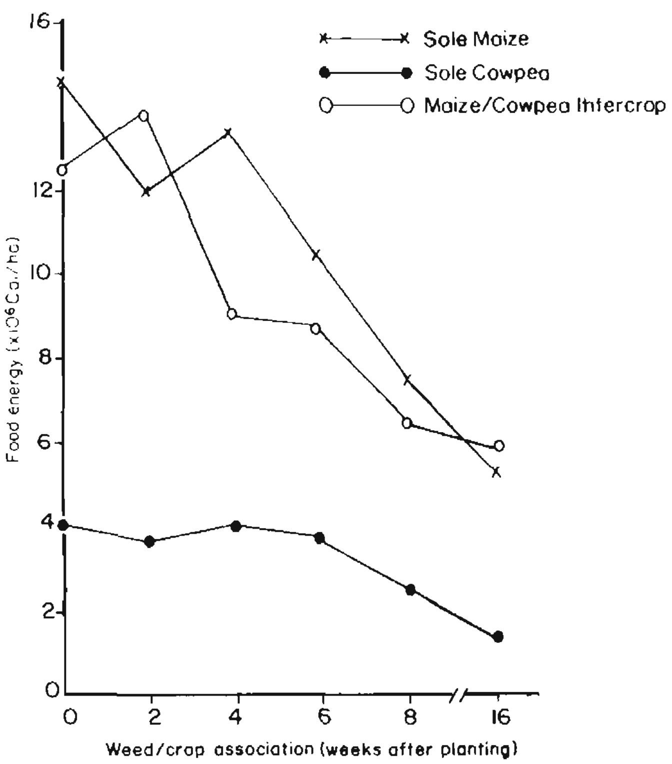


Fig. 37. Effect of weed interference on food energy in sole and intercrop of maize and cowpea.

Weeding included hoeing at 2, 8 and 16 weeks after planting and spraying with a pre-emergence herbicide Primextra (3.0 kg/ha a.i.) at the beginning of the cropping season and a directed post-emergence herbicide Gramuron (3.0 kg) at 10-12 weeks after planting. This method was practiced with both maise and yam (Table 49).

The melon, followed by sweet potato, provided for better maize and yam yield through better weed control than 4 hand weedings or a herbicide spraying. Two herbicide sprayings applied pre-emergence and directed late post-emergence were necessary for weed control.

Moderate-rainfall conditions. Weed infestation is less severe in the moderate-rainfall conditions. Consequently, only 2 properly timed hand weedings were necessary for weed control. Melon followed by sweet potato was as effective in suppressing weeds and maintaining good crop yield as 3 or 4 hand weedings in the various crop mixtures studied (Tables 50 and 51). Primextra applied alone was able to control weeds long enough for crop canopy to cover up and discourage weed reinfestation.

Maize/cowpea intercrop

A no-till field trial was carried out during the 1979 first season to examine the problem of weed interference during the early stages of crop development in a maize/cowpea intercrop. The fallow vegetation was sprayed twice with paraquat (0.7 kg/ha at each application) prior to planting. Subsequent weed control was by hoe weeding. Uncontrolled weed growth caused a 64 and 51 percent grain yield reduction in sole and intercropped maize, respectively, and a 67 percent seed yield reduction in both sole and intercropped cowpea. The yield of sole maize and cowpea became substantially reduced after four and six weeks, respectively; whereas, the critical time of weed interference in maize and cowpea grown in mixtures appears to occur after two and four weeks after planting, respectively (Fig. 37).

This indicates that a mazie/cowpea intercrop shows sensitivity to weed pressure earlier than either of the crops grown singly.

To measure weed crop interference, the weed/crop nutrient uptake ratio (WCNR) was used. WCNR was highest for N, P, K, Ca and Mg at 4 weeks after planting in sole maize (Fig. 38) while in both cowpea and maize/cowpea intercrop the highest values were obtained at three weeks after planting, showing that weeds reach their peak demand for the nutrients very early in the crop's life cycle. This explains in part the sensitivity of many crops to early weed competition.

Effect of yam staking and weed control

The effect of staking and weed control on tuber yield was studied in 1979 in each of two yam species, white yam (*Dioscorea rotundata*) and water yam (*Dioscorea alata*). The experiments were set up as split plots in a randomized complete block design. The staking treatments were the main plots and the weed control were the subplots. Weed control methods included hoe weeding and herbicides. A formulated mixture of diuron plus paraquat was applied post-emergence as a directed spray while other herbicides were applied pre-emergence. White yam showed sensitivity to staking. In plots with controlled weeds, there was a 40 percent yield increase in staked white yam over unstaked white yam.

Moreover, in plots with uncontrolled weeds, there was a 77 percent yield reduction in the unstaked white yam and only 36 percent reduction in the staked white yam. Weed control in unstaked plots was poorer than in staked plots in all weed control treatments used in the study. Yam yield in plots that were handweeded three times was similar to the yield in plots treated with formulated mixtures of either atrazine plus metolachlor (3.0 kg/ha) or diuron

Table 50. Effect of weed control method and cropping pattern on maize and cassava yields in an Alfisol (IITA, 1978).

	Maize grain yield (t/ha)					Cassava F.W. Cassava tuber (TMS 30395) (t/ha)			
Weed control	M[3]	M/C	M/Y	M/C/Y	Mean	C[3]	M/C	M/C/Y	Mean
1. Weeded at 3 + 5 WAP	3.95	3.55	2.63	3.53	3.42	28.06	23.42	6.71	19.40
2. Weeded at 3 + 8 + 16 WAP	4.02	2.94	3.17	3.37	3.38	31.85	19.07	7.36	19.43
3. Weeded at 3 + 5 + 8 + 16 WAP	4.31	2.07	2.59	3.29	3.07	31.03	13.66	7.65	17.45
4. Melon fb sweet potato cover	3.95	3.76	2.94	2.86	3.38	21.69	15.87	3.65	13.74
5. Melon + Herbicide[1]	4.16	2.86	3.52	3.34	3.47	21.40	11.17	2.91	11.83
6. Sweet potato + Herbicide	3.85	2.82	2.28	1.90	2.71	16.07	13.52	2.25	10.61
7. Primextra 2.5 PE	3.86	2.98	2.72	3.43	3.25	15.84	19.37	6.53	13.91
8. Alachlor + diuron 3.0 + 2.0 PE	3.31	1.73	2.12	1.87	2.26	17.93	21.48	7.93	15.78
9. *Weedfree*	5.17	4.38	3.21	2.87	3.90	37.37	18.86	6.93	21.05
10. Weedy check	3.28	1.79	2.51	2.02	2.40	11.33	12.10	3.27	8.9
Mean	3.99	2.89	2.77	2.85		23.26	16.85	5.52	
LSD (0.05)	2.41	1.78	1.14	1.44		13.96	9.67	5.08	

[1]*DCPA metolachlor 8.0 + 1.5 kg/ha PE.*

Table 51. Effect of weed control method and cropping pattern on yam yield and selected cropping patterns in an Alfisol (IITA, 1978).

	F.W. Yam tuber (t/ha)				F.W. weeds t/ha					
Weed control	Y	M/Y	M/C/Y	Mean	M	Y	YC	M/C	MY	MYC
1. Weeded at 3 + 5 WAP	8.52	11.27	8.30	9.36	8.07	8.87	4.67	3.63	4.60	4.40
2. Weeded at 3+8 + 16 WAP	7.75	3.63	12.0	7.79	1.73	4.70	1.77	1.53	2.70	2.93
3. Weeded at 3 + 5+8 + 16	15.75	14.12	12.37	14.08	4.40	5.73	2.23	1.23	0.90	0.39
4. Melon fb sweet potato	13.03	12.68	7.92	11.21	2.74	6.53	8.02	2.17	3.55	4.47
5. Melon + Herbicide	6.78	7.93	8.33	7.68	14.13	9.90	6.97	5.35	7.20	5.13
6. Sweet potato + Herbicide	5.53	4.92	6.12	5.52	7.33	12.60	3.50	6.72	8.67	5.60
7. Primextra 2.5 PE	4.15	6.72	2.83	4.57	2.90	9.63	10.20	2.09	10.67	10.70
8. Alachlor + diuron 3.0 3.0 + 2.0 PE	5.18	7.93	9.57	7.56	6.67	10.53	7.17	5.49	7.93	8.70
9. *Weedfree*	15.07	11.05	10.85	12.32	10.47	11.74	21.87	12.63	11.10	12.63
10. Weedy check	4.82	7.12	5.67	5.87	6.49	8.92	7.38	4.54	6.37	6.11
Mean	8.66	8.74	8.40		4.79	5.58	9.99	4.56	5.88	5.74
LSD (0.05)	5.00	4.06	4.14							
CV (%)	33.7	27.1	28.8							

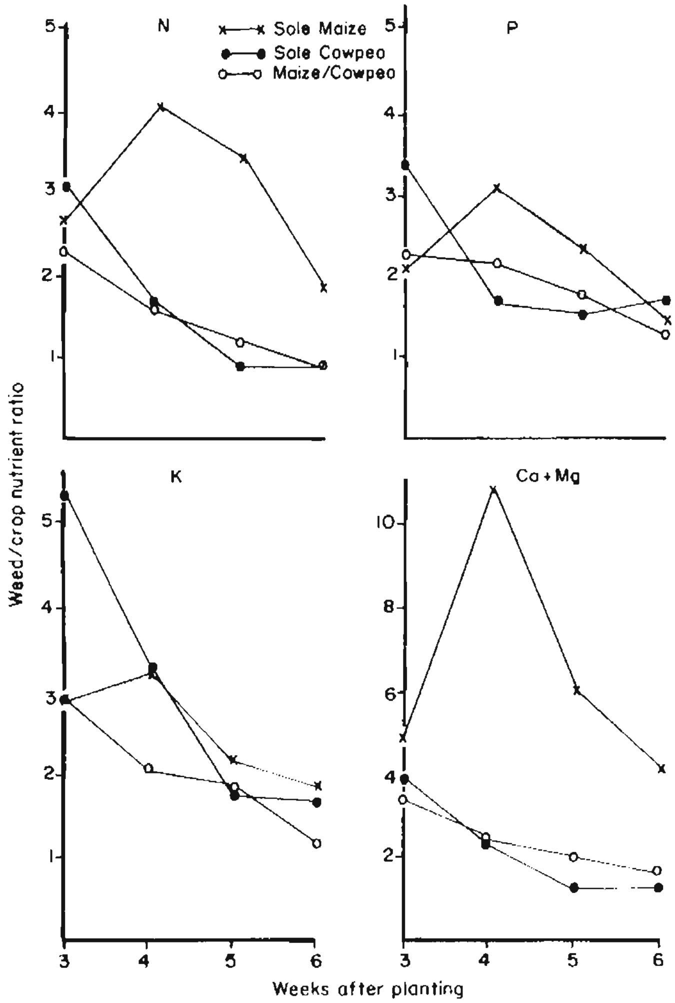


Fig. 38. Effect of weed interference on weed/crop nutrient ratio in sole and intercrops of maize and cowpea between three and six weeks after planting.

plus paraquat (3.0 kg/ha). A tank mixture of fluometuron plus metolachlor (2.0 + 2.0 kg/ha) was equally effective. Yam yield from these treatments was lower than the plots free of weeds possibly because these treatments could not protect the crop from weed competition beyond the third month after planting. (Table 52).

Water yam showed insensitivity to staking (Table 53). However, there was a 71 percent yield reduction in unstaked water yam and a 50 percent reduction in staked water yam; thus, staking reduces the sensitivity of water yam to weeds.

Weed control in no-till systems

Three sites, representing different ecological zones with different weed spectrums, soil types and rainfall regimes, were chosen for no-till weed control trials during 1979. The objectives of these experiments were to identify appropriate residual herbicides for pre-emergence weed control and evaluate soil-applied residual herbicides for long-season weed control.

Glyphosate and estermine were effective in controlling most weeds, except *Talinum triangulare* (Tables 54 and 55). A separate trial was conducted to determine the effect of glyphosate and monosodium methanearsonate (MSMA) on *Pennisetum purpureum* Schum (elephant grass) in no-till maize (Table 56). Glyphosate alone at 4.8 and 6.0 kg/ha gave excellent grass control. Adding MSMA (3.6 kg/ha) to glyphosate (2.4 kg/ha) increased control of the grass at the reduced glyphosate rate. Earlier trials indicated that glyphosate alone at 2.4 kg/ha was not effective in controlling elephant grass.

Weed control in conventional-till systems

Experiments were also conducted to evaluate soil-applied residual herbicides for pre-emergence weed control in conventional-till combinations of atrazine and pendimethalin. Each at 2.0 or 2.5 kg/ha gave better control than Primextra (Table 57.)

Table 52. Effect of staking and weed control on tuber yield in white yam** (D. rotundata)* ***c.v. Nwaopoko.

Treatment	Rate kg/ha	Time	D. W. Weeds[1] (t/ha) N.S.	S	Mean	F. W. tuber (t/ha) N.S.	S	Mean
1. Fluometuron	2.0	PE	3.09	1.97	2.53	4.54	18.21	11.38
+	+							
Metolachlor	2.0							
2. Primextra[2]	3.0	PE	3.84	3.25	3.55	7.30	17.17	12.24
3. Gramuron[3]	3.0	Post	3.03	2.72	2.88	6.00	18.38	12.19
4. Hoe weeding	3+8							
	+12	WAP	1.93	1.43	1.68	7.71	20.13	13.92
5. Weedfree			0.54	0.41	0.48	14.17	24.34	19.25
6. Weedy			4.52	3.01	3.77	3.29	15.61	9.45
Mean					-	7.17	18.97	-
SE (D)					0.45			1.58
LSD (0.05)					.95			3.29

LSD 0.05 for comparison of mean within group F.W. Tuber 4.64 tons.
LSD 0.05 for comparison of mean within group D.W. Weeds 1.34 tons.
[1]Dry weight of weeds at harvest, NS = No staking; S = Staking.
[2]Trade name of Ciba-Geigy's formulation of atrazine + metolachlor.
[3]Trade name of ICI's formulation of diuron + paraquat.

Live mulch crop production

Live mulch crop production is a production technique in which crops are grown directly in low-growing crops such as legumes or grasses with no-till or pre-plant vegetation control. To be effective, the live mulch should not compete with the crop but should suppress the weeds.

Several types of ground cover were assessed during the 1977 first season to determine the effect of ground cover on weed competition and maize yield. Maize, TZB, was spaced at 0.75 m × 0.25 m, and all treatments received fertilizer at the rate of 60 kg/ha a.i. for N, P_2O_5 and K_2O. The climbing tendency of *Centrosema pubescens* and *Psophocarpus palustris* was suppressed by spraying these plants with dwarfing hormones. Weed infestation was highest in no-till plots and conventional-till plots with *Desmodium triflorum* and *Indigofera* spp, average in conventional-till plots with *Arachis repens* spp. and maize stover plots and lowest in conventional till plots with *Centrosema pubescens* and *Psophocarpus palustris* (Table 58).

Crop yield varied, depending on the extent of weed infestation. Weeds did not significantly affect crop yield in plots where *Centrosema* or *Psophocarpus* spp. were used as ground cover. Yield stand was identical for conventional-till, maize stover, *Centrosema* and *Psophocarpus* plots. The difference in total yield was due to lower

Table 55. Effect of glyphosate and estermine on preplant vegetation control and yield of maize (TZE_4) (Mbiri, 1979 second season).

Treatment	Rate kg/ha	Weed control ratings[1] Aa.	Ac.	Tt.	Grain yield kg/ha
1. glyphosate	2.4	67	95	40	1338
2. Estermine	2.0	98	93	20	2701
3. Estermine	2.5	80	100	33	1310
Mean					1849
LSD (0.01)					1121

[1]*The following weed species were controlled 100 percent:* Sida acuta, Urena lobata, Centrosema pubescens, *and* Calopogonium mucunoides.

Table 53. Effect of staking and weed control on tuber yield in water yam (D. alata) CV 251,260.

Treatment	Rate kg/ha	Time	D. W. Weeds[1] (t/ha) N.S.	S	Mean	F. W. Tuber (t/ha) N.S.	S	Mean
1. Fluometuron + Metolachlor	2.0 + 2.0	PE	1.90	1.76	1.83	14.73	13.23	13.98
2. Primextra[2]	3.0	PE	2.28	2.17	2.23	14.17	13.00	13.58
3. Gramuron[3]	3.0	Post	2.34	2.40	2.37	14.20	11.57	12.88
4. Hoe weeding	3 + 8 + 12	WAP	1.64	1.67	1.66	12.60	10.67	11.63
5. Weedfree			1.33	1.38	1.36	16.23	14.33	15.28
6. Weedy			2.43	3.20	2.81	4.63	7.10	5.87
Mean			1.99	2.10		12.76	11.65	
SE (D)					0.32			1.81
LSD (0.05)					.66			

LSD 0.05 for comparison of means within staking group F.W. tuber = 5.34.
LSD 0.05 for comparison of means within staking group D.W. weed = 0.94.

Table 54. Herbicide screening for preplant vegetation control in no-till maize.

Treatment	Rate kg/ha	Weed control ratings[2] *Eupatorium odoratum*	Sa	Cp	*Talinum triangulare*	St. est[3]	Grain yield kg/ha
1. Estermine	1.5	100	100	100	83	99	1476
2. Estermine	3.0	100	100	100	97	105	1555
3. Asulam + Estermine[1]	4.0 + 3.0	100	100	100	100	99	1866
4. 2,4,5-T	3.5	100	100	100	90	97	1567
5. paraquat	1.5	75	83	95	25	90	1310
6. glyphosate	2.4	100	100	95	35	95	1073
7. glyphosate	4.8	100	100	70	70	100	1037
8. glyphosate	6.0	100	100	100	85	87	1397
Mean						96	1398
LSD (0.01)							611

[1]*Asulam applied as an overlay and not as a tank mix.*
[2]*Sa = Sida acuta, Cp = Centrosema pubescens, Tt = Talinum triangulare, Eo = Eupatorium odoratum.*
[3]*St. est = Stand establishment.*

plant populations and the legume covers due to poor live mulch management at the time of crop emergence.

There were marked differences in earthworm activities in no-till, conventional-till and live mulch plots (Fig. 39). The number and dry weight of earthworm casts were lowest in bare and conventional-till plots, average in maize stover plots and highest in *Centrosema* and *Psophocarpus* plots. This is an indication of a highly favorable soil environment for plant root growth in live mulch.

Indigofera spp. was a poor competitor against weeds and appeared to depress maize yield even when it was kept weed-free. Maize yield/stand was also lowest in this treatment, suggesting that interference with crop growth and development was caused by factors other than competition with weeds for light, water and nutrients.

Further studies on live mulch crop production focused on the performance of the most promising legumes *Arachis* spp., *Centrosema pubescens* and *Psophocarpus palustris*. Weed competition caused pronounced reduction in maize yield in no-till and conventional-till but did not affect crop yield in live mulch plots (Table 59).

Dry weight of weeds from unweeded conventional-till plots was at least eight times more than weight of weeds from unweeded *Centrosema* and *Psophocarpus* plots, confirming the superior competitive ability of these legumes against weeds. There were marked differences in weed flora distribution between live mulch and conventional-till systems (Table 60).

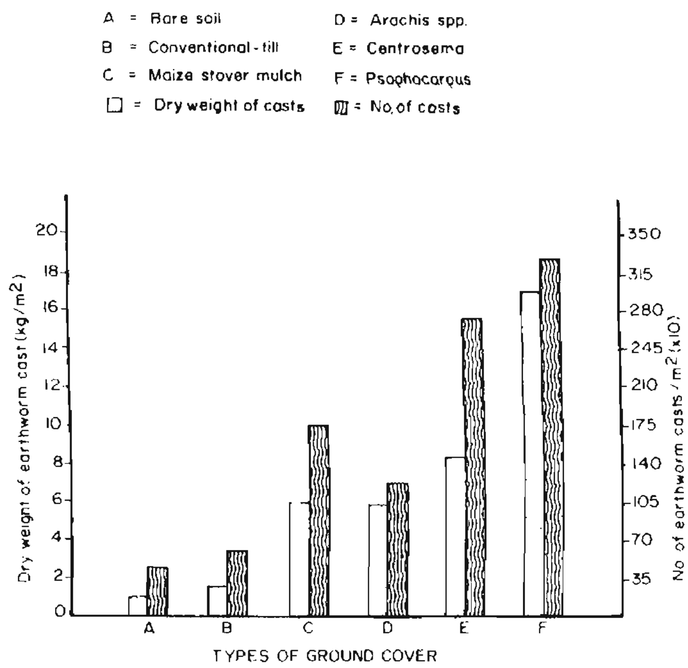


Fig. 39. Earthworm activity under selected ground covers.

Table 56. Effect of glyphosate and MSMA[1] on elephant grass and maize yield (Mbiri, 1979 second season).

Treatment	Rate kg/ha	Maize vigor	Elephant grass control ‡ 3 WAP	8 WAP	Grain yield kg/ha
1. glyphosate + MSMA	1.2 + 3.6	0	81	60	1110b
2. glyphosate + MSMA	2.4 + 3.6	0	96	100	1878c
3. glyphosate	4.8	0	99	100	2268c
4. slashing	-	30	00	00	108c

Means followed by the same letter are not significantly different at 1 percent level using Duncan's Multiple/Range Test.
[1]Monosodium methanearsonate.

Table 57. Effect of pre-emergence herbicides on weed control and maize yield in conventional-till (Mbiri, 1979 first season).

Treatment	Rate kg/ha	Weed control ratings[1] Tt[2]	Av	Cp	Sa	Ac	St. est.[3]	Maize yield kg/ha
1. Primextra	3.0	89	100	82	99	99	124	1915
2. Atrazine	2.5	89	100	76	100	98	132	2464
3. Atrazine	3.0	89	97	50	99	100	131	1945
4. Pendimethalin	2.5	86	100	90	100	98	126	2318
5. Pendimethalin	3.0	80	100	94	100	99	130	1567
6. Atraz. + pendi.	2.5+2.5	95	100	95	100	100	127	2074
7. Atraz. + pendi.	3.0+3.0	98	100	92	100	100	130	2342
8. Cutt. check	-	100	100	100	100	100	129	1683
Mean							129	2038
LSD (0.01)								664

[1]Weed ratings were based on a scale of 0 to 100 where 0 = no control, 100 = complete kill.
[2]Weed species Tt = Talinum triangulare, Av = Amaranthus viridis, Cp = Centrosema pubescens, Sa = Sida acuta, Ac = Ageratum conyzoides.
[3]Stand establishment.

Table 58. Effect of weed control and ground cover on yield of maize (TZB) (1979 first season).

Type of cover	Weed control	D.W. weeds[c] (kg/ha)	Grain yield (gm/stand)	Grain yield (t/ha)
Bare	1. Weed x 1	338	87.5	4.10
	2. Weedfree	0	102.8	4.67
	3. Weedy	1043	92.5	3.88
	Mean		94.3	4.21
Con. Till	1. Weed x 1	1088	107.1	4.27
	2. Weedfree	0	111.1	4.79
	3. Weedy	2613	97.12	4.04
	Mean		105.3	4.37
Desmodium	1. Weed x 1	738	109.1	4.43
	2. Weedfree	0	118.8	5.01
	3. Weedy	2343	95.5	3.73
	Mean		107.8	4.39
Arachis	1. Weed x 1	154	97.3	3.41
	2. Weedfree	0	98.24	4.10
	3. Weedy	795	88.7	3.33
	Mean		94.7	3.61
Indigofera spp.	1. Weed x 1	878	85.8	2.94
	2. Weedfree	0	79.3	3.29
	3. Weedy	2651	79.2	2.32
	Mean		81.4	2.84
Maize Stover	1. Weed x 1	110	105.5	4.54
	2. Weedfree	0	113.9	4.67
	3. Weedy	978	108.9	4.09
	Mean		109.4	4.33
Centrosema	1. Weeded x 1	175	120.4	3.36
	2. Weedfree	0	148.7	3.46
	3. Weedy	300	135.2	3.33
	Mean		134.7	3.38
Psophocarpus	1. Weeded x 1	283	129.2	3.34
	2. Weedfree	0	109.2	3.26
	3. Weedy	595	118.1	3.20
	Mean		118.8	3.27
[a]LSD (0.05)			20.3	0.74
[b]LSD (0.05)			26.4	0.95

[a]*For comparison of two means within ground cover.*
[b]*For comparison of means of different ground covers.*
[c]*Weeds sampled at 9 WAP*

Table 59. Effect of ground cover on weed species distribution.

Land management	Weed control	Weed flora distribution (kg/ha)[1] Broad leaves	Grasses
Bare	Weed once	50	900
	Weedy	430	1170
Bare cultivated	Weed once	130	560
	Weedy	700	2190
Arachis	Weed once	130	50
	Weedy	480	130
Centrosema	Weed once	80	0
	Weedy	270	90
Psophocarpus	Weed once	0	0
	Weedy	360	0

[1]*Mean of three replications.*

In the no-till plot, 27 percent of the weeds were broad leaves and 73 percent were grasses. In the live mulch, however, 25 percent of the weed were grasses, and 75 percent were broadleaved.

Maize response to fertilizer differed with the type of ground cover. Maize yield was lower in no-till and conventional-till plots that received no fertilizer than no-till and conventional-till plots that received 60 kg/ha of N, P_2O_5 and K_2O (Table 61).

Doubling the rate of nitrogen (120 kg/ha) did not increase maize yield. Maize yield from live mulch plots that did not receive fertilizer was significantly higher than in bare plots that received identical treatments. When fertilizer was applied to all types of cover, maize yield from live mulch plots were comparable to yield from no-till and conventional-till plots.

The effect of weed competition was more severe in no-till

Table 60. Effect of weed competition on maize yield in live mulch crop production system (IITA, 1979 second season).

Ground cover	Weed control	D. W. Weeds[c] (kg/ha)	Maize grain yield (t/ha)
Bare	Weed x 1	950	2.51
	Weedfree	0	2.78
	Weedy	1600	1.61
	Mean	-	2.30
Conventional-till	Weed x 1	690	2.71
	Weedfree	0	3.04
	Weedy	2890	2.27
	Mean	-	2.68
Arachis	Weed x 1	180	3.00
	Weedfree	0	2.98
	Weedy	610	2.47
	Mean	-	2.82
Centrosema	Weed x 1	80	3.39
	Weed free	0	3.51
	Weedy	360	2.65
	Mean	-	3.18
Psophocarpus	Weed x 1	0	2.93
	Weedfree	0	3.00
	Weedy	360	2.83
	Mean	-	2.92
LSD ($\bar{W}C$)			0.58
LSD ($\bar{C}$)			1.04

[a]*For comparison of mean within type of cover.*
[b]*For comparison of mean of different types of cover.*
[c]*Weeds sampled at crop harvest.*

Table 61. Effect of levels of fertilizer and ground cover on maize (TZE 41) yield (1979 second season).

Ground cover		Levels of Nitrogen (kg N/ha)	Grain yield (t/ha)
Bare		0	0.68
		60	2.78
		120	3.47
		Mean	2.31
Conventional-till		0	1.48
		60	3.04
		120	3.11
		Mean	2.54
Arachis		0	2.03
		60	2.98
		120	3.32
		Mean	2.78
Centrosema		0	1.97
		60	3.51
		120	2.54
		Mean	2.67
Psophocarpus		0	2.15
		60	3.00
		120	2.62
		Mean	2.59
SE (Fert.)	SE ($\bar{F}_1$-$\bar{F}_2$)		0.43
SE (Gr. Cov.)	SE ($G\bar{c}_1$-$G\bar{c}_2$)		0.42
LSD (0.05)			0.91
LSD (0.05)			0.90

and conventional-till plots that received no fertilizer than in corresponding live mulch plots. Fertilizer application tended to reduce the loss caused by weeds. Fertilizer application affects dry matter partitioning in maize. Results of the effect of fertilizer levels and type of ground cover show that the percentage of dry matter in the grain of maize planted on no-till soil receiving 120 kg N/ha was identical to the dry matter distribution pattern in the live mulch that received no nitrogen (Fig. 40). On the other hand, the lowest percentage of dry matter found in the grain occurred in no-till that received no fertilizer. Dry matter partitioning was identical in unfertilized and fertilized live mulch plots.

Studies on plantain

Yield decline. The fact that plantain grown under field conditions tends to decline in yield after the first or second harvest while plantain grown in village compound plots remains productive for many years is hypothesized to be related to soil factors and not intrinsic to field plantain. Village compound plantain remains productive for many years perhaps because of the constant supply of household refuse that maintains the fertility of the soil. Field plantain drops in yield once there is a decline in the natural fertility of the soil and fertilizer added, if any, is insufficient.

To determine the effect of fertilizer, mulch and household refuse plus ash on the growth and yield of plantain, a trial was set up in 1978-79 at the Onne substation. The plantain was spaced 3 m × 2 m planted in a randomized complete block design with 4 replications and 6 treatments. Fertilizer at the rate of 1 kg of 15-15-15 /mat/year was applied in 10 installments. Mulch was mostly grass, and household refuse consisted of yam and plantain peels.

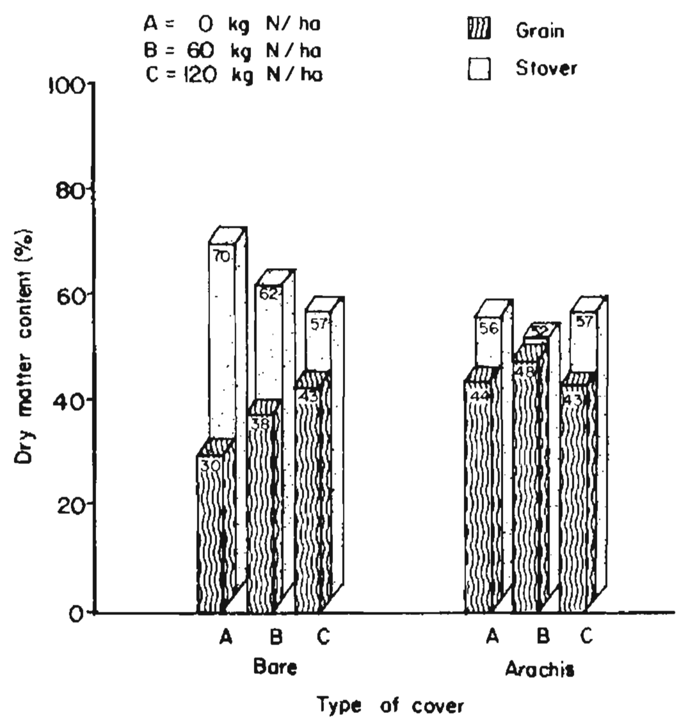


Fig. 40. Effect of N-level on dry matter partitioning in Maize.

The results, as presented in Tables 62 and 63, show the different treatments applied and their effects on yield, number of fruits per bunch, pseudostem height and girth (measured 1 m from the base) at shooting and number of days required for the shooting of the bunch.

Table 62 shows that plantain yield was not significantly affected by the various treatments. The absence of differences among treatments was in part due to variability and rather high natural fertility soil during first cropping. Also, since yield is determined by the amount of growth gained in the early stages of development, the release of nutrients from mulch and household refuse was probably not rapid enough for full utilization by the plant crop. This becomes evident in Table 63. Yields of ratoon crop growing on well decomposed mulch, including household refuse, are significantly higher than yields obtained from treatments not receiving mulch.

These results clearly demonstrate the importance of organic matter (derived from mulch and household refuse) in plantain production and the superiority of mulch as a soil amendment over the application of fertilizer alone. *Of greater significance, however, is the inclusion of* household refuse and ash, which increased yields remarkably. This confirms the concept that compound plantains are high yielders due to the constant supply of household refuse. Further, the results show that the incorporation of fertilizer in mulch treatment has no advantage on plantain yield over mulch alone. Similarly, fertilizer with nematocide was not better than fertilizer without nematocide.

The number of fruits per bunch of plantain is significantly affected by treatment (Tables 62 and 63) but not significantly different from one crop to the next (Table 64). Although the difference in the number of days to shooting is not significant between treatments, the number of days required by the ratoon is significantly greater than that required by the plant crop, which indicates a slower growth of the former due to shading by the latter. Plantain growth response is also illustrated by the differences in pseudostem height and girth. Again, these results show that mulching increases plantain growth more than fertilizer by providing soil organic matter. The greater heights attained by the ratoon crop, on the other hand, are due to shade effect.

Growth hormones and sucker development in plantain. Previous greenhouse trials indicated that growth regulators applied close to the meristem of young plantain (*Musa* sp.) suckers changed growth hormone balance and sucker development. This suggested the potential usage of growth regulators in shortening the harvest cycle interval between first and second ratoon crops. It also suggested the possibility for rapid multiplication without loss of yield from the mother plant. Studies in two field trials were conducted.

***Table 64.** Means of yield, growth components and number of days to shooting of plant crop and first ratoon.*

	Plant crop (1978)	First ratoon (1979)	LSD (0.05)
Yield (t/ha)	14.3	18.2	2.0
Fruits/bunch	27.3	30.1	2.8
Height (cm)	299.3	371.6	27.5
Girth (cm)	47.4	59.3	3.7
Days to shooting	290.5	317.0	17.1

***Table 62.** Effect of treatment on plantain yield, growth components and number of days to shooting of first planted crop.*

Treat. no.	Treatments	Yield (t/ha)	Fruits /bunch	Height (cm)	Girth at 1 m (cm)	Days to shooting
1	No fertilizer	13.53 a	25.9 ab	270.4 a	41.9 a	299 a
2	Fertilizer	13.95 a	28.0 c	291.8 b	45.6 bc	282 a
3	Fert. + nematocide	12.80 a	25.3 a	286.0 b	44.2 ab	299 a
4	Mulch	14.90 a	27.5 bc	300.6 b	48.0 c	286 a
5	Mulch + fertilizer	14.95 a	27.8 bc	326.1 c	52.6 d	291 a
6	Mulch + ash + household refuse	15.55 a	29.0 c	320.8 c	52.1 d	286 a

Means with common letters are not significantly different at 0.05.

***Table 63.** Effect of treatment on plantain yield, growth components and number of days to shooting of first ratoon crop.*

Treat no.	Treatments	Yield (t/ha)	Fruits /bunch	(cm)	Girth at 1 m (cm)	Days to shooting
1	No fertilizer	14.83 a	26.4 a	315.4 a	50.9 a	329 a
2	Fertilizer	16.22 a	28.3 a	352.0 b	55.0 a	315 a
3	Fert. + nematocide	16.62 a	25.8 a	329.6 ab	52.5 a	345 a
4	Mulch	20.29 bc	32.9 bc	403.2 c	64.1 b	298 a
5	Mulch + Fertilizer	19.32 b	31.6 b	411.6 c	65.7 b	293 a
6	Mulch + ash + household refuse	21.98 c	35.3 c	418.0 c	67.8 c	322 a

See footnote Table 62.

In the first trial, the pseudostem of a 7-month old mother plant was cut off and the apical meristem removed. The growth regulators; GA (Gibberilic acid), GA − NAA (Naphtylene acetic acid) , GA + NAA + cytokinin (Benzyl adenine), GA + cytokinin and ABA (abscisic acid); were applied on alternate days in 1 ml doses in concentrations of 10^{-2} and 10^{-4} *M*. Five peepers per mother plant were treated at 2-4 weeks after detopping of the mother plant.

In the second trial, the mother plant was retained. Treatment began at six months after planting. Only one peeper per plant was treated.

Preliminary observations in the first trial indicate that 10^{-2} *M* concentrations were too high. At this concentration, the growth regulators were translocated to the mother plant and to other suckers. Concentrations of 10^{-4} *M* appears to be within the desirable ranges for GA and cytokinin but was still too high for NAA.

In the absence of mother plant apical dominance, GA suppressed water sucker development and induced thin elongated swords. With an intact mother plant, sucker elongation accompanied GA application, but near normal development was observed only when GA was applied with cytokinin. Definite conclusions must, however, await observations on development and yield of treated suckers.

Agro-forestry

Begun in November, 1978, the Agro-forestry (taungya) project is an outgrowth of the experience and preliminary findings by IITA's Farming Systems Program that point to the increased need to consider the design and development of new and improved systems of land use in the humid and subhumid tropics.

The first effort of the project in 1979 was conducting field surveys to:

1. Identify and describe present traditional farming and land use systems with emphasis on tree crops.
2. Identify, describe and assess the actual and potential role of tree and shrubs, both cultivated and protected.
3. Review the taungya systems available for small holder food production.

The field survey for western Nigeria, now completed, involved 26 villages in six major locations (Ikorodu, Gambari, Agbor, and Auchi) in the coastal lowlands, rainforest and derived savanna zones, representing high and low populations. The assessment of the taungya systems was made through field visits to related development agencies in the region. The main survey showed that small holder agriculture and land use in the humid and subhumid lowlands of western Nigeria included: (1) traditional permanent tree crop farming, (2) taungya systems, (3) semi-sedentary arable crop farming, and (4) livestock (small ruminant and poultry) farming.

In the survey area, 67, 78 and 68 percent of the farmers had mixed enterprises of traditional permanent tree crop and arable crop farming, of which tree crop agriculture was dominant and on the increase with a corresponding decline of arable-crop farming (Table 65). Agricultural land use for tree or arable crop farming was confined to uplands under rainfed condition.

These two enterprises are operationally nonintegrated in their land use, except during the early phase of tree crop establishment when food crops are mix-cropped. Thus, tree crops occupy the land permanently and arable crop farming is carried out under short-rotation bush fallow or semi-sedentary systems of agriculture (Table 66).

The small holder farmer with his current level of technology (cutlass, hoe and fire) and family labor is able to cultivate less than 2 ha of arable crops but can operate more than 10 ha of permanent tree crops. His level of technology (and health hazards in hydromorphic lands) restricts his agriculture to uplands. Little use is made of bottomlands or irrigated agriculture. Agricultural use of bottomlands or irrigated agriculture also tends to conflict with upland tree crop farming, particularly for family labor. Where and when bottomlands are used, except for the type of crops and cropping calendar, they are used much like uplands. The land use factor (L) for both uplands and bottomlands is in Table 66 showing that the average for both upland and bottomland ranged between 1.6 and 5 years.

Traditional arable crop farming suffers from woody fallow. It keeps both the arable farm size and yearly farm income per farmer small. Traditional arable crop farming is undertaken, not so much as an economic enterprise, but as a subsistence food source as evidenced from farmers' reluctance to invest any accrued capital to expand arable crop farming. Returns to land and labor are significantly higher in tree crop farming than in arable crop farming, but the co-existence of these enterprises results in lower intensity of land use in the face of increasing human population.

Small holder arable crop farmers are under-employed during the dry seasons due to their two ha farm-size operation limit, resulting from critical seasonal bottlenecks, particularly weeding and land preparation. Farmers' response to this is to seek off-farm employment and other opportunities and develop traditional permanent tree crops, particularly if land is not limiting, or work on taungya schemes or attempt to work on hydromorphic land. While his efforts to combine tree crop and arable crop

Table 65. Patterns of small holder landuse in western Nigeria (1979).

	Derived savanna		Lowland forest		Coastal lowland	
Enterprises	Ogbomosho (ha)	Auchi (ha)	Gambari (ha)	Agbor (ha)	Ikorodu (ha)	Sapele (ha)
1. Tree crops only	6.95	7.05	8.0	6.45	13.0	15.81
2. Tree crops and arable crops mix	2.65	-	3.0	-	-	2.75
3. Arable crops only	5.7	7.96	2.62	8.26	3.63	6.98
4. Total cultivated	15.56	13.89	9.94	13.1	14.87	23.06
5. Area under fallow	-	15.15	3.54	4.27	22.14	19.35

farming enterprises on uplands are in response to his changing economic and natural environment and resources available to him, he has been unable to contain his production constraints, particularly land degradation.

Table 67 summarizes the major production constraints of the traditional farming systems. Credit, labor, pests, diseases, poor soils and land shortages were identified as the most limiting.

The inventory of useful woody plants associated with the traditional farming systems included 25 cultivated and 70 semi-cultivated retained (protected) species. With the increasingly shortened bush fallow cycles, the future of the semi-cultivated woody plants is uncertain, but their reduction in frequency is already evident. Table 68 summarizes the ecology and the agricultural systems of the region surveyed.

Table 66. Small holder land use patterns in western Nigeria: Type of land cropped and cropping/fallow duration (1979).

	Derived savanna				Lowland high forest				Coastal lowlands			
	Ogbomosho		Auchi		Gambari		Agbor		*Ikorodu*		*Sapele*	
Land use	Upland yr	Bottom land yr	Upland yr	Bottom land yr	Upland yr	Bottom land yr	Upland yr	Bottom land yr	Upland yr	Bottom land yr	Upland yr	Bottom land yr
Cropping year, average	5	5	2	2	4	4	1	1	3	3	2	2
Fallow years, average	7	3	4	3	4	3	4	4	5	4	4	3
Land use factor $\left(L = \frac{C + F}{C}\right)$	2.4	1.6	3	2.5	2	1.75	5	5	2.66	2.33	3	2.5
Frequency of upland/ bottomlands (% of farmers using)	95	35	100	65	100	65	95	10	100	30	100	35

L >10—Shifting cultivation.
L 5-10—Bush fallow agriculture.
L 2-4—Rudimentary sedentary agriculture.
L <2—Compound (permanent) agriculture.

Table 67. Major production constraints in the traditional permanent tree crop and arable crop farming systems of western Nigeria (1979).

	Derived savanna		Lowland forest		Coastal lowlands			
	Ogbomosho	Auchi	Gambari	Agbor	Ikorodu	Sapele	Total	%
Constraints	No	No	No	No	No	No	No	
1. Cash/credit	11	11	6	9	4	11	52	30
2. Old age	1	1	4	-	2	-	8	5
3. Pest/diseases/ poor soil	14	6	7	4	10	3	44	25
4. Poor yields/land suitability	4	-	1	2	-	7	14	8
5. Purchased inputs (seed, fert. etc.)	1	2	-	-	-	-	3	2
6. Labor cost/availability	4	2	3	-	4	2	15	9
7. Climate (rainfall)	-	3	3	-	-	-	6	3
8. Land shortage	-	1	2	13	4	1	21	12
9. Weed	-	-	1	-	4	-	1	1
10. Harvesting (duration)	-	-	-	1	-	1	2	1
11. Marketing (poor prices)	-	-	-	-	-	1	1	1
12. Fire outbreaks	-	-	-	1	-	2	3	2
13. No interest in farming	-	-	-	1	-	2	3	2
Total	35	26	27	31	24	30	173	

Taungya (agro-forestry) in western Nigeria: a current assessment. Taungya as practiced in Nigeria, is a system of forestry-plantation establishment, management and eploitation, in which arable crop farming is done during the initial two years from forest clearing.

After this, forest plantations are established, and the plantations are left for 15-60 years and the cycle may be repeated. The system is similar to the traditional shifting cultivation as it uses slash-and-burn techniques. The system is centered in both forest and savanna zones.

In western Nigeria, both departmental and traditional taungya are practiced. In the departmental taungya, income from arable crops goes to the departmental taungya, and the taungya farmers are paid wages. In the traditional taungya, income from the arable crops goes to the taungya farmer. But Nigerian farmers are not enthusiastic to participate, only 7,500 ha of the 89,000 ha of forest plantations established by the end of 1976 were developed using the taungya system. Where the system is operative, farmers plant up their plots to (cash) tree crops and attempt to use the taungya scheme to grow their food crops.

The cumulative effect in time of the taungya scheme and opportunities of off-farm employment is to increase the area under traditional permanent tree crops. With long cycles of plantation crops or taungya scheme made inoperative, farmers have tended to further shorten their bush fallow cycle, causing accelerated decline in soil fertility and crop yield. In some instances, the farmers with advancing age give up arable crop farming.

The current state and immediate future of the taungya system in its present form in Nigeria is uncertain. A modified taungya — modified to suit the small holders' interests and needs and national goals — is needed to solve the problem of maintaining sustained food production, conserving soil resources, expanding forests and improving the socio-economic level of the small holder farmers.

Establishment of research nurseries. Screening nurseries at IITA and the Onne substation and tree/shrub food crop intercropping trial at Onne, included planted or retained woody species (*Acio barteri, Anthonatha macrophylla, Alchornea cordifolia, Dialium guineense, Gliricidia sepum, Leucaenea leucocephala*, and *Tephrosia candida*), import multi-purpose trees and shrubs (*Treculia africana, Irvingia gabonensis, Dacryodes edulis, Pterocarpus* spp., *Monodora* spp. and *Samanea samau*), and fast-growing pulp, firewood and soil ameliorating species (*Cordia alliodora, Albizia falcataria, Cassia siamea, Sesbania grandiflora, congesta* and *Gmelina arborea*). These and others to be screened should give a range of choice of species to be intercropped, alley cropped or to be grown as planted fallow or taungya species.

Table 68. Agro-ecological regions and their traditional agricultural systems in western Nigeria (1979).

Agro-ecological regions and zones	Geomorphology	Climate	Vegetation	Land use
I. Cocoa/forest zone				
A. Northern belt	Pediments & Hills (Dissected basement complex) 200-600m	sub-humid	Derived savanna	Cocoa/kola/citrus/yam/cassava/maize/sorghum/cowpea
B. Central belt	Undulating plains w/inselberg 200m	humid	Secondary forest	Cocoa/kola/*musa*/cassava/maize/veg/rice
C. Southern belt	Level to gently undulating plains	humid	Swamp forest	Kola/cocoa/*musa*/cassava/veg.
II. Benin & coastal lowlands				
A. S.W. lowlands	Sedimentary rocks and sands	sub-humid		Rice/cassava/cocoa/kola
B. Lagos and adjacent	Lowland sedimentary plains	humid (sub-humid)	Swamp forest	
C. Benin lowlands	Sedimentary level to undulating	humid	Rubber oil, palm forest	Rubber/oil palm/Root crops/maize
III. Niger Delta				
A. Northern Delta	Sedimentary plains	sub-humid, humid	Ripparians forest	Yam-base agric.
B. Middle Delta	Sedimentary plains	humid	Ripparians formation	Root crop/oil palm complex
C. Lower Delta	Sedimentary plains	humid	Ripparians formation	Root crop/oil palm complex
IV. Mangroves and bearch ridge (largely non-agricultural region)				

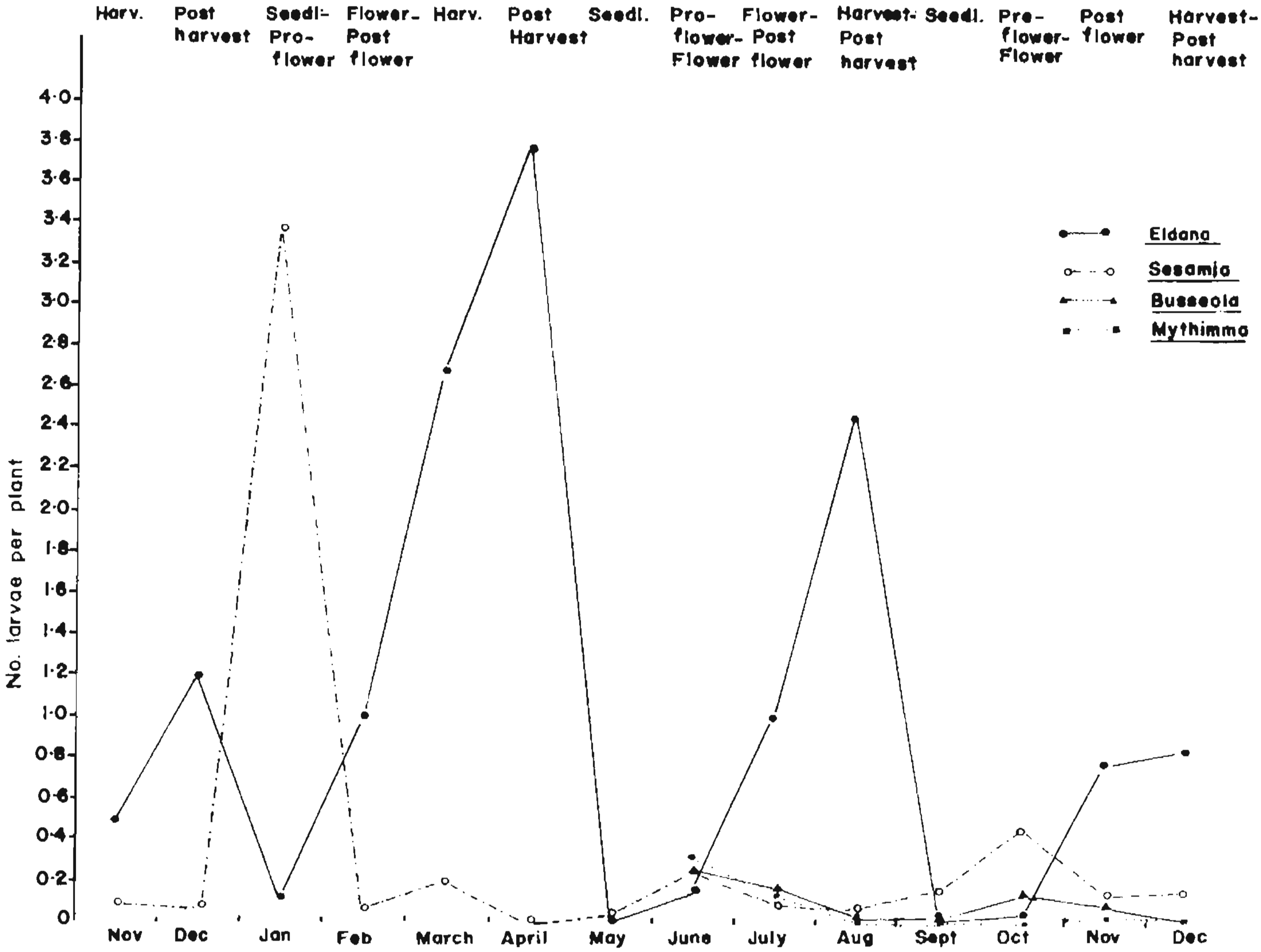


Fig. 41. Seasonal variation in number of stemborers per maize plant.

Ecology of maize stemborers

Ecology involving the population fluctuations and farming systems oriented population dynamics of four species of stemborers — *Eldana saccharina* (Pyralidae), *Sesamia calamistis* (Noctuidae), *Busseola fusca* (Noctuidae) and *Mythimma unipuncta* (Noctuidae) — has been investigated.

Population fluctuations in mono-cropped maize. Two main factors influence borer population, the developmental stage of the maize plant and season of the year (Table 69 and Fig. 41). In *Eldana*, larvae appear shortly before the host plant begins to bloom, increase gradually toward the ripening of cobs and increase sharply after the harvest if the plant is kept standing in the field. In *Sesamia* and *Busseola*, larvae infest seedlings and increase in number through the preflower period. The majority complete their development by maize bloom. *Mythimma* follows a similar pattern, but the larvae are less in the seedlings and more in the postflower period of the host plant.

The *Eldana* population is 2.5 times larger in the dry season than in the rainy season. Three population peaks occur every four months — April, August and December — each coinciding with the post-harvest period of maize.

The *Sesamia* population is three times more in the dry season with a peak in January. *Busseola* and *Mythimma* are both rainy season oriented species. The *Busseola* population peaks in June, July and October. It hibernates from November to April as a full-grown, last instar larvae. *Mythimma* is sporadic in occurrence with its peaks in June and July.

Population dynamics in conventional- and non-till plots. In the first season of May-August, from seedling to harvest, the number of borers in the no-till plot was more than five times the number in the conventional-till plots. This is to be expected as all species of borers are able to breed in maize debris (stems, cobs, roots) on the ground. In the post-harvest maize, however, the figures were somewhat reversed as the number of borers in the conventional-till plots almost doubled those in the no-till plots due probably to the migration of emerged adults from the more crowded no-till plots to less crowded conventional-till plots (Table 70).

In the second season of September-December, the number of borers in the no-till plots was less than 1.5 times those in the conventional-till plots. This was due to the fact that at the time of sowing seeds, the conventional-till plot was tilled but stubbles of maize were left scattered on the ground simulating no-till and inviting borers to breed. This shows clearly the importance of clearing the ground thoroughly if borers are to be avoided (Table 71).

Population dynamics in mono- and mixed-cropped systems. The number of borers in the mono-cropped maize was more than twice those in the mixed-cropped plots. This is due probably to the fact that in the mixed-cropped plots of maize and cassava, more voluminous cassava conceals the presence of maize, which, therefore, is less exposed to borer adults for oviposition. When cassava was small, the size of borer population in both plots differed little from one another.

Energy management — crop production engineering

Particular emphasis is paid to the resolution of three primary physical constraints to productivity:

1. Energy — the drudgery of traditional farming.
2. Time — the limitation of the extent of farming per season.
3. Logistics — transport and handling of inputs and produce.

Major environmental limitations specific to humid and sub-humid tropics farming systems are field (and seedbed) preparation techniques, which will least disturb the soil and expose it to erosion, and the time spent in preplanting preparations.

During 1979, emphasis of work was given to evaluation and modification of no-till planting equipment and cassava harvesting tools.

Improvement of IITA Rolling Injection Planter

Testing of the early models of the IITA Rolling Injection Planter showed the following problems:

1. Uneven number of seeds per *hill*.
2. Plugging on soils with high moisture content with and without high clay content.
3. Heavy to push.

A constant number of seeds per hill to conserve seeds and eliminate supplying and thinning and one seed per hill for maize for the 25 cm spacing of this planter are desirable. Earlier tests showed that the number of seeds per *hill* on maize varied from 0 to 5. The *final prototype* planter showed that about 60 percent of the hills have one seed per hill with very few complete misses.

Plugging is a problem with almost all types of planters. Minimum plugging is needed to minimize missed hills. Almost all planters plug when moved backward in the soil; the Rolling Injection Planter is no exception. Plugging when moving forward has definitely been reduced on the *Rolling Injection Planter. In the new prototype*, some modification was made in the opener (Fig. 42). By relocating the pivot point of the movable component, the opener is allowed to open after it has fully penetrated into the soil. The new hole opener consists of a split spear shaped component, which penetrates easily in the soil. The split opener also holds the hole free from soil for the next sequence. On light soils using the latest design, virtually no plugging occurs even in very moist soil conditions.

Table 69. Correlation between age of maize and borer populations (May-October, 1979).

Age of maize	*Eldana* (%)	*Sesamia* (%)	*Busseola* (%)	*Mythimma* (%)
Seedling	10 (0.7)	323 (27.8)	105 (22.0)	16 (0.3)
Preflower-flower	3 (0.2)	683 (60.8)	276 (57.6)	94 (54.3)
Postflower-harvest	461 (32.3)	88 (7.8)	84 (17.5)	63 (36.4)
Postharvest	955 (66.8)	30 (2.7)	14 (2.9)	0 (0.0)
Total	1429 (47)	1124 (37)	479 (16)	173 (6)

Table 70. Comparison of borer populations between conventional- and no-till plots (first season).

Month	Age of maize		No maize infested con.	No maize infested no	No borers found con.	No borers found no	No. of plants examined
May	Seedling		42	166	4	19	5,000
June	Preflower-flower		50	97	20	125	800
July	Postflower-harvest		73	142	74	359	1,000
		Total	165	405	98	503	6,800
Aug.	Post-harvest		40	56	232	137	400

Table 71. Comparison of borer populations between conventional- and no-till plots (second season).

Month	Age of maize		No maize infested con.	No maize infested no	No borers found con.	No borers found no	No plants examined
Sept.	Seedling		114	104	2	10	5,000
Oct.	Preflower-flower		183	136	164	106	1,000
Nov.	Postflower-harvest		78	57	94	231	800
		Total	375	297	260	347	6,800
Dec.	Post-harvest		52	52	34	54	400

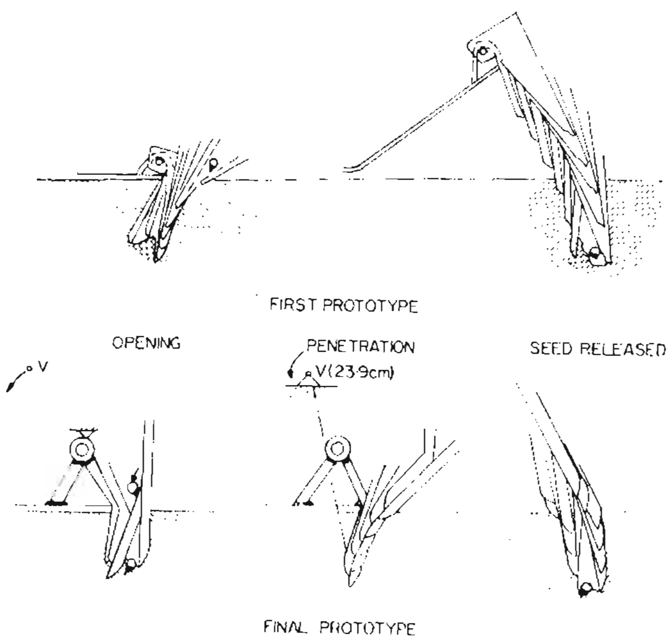


Fig. 42. Hole opener penetration of IITA Rolling Injection Planter (FSP engineering, 1979).

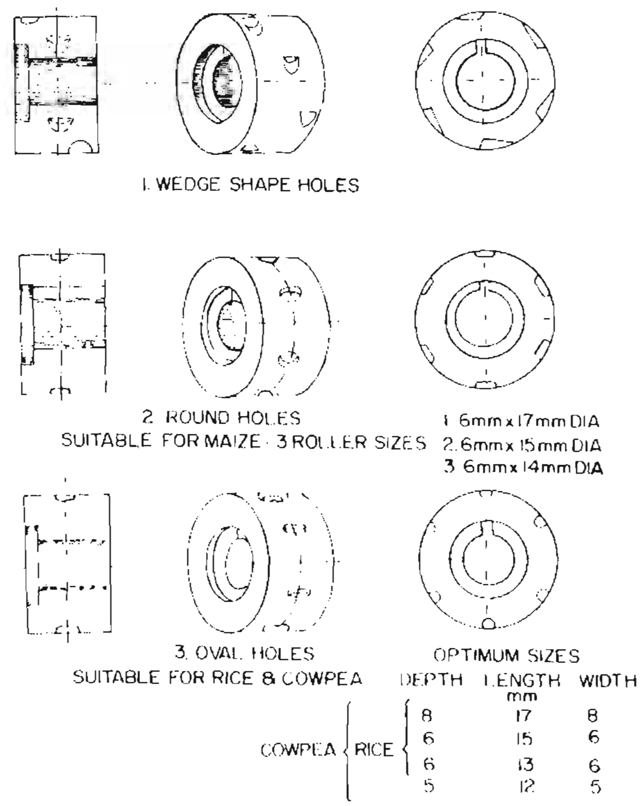


Fig. 43. Metering rollers of IITA Rolling Injection Planter (FSP engineering, 1979).

No design effort has been made on the force to push the planter. Yet, it has been improved through the changes made in the planter to reduce the plugging. The force required to push the planter has been reduced by 18 percent. The force was 11 kg for the single-row planter in early design and is now down to 9 kg on the present design.

The theoretical field capacity (work rate) for the single-row Rolling Injection Planter is 5.3 hr/ha and needs some improvement in efficiency.

The hopper design is vital to the efficiency of the metering roller. A number of hoppers were tried for faster movement of the seed inside the hopper. The bigger surface of the roller exposed inside the hopper gave better performance of filling the roller notches and avoiding lots of missing hills. Figure 43 shows a number of roller sizes suitable for maize, rice and cowpea. Roller sizes for other crops need to be determined for proper seed metering.

Four-row rice planter

Performance of the rice planter greatly improved with the efficiency of the hole opener mentioned earlier. For shallow planting on bunded paddy, this was achieved by cutting the hole opener to the desired planting depth. One of the vital constraints of the planter is its weight; this is needed for penetration. Other modifications to make planter lighter are in progress.

Evaluation of Farmobile

The performance of the Farmobile, which is an improved power tiller-trailor, was evaluated in 1979 on a 6.2 ha maize farm. For operation of the Farmobile, two men are needed. The first man operates the tractor, the second man keeps track of seed and herbicide on the spray/plant operation. When spraying with the CDA 4-m boom sprayer, the second man changes sitting markers so that the tractor operator can go in a straight path, affording complete coverage of the ground.

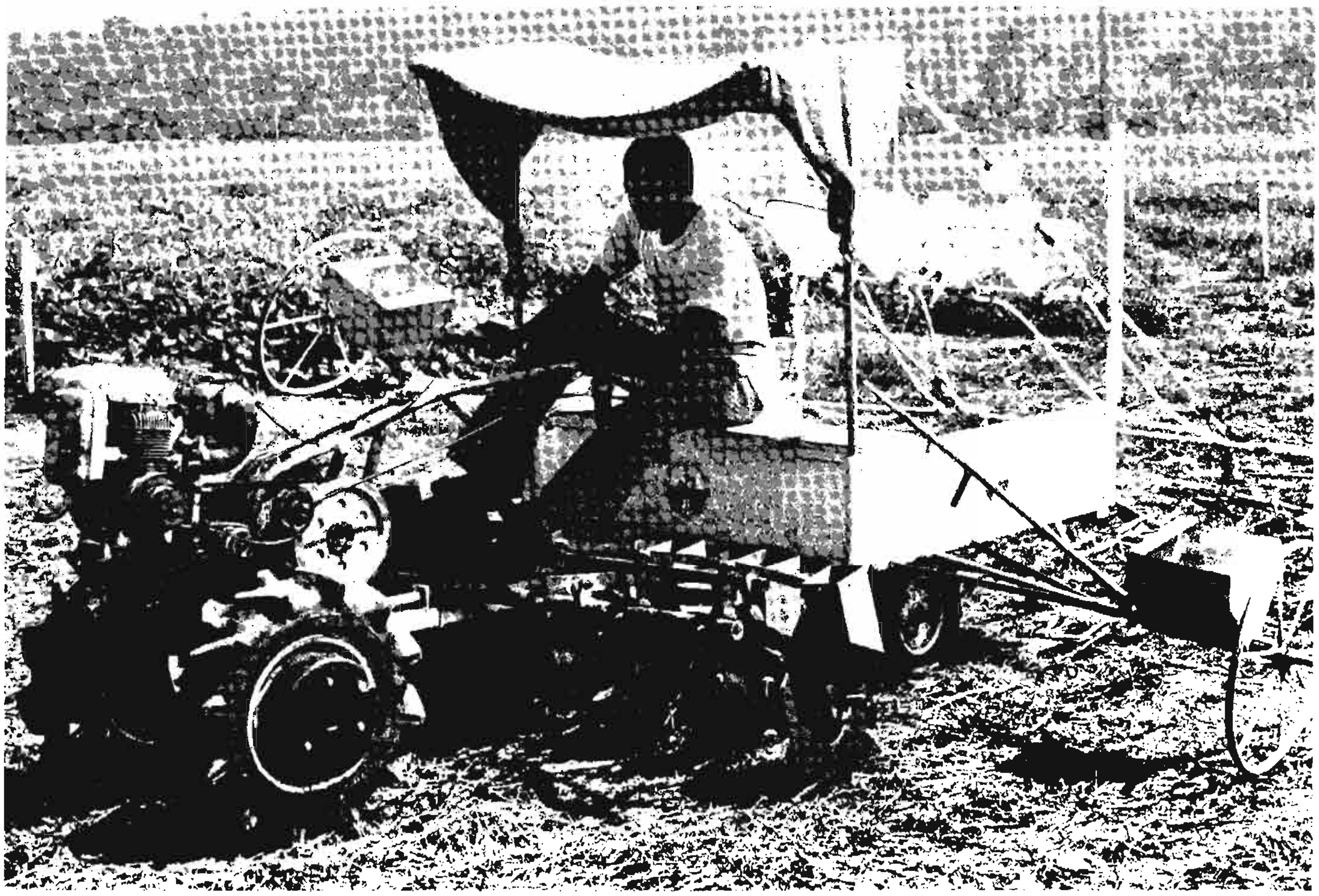
The field capacity of the Farmobile under its different operations is shown in Table 72 as tractor hr/ha/season.

Transporting is an important role of the Farmobile. This includes conveying inputs and labor to the field, the harvested crop to cribs and shelled maize to market.

Continuous problems were observed with the 5-hp petrol engine during the first season. A change to a diesel en-

Table 72. Summary of use of Farmobile on 6.2 ha maize farm operated on no-till.

Equipment	Total tractor hr	Total man hr	Total hr/ ha/season	Man hr/ ha/season
Herbicide application with 4-m boom	22	44	3.55	7.10
Spray plant	128	256	10.32	20.66
Transport	530	530	42.74	42.74
Total	680	830	56.65	70.50



Farmobile, an improved power tiller-trailor, was evaluated on a 6.2 ha maize farm. Its role includes not only tilling, seeding and spraying, but transporting inputs and labor to the field, the harvested crop to cribs and shelled maize to market.

gine during the second season eliminated these problems. However, some problems remain:

1. Traction problem: A second person is required to push the machine when going uphill, on soft ground or through holes in the field.
2. Large headlands are required on the ends of the field as it is difficult to make short turns with the tractor.

The CDA 4-m boom sprayer was satisfactory and worked effectively in controlling the weeds as expected. Additional tests were set up to determine whether the effectiveness of the descant herbicide is affected by fresh maize stalks covering the weeds. This test is important in relation to spray/plant operation. The tractor is set up in such a way that the herbicide is applied after the tractor has knocked down the maize stalks.

Two of the four fields were sprayed by hand with the CDA sprayer between the standing maize stalks just before planting. The other two were sprayed with the Farmobile where the stalks were knocked down by the tractor and then sprayed. Results were satisfactory; no difference in weed control was noted.

Evaluation of cassava harvesting tools

IITA cassava lever. This is designed for harvesting cassava in large quantities by reducing the force exerted to pull the cassava from the ground and increase the amount of cassava that 1 man can harvest in a day. The direct pull forces varied from 17 to 356 kg; the average was 78 kg. The force exerted on the handle of the cassava lever varied from 5 to 110 kg; the average was 24 kg.

To make comparisons, the kilograms of force exerted to harvest 1 kg of tuber is shown in Table 73. The ratio using force per weight of tuber for direct pull as compared to cassava lever is 3.67. This indicates that the force a man must develop to harvest 1 kg of cassava by the direct pull method will regain 3.67 times as much force as with the lever.

Stem breakages is a major problem in cassava harvesting in hard soils; in an investigation, 43 percent of the cassava stem could not be harvested in hard soil with the lever. Thirty percent of this was due to stem breakage

Table 73. Manual cassava harvesting. Comparison of forces exerted to direct pull of cassava vs. forces exerted on handle of IITA cassava lever.

Method	Ave. kg force exerted per kg tuber harvested	Ratio
Direct pull	18.20	$\frac{18.20}{4.96} = 3.67$
Cassava lever	4.96	

and 13 percent to stems that had a low angle to the soil. With stems below 35°, the cassava tends to move sideways instead of upwards.

Stems had to be pulled so that the force from the lever was in the same vertical plane as the cassava stem. When attempting to pull the stems in any other direction, the stem usually broke, except in the case of the stem having an angle of 80° or more to the soil. When a plant had three main stems or more, the stems were too weak to stand the tensile force that the lever exerted. With two main stems, the pulling was successful about 50 percent of the time. When a plant had one main stem with an angle of 35° or more to the soil, the pulling was successful about 95 percent of the time.

Tractor-pulled cassava harvester. Tests were conducted on three tractor-pulled cassava harvesters at IITA: IITA copy of CIAT, Ransomes and Alpha Accord. The objective was to compare these machines as to cassava tuber recovery and damage and on the field capacity and durability of the machines (Table 74).

The tests showed that the IITA copy of the CIAT harvester has the greatest potential. Factors contributing to the success of the CIAT harvester were as follows:

1. It is inexpensive and simple to build in relation to the other machines.
2. It is built very ruggedly. This allows it to be used at high speeds, thus, increasing the rate of work to 1 hr/ha.
3. It could be used where there are stumps and roots without damage to the machine.
4. Root damage and roots left in the soil were low.

The Ransomes had very little damage or losses, and its rate of work was comparable to the others, but it will need considerable additional design to improve durability. The cost of increasing its strength would be high.

The Alpha Accord caused a high rate of tuber damage and the blade bent very easily. These problems could be solved but would require considerable additional design and expense.

For a large-scale fully mechanized cassava harvesting, the Ransomes, which is a chain elevator potato harvester, has the potential to move the cassava directly into a trailer or truck. The harvester also can raise the cassava to a height of 60 cm above the ground and then can feed another elevator, which would deliver the cassava to any height needed.

The CIAT harvester can also be used as a large-scale harvester, but the cassava will have to be lifted from the ground by hand. Because it does not lift the cassava completely out of the ground, the CIAT machine is more labor intensive than the Ransomes. About 75 percent of the roots are above the ground after the CIAT harvester passes compared to 90 percent for the Ransomes harvester.

Agricultural economics

The agricultural economics approach at IITA is to select technologies that broadly apply to all of the mandate region. In general, these are not technologies that are ready for immediate adoption by farmers in a particular region since technologies should be "fine tuned" for specific locations. These potentially useful "notional" or "preliminary" technologies should ultimately be refined to become developed technologies.

The preliminary technologies are evaluated to provide useful feedback to scientists for redesign or abandonment of the technology. Because the technologies are preliminary, the method of evaluation is not a detailed study of how the technology performs under farm conditions in a specific region. The evaluation methodology is flexible and depends upon such factors as the technologies' stage of development and type (variety/new system, etc.) and the amount of resources available for the evaluation, including input from scientists. While the choice of technologies on which to focus is somewhat subjective, such a choice is necessary since the resources are not available to evaluate a large proportion of IITA preliminary technologies.

Early-maturing maize as a first-season crop

The most commonly grown maize varieties will mature in about four months (120 days). Early-maturing varieties are bound to yield less than four-month varieties if grown under optimal growing conditions. The question is whether there is a loss under practical conditions and, if so, whether the early maturity of the variety can compensate for the yield reduction.

IITA has developed short-duration (90 days) varieties, originally for the second season in the forest zone. This season lasts from September to November, and its duration is erratic because the rainfall at the end of the season is unreliable. It was thought that a short-duration maize would decrease the dependence on rainfall during the second half of the second season.

There are social and economic factors, indicating that an early-maturing maize variety might also be needed during the first season; maize is the first cereal crop usually harvested during the "hungry season," which is the period of food shortages that are associated with the exhaustion of the stocks accumulated from the last harvest(s) and prior to the arrival of the earliest crops of the next season.

To compare the productivity of a 3-month duration variety (TZE_4) with that of a 4-month variety (TZPB), a series of on-farm maize trials were carried out. The crops were grown at two forest sites in Nigeria, Lagun and Ikenne, each trial with three replications. Planting was done after

Table 74. Performance of four tractor-pulled cassava harvesters.

Harvester	Cut and skinned (%)	Roots left	Rate of harvest (hr/ha)	Durability rank (No. 1 best)
IITA copy of CIAT	3.00	4.00	3.0	1
Ransomes	2.00	2.00	4.5	2
Alpha Accord	27.00	0.25	5.1	3

Table 75. Revenue indices of TZE_4 and TZPB at different planting dates.

Planting	March		April	
Variety	TZE_4	TZPB	TZE_4	TZPB
Yield	2.765	4.025	2.510	3.180
Price index	122	88	88	78
Revenue index	377	354	221	248

the first heavy rain according to farmer's practices. The average yield figures per location are presented in Table 75.

A survey of seasonal maize prices of the last seven years (1973-79) showed that from June to July, the maize prices declined 34 percent, implying that farmers growing early-maturing maize had a large price benefit. During the same period, 80 farmers who were familiar with both varieties were interviewed.

Among other things, the results showed that a majority of the farmers were willing to give up two cobs of a four-month variety in order to obtain only one cob of a three-month variety. The general conclusions of this study were:

1. An early-planted, short-duration maize variety can shorten the "hungry season" by three to four weeks.
2. The earlier in the season that maize is planted, the higher yield is to be expected. An early planting date — even allowing for the risk of drought — offers the best chance of high yields.
3. The yield of the short-duration variety is lower than the yield of the four-month variety, but yield differences narrow if planting date is delayed.
4. There is a high price advantage (for dry maize) of the early maize variety which nearly offsets lower yield.

The conclusions imply that the farmers are ready to adopt an early-maturing maize as first-season crop. Because four-month varieties are superior in yield, these are grown for bulk sales and storage. Farmers could grow both the early-maturing and the medium-duration varieties, thereby, reducing their risk, improving their diet and cash-flow situation during the first seasons and increasing the flexibility within their farming systems because of the early clearance of some of the maize fields.

Performance of maize composite varieties

Presently, improved varieties available to farmers are "*composites.*" Cross pollination between plants ensures that the same characteristics of the population are carried into the next generation so that a continued yearly seed supply to the farmers is not required (as it is with hybrids).

With composites, it is preferable for the farmer to select his seeds for subsequent planting at random from a large field. Only then will the characteristics of the population be maintained over a longer period of time. On the other hand, if the farmer selects the seed for planting from a restricted number of plants — by selecting individual cobs on the basis of a particular criterion or selecting from a small field — he is narrowing the gene base of the population. If the narrowing of the gene base is severe, yield depression will occur and the farmer will lose the advantages of the improved variety.

It is, thus, important to know the manner in which the farmer selects his seeds as well as to estimate the impact of his behavior on the yield of improved varieties. Eighty farmers were surveyed on this topic in four different areas of southern Nigeria — Lokoja, Iseyin, Ilora and Ondo. The survey focused on:

1. Source of the seed that farmers use.
2. Quantity of seed that farmers store for the next planting season.
3. Place of storage.
4. Manner by which the selection takes place.
5. Relationship between green maize sales and seed selection.

The results show that nearly all farmers (92.5 percent) use their own maize as seed source. Smaller farmers always store their seed as cobs.

The smaller the seed sample, the greater the chance of inbreeding depression. It is believed that at least 100 cobs should be stored to maintain the genetic base of the maize population. A majority of the farmers (75 percent) stored 200 cobs or more for the purpose of planting, and only 15 percent stored less than 100 cobs. Generally, (in 84 percent of the case) the seed is stored inside the home, mostly above the fireplace for protection against weevils. The use of herbicides is not common. The average loss of cobs during storage was reported to be 15-20 percent.

Most farmers (87.5 percent) select their seed before selling any part of their dry crop. However, a considerable part of the maize crop is sold "green." Green maize is picked on the field by trading women who prefer the earliest and nicest-looking cobs. This method implies an unintended selection for longer-duration, lower-yielding maize as only the later-maturing small cobs are allowed to become "dry."

A continuous selection of big cobs may shift the genetic basis of the maize composite in the direction of taller plants with delayed flowering and maturity and lower yield. The cob size was the main criterion for seed selection for about 70 percent of the respondents. The size, however, is also determined by environmental factors.

Selection of individual seeds before planting (after shelling) is practiced by 30 percent of the farmers; again, the size was the main criterion. It is unlikely that this has an impact on the genetic base of the composite. However, bigger seeds may germinate better.

The maize seed selection survey indicates that the farmers are rather uniform in their selection behavior. The main differences are in:

1. Quantity of seed stored.
2. Seed selection after shelling.
3. Relative share of the maize harvest that is sold "green."

The impact of this selective behavior of farmers on the high-yielding characteristics of improved maize composites is not yet clear. In 1980, this project will be continued by comparing the yields of newly released TZPB with TZPB that was distributed to farmers several years ago and has been through their selection process several times.

On-farm trials

Some trials with improved maize were conducted on farmers immediately outside IITA. These include one high-yielding and profitable first-season trial sowing TZPB *in combination with chemical fertilizers and insec*ticides. However, a series of second-season trials designed to compare the performance of TZE and TZSR maize under farmers' conditions were plagued by insects and animals so that no meaningful comparisons could be drawn. However, the difficulty of growing second-season maize in the IITA environment without adequate protection from pests was reconfirmed.

*In combination with early-maturing maize evaluation sur*vey, on-farm trials were also conducted in two villages in the Lokoja area. Although the yields of the variety (TZE) were rather disappointing for a first-season crop, the farmers expressed great satisfaction with the early maturity of the crop.

Bitter and sweet cassava acceptance

Historically at IITA and elsewhere, cassava breeding programs have emphasized high yield and disease resistance. In recent years, however, there has been an increasing awareness of the importance of hydrocyanic acid content from a public health viewpoint and of the acceptability of new varieties by producers and consumers. Whether a consideration of cyanide in relation to cassava processing and utilization is so important in Nigeria to warrant its research is the issue that this study examined.

Data were collected by administering a questionnaire to a sample of 122 farmers selected from two villages each in Anambra, Bendel, Ogun and Kaduna States. These states were selected on the assumption that the different forms of cassava depend on geographic location and ethnic origin. Only villages that had significant production and consumption of *cassava and access to markets* were selected. These were the results:

1. All farmers recognized that two major types of cassava exist. The sodium picrate leaf test showed that 76 percent of all cassava distinguished by farmers as sweet was, in fact, low or medium in cyanide content. Of the varieties classified by the farmers as bitter, 81 percent had high cyanide. Farmers are, *thus, good at identifying low- and high-cyanide* cassava.
2. The amount of sweet grown as a proportion of total cassava grown ranged from 0 to 79 percent in Anambra and Kaduna State, respectively.
3. In the states where both types of cassava were grown, the percentage of farmers who grew both bitter and sweet was the highest in Bendel State (47 percent) followed by Ogun State (45 percent). In Kaduna State, only 3 percent of the farmers grew both varieties.
4. All farmers surveyed would not eat boiled or roasted cassava roots of the bitter varieties; most recognized hazards such as stomach ache, constipation, vomiting and death in consuming bitter varieties in these forms. These hazards result from high cyanide.
5. *Consumers in the North prefer* to eat unprocessed cassava; thus, the farmers grow mostly sweet cassava. In the South, processed cassava is preferred. Because bitter varieties are higher-yielding than sweet, and the cyanide content is reduced to safe levels by processing, most cassava grown in the South is bitter.
6. Sixty-six percent of the farmers said that fermen*tation during processing was responsible for a* good *gari* flavor. Ninety-four percent said that the processing of *gari* is the same, irrespective of which variety is used. Thus, it appears that no cost savings in *gari* making would accrue as a result of widespread use of the sweet varieties.
7. All farmers surveyed also had no preference between *gari* made from the sweet or bitter cassava. The *gari* yield of the cassava roots was important.
8. Ninety percent of the farmers growing both sweet and bitter varieties complained of rodent attack, which led to annual losses averaging about 12.5 percent. Thirty-seven percent of the farmers observed that these rodents have a preference for the bitter varieties; 35 percent had not observed any preference for any particular variety while 26 percent had observed a preference for the sweet varieties.
9. When offered the prospect of a high-yielding sweet cassava, 53 percent indicated that they would switch outright to sweet varieties if yields were as high as the bitter. Thirty-five percent would experiment with both varieties before switching.

Conclusions. High cyanide is not a prerequisite for good *gari* flavor. Furthermore, the processing of *gari* is the same regardless of whether sweet or bitter cassava is used. Thus, in terms of traditional *gari* making, no advantages or disadvantages can be foreseen from low cyanide cassava.

At current yield levels, it seems that small amounts of sweet cassava will continue to be grown by farmers who prefer to eat non-processed forms of cassava or do not have access to *gari*-making equipment or technology. However, high-yielding sweet cassava would quickly be adopted by farmers currently growing sweet cassava since these farmers recognize that the sweet cassava presently being grown is low-yielding relative to bitter varieties. Rodent damage is not an important consideration in evaluating the future demand for high-yielding sweet cassava.

A high-yielding sweet cassava would be important if cassava began to be used for animal feed in the future. Expensive processing for this purpose would not be justified. A new squeeze press method for *gari*-making has recently been gaining popularity with *gari* processors. This method omits the time-consuming fermentation process. If, as expected, the resulting *gari* is high in cyanide, then sweet cassava would become of increasing importance. These implications of the squeeze press method are currently being more carefully assessed.

National Accelerated Food Production Project

IITA continued to be an active participant in the National Accelerated Food Production Project (NAFPP) in 1979, working in a number of key areas at the request of the Nigerian Government. Established in 1973, the NAFPP was developed jointly by IITA and national agricultural organizations to check the growing disparity between food production and demand. After four years of research, the project began its implementation phase in 1977 based on a system that incorporated research and extension on a crop commodity basis. Using this system, NAFPP extension workers found that they could achieve farmer acceptance of high-yielding, disease resistant crop varieties in only 3 years instead of the 7-10 years required under existing extension systems.

Now being adopted as Nigeria's "cardinal" food production program, the NAFPP works toward the goal of agricultural self-sufficiency by 1984. Assisting the Federal Government of Nigeria in realizing that goal, IITA specialists and counterparts are serving the Project on maize, cassava, agro-service, economics and communications components. Their activities give special emphasis to systems development and staff training as described below.

Maize. IITA specialists working with the National Rice and Maize Center assisted the state governments in establishing over 20,000 ha of high-yielding maize varieties such as IITA's TZPB throughout Nigeria in 1979. Research activities also included analysis of the NAFPP's package of practices for maize consumer acceptability of improved varieties and the practicality of no-till farming.

Cassava. Working with the National Cassava Center, IITA staff collaborated in the multiplication of disease resistant, high-yielding varieties such as TMS 30555 and 30572, developed by IITA in cooperation with the National Root Crops Research Institute, at Umudike. Research activities emphasized the adaptation of improved farming systems using maize and cowpea as an intercrop.

Economics. To determine what inputs and services farmers need most and examine the cost/benefit ratio of their adoption, studies were undertaken by IITA's NAFPP economist. Survey results in the derived savanna zone indicate that maize variety TZB is highly acceptable for feed production while local varieties are still preferred for green consumption. Further studies indicate that improved cassava varieties are also highly acceptable due to their high yields and early maturity though storage remains a problem. Results also show that herbicides are generally economically viable where weeding is the main factor limiting the expansion of production.

Agro-service. By the end of 1979, approximatively 200 agro-service centers were established to supply fertilizer, improved seed and other agricultural inputs to farmers. IITA specialists working with the National Agro-Service Units of the Federal Department of Agriculture are assisting in the further development of the program with continued emphasis on training and the development of logistical systems to facilitate the smooth flow of supplies.

Communications. NAFPP's communication program was established in 1978 and implementation began in 1979. Emphasis has been placed on communication within the project through publications and audio visual materials. A continuing service training program serving all 19 states is also underway to facilitate farmer education programs scheduled to begin in 1980-81.

ROOT AND TUBER IMPROVEMENT PROGRAM

Introduction

Scientists in the Root and Tuber Improvement Program are engaged in the improvement of four food crops of the tropics: cassava, yam, sweet potato and cocoyam. The cultivation of these crops provides the main livelihood for the small farmers, and the products serve as the major food for urban poor. However, there are serious problems being encountered by these crops, which if not resolved, will greatly reduce production and cause supplies to become insufficient at the farm level and extremely expensive in other economic sectors. Improvement in production will be of immense benefit for many millions of small-scale farmers who grow these crops throughout the tropics.

The ultimate goal of the program is to develop a package of improved technology in terms of varieties and improved cultural methods for high stable yields, high economic returns and high consumer acceptance of cassava, yam, sweet potato and cocoyam and to transfer the package of technology to farmers by training scientists of national programs and by close cooperation with these programs in the tropics.

The objectives of the program are to:

1. Develop improved varieties with: (a) high yield; (b) resistance to major diseases and insect pests; (c) adaptation to a wide range of climate, soil and cultural conditions; (d) high storability; (e) high consumer acceptance; and (f) improved plant types (conformation and tuber characteristics) which are suitable to easier harvesting and non-staking (yams).
2. Develop improved cultural methods that are readily acceptable to farmers and guarantee maximum returns with minimum management inputs.
3. Assist in the development of strong national root and tuber research and development programs.

Cooperative programs have been established with the Programme National du Manioc (PRONAM) in Zaire, the Cameroon Root Crops and Farming Systems Program and the National Accelerated Food Production Project (NAFPP) in Nigeria. Reports on these projects are included in Cooperative Projects and individual annual reports are available from the respective governments.

This program also interacts with the Farming Systems Program in testing cultivation practices and appropriate technology, and it receives assistance from the Genetic Resources Unit in introducing new germplasm. The program is involved in training researchers from the national root and tuber improvement programs. It also coooperates with the International Center for Tropical Agriculture (CIAT) in Colombia in cassava improvement and the Asian Vegetable Research and Development Center (AVRDC) in Taiwan in sweet potato improvement through staff visits and the exchange of materials and information.

Cassava

The recent incidence of two new insects in Africa on cassava — mealybug (*Phenacoccus manihot*), CM, and green spider mite (*Mononychellus tanajoa*), CGM — has been a new problem in IITA's research. Research into biological control of the mealybug is underway while the emphasis on the green spider mite is to seek host plant resistance through genetic improvement in cassava. Methods for control of two other economic diseases of cassava — cassava mosiac disease (CMD) and cassava anthracnose disease (CAD) — also are sought.

Genetic improvement

IITA-improved clones continue to be tested in different locations within Africa covering a wide range of environmental conditions in Seychelles, Liberia, Congo, Gabon, Zaire, Cameroon and Nigeria.

Table 1 shows the fresh tuberous root yields of IITA cassava clones that have been tested without fertilizers in trials during 1974-79 in four different locations within Nigeria. Clones that showed superior performance, across the locations tested, were TMS 30555, TMS 30572, TMS 30786, TMS 30337 and TMS 30157 with yields of 40.8, 36.0, 33.2, 33.0 and 28.5 t/ha fresh yield, respectively.

Mokwa gave the highest average yields for the clones with 37.9 t/ha while IITA gave 28.1 t/ha; Onne, 27.5 t/ha; and Warri, 14.9 t/ha. At IITA, TMS 30572 performed best with an average yield of 37.2 t/ha. It gave 68 t/ha in 15

High-yielding, disease-resistant cassava varieties resulting from IITA breeding material are being multiplied and supplied to many farmers in Nigeria, Sierra Leone, Liberia, Zaire, Gabon, Tanzania, and Seychelles.

months without fertilizers in a field where cassava was consecutively planted for two years.

To estimate the expected yields of each clone over four locations, the yields of each were regressed on the mean yields of all the clones tested at the four locations. The expected yields of each clone at each location are estimated in Table 2. The reliability estimates (R^2) for expected yields of each clone at different locations are high. This provides useful information for future varietal performance tests and recommendation of the IITA improved clones at each location in Nigeria.

Promising clones (1975 series). The performance results of some promising clones are summarized in Table 3. The most promising was TMS 50395. It is high-yielding (58.5 t/ha), resistant to CMD and cassava bacterial blight (CBB) and has good *gari* quality. TMS 50321 is high-yielding (41.0 t/ha) and has good *gari* quality, but it is not resistant to CMD or CBB. TMS 50193 is resistant to CMD and CBB.

Varietal differences to mycorrhiza infection

The fact that cassava gives high yields in soils with low available P may be due to vesicular arborscula (VA) mycorrhizal fungi. They may mobilize the available P.

In a test to mycorrhiza infection of 26 improved cassava clones, differences were significant among the varieties (Table 4). TMS 51260 showed the highest mycorrhiza infection, 77.4 percent, followed by TMS 4(2)1443, 59.4 percent. The clones that showed the lowest infection were 53101, 60447 and TMS/W4488.

Low cyanide

Breeding values for low cyanide of 44 low-cyanide clones were tested through open pollination and by crossing each clone with bulked pollen from seven other low-cyanide clones. From this, parents were selected that produced a high frequency of low-cyanide progenies. A total of 903 seedlings from 44 families were tested for cyanide, using the picrate leaf test. Among the 44 clones tested, LCN 6035, LCN 6044, LCN 50548 and LCN 50077 gave the highest breeding values for low cyanide.

Source-sink relationships

The relationship between source potentials and sink capacities of the tuberous roots of four cassava clones was investigated by means of reciprocal grafts with four cultivars. Marked varietal differences were observed in sink capacities (average stock effects) and source potentials (average scion effects) (Table 5). An IITA improved cassava clone, TMS 30211, had both the largest source potential and sink capacity. Both source potential and sink capacity of this clone appear to be equally efficient in producing high tuberous root yield.

The grafts that used clone TMS 30211 as scion and, in

Table 1. Performance in terms of fresh yield (t/ha) of IITA improved cassava clones (IITA, Onne, Mokwa and Warri, 1974-79).

	Location												Overall location		
	IITA			Mokwa			Onne			Warri					
Clone	Ave.	SE	No of tests	Ave.	SE	No of tests	Ave.	SE	No of tests	Ave.	SE	No of tests	Ave.	SE	No of tests
TMS 30017	28.0	5.5	11	38.2	12.2	6	28.1	5.1	5	15.3	2.5	9	27.4	6.3	31
TMS 30040	30.4	3.5	14	36.5	8.8	5	26.2	7.4	6	14.3	3.3	9	26.9	5.8	34
TMS 30054	32.7	7.9	7	-	-	-	-	-	-	14.9	5.1	3	23.5	6.5	10
TMS 30110	37.5	9.1	7	-	-	-	-	-	-	17.5	10.9	2	27.5	10.0	9
TMS 30157	27.3	2.3	10	38.9	5.0	5	30.9	10.4	5	17.0	3.4	7	28.5	5.3	27
TMS 30158	26.8	3.7	12	26.3	11.0	4	28.0	5.4	5	14.4	2.7	8	23.9	5.7	29
TMS 30211	25.8	2.9	11	44.2	7.0	4	30.1	17.6	3	13.4	2.2	7	28.4	7.4	25
TMS 30337	29.6	4.5	13	48.2	11.8	5	34.5	7.3	5	19.7	4.1	7	33.0	66.9	30
TMS 30395	27.6	3.5	14	38.7	9.5	5	29.2	4.2	5	12.0	1.6	5	26.7	4.7	29
TMS 30555	34.0	4.6	13	77.3	25.8	4	31.2	11.7	5	20.9	3.7	6	40.8	11.5	28
TMS 30572	37.6	4.0	15	49.0	13.6	5	41.1	13.0	6	16.1	2.9	7	36.0	8.4	33
TMS 30786	26.7	4.6	11	47.2	8.9	5	32.5	9.1	4	26.4	5.9	6	33.2	7.1	26
TMSC30835	30.0	6.2	8	-	-	-	-	-	-	6.8	1.9	2	18.4	4.1	10
60444‡	18.9	2.9	10	15.6	-	1	-	-	-	1.0	-	1	11.8	2.9	10
Average	28.1	3.2	15	37.9	9.7	6	27.5	6.8	6	14.9	2.3	9	27.1	5.5	36

‡*Standard variety (local).*

Table 2. Predicted yield (t/ha) of a cassava clone at each location.

			Location			
Clone	No of tests	Reliability estimate (R^2) (%)	IITA (28.1)'	Mokwa (37.9)	Onne (27.5)	Warri (14.9)
TMS 30017	31	100	28.3	38.0	27.7	15.2
TMS 30040	34	97	27.9	37.5	27.3	15.0
TMS 30054	10	100	32.7	46.0	31.9	14.9
TMS 30110	9	100	37.6	52.5	36.4	17.6
TMS 30157	27	96	29.6	38.9	29.0	17.0
TMS 30158	29	67	24.5	29.8	24.1	17.2
TMS 30211	25	96	29.7	42.7	28.9	12.3
TMS 30337	30	93	34.1	46.0	33.4	18.1
TMS 30395	29	99	28.2	39.6	27.5	12.7
TMS 30555	28	96	42.9	65.9	41.5	12.1
TMS 30572	33	92	37.4	51.6	51.6	18.2
TMS 30786	26	68	34.0	42.3	33.5	22.8
TMS 30835	10	100	30.1	47.3	29.0	6.8
60444†	12	97	19.4	19.4	12.3	3.8
No of tests			15	6	6	9

'*Average yield for 14 clones at a location*
†*Standard clone (local).*

Table 3. Performance of clones of 1975 series tested (IITA, 1977-78).

Clones	Fresh yield (t/ha)	Dry matter (%)	Dry yield (t/ha)	CMD score	CBB score	Gari quality
TMS 50395	58.5	27.5	16.1	2.3	1.4	VG
TMS 50321	41.0	26.7	10.9	3.3	2.0	VG
TMS 50193	36.5	22.6	8.2	2.5	1.5	G
TMS 51972	32.6	27.4	8.9	3.0	1.8	VG
TMS 50207	31.8	24.4	7.8	2.5	1.5	G
TMS 50548	31.8	23.5	7.5	2.6	1.5	G
TMS 51260	30.6	27.0	8.3	2.4	1.5	G
TMS 52026	30.2	27.4	8.3	2.3	1.5	G
TMS 51077	28.3	31.1	8.8	2.4	1.5	VG
60444‡	9.4	21.8	2.0	2.9	3.3	VG

‡*Standard clone (local).*

turn, was used as stock produced the highest number of tuberous roots and the highest total plant dry matter and dry tuberous root yield.

The grafts that used clone TMS 30211 as stock deposited the highest percentage of total plant dry matter (51.6 percent) in the tuberous roots. Averages of 30.2, 37.4 and 23 percent total plant dry matter were deposited in the tuberous roots of grafts that used cultivars 58308, Arubielupupa and Isunikankiyan as stocks, respectively. This suggests that large and active tuberous root sink coupled with an efficient source are important in obtaining cassava tuberous root yield.

Table 4. Varietal differences of cassava to mycorrhiza infection.

No	Cultivar	Mycorrhiza infection
1	TMS 51260	77.4a*
2	TMS 4(2)1443	59.4b
3	TMS 50207	55.0b
4	Isunikakiyan	50.8bcd
5	TMS 30555	49.7bcd
6	TMS 40081	49.4bcd
7	TMS 4(2)0850	48.0bcde
8	60444	47.6bcde
9	TMS 52390	47.2bcde
10	TMS 30211	44.9bcde
11	TMS 30001	43.5bcde
12	TMS 40533	42.7bcde
13	TMS 4(2)0763	42.3bcde
14	TMS 4(2)1364	42.2bcde
15	TMS 50395	39.6 cded
16	60506	38.5 cded
17	TMS 30786	38.5 cded
18	TMS 41832	38.2 cded
19	TMS 30017	37.8 cded
20	TMS 30572	37.5 cded
21	TMS 30395	36.1 ded
22	U/1421	35.0 ded
23	TMS 30337	33.1 ded
24	TMS/W4488	30.6 ed
25	60447	30.4 ed
26	53101	22.1 d

Means having common letters are not significantly different at 0.05 level according to Duncan's Test.

Leaf harvest

Although cassava is known mainly for its tuberous roots, the leaves are popular vegetable for many African people. Cassava foliages is an inexpensive source of protein, vitamins and minerals. An experiment was conducted to investigate the effects of intervals of leaf harvests on fresh leaf and tuberous root yield and its components.

Total fresh leaf yield of cultivar Isunikankiyan was not significantly affected by harvesting the top leaves at one, two or three-month intervals, but plants of clone TMS 30211 with leaves harvested at one- or two-month intervals produced significantly more fresh leaves than plants of this clone with leaves harvested at three-month intervals (Table 6).

International cooperation

The following national programs were recipients of IITA improved cassava clones:

Seychelles. The five most promising cassava clones selected from the IITA introductions were evaluated for yield and resistance to CMD in 1979, and they performed as follows : yield range was 31.5-45.4 t/ha, very good to fair levels of resistance to CMD, very good to fair root conformation, and all were sweet in taste.

Liberia. The seven most promising cassava clones selected from the IITA introductions were evaluated for yield and resistance to CMD and CAD in 1979, and they performed as follows : yield ranged from 33.9 to 63.7 t/ha; four clones were free of CMD throughout their 12-month growth cycle while three others showed signs of mild CMD infection. All clones were highly resistant to CAD.

Table 5. Dry tuberous root yield components, total dry matter production and distribution of reciprocal grafts of four cassava clones.

Graft combination: Stock	Scion	No of tuberous root/plant	Dry wt. per tuberous root (g)	Total plant dry wt. (g/plant)	Percent of total dry weight: Laminae (%)	Petioles (%)	Stems (%)	Tuberous roots (%)
Arubielupupa	Arubielupupa	3.7efg	154.2abc	1176.7de	4.9	1.5	44.8	48.8
Arubielupupa	Isunikankiyan	4.4efg	89.0c	1086.8de	6.5	1.9	54.9	36.7
Arubielupupa	TMS 30211	7.9abcd	145.5abc	3351.2abc	11.2	4.0	52.3	32.5
Arubielupupa	58308	6.0bcdef	151.8abc	2834.1abcd	6.3	1.8	60.3	31.6
Isunikankiyan	Arubielupupa	2.4g	100.1bc	908.6e	8.9	2.7	64.9	23.5
Isunikankiyan	Isunikankiyan	2.6g	98.6bc	857.5e	8.3	2.4	59.2	30.1
Isunikankiyan	TMS 30211	6.2bcdef	173.6ab	3999.2ab	11.0	3.9	56.8	28.3
Isunikankiyan	58308	3.0fg	98.4bc	2036.4cde	10.0	2.9	77.2	9.9
TMS 30211	Arubielupupa	5.4cdefg	174.6ab	1874.5cde	6.0	1.8	40.9	51.3
TMS 30211	Isunikankiyan	8.5abc	156.1abc	2296.3bcde	3.4	1.0	38.9	56.7
TMS 30211	TMS 30211	9.7a	194.0a	3869.8ab	6.2	2.2	42.9	48.7
TMS 30211	58308	8.9ab	185.5a	3338.8abc	4.9	1.4	44.1	49.6
58308	Arubielupupa	6.1bcdef	47.4abc	1868.4cde	6.2	1.9	44.0	47.9
58308	Isunikankiyan	5.0defg	104.3bc	1521.6de	3.9	1.2	60.6	34.3
58308	TMS 30211	10.1a	181.0a	4108.7a	5.9	2.1	47.2	44.8
58308	58308	7.0abcde	145.9abc	3814.1ab	10.5	3.0	56.8	29.7

Means with a common letter are not significantly different at 0.05 according to Duncan's Test.

Congo. The 15 most promising cassava clones selected from the IITA introductions were evaluated at Mbe, a location with severe pressure from CBB, CMD, CAD and CM. The yields ranged from 16 to 65 t/ha, and all 15 clones showed good resistance to all major diseases as well as to CM.

Gabon. *The five most promising clones selected from* IITA introductions were evaluated for yield, resistance to CMD and cassava root rots. The yield range was 22.5-32.8 t/ha, and all five clones showed good resistance to CMD and root rots. They are multiplied and distributed to many farmers. Planting material for the clones are in high demand.

Nigeria. IITA improved cassava clones were tested at farm level throughout Nigeria. They were multiplied and distributed as foundation stock to state ministries and farmers to cover 350 ha in collaboration with the National Root Crop Research Institute (NCRI), Nigeria. Planting material from the improved clones is in high demand at farm level.

Entomology

The two new pests — *Phenacoccus manihot* (CM) and *Mononychellus tanajoa* (CGM) — are spreading rapidly over the main cassava growing areas in Africa. The seriousness of the damage and the rapid spread in Africa emphasizes the urgency in solving these problems.

Screening for resistance

A total of 200,000 cassava seedlings within families were screened for resistance to CGM with a scoring system, ranging from 1 to 5:

1. No obvious damage.
2. Few whitish dots on young unfolded and newly expanded leaves.
3. *Young leaves do not expand and remain spiny.* Older expanded leaves covered with distinct chlorotic spots. Leaf size reduced by 25 percent.
4. Young leaves do not expand and defoliate. Reduction of leaf size more than 50 percent. Severe chlorosis on older leaves. Infestation on lower leaves may or may not occur.
5. Shoot dead or does not produce new leaves. Older infested leaves dropped. Mild or no infestation of lower expanded leaves.

Scoring of the seedling was done on 10-month old plants, which produce young shoots. As young shoots are essential for screening for CGM resistance, three cuttings of each selected seedlings were planted in pots to produce young shoots. These were then artificially infested with CGM. After three weeks, they were scored according to symptom development and the number of mites counted on the newly expanded leaves. Table 7 shows the score and mite count results on 26 families.

All the seedlings within the 26 families showed symptoms of attack although some variation could be observed. Most seedlings fell into the score classes 3 and 4. The

Table 7. Score and mite count results on 26 selected families (seedlings).

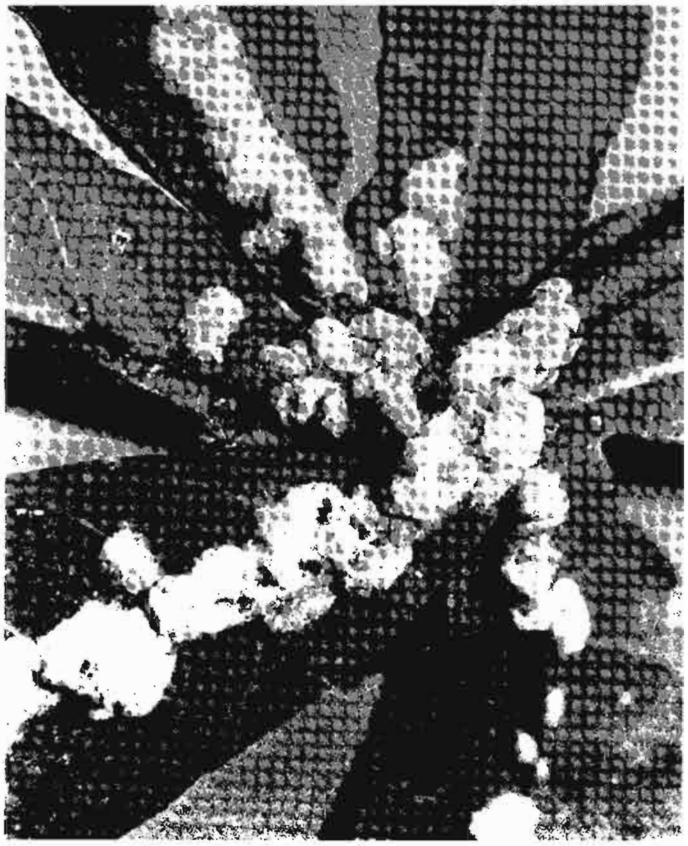
Family No.	No. of mites on 3rd leaf*	Damage score	Remarks
90037	203	5	
90720	58	3	
90980	54	3	
90989	54	3	
91012	30	2	
91229	212	3	very hairy
91232	88	3	
91233	194	3	hairy
91275	66	3	
91280b	24	3	
91280c	28	3	hairy
91281	26	3	hairy
91288	61	3	
91290b	52	3	
91349	72	3	
91351	25	4	
91352	35	3	
91354	46	4	hairy
91403	110	3	very hairy
91452	46	4	
91458	68	4	
91473	91	3	hairy
91478	81	4	hairy
91479b	89	3	
Local clone	100	3	

**Average of three replicates.*
Damage score from 0-5, 0 = no mite damage; 5 = severe damage.

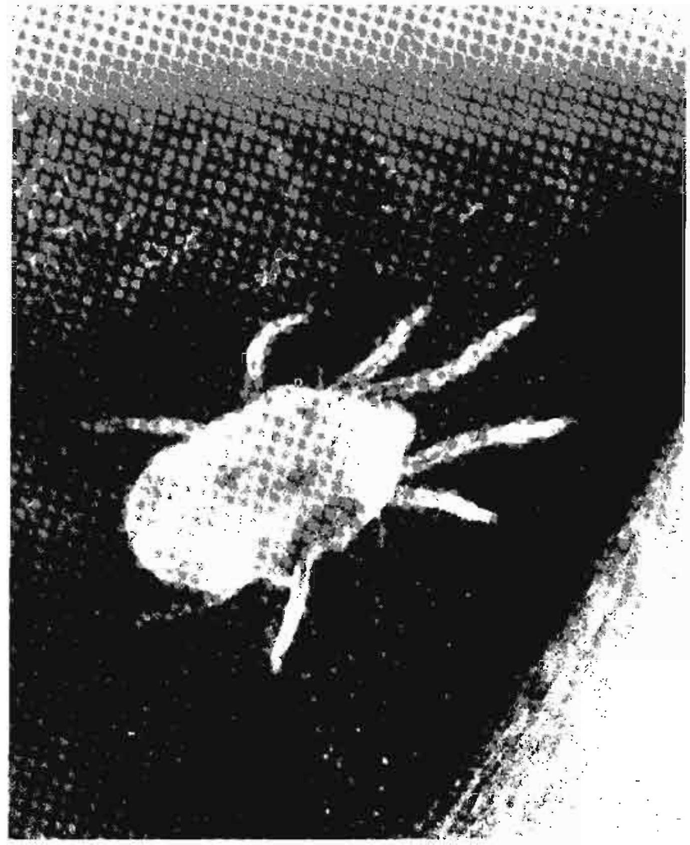
Table 6. Effects of interval of leaf harvests on plant dry matter, fresh leaf and tuberous root yields and tuberous root yield components of cassava.

				Tuber roots			Marketable tuberous roots		
Clone	Frequency of leaf harvest	Total plant dry matter (g/plant)	Fresh leaf yield (kg/ha)	No. per plant	Fresh yield (t/ha)	Fresh wt. per root (g)	No. per plant	Fresh yield (t/ha)	Fresh wt. per root (g)
Isunikankiyan	None	1352.0bc	0.0c	4.4b	14.4bcd	328.4b	1.9de	11.2bc	589.9ab
Isunikankiyan	Once/3 months	1376.5bc	4.5bc	5.1b	12.2cd	239.8bc	1.9de	8.4bc	440.1cd
Isunikankiyan	Once/2 months	916.6cd	4.1b	3.4b	5.5cd	162.4cd	0.8e	3.2c	39.59de
Isunikankiyan	Monthly	714.5d	7.7b	3.6b	3.5d	95.9d	0.6e	1.4c	239.2e
TMS 30211	None	2298.4a	0.0c	9.2a	37.3a	405.6a	4.7a	30.9a	656.6a
TMS 30211	Once/3 months	1589.8b	7.6b	8.4a	25.2b	300.4b	3.3bc	17.8b	391.7de
TMS 30211	Once/2 months	1526.1b	11.9a	9.2a	24.6b	269.9bc	3.8ab	18.5b	487.5bcd
TMS 30211	Monthly	1178.9bc	13.6a	9.6a	16.6b	173.1cd	2.3cd	9.0bc	540.2abc

Values with a common letter are not significantly different at 0.05 according to Duncan's Test.



Cassava mealybug (**Phenacoccus manihot **Mat.-Ferr.), which has been introduced into Africa from Latin America, is threatening cassava production in the continent. The insect pest is reported to be present in Zaire, Congo, Gabon, Angola, Nigeria, Benin, Togo, and Senegal.



Cassava green spider mite (**Mononychellus tanajoa **Bondar), which was accidentally introduced into Africa from Latin America in 1971, has now spread to many countries in the continent causing serious damage to cassava.

results are not necessarily reflected in the actual mite counts. This shows that symptom development depends also on the sensitivity of the plant to mite attack. Therefore, plants with low symptom development and adverse reaction to mite development should be selected.

Biological control

Taking up the goal of solving the problem of CM and CGM is a new biological control program at IITA. Initiated in late 1979, the program calls for the procedures underlying the philosophy of classical biological control — the importation of natural enemies against the pests followed by large-scale release and monitoring operations. Plans for exploration for natural enemies of both CM and CGM include areas of Central and South America.

Pathology

Cassava mosaic disease (CMD)

The major objectives of the CMD investigations in 1979 were to determine the CMD resistance reaction and the environmental effects on the seasonal variation of CMD severity in selected cassava (improved and local) varieties.

Productivity and resistance. The effect of CMD on yield was studied in a paired comparison design where plants from virus-free and virus-infected stocks were grown in the same plots. The results indicated that CMD infection reduced the yield by 32.3-48.2 percent after seven months of growth (Table 8).

TMS 30572 had the highest yield with 40.4 t/ha, but it also had the highest yield depression, 48.2 percent, due to CMD compared to TMS 30040, 32.3 percent, and TMS 30555, 35.0 percent. The CMD severity ratings (based on 1-5 scale of increasing severity) were 2.8 for TMS 30572, 3.0 for TMS 30555 and 3.2 for TMS 30040.

TMS 30835 established from CMD-infected cuttings yielded significantly less than when established from CMD-free cuttings and later infected by the transmission of CMD by *Bemisia tabaci* (Table 9).

TMS 30395 and five other cultivars from CMD-free cultivars were compared for their resistance to vector CMD infection (Fig. 1). The cultivars had 30 days field exposure to CMD-borne *B. tabaci*. The susceptibility of the five cultivars to vector CMD infection was high, 33.8-79.1 percent, compared to TMS 30395, 5.8 percent (average of two-year data). After 150 days exposure to vector CMD infection, CMD incidence among the 5 varieties ranged from 71.2 to 97.7 percent compared to 16.1 percent for TMS 30395.

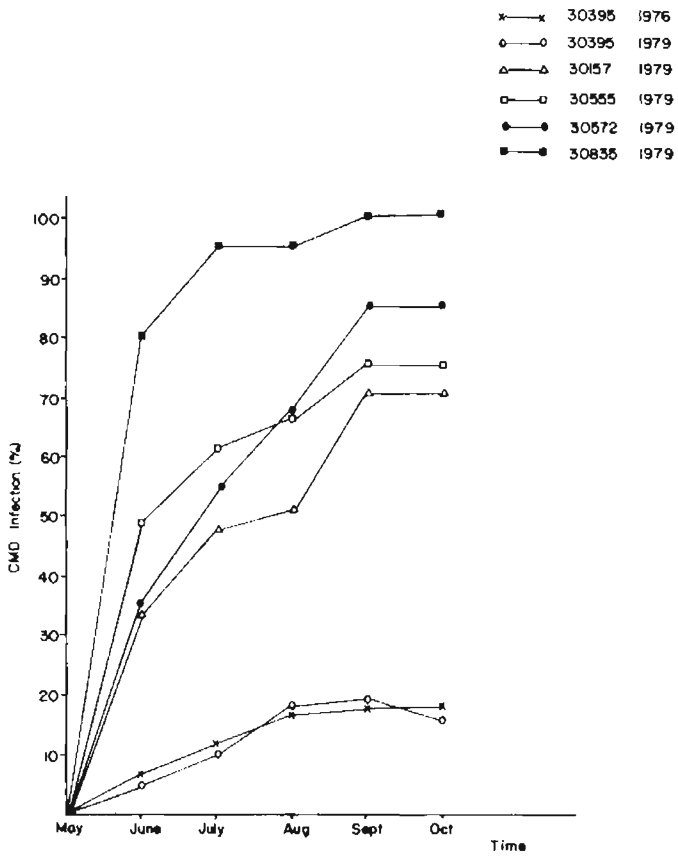


Fig. 1. Rate of field CMD infection of disease free plants.

The level of resistance to CMD in the test varieties was quantified by adopting the following formula:

$$a = \frac{x - yb}{xy}$$

y – percentage of vector transmission; b – constant, representing a measure of available sites for vector inoculation; x – period of field exposure to CMD-borne *B. tabaci;* and a – level of resistance.

TMS 30395 has the highest level of CMD resistance, 0.04; compared to Isunikankiyan, 0.008; and TMS 30835, 0.009 (Table 10).

Table 8. Effect of CMD infection on yield potential of three improved cassava varieties at seven months (IITA, 1979).

Variety	CMD-free	CMD-rating	CMD-infected	CMD-rating	loss (%)
TMS 30572	40.4	1	20.9	2.8	48.3
TMS 30555	15.4	1	10.0	3.0	35.1
TMS 30040	20.4	1	13.8	3.2	32.4

Table 9. Yield potential of vegetatively borne and vector-transmitted CMD infection in cassava cultivar 30835 at seven months (IITA, 1979).

Vegetatively borne	Vector-transmitted	loss (%)
7.3 (3.5)*	18.3 (2.0)*	60.1

**( ) CMD severity rating on a scale of 1-5 of increasing severity.*

Table 10. CMD resistance levels of six improved and one local cassava variety (IITA, 1978-79).

Variety	Resistance level
30835	0.0094
Isunikankiyan 1	0.0085
30572	0.0072
30040	0.0056
30157	0.0110
30555	0.0114
30395	0.0445

Table 11. Effect of environmental factors on the seasonal fluctuation of CMD severity in eight cassava varieties (IITA, 1978-79).

Treatments No	N*	V*	D*	Mean CMD severity
10	1	0	1	2.20 a
6	0	1	1	2.21 a
7	0	1	2	2.29 a
5	0	1	0	2.31 a
1	0	0	0 check	2.32 ab
2	0	0	1	2.32 ab
11	1	0	2	2.32 ab
14	1	1	1	2.35 b
4	0	0	3	2.36 b
3	0	0	2	2.38 b
9	1	0	0	2.38 b
13	1	1	0	2.38 b
15	1	1	2	2.38 b
8	0	1	3	2.39 b
12	1	0	3	2.39 b
16	1	1	3	2.43 b

**Nitrogen (N) and Vector (V); 0 = low level, 1 = high level Detop (D): 0 = no detop, 1 = detop in June, 2 = detop in Aug. and 3 = detop in Oct.*

Means with a common letter are not significantly different at 0.05.

Table 12. Effect of period of growth cycle on CMD severity averaged over eight cassava varieties (IITA, 1978-79).

Mean severity scores at				
0 month	3 months	6 months	9 months	12 months
3.34	3.25	2.07	1.16	1.85

SE ($\bar{X}$) = 0.0224.

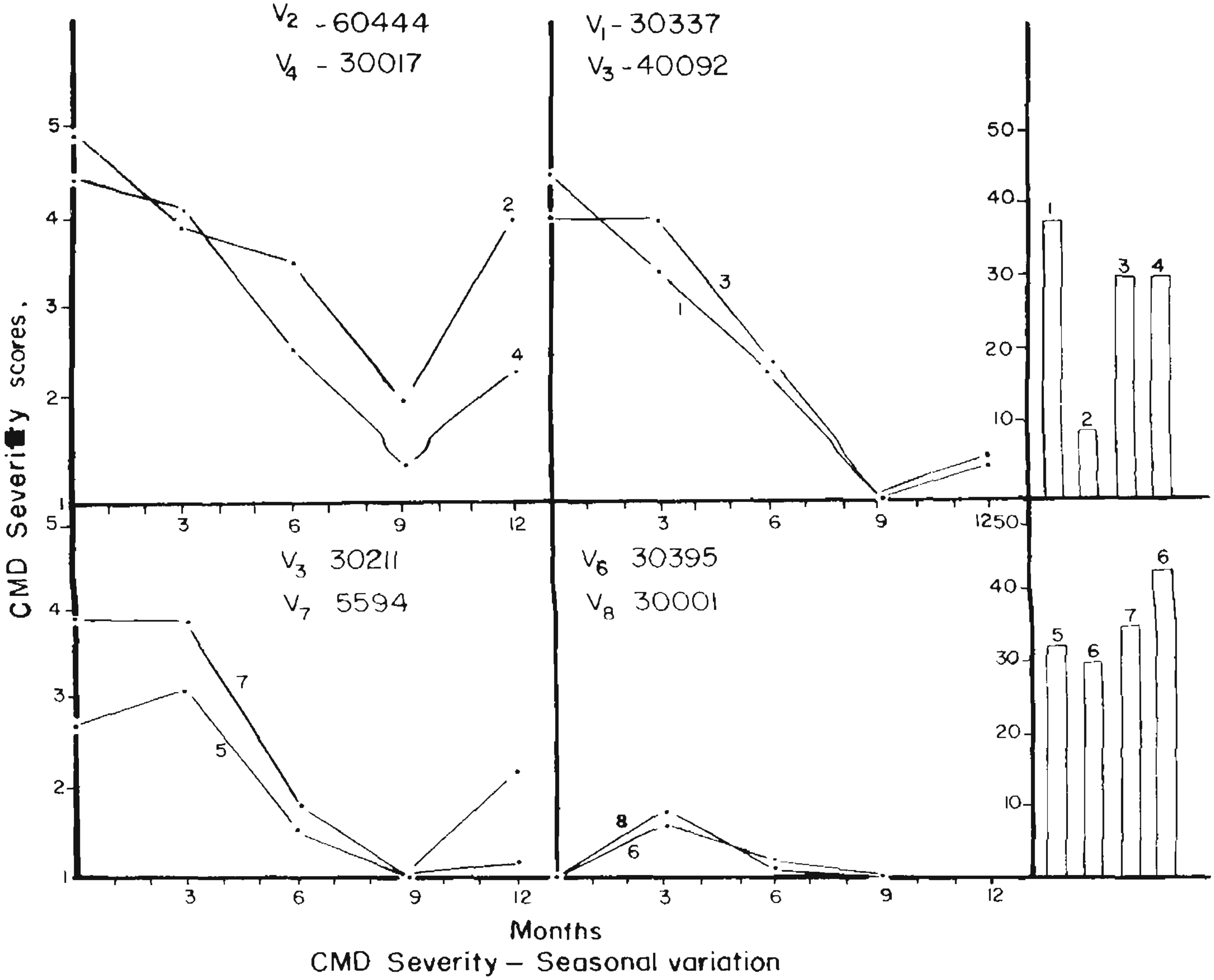


Fig. 2. Mean variation in CMD severity during cassava growth cycle.

Varietal and environmental effects on the seasonal variation of CMD severity and yield. In a 2 × 2 × 4 × 8 factorial experiment compounded in eight blocks of 16 plots each, eight selected cassava cultivars were subjected to 16 treatment combinations, including N application, vector infectation and detopping in June, August and October. Each application had appropriate check treatments. The effect of these treatments on the CMD severity and yield in varieties during the growth cycle was determined.

Ten of the treatment combinations resulted in significantly different levels of CMD severity in the test varieties, but the CMD severity for the untreated check was not insignificantly different from any of the other 15 treatments (Table 11).

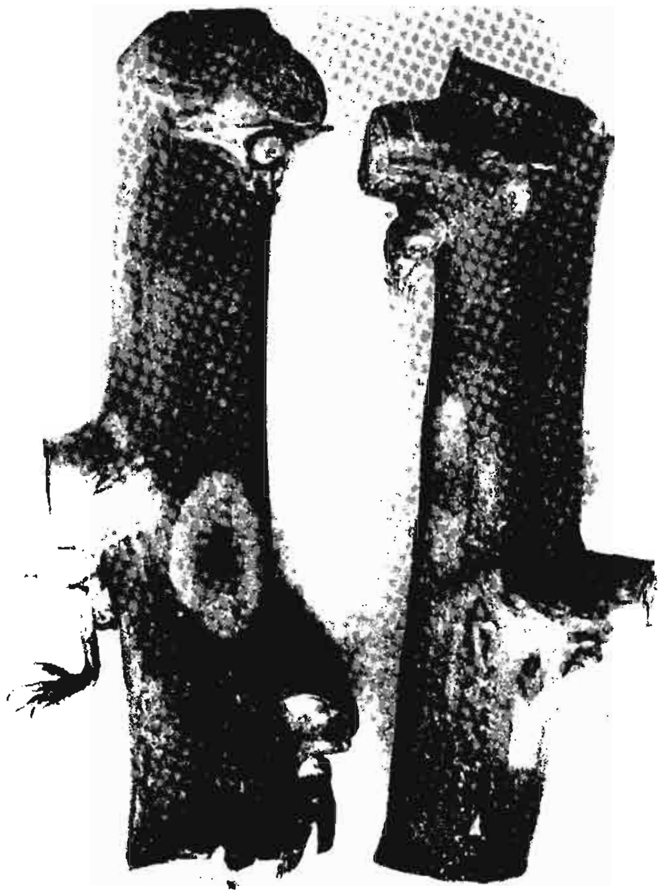
Differences were significant in CMD severity during selected phases of the plant growth cycle with a tendency toward an expression of the highest level of severity just after sprouting. Almost total recovery from the disease was evidenced by the absence of CMD symptoms on new leaf growth in January after the drought induced leaf-drop phase (Table 12).

Differences were significant in CMD severity and yield among varieties with 60444 scoring the highest CMD severity, 3.67 (1-5 scale), and the lowest yield, 7.1 t/ha, and TMS 30001 scoring the lowest CMD severity, 1.17 (1-5 scale), and the highest yield, 43.0 t/ha (Table 13 and Fig. 2). Further, 60444 was severely affected by CBB during the 1978 growth cycle while TMS 30001 was hardly infected.

The data indicate a significant interaction between treatment combinations and variety and a highly significant interaction between the selected growth phases and varieties in respect to CMD severity.

There were no significant differences in yield due to treatment combinations. Eight varieties averaged 30.8 t/ha with a standard error of 2.9 t/ha; yields ranged from 22.1 to 35.3 t/ha.

Conclusions. The methodology, which utilizes the paired comparison of sample means of selected yield components, provides a useful procedure for quantifying the performance of improved cassava varieties. The comparison of the rate of increase of vector CMD infection to disease-free plants has proven to be a useful approach in



A rapid and efficient laboratory screening method to test cassava breeding lines for resistance to cassava anthracnose disease (CAD) shown here has been developed and is being applied routinely for resistance screening.

quantifying levels of resistance to vector CMD infection in the field. The data clearly show that TMS 30395 is genetically the most CMD-resistant cassava variety tested to date, and it also yields well.

The data from the experiment on varietal and environmental effects on the seasonal variation of CMD severity and yield of cassava indicate that the genetic factors may be stronger than environmental factors selected for this test.

Cassava anthracnose disease (CAD)

In 1979, the major objectives of the CAD investigations were to establish the role of latent infection of cassava by the CAD pathogen *Colletotrichum manihotis* on the subsequent incidence and severity of CAD. This was to determine the genetical and environmental factors responsible for the transition from CAD latent to CAD active infection phases and utilize this knowledge to develop a rapid and efficient method to screen cassava for resistance to CAD.

Cassava anthracnose latent infection. In four sets of preliminary laboratory studies, 289 detached stem pieces without CAD symptoms from a total of 64 cassava seedling families were assembled on moist filter paper in Petri dishes and observed. Within three days, characteristic CAD lesions accompanied by the production of a large number of acervuli (mats of hyphae, giving rise to short conidiophores and conidia closely packed together, characteristic of *Colletotrichum* sp.) developed on 68.0, 55.0, 60.0 and 48.8 percent of stem pieces, respectively, in the four tests (Table 14). These observations strongly suggest the existence of *Colletotrichum* sp. latent infection on a large percentage of symptomless cassava plants in the field.

Field observations on stems of an average of 1,788 actively growing plants from 150 families in the 1978 IITA cassava seedling nursery indicated an increase from 5.09 to 26.4 percent incidence of the characteristic CAD lesions between August 1 and October 9 (Table 15). These observations strongly suggest a progressive transition from the CAD latent infection phase to the active infection phase.

Genetical and environmental factors affecting CAD. Field observation of 675 plants from 25 families in the 1979 IITA cassava seedling nursery indicated that among the 563 early flowering types (low-branching), 16.6 percent developed large expanding CAD lesions while 8.1 percent developed small non-expanding lesions. The remaining 75 percent were CAD free. Among the 112 late-flowering types (high-branching), 16.3 percent developed large expanding lesions and 9.8 percent had small non-expanding lesions while 73 percent were CAD free (Table 16). The field observations, however, revealed that a large number of *Manihot esculenta* pollen grains were

Table 13. Effect of genotype characteristics on CMD severity and yield potential of eight cassava varieties (IITA, 1979).

Variety	Mean CMD score	Mean yield (t/ha)
TMS 30337	2.56	3.71 cd
TMS 60444	3.77	7.1 a
TMS 40092	2.61	28.3 b
TMS 30017	2.98	31.2 bc
TMS 30211	1.93	33.3 bc
TMS 30395	1.19	30.6 b
TMS 5594	2.60	36.6 c
TMS 30001	1.17	43.0 cd

SE (X) 0.5636.
Means with a common letter are not significantly different at 0.05.

Table 14. Cassava seedling nursery, CAD latent infection (IITA, 1979).

No. of families	No. of detached stem pieces	Latent infection (%)
24	129	58.7 · 68.2 · 76.3
27	80	43.5 · 55.0 · 66.2
12	35	42.1 · 60.0 · 76.1
1	45	33.7 · 48.8 · 64.2

All confidence limits of 0.05 overlap so that the latent infection is the same in all families.

Table 15. Cassava seedling nursery, rate of increase of CAD incidence (IITA, 1979).

Family	No. of plants	Observation period	Anthracnose incidence (%)
90250-90400	1787	1/8/79	3.51 < 5.09 < 5.55
	1742	9/10/79	24.39 < 26.4 < 28.53

Table 16. Cassava seedling nursery, flowering characteristics/anthracnose cankers (IITA, 1979).

	No. of plants	Aggressive canker	Non-aggressive canker	Canker free
Early flowering	563	13.78 < 16.6 < 19.90	6.10 < 8.1 < 10.66	71.33 < 75.1 < 78.41
Late flowering	112	10.02 < 16.3 < 24.66	5.10 < 9.8 < 17.24	63.38 < 73.2 < 80.73

Table 17. Effect of Manihot esculenta *pollen on initiation of CAD (IITA, 1979).*

Treatment	Detached cassava stem pieces with CAD infection (%) 2 days	3 days	4 days	5 days	6 days
Frozen pollen	15.0	45.0	62.5	72.5	75.0
Stored pollen	7.5	27.5	47.5	80.0	85.0
Fresh pollen	5.0	15.0	47.5	65.0	77.5
Control (no pollen treatment)	0.0	5.0	30.0	47.5	67.5

Table 18. Effect of moisture on onset of senescence in Manihot esculenta *(IITA, 1979).*

Days to onset of senescence	Detached stem pieces senescing based on samples of 40 (%)
4	7.5
5	22.5
6	17.5
7	32.5
8	20.0

Weight of stem pieces 0.7-1.68 g.
Diameter 0.34-0.65 cm.

Table 19. Effect of moisture stress on onset of senescence in Manihot esculenta *(Germplasm IITA, 1979).*

Days to onset of senescence	Detached stem pieces senescing based on samples of 36 (%)
6	5.5
7	5.5
8	13.9
9	25.0
10	16.6
11	13.8
12	8.3
13	11.1

Table 20. Effect of heat on induced susceptibility of Manihot esculenta *to CAD infection (IITA, 1979).*

Days after heat treatment	Lesion development at heat treatment point based on samples of 40 (%)	Lesion development at distance from heat treatment point based on samples of 40 (%)
4	23.13	58.75
7	53.13	81.25
10	75.63	96.88

consistently present on green stems with large expanding lesions.

Effect of *Manihot esculenta* pollen grains on initiation of active CAD infection. Detached cassava stem pieces from 40 clones each replicated four times were treated as follows:

1. Frozen pollen.
2. Fresh pollen.
3. Pollen stored at 30° C.
4. Untreated.

The treatment with the highest percentage of clones that developed CAD lesions after two days (15 percent) was the frozen pollen treatment. The untreated check had 0 percent, and the two other treatments had 5 and 7 percent, respectively (Table 17). After six days, the percentage of clones with CAD lesions ranged from 67.5 percent for the untreated check to 85.0 percent for the stored pollen treatment.

Results with respect to the role of pollen on the initiation of active CAD infection are inconclusive. Results with respect to the untreated check stem pieces strongly suggest an association between the gradual senescence of the detached stem pieces and the onset of CAD lesions. After six days, a majority of the detached stem pieces had developed a large number of acervuli with *Colletotrichum* sp. conidia, confirming the existence of a latent infection before the stem pieces were detached from the growing plants.

Susceptibility to premature senescence and CAD infection. To determine differences in susceptibility to senescence and susceptibility to CAD infection between cassava genotypes, the period between senescence (evidenced by browning) due to stem detachment and the CAD active infection phase (evidenced by developing CAD lesions and acervuli) due to applied moisture stress (1.5 ml sterile water/Petri dish) was measured. The results indicate that stem pieces from only two clones (7.5 percent) had completely senesced after four days, and the moisture-stressed stem pieces from certain other clones had completely senesced after 13 days (Tables 18 and 19).

The data also indicate that stem pieces from 9 of the 40 clones tested did not develop acervuli even after they were senescent while others had large numbers of acervuli, ranging from 200 to 600 per stem piece. These results strongly suggest that there was no latent infection in the stem pieces of certain clones at the time of their detachment. This may also indicate that there is some resistance to CAD latent infection among IITA clones.

Heat induced susceptibility to CAD infection. To induce CAD susceptibility, detached stem pieces were punctured with a hot inoculating needle at the point of attachment of a petiole and transferred to moist filter papers in Petri dishes for observation.

The percentage of test clones that developed CAD lesions and acervuli either at the puncture point or some distance from the puncture point was recorded after 4, 7 and 10 days. Stem pieces developed lesions and acervuli at some distance from the puncture point more often than at the puncture point (Tables 20 and 21).

These results suggest that the susceptibility induced by the heat treatment is more effective farther away from the point of puncture, the cells at the puncture point may be killed by heat while the cells at some distance may only be weakened to the degree necessary for a week parasite such as *C. manihotis* to initiate an active infection phase.

***Table 21. Effect of heat production of** Colletotrichum manihotis* **acervuli on** *Manihot esculenta* **stem pieces (IITA, 1979).**

Days after heat treatment	Stems with acervuli at treatment point based on samples of 40 (%)	Stems with acervuli at distance from treatment point based on samples of 40 (%)
4	5.63	30.0
7	23.13	55.0
10	30.63	56.0

Conclusions. An association exists among the magnitude of CAD latent infection, susceptibility to early senescence and critical transition from latent to an active CAD infection phase. Investigations are being designed to determine correlations between these factors to aid the development of a method for CAD resistance screening based on these factors.

Yam

For yams, production is costly because of the large quantity of planting material required and the high number of man-days needed for staking and harvesting. Yams are attacked by virus, leaf spot diseases and nematodes. Storage losses are very high, often as high as 50 percent during a storage period of 4-5 months. Research is directed toward solving these problems by developing high-yielding clones, which are disease and pest resistant, easier to grow and harvest and store well.

Genetic improvement

White yam (*Dioscorea rotundata*)

In 1979, the routine breeding of white yam continued with evaluation and selection carried out in a selection sequence, consisting of Seedling Nursery, Hill Trial and Intermediate and Advanced Yield Trials. Breeding populations were grown at IITA and three off-site locations in Nigeria. Both staked and unstaked breeding trials were grown at IITA.

IITA breeding trials. One hundred and twenty families, giving approximately 10,000 plants, were directly seeded in nursery beds and evaluated for virus and leaf spot resistance and tuber size and shape; 130 plants were selected for advancement to the 1980 Hill Trials.

In the unstaked trial sequence, 164 clones were evaluated in the Hill Trial for vine vigor, virus and leaf spot resistance, thorniness, tuber number, size, shape and smoothness and nematode resistance, and 24 were selected for advancement. Fifty-one clones were tested in the unstaked Preliminary Yield Trial and nine in the unstaked Intermediate Yield Trial. These were evaluated, using the same selection criteria, and 10 clones were selected for further testing.

In the unstaked trials, the selection intensity continued to be very high because nematodes and foliar leaf spot disease cause severe reduction in yields when yams are grown without staking in the forest zone.

In the staked trials sequence, 479 clones were compared in the Hill Trial, and 75 in the Preliminary Yield Trial. These were evaluated for vine and tuber characteristics, and 72 and 20 clones, respectively, were selected for advancement.

In the staked Intermediate Yield Trial, 16 clones were compared with two cultivar checks. The total fresh weight yields ranged from 0.98 kg/plant (9.8 t/ha) to 3.92 kg/plant (39.2 t/ha) compared to 4.18 kg/plant (41.8 t/ha) and 1.18 kg/plant (11.8 t/ha) for the local checks. The marketable fresh weight yields ranged from 0.26 kg/plant (2.6 t/ha) to 3.16 kg/plant (31.6 t/ha) compared to 4.18 kg/plant (41.8 t/ha) and 0.50 kg/plant (5.0 t/ha).

In the staked Advanced Yield Trial, four hybrid clones and two germplasm selections were compared with two local cultivar checks at 1 m × 1 m spacing, using a randomized complete block design with three replications and five plants per plot. The results are given in Table 22.

Although four of the clones tested had marketable yields comparable to the local cultivar checks, each was deficient in one or more of the characters essential for good performance. TDr 779 was selected for continued trial and W 4-B58 and TDr 148 for use as parents in the breeding program.

Obviously, the number of plants per plot observed in the Advanced Yield Trial is less than desired, but the slow rate of vegetative multiplication and excessive losses of planting material in storage severely limit the number of plants that can be observed at each step of the clonal selection sequence.

Off-site breeding trial. At Mbiri, all trials were planted at 1 m × 1 m spacing and staked and intercropped with *egusi* melon. Selections were from the Seedling Nursery, and 62 clones in the Hill Trial, Preliminary and Intermediate Yield Trials. In the Advanced Yield Trial, six clones were tested. The total fresh tuber yields ranged from 0.57 kg/plant (5.7 t/ha) to 1.63 kg/plant (16.3 t/ha), and the marketable fresh tuber yields ranged from 0.21 kg/plant (2.1 t/ha) to 0.81 kg/plant (8.1 t/ha). All hybrid clones and the 1 germplasm selection outyielded the local cultivar check, Asuku. Three hybrid clones were selected for further testing. At this site, the "Odu" disease is the major production problem.

At Mokwa, all trials were planted at 1 m × 1 m spacing without staking. Selections were from the Seedling Nursery and 85 clones in the Hill Trial and Preliminary Yield Trial. In the Advanced Yield Trial, six clones were compared. The total fresh tuber yields ranged from 0.80 kg/plant (8.0 t/ha) to 1.41 kg/plant (14.1 t/ha) and the marketable fresh tuber yields from 0.35 kg/plant (3.5 t/ha) to

1.05 kg/plant (10.5 t/ha). All hybrid clones and the 1 germplasm selection outyielded the local cultivar check, Angbara. The germplasm selection, TDr 280, was selected for further testing, but since all the hybrid clones were deficient in at least one important characteristic, they will be continued as parents in the breeding program.

At Yandev, all trials were planted and staked, and selections were from the Seedling Nursery and 80 clones in the Hill Trial.

Water yam (*Dioscorea alata*)

Evaluation continued on water yam. Twenty-five accessions were planted in a staked trial at 1 m × 1 m spacing, 10 plants per plot, at IITA. These accessions were compared for scorch severity, yield, tuber conformation and quality. The results are given in Table 23. There were highly significant differences among accessions for fresh and dry yield, scorch score and total N, which is related to protein content.

Table 22. Performance of eight clones of staked white yam in the Advanced Yield Trial (IITA, 1979).

Clone	Fresh tuber yield (kg/plant) Total	Marketable	Virus score 1	Leaf spot score 2	Tuber shape 3	Nematode resistance 4
TDr 779	2.9	2.7	1.9	1.3	average	MR
W 519	3.3	2.1	3.3	3.1	average	S
W 4-B58	2.8	2.1	3.7	1.9	good	LS
Nwapoko (ck)	2.1	1.9	1.9	1.6	good	MR
TDr 148	3.1	1.6	2.1	1.5	good	S
TDr 821 (ck)	3.4	1.3	1.7	2.1	good	LS
R16-215-291	0.7	0.1	4.0	1.8	good	S
W 47-C248	0.7	0.0	3.6	2.7	good	S
SE	0.24	0.30	0.22	0.26		

1. Subjective score (1-5), representing no disease to all leaves showing symptoms.
2. Subjective score (1-5), representing no disease to all leaves showing symptoms.
3. Subjective score (S, LS, MR), representing susceptible, less susceptible, moderately resistant.

Table 23. Fresh tuber yield, dry tuber yields and scorch and percent N of 25 accessions of staked water yam (IITA, 1979).

Accession number	Tuber yield (t/ha) Fresh Total	Fresh Marketable	Dry Total	Scorch score	Total N (% dry wt.)
TDa 310	39.1	36.1	10.4	2.4	1.08
*TDa 204	29.3	23.4	8.6	4.8	1.20
TDa 291	24.8	19.0	7.2	2.3	0.94
TDa 297	24.6	21.8	6.6	2.5	1.13
*TDa 262	23.8	20.6	6.8	5.0	1.32
*TDa 272	23.3	20.4	6.5	4.7	1.31
*TDa 261	23.3	19.7	6.4	4.9	1.30
*TDa 178	22.6	17.1	6.1	4.7	1.39
*TDa 217	21.7	17.2	6.0	4.9	1.44
*TDa 187	21.4	16.4	6.0	4.8	1.42
*TDa 260	21.3	17.3	6.0	4.8	1.21
*TDa 251	20.9	18.8	6.0	4.9	1.33
TDa 5	20.0	17.4	4.9	4.7	1.44
*TDa 226	19.8	15.3	5.3	4.7	1.36
*TDa 246	17.9	11.6	4.6	4.9	1.46
*TDa 263	17.8	13.0	4.8	4.9	1.38
TDa 307	17.2	9.5	5.1	4.7	1.17
TDa 300	17.1	12.8	4.6	4.8	1.24
*TDa 234	16.9	11.8	4.3	4.9	1.40
*TDa 167	16.6	10.5	4.4	4.9	1.43
*TDa 231	16.2	10.8	4.2	4.9	1.38
TDa 308	15.4	12.0	3.9	4.8	1.23
*TDa 188	15.3	11.8	4.1	4.9	1.34
TDa 309	12.1	9.6	2.4	4.7	1.53
TDa 7	10.6	5.3	3.0	4.7	1.34
SE	1.87	2.04	0.52	0.08	0.060

1. Subjective score (1-5), representing no disease to all leaves showing symptoms.
**Similar phenotypes.*

At Mbiri, a smaller trial was conducted to compare five accessions with a local cultivar check. These were grown with stakes at 1 m × 1 m spacing and intercropped with *egusi* melon, using a randomized complete block design with three replications, 10 plants per plot. Scorch severity, yield, tuber conformation and quality were evaluated (Table 24). Differences for fresh and dry yield and scorch scores were highly significant. There were no significant differences among the accessions for percentage of total N.

At IITA, TDa 291, TDa 297 and TDa 310 had significantly lower scorch scores and yielded well. At Mbiri, TDa 290 also had a low scorch score, but its yields were not higher than the local cultivar check because it did not compete well with the *egusi* melon intercrop.

TDa 251, TDa 272, TDa 204, TDa 187 and TDa 179 and several other accessions with similar phenotypes yielded well even though they were susceptible to scorch.

Farm level testing multiplication and distribution of IITA improved water yam accessions. Based on the data obtained during the past four years, three accessions have been selected from the water yam collection for multiplication and distribution, TDa 251, TDa 291 and TDa 297.

TDa 251 has been tested at IITA and several off-site locations; it consistently yields well even under heavy scorch pressure even though it has high scorch scores. Sprouting of planting setts is excellent and the vines are very vigorous. Tubers are variable in shape, often deltoid or fan-like. The skin is smooth, and resistance to nematodes is very good. The flesh is white, flecked with purple, with only some tendency to oxidize. The eating quality is very good and cooked tubers can be pounded.

TDa 291 has been tested at IITA and several off-site locations and, except under very poor growing conditions, had a high level of resistance to scorch and yields well. The tubers are oval in shape. The flesh is white and free of oxidation. It can be pounded, and the eating quality is very good; however, the tubers have less than average total N on a dry weight basis. Although TDa 291 is an excellent cultivar in most respects, the sprouting of planting setts is only fair, which can result in poor stands under some conditions. Also, vines are medium for vigor and do not compete well with companion crops in mixed crop systems or weeds early in the growing season. Because TDa 291 is male flowering, it can be used as source of scorch resistance in future breeding programs, an attribute that makes this clone doubly valuable.

TDa 297, supplied by Nigeria's National Root Crops Research Institute (NRCRI), also exhibited a high level of resistance to scorch. Sprouting of planting setts is good and vines are vigorous. Tubers mature late and are irregular in shape and rough, but yields are high. Flesh is purplish, grainy and with some tendency to oxidize, but the eating quality is good, and it can be pounded. Total N tends to be less than average.

TDa 310 has been tested for only one year, but the results suggest that this accession has a high level of resistance to scorch and yields well. Sprouting of planting setts appears to be good, and the vines are very vigorous. The tubers are somewhat variable in shape, but mostly oval. The flesh is pale yellow and free of oxidation, but the eating quality is only average. The total N tends to be lower than average. This clone will be multiplied for distribution if further testing confirms its scorch resistance and high yields.

Seed production. Efforts to produce true seed of *D. alata* continued. A large crossing block, containing 13 flowering clones, was planted. Flowering was excellent and the delayed, staggered planting of the male clones gave good nicking. Thousands of hand pollinations were made, but only 600 fruits and 40 seeds were harvested. The low percentage of fruit set and high frequency of aborted seeds suggest that these clones have a high degree of sterility. Thirteen seedlings were reared from the seeds produced in 1978 at IITA and imported from the National Biological Institute, Indonesia.

Cluster yam (*Dioscorea dumetorum*)

A small-scale breeding program on cluster yam was continued at IITA to gain knowledge about this species, which is important in Cameroon and parts of Central Africa. Five families were directly seeded in nursery beds and evaluated for resistance to virus and leaf spots and cluster size and shape and tuber size, shape and smoothness. The best individuals were selected for advancement. In a Hill Trial, 40 clones were evaluated for nine characteristics, nematode resistance, reduced post-harvest hardening as well as cluster size and shape and tuber size, shape and smoothness. Two clones were selected for further testing.

Table 24. Fresh tuber, dry tuber yields, scorch scores and percent N of six accessions of staked water yam (Mbiri, 1979).

Accession number	Tuber yield (t/ha) Fresh Total	Tuber yield (t/ha) Fresh Marketable	Tuber yield (t/ha) Dry Total	Scorch score	Total N (% dry wt.)
*TDa 251	28.8	23.4	8.3	2.6	1.13
*TDa 272	20.9	12.6	6.0	2.8	1.09
TDa 314 (local ck)	20.1	15.4	5.5	2.3	1.11
TDa 291	17.6	9.5	5.2	1.4	0.97
*TDa 167	15.3	6.6	4.2	3.9	1.33
*TDa 178	13.1	5.5	3.8	3.1	1.22
SE	2.77	2.95	0.87	0.20	0.082

1. Subjective score (1-5), representing no disease to all leaves showing symptoms.
**Similar phenotypes.*

Seeds of half-sib progenies have been distributed to the cooperative program in Cameroon for a breeding program on this species.

Storage

During the 1978-79 dry season, an experiment to determine the effects on storage of pre-storage curing at high temperature and humidity was conducted in cooperation with the FAO's African Rural Storage Center at IITA. Freshly harvested tubers of the cultivar Nwapoko grown under uniform conditions at IITA were cured for four days (C-4), six days (C-6) or placed into storage (C-0).

Curing treatments were carried out in a large crib with roof and walls covered by tarpaulin. Temperatures inside the crib during the day averaged 24-36° C, and the relative humidity averaged 60-95 percent. After curing, tubers were placed either in the traditional yam barn (ambient temperature and R.H.). A randomized complete block design with seven replications, 10 tubers per treatment, was used. Weight losses during curing were 3.4 percent for C-4 and 4.2 percent for C-6. The effects of curing on the percent tubers that rotted and sprouted after one, two, three, four and five months of storage are given in Tables 25 and 26.

Tubers stored in the barn were less affected by rots than those in the reduced temperature store. In the traditional yam barn, curing significantly reduced rotting only during the first month. In the reduced temperature store, curing significantly reduced rotting during two, three, four and five months. In general, curing for four days gave better results than curing for six days.

Sprouting began later and was less frequent in the reduced temperature store compared to the traditional yam barn. Curing for four days did not affect sprouting, but curing for six days resulted in increased sprouting in the reduced temperature store.

These data indicate that a four-day curing treatment carried out immediately after harvest reduced rotting by about 20 percent without increasing sprouting when tubers were stored in a reduced temperature store. When yams were stored in the traditional yam barn, the benefits of curing were less pronounced.

Sprout control

A preliminary experiment carried out in 1978 indicated that etephon, trimethyl amonium chloride (CCC), 6-benzyladenine (BA), and high concentrations of Gibberellic acid (GA), applied as pre-harvest foliar sprays, promoted sprouting in white yam (*D. rotundata*). In contrast, GA at low concentrations delayed sprouting. A 35° C oven treatment accelerated sprouting.

In 1979, a larger experiment was conducted, using pre-harvest foliar application of etephon, CCC, chloramphenicol, cycloheximide, abscisic acid (ABA) and GA applied two, three and four times in various time sequences. In addition, etephon, CCC, chloramphenicol, cycloheximide, GA and BA were applied to tubers as post-harvest soaks (20 hours) and other tubers were held in the oven at 35° C for 10, 15, 20 and 25 days.

In contrast to 1978, none of the treatments markedly accelerated sprouting. However, compared to the controls, sprouting was earlier for tubers from plants treated before harvest with foliar sprays of ABA at 5, 25 and 50 ppm. There was a tendency for the pre-harvest foliar application of 20 ppm GA and the post-harvest soak of 40 ppm to delay sprouting. The oven treatments gave inconclusive results.

Flowering

A preliminary experiment to study the effects of various chemicals on flowering and aerial tuber formation was conducted, using one clone of *D. alata* (non-flowering), one clone of *D. esculenta* (non-flowering) and two clones of *D. rotundata* (non-flowering and male flowering).

Benzyl Adenine (500 ppm), GA (1000 ppm) and etephon (25 ppm) were compared with a water control. These were applied as foliar applications one to three times at one-week intervals, beginning just prior to tuber initiation. Benzyl Adenine in lanolin paste (1.0 percent) was also applied to the nodes of some plants. No effects on flowering, sex expression or aerial tuber formation were observed although the treatments did stimulate changes in the vegetative growth, indicating that the chemicals had been absorbed by the plants.

Sweet potato

The major constraints of sweet potato production in the tropics are weevil, virus, poor storability and low yield. Efforts have been directed toward minimizing these constraints. Significant progress is being made in improving sweet potato for high yield combined with field resistance to weevil, *Cylas puncticollis*, and to virus and with good storability under ambient conditions.

Table 25. The effect of curing on the percent tubers rooted after months of storage in traditional yam barn and reduced temperature room.

	Months stored				
Treatment	1	2	3	4	5
C-0 barn	7.1	11.4	14.3	20.3	32.8
C-4 barn	0.0	5.7	8.6	11.4	35.7
C-6 barn	0.0	7.1	10.1	11.4	24.3
C-0 store	10.0	54.3	57.1	67.1	78.6
C-4 store	8.6	32.8	35.7	44.3	57.1
C-6 store	5.7	42.8	44.3	51.4	61.4
SE	2.13	4.73	4.40	5.74	5.16

Table 26. The effect of curing on the percent tubers sprouted after months of storage in traditional yam barn and reduced temperature store.

	Months stored				
Treatment	1	2	3	4	5
C-0 barn	0.0	27.7	81.2	91.9	100.0
C-4 barn	0.0	33.7	74.6	81.5	93.6
C-6 barn	0.0	29.3	77.2	88.9	100.0
C-0 store	0.0	0.0	11.7	16.4	20.5
C-4 store	0.0	0.0	11.0	17.0	31.8
C-6 store	0.0	0.0	27.3	29.3	49.0
SE		4.17	6.35	6.11	6.09

IITA improved sweet potato lines regularly produce fresh yields of more than 30 t/ha in four months without fertilizers at locations within Nigeria and other countries. IITA improved lines are giving the highest fresh yield in Cameroon, Sierra Leone, Liberia and Gabon when compared with their introductions and local varieties.

Genetic improvement

IITA improved sweet potato cultivars have been tested without fertilizers at five locations in Nigeria, during 1972-79. Table 27 summarizes the fresh tuberous root yield. The cultivar that performed best over the locations and years was TIS 2498, averaging 14.2 t/ha in four months, followed by TIS 2534, TIS 1499, TIS 2544, TIS 1487 and TIS 3277.

The highest average yield for all the cultivars tested was obtained at IITA (1200 mm rainfall per annum) with 21.1 t/ha, followed by Mokwa (1000 rainfall per annum) with 12.7 t/ha, Mbiri (2500 mm rainfall per annum), Onne (2500 mm rainfall per annum) and Warri (2700 mm rainfall per annum). At IITA, cultivars TIS 1499 and TIS 2498 gave average tuberous yields of about 29 t/ha in four months without fertilizers. These results indicate that sweet potato has lower yields in areas with high rainfall (often "poor" soil conditions), and sweet potato has higher yields in areas with moderate rainfall (often "good" soil conditions).

To estimate the expected yield of each cultivar by location, the yield data of each cultivar was regressed on the average yield of 25 cultivars at each location (Table 27). The expected yields, so estimated, are presented in Table 28. The reliability estimates (R^2) for expected yields of each variety at different locations are high. This provides useful information for future varietal performance tests and recommendation of the IITA improved cultivars at each location in Nigeria.

Promising clones (1977 and 1978 series). The performances of promising clones are summarized in Table 29. TIS 8437 gave the highest fresh tuberous root yield with 25.2 t/ha in four months without fertilizers, followed by TIS 8441, TIS 8164, TIS 8266 and TIS 8250. They all outyielded TIS 2498 and the standard cultivar T1B 4. TIS 71102 and TIS 8141 showed resistance to weevil and viruses. TIS 8141, TIS 8086 and TIS 2498 showed dry matter content of 35.0, 34.0 and 35.7 percent, respectively, while TIS 8250 only had 19.7 percent.

Resistance to weevil

Twenty IITA cultivars were tested for resistance to weevil in both wet and dry seasons during 1976-79 (Table 30). The most weevil-resistant cultivars in terms of tuberous root damage were TIS 3053 and TIS 3030 and in terms of shoot damage were TIS 2532, TIS 3017 and TIS 3030. Weevil resistance was compared to dry matter and starch content and yield. Analyses showed the same relationship ($r = -0.56$) between weevil resistance and both dry matter and starch content. The varieties with higher dry matter and starch content were more weevil resistant. However, there is no relationship between weevil resis-

Table 27. Performance in terms of tuberous root yield (t/ha) of IITA improved sweet potato varieties (IITA, Mokwa, Onne, Warri and Mbiri, 1972-79).

	Location																	
	IITA			Mokwa			Onne			Warri			Mbiri			Overall		
Variety	Ave.	SE	No. tests	Ave.	SE	No. tests	Ave.	SE	No. tests	Ave.	SE	No. tests	Ave.	SE	No. tests	Ave.	SE	No. tests
Tlb 2	20.2	2.4	17	8.8	3.9	4	4.3	0.8	6	3.5	1.2	2	8.6	2.5	4	9.1	2.2	33
Tlb 4	17.0	1.4	17	7.6	3.0	4	4.3	0.4	6	2.4	1.6	2	5.1	0.9	4	7.3	1.5	33
Tlb 8	17.2	3.0	13	13.0	6.1	4	4.7	0.9	6	4.2	2.9	2	8.0	0.9	4	9.4	2.8	29
Tlb 9	18.1	2.1	13	14.7	5.0	4	4.0	0.4	6	4.5	3.4	2	12.8	1.5	4	10.8	2.5	29
Tlb10	17.7	2.5	13	10.9	2.7	4	5.0	0.8	6	2.5	0.9	2	11.3	1.7	4	9.5	1.7	29
Tlb11	20.7	2.3	9	13.0	3.4	4	6.2	0.9	6	5.6	1.3	2	13.1	1.4	4	11.7	1.9	25
TIS 1145	27.8	2.5	12	12.0	5.8	4	4.3	0.5	6	2.1	0.9	2	14.1	2.5	4	12.1	2.4	28
TIS 1487	24.4	1.8	15	16.4	5.5	4	5.1	0.7	6	5.9	0.9	2	13.8	2.3	4	13.1	2.2	31
TIS 1499	28.8	2.1	15	15.6	4.2	4	5.7	0.4	6	4.7	1.5	2	12.1	2.9	4	13.4	2.2	31
TIS 2153	16.6	1.6	13	8.2	3.2	4	3.6	0.7	6	5.9	1.3	2	10.3	1.6	4	8.9	1.7	29
TIS 2154	15.5	1.7	13	6.2	2.8	4	3.5	0.7	6	4.1	0.1	2	9.6	0.6	4	7.8	1.2	29
TIS 2328	12.1	2.2	10	5.6	3.1	2	2.8	0.7	4	3.0	1.3	2	7.0	2.0	3	6.1	1.9	21
TIS 2330	25.8	2.4	14	11.6	4.9	4	5.7	0.8	6	6.5	4.2	2	12.8	3.1	4	12.5	3.1	30
TIS 2498	28.7	3.0	12	15.0	4.4	4	7.4	1.0	6	7.1	2.8	2	12.7	1.3	4	14.2	2.5	28
TIS 2532	21.7	2.3	10	10.7	5.1	4	5.8	1.0	6	6.6	1.4	2	14.5	1.6	4	11.9	2.3	26
TIS 2534	23.6	1.9	14	13.8	3.9	4	7.4	0.8	6	7.4	0.7	2	16.7	1.9	4	13.8	1.8	30
TIS 2544	24.3	2.4	13	16.2	5.0	4	6.4	0.5	6	6.0	0.5	2	13.3	1.7	4	13.2	2.0	29
TIS 3017	20.4	2.3	11	15.6	4.5	4	5.8	1.4	6	4.1	0.9	2	17.0	1.6	4	12.6	2.1	27
TIS 3030	22.3	2.1	12	13.8	3.3	4	5.7	0.9	6	5.0	0.5	2	14.0	2.1	4	12.2	1.8	28
TIS 3053	15.5	1.8	11	9.0	3.8	3	2.6	0.6	5	3.3	0.1	2	13.0	5.4	4	8.7	1.6	25
TIS 3228	19.3	1.9	10	18.1	3.2	2	3.6	1.2	3	3.9	2.8	2	13.2	1.6	3	11.6	2.1	20
TIS 3247	23.9	3.3	11	16.8	5.5	4	4.5	0.9	6	3.5	2.1	2	10.9	1.4	4	11.9	2.6	27
TIS 3270	21.5	2.5	12	12.0	4.0	4	3.4	0.5	5	3.9	2.9	2	12.8	1.7	4	10.7	2.3	27
TIS 3277	23.7	3.1	11	18.1	6.7	3	5.1	0.6	5	3.7	2.1	2	14.7	2.7	4	13.1	3.0	25
TIS 3290	20.6	2.9	12	13.7	4.7	4	6.5	0.7	6	4.4	2.4	2	10.5	1.3	4	11.1	2.4	28
Average	21.1			12.7			4.9			4.6			12.1			11.1		

Standard variety, Tlb 4.

tance and tuberous root yields, indicating that the two characters may be combined through breeding.

Resistance to virus (SPVD)

Twenty-four cultivars were tested for resistance to viruses in the field over three years and four locations in Nigeria and by tuberous root graft transmission (RGT) test (Table 31). Sweet potato virus disease (SPVD) is a widespread, serious disease and an important limiting factor to sweet potato production in the tropics. The disease can cause tuberous yield reductions of up to 78 percent. Field test scores of resistance to SPVD were significantly related to RGT test scores ($r = 0.60$). The

Table 28. Predicted yield (t/ha) of a sweet potato variety at each location.

			Location				
Variety	No. of tests	Reliability estimate (R^2) (%)	IITA 21.1[+]	Mokwa 12.7	Onne 4.9	Warri 4.6	Mbiri 12.1
Tlb 2	33	95	18.7	10.7	3.2	2.9	10.1
Tlb 4	33	87	15.2	8.6	2.4	2.2	8.1
Tlb 8	29	92	17.3	10.7	4.6	4.3	10.2
Tlb 9	29	92	19.7	12.2	5.3	5.0	11.7
Tlb 10	29	97	18.2	10.9	4.2	3.9	10.4
Tlb 11	25	100	20.9	13.2	6.1	5.8	12.7
TIS 1145	28	98	26.7	14.3	2.7	2.3	13.4
TIS 1487	31	99	24.9	15.0	5.9	5.6	14.3
TIS 1499	31	97	27.5	15.6	4.6	4.2	14.8
TIS 2153	29	92	15.9	10.0	4.6	4.3	9.6
TIS 2154	29	90	14.7	8.9	3.5	3.3	8.5
TIS 2328	21	96	11.6	7.0	2.7	2.6	6.7
TIS 2330	30	95	24.1	14.2	5.1	4.8	13.5
TIS 2498	28	95	27.0	16.3	6.4	6.0	15.5
TIS 2532	26	94	21.2	13.4	6.1	5.9	12.8
TIS 2534	30	97	23.7	15.4	7.7	7.4	14.8
TIS 2544	29	99	24.3	15.0	6.4	6.0	14.4
TIS 3017	27	89	22.6	14.2	6.4	6.1	13.6
TIS 3030	28	100	22.5	13.8	5.7	5.4	13.2
TIS 3053	25	88	16.6	10.0	3.8	3.6	9.5
TIS 3228	20	85	21.8	13.2	5.3	5.0	12.6
TIS 3247	27	95	24.2	13.9	4.3	3.9	13.1
TIS 3270	27	99	21.6	12.4	3.9	3.6	11.8
TIS 3277	25	95	24.9	14.7	5.2	4.8	14.0
TIS 3290	28	97	20.5	12.7	5.4	5.2	12.1

[+] *Average of 25 varieties at each location.*

Table 29. Performance of clones of 1977 and 1978 series tested (IITA).

Clone	Fresh yield (t/ha)	Dry matter (%)	Dry yield (t/ha)	Weevil score[*]	Virus score[*]	Storability
TIS 8437	25.2	31.6	8.0	0.5	0.5	G
TIS 8441	24.9	29.2	7.3	1.5	0.8	G
TIS 8164	23.9	30.6	7.3	0.8	0.5	G
TIS 8266	22.0	31.6	7.0	0.3	0.8	G
TIS 8250	21.4	19.7	4.2	0.8	0.3	VG
TIS 8140	20.7	25.7	5.3	0.5	0.3	G
TIS 8143	20.1	31.2	6.3	0.5	0.0	M
TIS 2498	20.0	35.9	7.2	1.6	0.1	G
TIS 8244	19.9	27.0	5.4	1.0	0.8	M
TIS 71102	18.3	32.2	5.9	0.0	0.0	VG
TIS 8064	18.3	31.4	5.7	0.5	0.0	M
TIS 8141	16.4	35.0	5.7	0.0	0.0	VG
TIS 8163	15.0	33.7	5.1	1.0	0.8	P
TIS 70083	14.8	30.9	4.6	1.0	0.3	G
TIS 70314	14.8	36.1	5.3	0.8	0.5	M
TIS 8086	13.3	34.3	4.6	0.0	1.0	VG
Tlb 4	14.3	34.3	4.9	3.0	0.8	G

[*] *Scores from 0 to 5; 0 = no visible damage or symptoms; 5 = severe damage or symptoms.*
Standard variety, Tlb 4.

cultivars that were resistant to SPVD in both tests were TIS 2498, TIS 3228, TIS 3053, TIS 2544 and TIS 2534.

High heritability of resistance to SPVD was estimated as $h^2 = 0.95 \pm 0.02$ with the RGT test scores while low heritability was estimated as $h^2 = 0.48 \pm 00.02$ with the field test scores (Table 32). This suggests that RGT is more efficient in screening sweet potato for resistance to SPVD.

The mechanism of resistance of sweet potato to SPVD appears to be related to both resistance to infection and resistance to spread of disease agents within plants.

Methods of SPVD. The major objective of SVPD investigations in 1979 was to develop a rapid efficient method for screening sweet potato for resistance to SPVD and identify appropriate criteria for the determination of the nature of SPVD resistance.

Table 32 indicates that the clones from seedling families TIS 3247 and TIS 3017 were positively challenged with SPVD by tuber grafting. Their foliage developed the characteristic SPVD symptoms within an average time interval of 11-13 days. Nine other clones from seedling families, which had only one tuber per clone, were also positively challenged. All four tubers of a clone from seedling family Tlb 8 were negatively challenged. Foliage of plants from unchallenged (untreated) tubers did not develop SPVD symptoms. The data also indicate the number of clones within segregating families that were positively challenged with SPVD.

Table 33 indicates that tubers from all the vegetatively propagated clonal material harvested from the field were positively challenged with foliage symptoms developing between 11 and 22 days. TIS 3017 and Tlb 8 consistently expressed severe SPVD symptoms while cultivar TIS 2534 plants developed only mild to moderately severe symptoms. In TIS 2498, only 8 of the 61 tubers challenged produced SPVD foliage symptoms and in only two of these did the symptoms persist. In the remaining six plants, the mild SPVD symptoms were transient. As growth progressed, symptoms disappeared. None of the unchallenged (untreated) produced foliage with SPVD symptoms during the observation period.

TIS 2498 vines, which were either negatively or positively challenged but eventually recovered from tests, were indexed by the approach graft method to the sensitive indicator *I. setosa*. Vines from the few plants that were positively challenged with persistent symptoms were similarly indexed to serve as infected checks. All five negatively challenged plants indexed negatively when grafted to *I. setosa*. One plant, which was positively challenged but subsequently recovered, indexed negatively when grafted to *I. setosa*. All four of the infected check plants, which had been positively challenged, indexed positively on *I. setosa*. The symptoms on *I. setosa* developed between 12 and 20 days.

The large number of positively challenged test tubers by the tuber graft method, resulting in the development of the characteristic SPVD symptoms, indicates the efficiency of this method for transmitting the sweet potato virus to test plants. Negative challenge by this method may indicate the existence of a resistance mechanism, which may be utilized in a breeding program.

TIS 2498 appears to possess the most efficient mechanism for resistance among those tested. Although TIS

Table 30. Sweet potato weevil damage (score) of tuberous root and shoot and dry matter percent, starch content, virus (score) and yield for 20 sweet potato cultivars.

Cultivar	Weevil damage (score)' Tuberous root	Weevil damage (score)' Shoot	Virus (score)'	Dry matter (%)	Starch content (%)	Yield (t/ha)
Tlb 4	3.3 a*	4.8 ab*	2.2	29.6	18.2	14.3
Tlb 11	3.2 ab	4.3 abc	1.8	26.5	15.0	18.7
TIS 1145	3.0 abc	4.5 ab	3.2	29.5	18.1	22.2
Tlb 2	2.9 abcd	5.0 a	2.9	28.9	17.5	12.8
TIS 2330	2.8 bcd	4.0 bcd	1.8	22.2	10.4	21.4
Tlb 10	2.7 cd	4.5 ab	2.1	30.1	18.8	15.3
TIS 3247	2.5 de	4.3 abc	2.1	28.4	17.0	22.8
TIS 3270	2.5 de	3.3 de	2.4	28.4	17.0	21.5
TIS 1487	2.3 ef	2.8 efg	2.5	32.7	21.5	18.5
TIS 2498	2.3 ef	3.0 ef	1.0	31.7	20.4	24.7
TIS 1499	2.2 efg	2.0 fgh	2.8	28.1	16.6	24.0
Tlb 8	2.0 fgh	2.8 efg	2.4	32.8	21.6	13.3
Tlb 9	2.0 fgh	3.0 ef	2.3	36.0	25.0	15.0
TIS 2532	1.9 fgh	1.0 i	1.6	29.3	17.9	18.8
TIS 3017	1.9 fgh	1.5 hi	1.6	32.1	20.9	14.7
TIS 3290	1.9 fgh	3.0 ef	2.4	34.1	23.0	19.4
TIS 2153	1.8 gh	3.0 ef	1.9	38.0	27.1	14.1
TIS 2154	1.8 gh	3.0 ef	1.8	37.6	26.7	13.0
TIS 3030	1.6 hi	1.8 ghi	1.6	31.1	19.8	19.4
TIS 3053	1.4 i	3.5 cde	1.4	29.4	18.0	13.1

Figures for all the traits are average of data of two seasons each for three years except shoot weevil damage rating which is average of two trials at different sites in one year. The data of tuberous root weevil damage and shoot damage come from different trials.

'Scores from 0 to 5; 0 = no damage by weevil and viruses; 5 = severe damage.

**Means with a common letter are not significantly different at 0.05 according to Duncan's Test.*

Table 31. Sweet potato virus scores when tested in the field over three years and four locations and by tuberous root graft transmission (RGT) test.

Cultivars	Field test (score)⁺	Tuberous root graft transmission test (score)⁺
TIS 2534	1.0 a*	2.0 bc
TIS 2498	1.0 a	1.0 a
TIS 3228	-	1.0 a
TIS 2544	1.2 ab	1.5 ab
TIS 3053	1.4 abc	1.0 a
TIS 2532	1.6 bce	2.0 bc
TIS 3017	1.6 bce	2.0 bc
TIS 3030	1.7 bce	2.5 cd
TIS 2154	1.8 bcef	3.0 d
TIS 2330	1.8 bcef	2.5 cd
TIb 11	1.8 bcef	4.0 ef
TIS 3270	1.8 bcef	4.0 ef
TIS 2153	1.9 cefg	3.3 de
TIb 10	2.1 efg	5.0 g
TIS 3247	2.1 efg	2.5 cd
TIb 4	2.2 efgh	5.0 g
TIb 9	2.3 efghi	2.5 cd
TIS 3290 2	2.4 fghi	3.0 d
TIb 8	2.4 fghi	5.0 g
TIS 1487	2.5 ghi	2.5 cd
TIb 2	2.9 ij	2.8 c
TIS 3277	2.9 ij	3.0 d
TIS 1145	3.2 j	4.3 fg

⁺*Scores from 0 to 5; 0 = no visible virus symptoms; 5 = severe symptoms.*

**Means with a common letter are not significantly different at 0.05 according to Duncan's Test.*

The coefficient of correlation between the field test scores and tuberous root graft transmission test scores was obtained as r = 0.60.

Table 32. Sweet potato virus transmission by the tuber graft method.

Seedling families	No. tubers challenged	No. positive response
TIS 3247*	4	1
TIS 3017*	4	4
TIb 8*	4	0
OP (bulk) (Taiwan)	23	6
OP (bulk) (Japan)	24	13
Crosses (Taiwan)	32	8
Sibs (Taiwan)	31	19

**Parents.*

Table 33. Sweet potato virus transmission efficiency by the tuber graft method.

Variety	No. tubers challenged	No. positive response
TIS 2498	61	8
TIS 2534	27	14
TIS 3017	30	27
TIb 8	20	17

2498 is susceptible to challenge from a virus source by tuber grafting, it apparently has the capacity to grow vigorously *and recover from the infection*. Since only a small number of plants in this cultivar were posivitely challenged, the nature of resistance is resistance to infection where plants of a particular clone are not very liable to become infected. However, once individual plants become infected, although symptoms expression occurs, infected plants of this clone have the capacity to recover and make symptom-free growth.

Cultivars with high dry matter content

The IITA improved sweet potato cultivars TIS 2154, TIS 2153 and TIb 9 consistently showed high dry matter content of *38.9, 38.3 and 36.5 percent, respectively (Table* 34). Consumer acceptance of the cultivar is good. However, these cultivars are low yielders. They may be used as parents for breeding improved cultivars with both high yields and dry matter content.

Table 34. Dry matter percent of sweet potato cultivars tested (IITA, 1974-79).

Variety	No. of tests	Dry matter (%)	Yield (t/ha)	Dry yield (t/ha)
TIS 2154	10	38.9	17.5	6.8
TIS 2153	8	38.3	16.7	6.4
TIb 9	9	36.5	18.8	6.9
TIS 2498	8	33.2	27.3	9 1
TIb 4	11	30.8	18.9	5.8
TIS 2330	10	22.8	29.1	6.6

Source-sink relationships

The relationships between source potentials and sink capacities measured as the dry tuberous root weights of four cultivars were studied by reciprocal grafts (Table 35). Cultivar TIS 2534 had a high sink capacity but low source potential while cultivar TIS 2498 had a high source potential but low sink capacity. The use of cultivar TIS 2534 as stock and cultivar TIS 2498 as scion resulted in significantly higher tuberous root yield. Since both cultivars are high-yielding, crosses between them may produce progenies with both good sink capacities and source potentials, *resulting in higher yields*.

Leaf harvest and tuberous root yield

Sweet potato is generally grown for its tuberous roots; however, the stems, petioles and leaves are sometimes eaten by some people. Thus, to determine the effects of pattern and frequency of detopping on yields of tuberous roots of sweet potato, a detopping investigation was conducted. Detopping plants at 48 and 86 days after planting gave 34-42 percent less shoot yield than cutting plants 10 cm from ground level. Shoot yield was not affected by detopping at two-, three- or four-week intervals.

Compared with non-detopped plants, tuberous root yield was reduced by 31-48 percent by detopping and 48-62 percent by cutting plants 10 cm from ground level. The number and size of individual tuberous roots were reduced as the frequency of detopping increased. Detopping at 4-week intervals is recommended for reasonable yields of both shoot tips and tuberous roots.

International cooperation

The following national programs were recipients of improved sweet potato genetic material introduced as true seed: Liberia, Sierra Leone, Gabon, Seychelles, Cameroon, Rwanda, Burundi, India, Sri Lanka, Taiwan, Papua New Guinea, Fiji, Nigeria, Venezuela, Argentina and U.S.A.

Liberia. Eight promising clones have been evaluated in a preliminary yield trial in Liberia. Yields from the clones ranged from 15.3 to 27.1 t/ha; all showed good resistance to SPVD and the sweet potato weevil.

Seychelles. Five most promising clones have been evaluated for flesh and skin color, shape and taste in Seychelles. TIS 3017 showed a high level of tolerance to Fe and P deficiencies, which are quite severe on the sandy beach soils of Seychelles.

Indonesia. Many clones have been selected for Indonesia. Some showed resistance to scab disease, which is serious in Southeast Asia. The selected clones are undergoing evaluation in different locations within Java.

Rwanda. One hundred and twenty promising clones were selected from breeding material supplied by IITA and were evaluated at altitudes of 1,200-2,000 m in Rwanda. TIS 2498 and TIS 2534 gave the highest yields.

Gabon. Eighty-one clones were selected from IITA breeding material and were evaluated in Gabon. Several clones gave yields of 25-30 t/ha without fertilizers in 4 months. They are resistant to viruses. These clones were multiplied and distributed to farmers whose demands for the planting material are high.

Entomology

Resistance to sweet potato weevil

To investigate the mechanism of resistance and level of resistance to different clones to the sweet potato weevil (*Cylas puncticollis*), IITA scientists intensively tested 10 sweet potato clones, including resistant and susceptible types, under rigorous field and laboratory screening tests.

In the field trial during the 1979 wet and dry seasons, the weevils were counted once a week for four months in each of the experimental plots, and the depth of the tuberous roots was measured at harvest (Table 36). Results show that TIS 3030, TIS 3017 and TIS 2532 had the lowest tuberous root damage by weevils despite medium tuber depth.

These three clones were retested under more rigorous conditions in the laboratory. Tuberous roots (2.5 kg) were infested with 20 females of 10 males of equal age and the females allowed to oviposit for 10 days after which the insects were removed. From 19 to 38 days of test, emerging adults were collected and counted daily. This test was repeated over five generations of the weevils using tubers from the same clones (Table 37). (The results of only the F_2 generation are shown in Fig. 3).

TIS 2532 showed a six-day delay in adult hatching over the control, TIb 4, while TIS 3017 and TIS 3030 showed only a 4-day delay. The same trend was observed in F_3, F_4 and F_5 generations.

To find the cause of the differences observed in the field and laboratory tests, an additional replicated experiment was set up to monitor the eggs laid per female over 14 days on the tuberous roots from each clone. These roots were left for 14 days, the number of emerging adults counted while adult females and males were weighed separately (Table 38).

The average weight of adult males, emerging from TIS 2532, TIS 3017 and TIS 3030, was lower than the control TIB 4. However, the average weight of adult females, emerging from only TIS 3017, was different from those from the other clones.

The results show that in TIS 2532 and TIS 3030, a factor influencing oviposition seems to operate because the lowest number of eggs were laid on the tuberous roots of these clones. The larvae or pupae mortality was low and is not significantly different from that of the control TIb 4. In the case of TIS 3030 and TIS 3017, relatively low numbers of eggs were laid, and mortality was about 50 percent. Weight differences may also be observed in adults, particularly males obtained from test clones compared with the control.

Table 35. Dry tuberous root yield (g/plant) of reciprocal grafts of four sweet potato varieties.

	Scion					
Stock	TIS 2328	TIS 2330	TIS 2498	TIS 2534	Mean stock (sink) effects	b_j**
TIS 2328	153.5 de	198.5 de	259.0 bcde	131.3 de	185.58	0.50
TIS 2330	188.4 de	221.6 cde	385.2 b	133.6 a	232.20	1.01
TIS 2498	243.7 bcde	250.0 bcde	387.1 b	234.1 cde	278.73	0.69
TIS 2534	294.0 bcd	350.4 bc	713.4 a	351.9 bc	427.43	1.80
Mean scion (source) effect	219.90	250.13	436.18	212.73		
b_i**	0.57	0.64	1.82	0.97		

Values with a common letter are not significantly different at 0.05 according to Duncan's Test.

**The figures underlined are for self grafts.*

***b_i refers to the regression of the i^{th} scion on the average stock effect and b_j to that of the j^{th} stock on the average scion effects where b_i is the estimate of the response of the i^{th} scion or source to sinks and b_j is that of the response of the j^{th} stock or sink to sources.*

Varietal differences in oviposition, larvae mortality and weevil growth indicate the operation of antibiosis as the plausible mechanism of resistance. A combination of these factors might increase the level of resistance against the weevil.

Tissue culture and virus indexing

With a view to accelerating the testing procedures of new clones, tubers of different varieties were harvested in the field and planted in pots in a greenhouse. When the tubers had sprout of about 30 cm high, buds were excised, surface sterlized in 70 percent ethanol for two minutes and in a 4 percent (w/v) filtered solution of calcium hypochlorite for 20 minutes and rinsed twice in sterile distilled water. The buds were then asceptically dissected under a stereoscopic microscope in a laminar flow transfer cabinet.

The length of dissected meristem tips ranged from 0.25 to 0.4 mm. The meristem tips were transferred to 16 mm × 25 mm glass culture tubes, containing 5 ml of medium with the following composition per liter : salts solution; sucrose, 30 g; Myoinositol, 200 mg; adenine sulfate, 80 mg; thiamine HC1, 0.2 mg; pyridoxine HC1, 1 mg; nicotinic acid, 1 mg; glycine, 4 mg; indol acetic acid (I.A.A.), 0.2 mg; Benzyl amino purine, 0.5 mg and agar, 8 g. The pH was adjusted to 5.7 before sterilizing. Meristem tips were grown in a culture room under white fluorescent lamps giving 2,500 lux at plant level with a 12-hour photoperiod at a temperature of 20° C by night and 26° C by day and a relative humidity between 50 and 70 percent.

Plantlets, which developed from meristem tips, were transferred to jiffy-7 peat pellets when they reached the height of 3-5 cm and kept in a glass box with high relative humidity for about one week. They were then transferred into 15-cm pots filled with sterilized soil in an insect-free isolation room.

Plantlets of sufficient size for transplanting to soil were obtained after two to three months. The percentage of success in producing plantlets after 10 weeks varied widely between the different clones (20-90 percent). When transferred to jiffy-7 peat pellets and later to soil, all plantlets survived even if they had no roots in the test tubes. Presently, plants from 30 varieties have been produced by meristem tip culture and are being indexed.

Virus indexing was accomplished as follows: after one to two months, plants from tissue culture tube were approach grafted to *I. setosa* seedling grown in isolation, and the *I. setosa* was observed for virus symptom devel-

Table 36. Harvest results of wet/dry season trials and factors influencing weevil damage.

Clone	t/ha	Average wt./tuber (kg)	Tuber depth*	Average no. weevils/ week	Percent infested tubers
Tlb 4	17.5	0.12	shallow	24.4	73.0
TIS 2532	25.1	0.18	medium	7.7	10.2
TIS 3030	23.7	0.19	medium	9.4	16.7
TIS 3017	23.2	0.27	medium	8.7	19.0

**Shallow, 0-2 cm; medium, 2-4 cm; deep, 4-6 cm.*

Table 37. Clonal differences in average number of weevils hatched from the tuberous roots infested with 20 females and 10 males for 10 days over five generations.

Clone	Mean number of adults
Tlb 4 (control)	1022
TIS 2532	502
TIS 3017	614
TIS 3030	657

LSD (0.05) = 104.38.
**20 females and 10 males were used for each clone in each generation.*

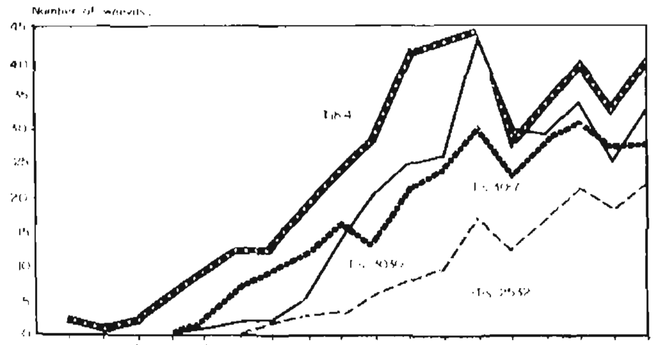


Fig. 3. Observed weevil emergence over 18 days on four sweet potato clones (F_2 generation).

Table 38. Number of eggs laid by five females, percentage of adult emergence and average adult weight on tuberous roots from four sweet potato clones.

		Male		Female		
Clones	Mortality (%)	No. weighed	Avg. wt. (mg)	No. weighed	Avg. wt. (mg)	No. of clones
Tlb 4	17.0 a*	210	8.0 a	222	8.6 a	520 aa
TIS 2532	28.1 a	71	7.3 b	62	8.1 a	185 b
TIS 3017	46.3 b	86	7.1 b	94	7.1 b	335 ab
TIS 3030	49.7	73	7.2 b	85	7.7 ab	314 b

**Figures with a common letter are not significantly different at 0.05.*

opment. The susceptibility of *I. setosa* was tested by approach grafts to plants known to be virus infected. Plants of different varieties showing different degrees of severity in symptom expression were used. All the *I. setosa* plants grafted to virus infected plants, including symptomless plants, showed symptoms of vein clearing after 12-21 days. Ninety-five percent of the plants issued from meristem tip culture were found virus free after being indexed twice at two-month intervals.

Methodologies for rapid multiplication and maintenance of virus-free material have been developed. Negatively indexed plants, which after being grafted twice to *I. setosa*, did not induce symptoms on that plant within 35 days, were multiplied by single node cuttings *in vitro* in a medium with the following composition per liter : salts solution; sucrose, 30 g; $NaH_2PO_4.H_2O$, 170 mg; adenine sulfate, 80 mg; thiamine HC1, 0.5 mg; glycine, 0.2 mg; I.I.A. 0.3 mg; 6 (α,α) Dimethylallyl-amino-purine, 10 mg and agar, 8 g. The pH was adjusted at 5.7 before sterilizing. The rate of multiplication obtained by single node cuttings *in vitro* was 4.2 per month. This means that more than 30×10^6 plants can be obtained from one bud in one year.

The establishment of a germplasm collection in tissue culture form makes it possible to maintain virus-free clones in a virus-free state without any risk of recontamination. The composition of a culture medium and conditions required for slow growth are under investigation. About 80 clones are now in a germplasm collection under tissue culture form.

Agreement with plant quarantine services are being settled and all the improved clones of IITA will be available for distribution in early 1980.

Cocoyam

Work on cocoyam was intensified in 1979 based on successful flower promotion and hand pollination as breeding tools. Serious disease problems on this crop occur in Cameroon where cocoyam is a staple food. Work is being intensified there in close collaboration with the research team at IITA to identify the disease complex and to seek the means to overcome it.

Genetic improvement

Promotion of flowering

Research during the 1978 wet season indicated that GA at 1500 ppm applied as a foliar spray with surfactant (0.01 percent) successfully promoted flowering in Nigerian clones of *Xanthosoma* and *Colocasia*. Observation trials were conducted during the 1978-79 dry season to test the promotion of flowering over a broad range of environments, planting times and genotypes. Six clones and five populations were planted in these trials. The results obtained were similar to those reported for the 1978 wet seasons. Although there were differences in the absolute values between the two seasons, the general flowering behavior of each clone remained the same, suggesting that clonal response to GA can be characterized. This permits the planning of stagger planting to ensure simultaneous flowering of proposed parents.

GA also successfully induced flowering in all materials tested, indicating that the technique is appropriate for a range of genotypes. However, the GA concentration should be reduced to 750 ppm for clones or seedlings that frequently flower naturally.

Although abundant flowering was promoted under irrigation, during the dry season, the majority of the inflorescences failed to produce pollen and seed production was severely limited. For seed production in the dry season, shading or other precautions against incipient wilting will need to be tested.

During the 1979 wet seasons, an experiment was also carried out to test different methods of application of GA to compare the technical grade 75 percent potassium salt of GA with Pro-Gibb Plus (Abbott Laboratories), a commercial formulation that is easier to handle when accurate balances are not available. Two Nigerian clones of *Xanthosoma*, TXs 17 and TXs 18, and three Nigerian clones fo *Colocasia*, TCe 15, TCe 23 and TCe 36, were grown in a randomized complete block design with three replications, four plants per plot. Fertilizer at the rate of 50 kg N/ha, 50 kg P/ha and 40 kg K_2O/ha was applied one time during the growing season to insure vigorous growth.

The following treatments were applied:

1. Foliar spray, technical grade, 0.01 percent surfactant, 1,500 ppm, 3-5 leaf stage.
2. Foliar spray, technical grade, 0.25 percent surfactant, 1,500 ppm, 3-5 leaf stage.
3. Foliar spray, Pro-Gibb Plus, no surfactant, 1,500 ppm, 3-5 leaf stage.
4. Pre-plant soak, Pro-Gibb Plus, no surfactant, 1,500 ppm, 30 minute soak.
5. Control of foliar spray water, 0.25 percent surfactant, 3-5 leaf stage.

All GA treatments promoted flowering. In contrast, the water control produced no inflorescences up to six months after planting when the dry season terminated the experiment. The time to first inflorescence from the time of GA application was significantly less for plants treated with foliar sprays than those soaked with water (Table 39). Plants soaked with water flowered earlier; application was five weeks earlier. There were also significant differences among clones for time of flowering.

Although the percentage of flowering for plants soaked with water was lower, differences were low among treatments or clones (Table 40). The average number of inflorescence per plant was highest for the foliar spray, technical grade GA, 0.25 percent surfactant (Table 41).

Soaking with Pro-Gibb Plus gave the poorest results in this respect. Since the plants soaked with water tended to be smaller at the time of flowering, spadices were weaker and less suitable for seed production. Significant differences among clones were also observed.

These results suggest that for Nigerian clones of *Xanthosoma* and *Colocasia*, all the GA treatments gave satisfactory results. Although the foliar spray of technical grade GA at 1,500 ppm applied with 0.25 percent surfactant was the best.

Breeding

Using GA flower promotion and hand pollination, large quantities of seed have been produced for the initiation of breeding programs at IITA and Cameroon and for international distribution. In 1979, seeds were distributed to Cameroon, Nigeria, Puerto Rico, India, Italy and U.K. To broaden the genetic base of the breeding program, seeds have been imported from the Solomon Islands and Puerto Rico, and crosses between these exotic and the Nigerian clones have been made.

At IITA, selection of superior clones from segregating breeding populations was carried out in both *Xanthosoma* and *Colocasia*. Two seedling nurseries of *Xanthosoma* were established in the field, the first with seven families gave 400 plants and the second with four families gave 466 plants. Seedlings were evaluated for resistance to Dasheen Mosaic Virus (DMV) and distortion, petiole color, plant vigor and cormel development and flesh color. Segregation for all these characteristics was observed. Selections from the first nursery have been harvested and advanced to a Preliminary Yield Trial, where 41 hybrid clones and 75 inbred clones are being evaluated.

A *Colocasia* seedling nursery, containing 200 plants in three families, was evaluated for resistance to DMV and *Sclerotium* rot and for plant vigor, petiole color and corm development. Forty-seven selections were advanced to the Preliminary Yield Trial and are being evaluated.

Pathology

Disease resistance screening

To select out cocoyam susceptible to DMV early in the breeding program, a method of mechanical inoculation has been employed to challenge seedling plants. A significant number of true seed progeny have been found susceptible to DMV. New segregates soon become infected in the field and express symptoms often more severe than any of the parental stocks. Previous work has shown that this virus is not seed-borne; therefore, the seedling plants, which show symptoms, may have been infected by a vector-borne virus.

The mechanical inoculation method involves the solution and maceration of symptomatic leaves. Small portions of leaves (3-45) are macerated with a buffer (pH 7.7) of 0.1 *M* $NaKPO_4$ plus 0.01 EDTA and 0.001 *M* cysteine. The candidate plants are grown from seed to 10 weeks of age, dusted with carborundum and mechanically inocu-

Table 39. The effects of GA treatments on the mean number of weeks from treatment to first spadix in cocoyam.

Treatment	TXs 17	TXs 18	TCe 15	TCe 23	TCe 36	Mean ($\bar{T}$)
1	9.5	10.3	8.8	12.5	9.2	10.1
2	10.4	11.3	8.3	14.9	8.7	10.7
3	10.1	11.3	9.0	11.6	10.3	10.5
4	12.0	12.5	10.8	15.7	11.2	12.4
5	NF	NF	NF	NF	NF	NF
Mean (cl)	10.5	11.3	9.2	13.7	9.9	

SE ($\bar{X}$) 0.48.
SE ($\bar{T}$) 0.21.
SE ($\bar{Cl}$) 0.27.
NF : No flower produced.

Table 40. The effects of GA treatments on the percent plants flowering in cocoyam.

Treatment	TXs 17	TXs 18	TCe 15	TCe 23	TCe 36	Mean ($\bar{T}$)
1	100.0	100.0	100.0	66.7	100.0	93.4
2	100.0	100.0	100.0	83.3	100.0	96.7
3	100.0	91.7	100.0	75.0	100.0	93.3
4	100.0	80.7	75.0	100.0	83.3	87.8
5	0.0	0.0	0.0	0.0	0.0	0.0
Mean (cl)	80.0	74.5	75.0	56.7	76.7	

SE ($\bar{X}$) 8.74.
SE ($\bar{T}$) 3.91.
SE ($\bar{cl}$) 3.91.

Table 41. The effects of GA treatments on the number of spadices per plant of cocoyam.

Treatment	TXs 17	TXs 18	TCe 15	TCe 23	TCe 36	Mean ($\bar{T}$)
1	8.9	5.8	18.4	1.9	5.2	8.1
2	11.7	6.9	27.0	3.3	7.6	11.3
3	9.5	7.7	9.4	2.6	5.7	7.0
4	6.8	5.6	6.0	3.3	2.6	4.8
5	0.0	0.0	0.0	0.0	0.0	0.0
Mean (cl)	7.4	5.2	12.2	2.2	4.2	

SE ($\bar{X}$) 1.60.
SE ($\bar{T}$) 0.72.
SE ($\bar{cl}$) 0.72.

IITA cultivars Tlb 1 and Tlb 2 were tested at four locations in low- and high-humid forest regions and at five locations in high-altitude regions (1,330 m-1,600 m). Cultivars Tlb 1 and Tlb 2 gave average yield of 30.8 and 16.7 t/ha, respectively, over four locations, in low- and high-humid forest regions. They also gave 25.0 and 18.4 t/ha, respectively, in high-altitude regions in four months without fertilizers. In the tests, cultivar Tlb 1 outyielded the local cultivars by about 45 percent in the low- and high-humid regions and by about 113 percent in the high-altitude regions.

Cocoyam

To breed cocoyam (*Xanthosoma* spp.) for resistance to root rot, IITA's work in Cameroon, where root rot is a limiting factor for cocoyam production in many parts of the south and southwest, included several trials to identify the pathogen and study the epidemiology of the disease. Root rot, which may be caused by a fungus of the family *Pythiaceae*, has two different forms, one leads to dwarfed plants that do not produce cormels while the other to yellowing and root rot of well-developed, vigorous plants.

To study the mode of spread, healthy and diseased cocoyams were planted in containers with soil from fields where the disease was present and, in absence of sterilization facilities, in soil from fields that had been under bananas for approximately 10 years. Healthy cocoyam planted in the unhealthy soil developed into dwarfs. Diseased cocoyam planted in the healthy soil also developed into dwarfs, but after two months of growth. Only healthy cocoyam planted in the healthy soil developed into vigorous plants.

To study the control of root rot, trials with new systemic fungicides, RIDOMIL and ALEITTE, were applied. Except dipping of planting material, treatments started four weeks after planting.

Two tests were conducted. The first test was planted on a field with apparently healthy soil, using healthy cocoyam. The second test was planted on a field with apparently unhealthy soil, using diseased cocoyam. In the first trial of both tests, the plants developed vigorously until the disease wiped out the whole field, regardless of treatments. In the second trial of both tests, most of the plants had completely recovered with RIDOMIL although they did not develop as vigorous plants. RIDOMIL showed the same effect on another site. Since microorganisms other than a fungus may be involved in the disease, different antibiotics such as tetracycline, oxytetracycline, chloramphenicol and penicillin were used in various concentrations but without any effect.

The epidemiology of the root rot was studied in an observation plot containing 50 × 50 plants. All plants were scored regularly, and the spread of the disease was mapped. The disease started mid-July in some foci that rapidly expanded. Within three weeks, 50 percent of the plants were affected. Within five weeks, nearly 100 percent were affected. Since the disease started at the same time as cormel formation, the yield of marketable tubers was nearly zero.

The first symptoms developed on the second or third expanded leaf with the entire blade becoming chlorotic. Within three to four weeks, all the leaves turned yellow and necrosis had started from the tips and margins. Only one or two small leaves remained green.

When the first aerial symptoms appeared, root rot had already started. Some roots were completely rotten while others showed brown lesions. When the plants had 3-4 yellow leaves, the root system was completely decayed. There seemed to be no differences in resistance between cultivars from different regions. Isolation from roots of diseased plants from different regions always gave a *Pythium* sp. and *Rhizoctonia* sp. From dwarfed plants, only *Rhizoctonia* could be isolated probably because it was nearly impossible to find roots with fresh lesions. The yellowing symptoms suggest that the presence of other microorganisms like virus,mycoplasm or rickettsia-like bacteria, but none could be identified in root samples. Infection tests with *Pythium* isolates and to some degree with *Rhizoctonia* isolates gave positive results. Plants germinated in plastic bags with infested soil remained dwarfed. *Pythium* could be reisolated from lesions on roots. However, it still has to be proven that healthy undisturbed plants in the field can also be infected.

No explanation was found to explain why RIDOMIL was not effective against the yellowing even though treatments had started long before the outbreak. However, infested plants that were dipped in RIDOMIL and transplanted and then regularly treated with RIDOMIL were 80 percent cured.

The factors leading to the sudden outbreak of the disease in July or August are not known. The disease may favor the higher rainfall or the lower temperature in July.

The relatively high planting density of 1 m × 1 m seems to be a factor as well. Since the disaese spreads in foci, it probably starts from single plants that were infected incidentally by a *Pythium* propagule present in the soil. In farmers' fields, where planting density is normally less, the spread is relatively slow. Unfortunately, mixed cropping trials that should give an answer to this question gave no consistent results.

Even though breeding for resistance is the best solution for this disease problem, it is necessary for the short term to find some help with agronomical measures. If the onset of the disease could be delayed by some weeks and the infection rate reduced to some extent, yields could be increased by 50 percent or more.

USAID: Zaire's National Manioc Program (PRONAM)

This grant from USAID provides support to IITA researchers stationed in Zaire to work on root and tuber crop improvement. Participation in the program enables IITA to extend its cassava research into an area representative of a large part of Central Africa. In addition, IITA works in Zaire on two extremely important insects, the cassava mealybug and green spider mite, both of which cause severe yield reduction.

Cassava

PRONAM has concentrated its cassava genetic improvement in three major cassava growing regions, Bas-Zaire, Bandundu and Kivu. Over 100,000 seedlings were raised in the Bas-Zaire region, 20,000 in the Bandundu region and 5,000 in Kivu region.

Preliminary, Advanced and Uniform Yield Trials were conducted at many locations in these regions. Through

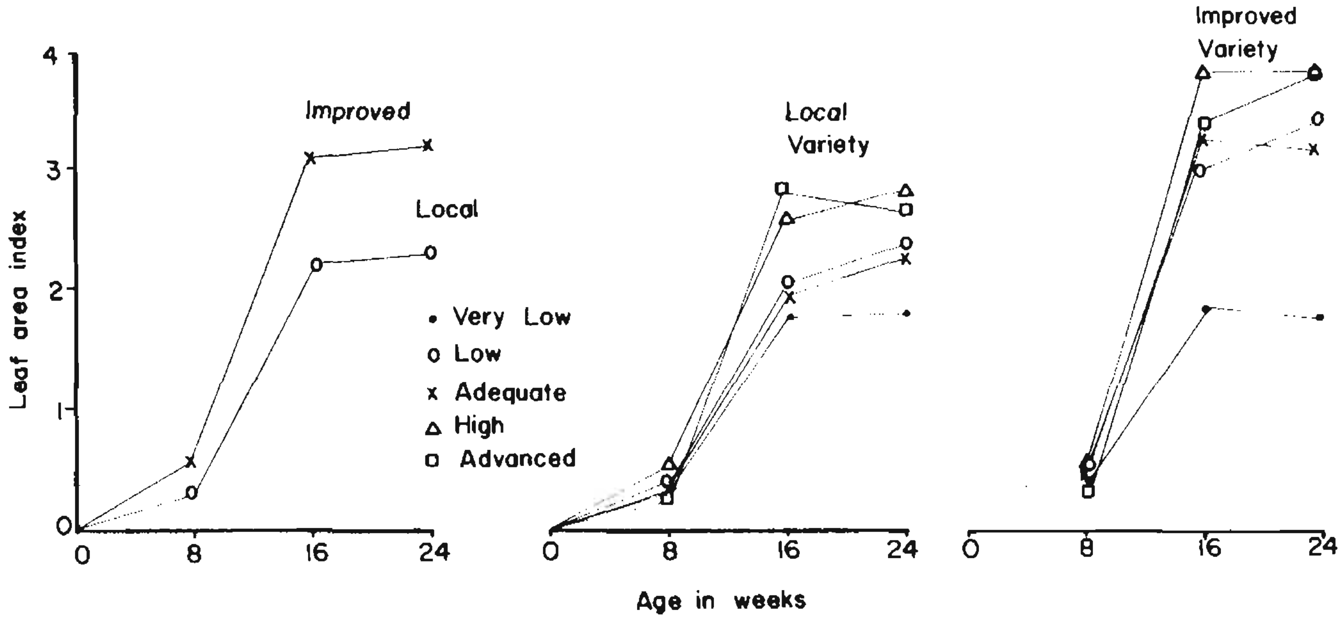


Fig. 4. Effects of various levels of technology on leaf area of two cassava varieties.

the trials, several promising clones were identified. Clone 300704 consistently showed the highest average yield with 20 t/ha in the Bas-Zaire region, followed by A 56, 30346 and 301792. The consumer acceptance quality of the clones were tested to be good. Many promising breeding clones, which are resistant to CM, CGM, CMD, CBB and CAD, were identified for further performance tests.

Effect of planting pattern and intercrop with peanut on cassava and peanut yields. The most common cassava planting pattern in Bas-Zaire is the double row; cassava is spaced in two rows, 50 cm apart on ridges usually 1-1.5 m apart. In three out of four observations, peanut yield was consistently and significantly higher when in association with double row planted cassava than with other planting patterns (Table 44a). There was no difference in peanut yields associated with 75 cm × 100 cm and 100 cm × 100 cm cassava planting pattern. Irrespective of pattern, peanut populations of 100,000/ha yielded 159 percent higher than peanut populations of 50,000/ha.

Increasing peanut population from 50,000/ha to 100,000/ha had no significant effect on cassava root yield. However, peanuts significantly reduced cassava root yield compared with cassava planted alone (Table 44b).

Preliminary data also show significantly less peanut yield when in association with the improved variety of cassava compared with the unimproved Mpelolongi (Table 45). This may be partly attributed to mutual shading by the more vigorous, early-maturing improved cassava whose leaf area index increased sharply from 0.5 at 8 weeks to 3.2 at 16 weeks. Corresponding leaf area changes for Mpelolongi were from 0.3 to 2.2 (Fig. 4). This period is critical for peanut growth and development.

Leaf area of both local and improved varieties increased at different rates with increasing management levels and with age up to 16 weeks. Thereafter, leaf area indices remained constant with change in management levels up to 24 weeks.

Table 44. Effect of planting pattern of cassava and peanut density on yields.

(a) **Peanut yield.**

Planting pattern of cassava	Peanut population: Low 50,000/ha (kg/ha)	High 100,000/ha (kg/ha)	Mean
Double row	602	760	681
75 cm x 100 cm	414	718	566
100 cm x 100 cm	461	698	525
Mean	492	725	
LSD (0.05)	110	36	

(b) **Cassava yield.**

Planting pattern of cassava	Peanut population: Low (kg/ha)	High (kg/ha)	Cassava sole (t/ha)	Mean
Double row	9.2	9.9	12.4	10.5
75 cm x 75 cm	8.1	10.7	13.3	10.7
100 cm x 100 cm	13.0	10.5	14.5	12.7
Mean	10.1	10.4	13.4	
LSD (0.05)	2.9	0.5	1.2	

Table 45. Effect of different levels of cassava management on peanut yield.

Treatments Input levels	kg/ha peanut: Mpelolongi (local)	02864 (improved)	Mean
Very low	-	-	-
Low	1068	740	904
Adequate	1288	800	1044
High	1568	1320	1444
Advanced	1415	1360	1388
Mean	1335	1055	
LSD (0.05)	207	324	257

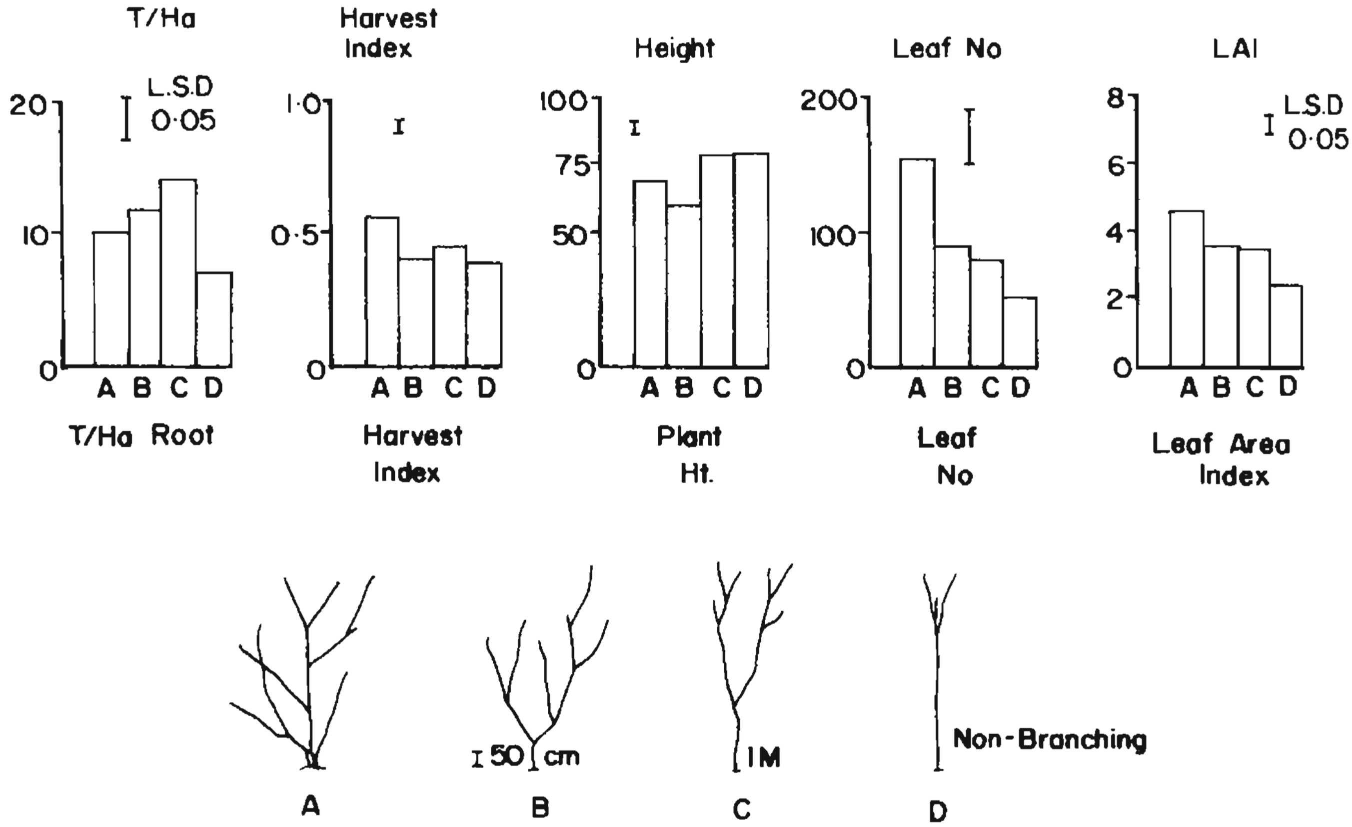


Fig. 5. Effect of cassava plant type on some agronomic characters.

Cassava plant type in relation to different agronomic characters. Mechanical modification of plant types, using a given cassava variety, requires a large number of plants. This opportunity was provided by multiplication plots established in the Bas-Zaire region. Modifications made are shown in Figure 5. Root harvest was at 12 months.

Figure 5 shows that the highest cassava root yield was obtained in plant type C, followed by B, A and D. Type D required closer spacing than the standard 1 m × 1 m per plant used in the study. Plant type A had significantly higher harvest index, leaf number and leaf area index than the older types while type C and D were higher in size. More information is necessary, but type C seems to be the best for high root yield.

GRAIN LEGUME IMPROVEMENT PROGRAM

Introduction

Objectives of the program remain to develop improved varieties and genetic stocks of cowpea and soybean adapted to a range of environments and capable of providing high and consistent yields. While part of the research to attain these objectives is directed toward the creation and selection of new genetic combinations for high yield, an equally important part is concerned with measures to overcome the problems that limit yield.

For cowpea, the damage caused by pests and diseases is a major constraint, and the main approach to overcome it is to identify sources of resistance that can be combined to give broad-based stable resistance in improved cultivars.

The goals in soybean improvement are to combine the ability of seed to maintain viability in storage, promiscuity (compatibility with a wide range of rhizobia strains) and the good agronomic characters associated with the best American cultivars.

Elite lines and improved genetic stocks of cowpea and soybean are distributed to several national programs for use directly as varieties or breeding materials.

Cowpea

Although diseases were the most conspicuous constraint to improved cowpea yields in the humid tropics of West Africa when the program began eight years ago, the advanced breeding lines and the elite lines now available possess good resistance to most of the important diseases of the region. The successful control of diseases has been based entirely on the development of host plant resistance. The availability of a large, diverse cowpea germplasm collection, the development of techniques to create epidemics of major pathogens for successful field screening and the occurrence in the germplasm collection of sources of resistance and of combined resistances to major pathogens have been important factors contributing to this success.

A system of recurrent selection of breeding lines at selected locations provides information on the distribution and importance of cowpea pathogens and has led to a clearer definition of disease priorities in each of the principal ecological zones of the region. In 1979, emphasis was given to the development of techniques for screening for resistance to major diseases of the African savannas and screening breeding material for comprehensive resistance to the diseases of the forest belt.

Progress made in the control of diseases has revealed more clearly the extent of losses caused by insects. High priority is given to the search for sources of resistance to the major insect pests of cowpea: flower thrips that cause flower bud shed; *Maruca testulalis*, a pod borer that damages stems and pods; hemipteran pod-sucking bugs that can cause extensive damage within a short time; and a bruchid beetle that destroys about one-third of the harvested crop each year.

In the search for resistance to thrips, early-generation breeding materials are exposed to moderate thrips populations. Several lines found to have low levels of resistance are being used as parents in the breeding program.

The biology and behavior of *Maruca* are being studied as the first step in the development of control methods based on host plant resistance. A *Maruca* colony will be established to provide insects needed to infest field nurseries, whose purpose is to identify sources of resistance among large numbers of breeding lines. Recent investigations have shown variation in resistance to pod-sucking pests to be associated with pod color and effective means will be employed to incorporate resistance into new cowpea lines.

Resistance to the bruchid (*Callosobruchus maculatus*) was first identified by IITA in TVu 2027, a local land race from northern Nigeria, and was subsequently shown to be associated with higher than normal levels of trypsin inhibitor in the seed. Extreme susceptibility to cowpea yellow mosaic virus (CYMV) limited the value of the variety, but studies conducted in cooperation with the Tropical Stored Products Center and the University of Durham, U.K., of the mechanism of resistance and its inheritance have helped in the successful transfer of resistance into new genotypes. The new lines are now being used in the breeding program to combine bruchid resistance with resistance to other insect pests.

Studies conducted between 1976 and 1979, as part of an effort to overcome the factors that limit cowpea production in the forest zone, have shown that cowpea is more tolerant of high levels of Al in the soil than soybean or lima bean. Further Ca deficiency, and not Al toxicity, is the main factor limiting growth on the acid soils in southeast Nigeria. The primary effect of additions of Ca is to improve the nodulation and N fixation of the plants.

Variation among varieties in their tolerance to deficiency of Ca has been demonstrated, and, as part of a UNDP special project to examine ways of improving biological N fixation, there are plans to examine the role of the host plant, rhizobia and symbiosis in determining the calcium requirement of different host strain combinations. The work also aims to determine whether rhizobia indigenous to these soils are more tolerant than strains collected from other environments.

Some unexplained variation in yield of some breeding lines in extremely dry environments led to an investigation of differences in adaptation to temperature and water deficits. Further work has shown that accessions from dry environments are more tolerant of high temperatures and are able to maintain a consistently higher plant water status through periods of high temperature and soil drying than varieties from southern Nigeria. The work is to be continued and will provide a basis for stratification of breeding materials, according to the environments for which they are intended.

The system of recurrent selection, based on the evaluation of early and advanced breeding generations at locations that represent principal ecological zones, has contributed significantly to the progress made in the development of better varieties of cowpeas.

As a product of this work, more than 200 yield trails and nurseries, containing elite lines with good yield and disease resistance, were distributed to more than 50 countries in 1979. In some of these, notably Nicaragua, Somalia, Yemen and southwest India, lines have found immediate acceptance in commercial production. In others where little interest existed previously, the new improved varieties are stimulating interest in the potential of cowpeas as a crop well adapted to hot lowland environments.

Cowpea improvement projects in Upper Volta, Tanzania and Brazil complement the work done at IITA and are centers for development and utilization of improved lines of cowpeas in the countries they serve. Reports on these programs are included in Cooperative Projects and individual annual reports on them are available from the respective governments concerned.

Genetic improvement

Conventional crossing and recurrent selection

Hybridization and early generation. To initiate a new cycle to breed cowpea varieties with high yield and disease and insect resistance, 426 crosses from Advanced and International Trials were grown as F_1's at IITA in the 1978-79 dry season. Then, 117 of these crosses were selected and advanced to F_2 in the 1979 first season. Both an infector row of highly susceptible material sown two weeks prior to the populations and the populations were inoculated with CYMV, anthracnose, bacterial blight and bacterial pustule. Pigeon pea was sown alongside the nursery. Insecticide application was delayed until 50 days after sowing to allow a population of thrips to increase. Disease susceptible plants were rogued, but the infestation of thrips was insufficient for effective selection for thrips resistance.

About 1,400 plants were harvested separately and, after eliminating those with small seeds, 873 F_3 rows (plus 211 reselections from the back-up population) were sown with standard checks at three locations in Nigeria; IITA, Funtua and Mokwa, and one location in Upper Volta, Ouagadougou. Two sets were sown at IITA; the first was treated with ethylene to simulate thrips damage and was rated for flower bud abscission; the second was inoculated with CYMV, anthracnose, bacterial blight and bacterial pustule and received no insecticide until more than 50 days after sowing. Disease and insect pressures were high, and the best plants were harvested singly. The performance of F_3 family rows across locations for pod yield, agronomic and disease characters determined the final selection for multiplication for Preliminary Trials.

Also, random and select bulks, constituting F_2 populations of promising crosses, were selected and compared in randomized complete block trials at IITA, Funtua, Mokwa and Ouagadougou, and 193 single plants were harvested from the bulks at IITA. After eliminating those with small seeds, 494 F_4 single plant selections, F_4 rows, F_3 random bulks and F_4 select bulks were multiplied during the 1979-80 dry season as possible entries for Preliminary Trials in 1980.

Preliminary Trials. From the previous cycle, 203 selections were compared with reselections from earlier cycles and 16 standard entries in two 12 × 12 single lattice square trials. The locations and purposes of the trials are summarized in Table 1.

None of the trials at IITA gave yield results; in the first season, there was erratic emergence. In the second season, there was stand loss due to insect damage. However, in the first season, high levels of *Colletotrichum* brown blotch enabled an effective screening and reselection for resistance against this disease.

Yield data were extremely variable; coefficients of variation ranged up to 52 percent in trial No. 2 at Gusau, Nigeria. Few lines gave significantly higher yields than standard varieties at individual locations, and none was significantly higher across locations. This parallels the

Table 1. Locations and purpose of Preliminary Trials (1979).

Location		Purpose
Onne	(second season)	Agronomic performance
IITA	(first season)	
IITA	(second season)	
Mokwa	(main season)	
Gusau	(main season)	
Ouagadougou	(main season)	
Onne	(first season)	Disease (CGYM, WB)
IITA	(first season)	Disease (CYMV, BB, BP, Anth, Cerc)
IITA	(screenhouse)	Disease (CAMV)
IITA	(first season)	Insect (thrips)
IITA	(first season)	Ethylene
IITA	(first season)	Insect (Pod bugs)
Funtua	(main season)	Disease (Scab, Coll. BB)

situation in single-row plot trials in previous years with lines that have subsequently and consistently exceeded standard varieties in multi-row plot trials. This casts doubt on the effectiveness of selection for yield in Preliminary Trials. Selection, therefore, has been based primarily on other plant characters and disease and insect reactions.

Wide ranges of variation, exceeding that of the standard varieties, were recorded in the trials for plant type, time to flowering and canopy width and height (Table 2).

Wide variation was also observed in disease indices with several lines exhibiting similar or better multiple resistance than the standard varieties (Table 3).

Twenty-five lines and 143 re-selections from lines, combining disease and insect resistance and large seeds, are being multiplied for Advanced Trails in 1980.

Advanced Trials. Fifty-two lines from the cycle initiated in 1977 were compared with standard lines and seven selections from the back-up population in three 5 × 5 balanced lattice square trials. The locations and purposes of the trials are summarized in Table 4.

Environmental and plant character data are shown in Table 5 with the mean seed yields of the four varieties: VITA-1, VITA-4, VITA-5 and Ife Brown being common to all trials.

The highest mean seed yield was obtained at IITA in the first season and lowest at Funtua where heavy *Acanthomyia* infestation reduced the yield of a promising crop to zero. At Mokwa, following excellent emergence, stands were substantially reduced by *Alcidodes*. In trials one and two at IITA in the second season and at Gusau, yields were low and coefficients of variation were high in the former due to low temperatures and excessively wet conditions and in the latter due to heavy *Striga* infestation. As in 1978, seed yields increased with increasing post-flowering rainfall to about 200 mm and then seed yields decreased. Maradi, in Niger Republic, gave a mean seed yield of 1,362 kg/ha on only 42 mm of rain. This is possibly attributable to a deep soil with high, moisture-storage capacity. Also as in 1978, significant correlations were recorded between seed yields and pods per/m^2 (r 0.89, p 0.001), seed yield and canopy height (0.64, p 0.01) and canopy height and width (0.73, p 0.001).

Table 3. Disease indices[1] of lines in preliminary trials (1979).

	Humid tropics[2]		Savannas[3]	
	Range	Mean	Range	Mean
Trial 1				
Standards	2.2-3.9	3.1	2.3-5.1	2.9
Test lines	1.7-4.5	2.9	1.6-5.5	2.8
SE($\bar{x}$)	0.25		0.41	
Trial 2				
Standards	2.3-3.9	3.1	2.2-5.0	3.3
Test lines	1.7-4.6	3.0	1.8-5.0	3.4
SE($\bar{x}$)	0.28		0.40	

1. On a scale of 1-9, where 1 indicates absence of symptoms.
2. Mean score for CGMV CYMV, BB, BP, Anth, Cell, BB, WB, Rust.
3. Mean score for CAMV, BB, Cell, BB, Scab Sept

Table 4. Location and purposes of Advanced Trials (1979).

Location	Season	Purpose
Onne	Second	Agronomic Performance
IITA	First	Agronomic Performance
IITA	Second	Agronomic Performance
Mokwa	Second	Agronomic Performance
Farakoba	Main	Agronomic Performance
Funtua	Main	Agronomic Performance
Kamboinse	Main	Agronomic Performance
Gusau	Main	Agronomic Performance
Maradi	Main	Agronomic Performance
Saouga	Main	Agronomic Performance
Onne	First	Disease (CGYM, WB)
IITA	First	Disease (BB, Anth, CYMV)
IITA	Screenhouse	Disease (CAMV)
Funtua	Main	Disease (Scab, Sept, BB, BP)
IITA	First	Insects (Thrips)
IITA	Second	Ethylene

Table 2. Plant characteristics of lines in Preliminary Trials (1979).

	DFF[1]		Plant type[2]		Plant width[3]		Plant height[3]	
Entries	Range	Mean	Range	Mean	Range	Mean	Range	Mean
Trial 1								
Standards	42.8-46.9	45.6	1.9-3.3	2.6	49-79	66	37-48	42
Test lines	37.5-50.2	43.4	1.5-3.4	2.4	39-99	63	35-54	43
SE	1.24		0.12		5.2		2.2	
CV %	6.9		14.9		19.2		14.6	
Trial 2								
Standards	42.1-47.0	45.4	1.6-3.4	2.7	54.81	68	36-51	43
Test lines	41.0-49.2	44.3	1.5-3.1	2.5	44-100	69	34-54	45
SE	0.90		0.13		4.2		2.0	
CV %	5.0		13.9		15.8		13.2	

1. Number of days from sowing to 50 percent of plants with a flower.
2. On scale of 1-4, where 1 indicates acute erect.
3. Mean canopy height or width in cm.

Pronounced interactions were recorded between breeding lines and environments. Part of this could be accounted for by the regressions of individual variety on environment mean seed yields, but there were again unexplained deviations from regression for some lines.

In all three trials, VITA-1 was the lowest-yielding of the VITA lines with a regression coefficient of 0.38-0.63, indicating low yield potential across environments (Table 6).

VITA-4, VITA-5 and Ife Brown showed similar yields and regression coefficients, but deviations from regression tended to be greater for Ife Brown, perhaps attributable to differences between environments in levels of brown blotch; Ife Brown is highly susceptible to this disease.

In Trial 1, VITA-7 was the highest-yielding of the VITA lines with a regression coefficient of 1.48, indicating high yield potential in favorable environments. TVX 3381-02F, TVx 3405-014E, TVx 3410-05E and TVx 7R-0189D gave similar yields to VITA-7 and were better in lower-yielding environments.

In Trial 2, VITA-6 was the highest yielding of the VITA lines with a regression coefficient of 1.00, but TVx 2724-01F was the highest-yielding of all the lines with a regression coefficient of 1.38, indicating high yield potential in favorable environments.

In Trial 3, TVx 3382-033E, TVx 3337-015E, TVx 3425-03E and TVx 3428-03E exhibited similar or better yields than the VITA lines.

Cluster analysis of characteristics from the 1978 Advanced Trials indicate site associations unrelated to ecological conditions (Table 7). For example, the most consistent groupings were IITA first season with Kamboinse, Upper Volta, and IITA second season with Farako-Ba, Upper Volta. Examination of the plant and environmental data from three-year trials is in progress to determine an effective testing strategy.

International Trials. In 1979, 120 sets of International Trial 1 and International Trial 2 and 82 observation nurseries were distributed to 50 countries. Few results have been received at the time of writing.

In 1978, 86 sets of Trial 1 and 93 sets of Trial 2 were distributed to 43 countries. The results of the trials confirm the consistent performance of the new VITA lines — VITA-7 and VITA-6 — which were the highest yielders in Trial 1 and Trial 2, respectively (Table 8).

Breeding for insect resistance

Two main courses have been pursued in breeding for insect resistance: to breed cowpea varieties for insect resistance selection under minimum insecticide conditions to improve the levels of insect resistance of Advanced breeding lines and crosses between confirmed sources of resistance and Advanced materials.

Thrips resistance. Selection of F_2 and F_3 generations of crosses among Advanced breeding lines has been carried out under minimum insecticide conditions for 4 cycles of the recurrent selection scheme. In 1979, lines in Preliminary, Advanced and International Trials selected in this way were rated for thrips damage and peduncle abscission, following ethephon application to simulate the effects of thrips damage. Significant differences were recorded between the lines in all trials for both assessments.

Several lines showed less thrips damage than VITA-5 and 4R-0267-1F, which have shown less thrips damage than standard lines. This indicates the occurrence of useful variation in resistance among the Advanced breeding lines. In Preliminary trials, certain crosses were notable for the proportion of selections with thrips, including TVx 3891, TVx 3901, TVx 3410, TVx 4065, TVx 4238 and TVx 4255. Most involved TVu 946 as a parent.

Similarly, several lines showed less penduncle abscission, following ethephon application, than 4R-0267-1F, which has shown good levels of tolerance. However, there was no significant correlation between thrips damage and peduncle abscission, although in Preliminary Trial 2, which received lower rates of ethephon, 10 of 31 lines showing reduced thrips damage were also tolerant of ethephon application. The thrips and ethephon reactions of 64 lines will be evaluated to confirm these results. Reselections from lines with reduced thrips damage will be assessed under different levels of thrips populations in 1980.

Table 5. Locations of Advanced Trials (1979).

		Environmental data									Plant characters			
				Rainfall (mm)		Soil Analys.		Pod. Characters			Plant characters			
Location	Season	Lat. °N	Sowing date D/M	Veg. per	Rep. per	Clay (%)	pH	Pods /m²	Seeds /pod	SW (1,000) (g)	DFF	Width (cm)	Height (cm)	Seed yield (kg/ha)*
Onne	Second	4.7	13/11	118	1	15.1	4.4	28	13.8	130	44.5	40	23	494
IITA	First	7.4	6/4	206	198	17.1	6.5	104	13.9	122	45.4	63	56	1,601
IITA	Second	7.4	19/8	435	150	15.6	5.9	29	11.9	124	50.4	24	18	402
Mokwa	Main	9.3	13/8	358	36	7.6	6.0	72	13.0	119	44.4	51	49	979
Farakoba	Main	11.1	11/7					146	12.3	114	47.6	68	42	1,448
Funtua	Main	11.4	7/8	-	-	11.6	5.9	-	-	-	49.1	67	33	-
Kamboinse	Main	12.3	6/7	240	255	14.2	5.7	89	13.2	143	45.4	60	39	1,197
Gusau	Main	12.5	31/7			11.6	5.7	38	9.1	144	53.0	49	33	499
Maradi	Main		17/7	204	42	7.2	6.1	-	-	-	-	-	38	1,362
Saouga	Main	14.3	12/7	204	20	13.2	5.9	49	13.6	130	51.5	66	42	810

**Means of 4 common entries, VITA-1, VITA-4, VITA-5 and Ife Brown*

Veg. per =vegetative period.

Rep. per = reproductive period.

Specific crosses to incorporate thrips resistance identified among the germplasm into Advanced breeding lines were begun in 1978. A total of 192 F_3 progenies from single crosses between Advanced and thrips resistant breeding lines and 277 F_3 progenies from multiple crosses between different thrips resistant breeding lines were selected for ethephon tolerance in the first season. Two hundred and six selected progenies were screened under natural thrips infestation and for ethephon tolerance in the second season. There was no significant correlation between thrips and ethephon tolerance ratings or for ethephon tolerance between generations. Lines exhibiting the highest levels of thrips resistance will be subjected to confirmatory tests in 1980.

In addition, F_2 populations from 63 four-way crosses among thrips resistant, large seeds and Advanced breeding lines were selected for ethephon tolerance in the first season; 462 progenies were selected for large seeds and ethephon tolerance in the second season. Recovery of ethephon tolerance in the F_3 varied among crosses but was low (25 percent overall) despite indications from genetic studies of a moderate level of broad-sense heritability. Further selection for large seeds resulted in 44 F_4 bulks, which will be evaluated for thrips resistance in 1980.

F_1 generations of crosses among thrips resistant, Kenya, Advanced and pod pest resistant breeding lines were grown during 1979.

The absence of correlation between ethephon tolerance and thrips resistance indicates that more than one resistance mechanism may be involved. This, in turn, indicates a need to start screening early generation for thrips resistance and delay assessing late generation for ethylene tolerance.

Bruchid resistance. TVu 2027 is the only source of bruchid resistance yet identified, conferred by a high seed trypsin inhibitor level. The variety is highly susceptible to virus diseases. One hundred and fifty-three F_3 progenies from five crosses among TVu 2027, TVu 408-P_2 and TVu 410 and TVx 289-4G, TVx 1193-7D and TVx 1193-9F were screened for bruchid resistance at IITA and Tropical Products Institute (TPI), U.K., and are being assessed for trypsin inhibitor levels at the University of Durham, U.K. Resistant virus-free lines were further screened for bruchid resistance and will be multiplied, evaluated for agronomic type and later distributed. The new lines with CYMV resistance will be extremely valuable as donors of bruchid resistance in future crosses.

In addition, 46 F_2 populations from four-way crosses, involving TVu 2027, large seed lines and Advanced breed-

Table 6. Regressions of individual variety on environment mean seed yield (kg/ha) in Advanced Trials (1979).

Variety	Mean	Regression Coefficient	r^2
Trial 1			
VITA-1	703	0.50	0.52
VITA-4	1,088	1.14	0.88
VITA-5	981	1.00	0.89
VITA-7	1,137	1.48	0.94
Ife Brown	1,064	0.95	0.72
TVx 3381-02F	1,142	1.30	0.91
TVx 3405-014E	1,195	1.04	0.87
TVx 3410-05E	1,165	1.24	0.86
7R-0189D	1,156	1.11	0.91
Trial 2[1]			
VITA-1	808	0.63	0.62
VITA-4	908	1.03	0.86
VITA-5	1,026	1.23	0.97
VITA-6	1,088	1.00	0.84
Ife Brown	961	0.95	0.76
TVx 2724-01F	1,246	1.38	0.91
TVx 3336-040E	1,103	1.22	0.99
TVx 3379-01F	1,044	1.20	0.96
TVx 3404-012E	1,039	1.05	0.92
Trial 3[2]			
VITA-1	990	0.38	0.96
VITA-4	1,224	1.28	0.80
VITA-5	1,176	1.02	0.75
Ife Brown	1,265	1.30	0.89
TVx 3382-033E	1,304	1.29	0.89
TVx 3337-015E	1,392	1.10	0.88
TVx 3425-03E	1,261	1.30	0.92
TVx 3428-03E	1,261	1.37	0.80

1. *Means of nine environments.*
2. *Means of eight environments.*

Table 7. Site groupings from cluster analysis of seed yields in Advanced Trials (1978).

Group	Trial		
I	IITA—1st	IITA—1st	IITA—1st
	Kamboinse	Kamboinse	Kamboinse
II	IITA—2nd	IITA—2nd	IITA—2nd
	Farako-Ba	Farako-Ba	Farako-Ba
III	Gusau	Gasau	Gusau
	Onne—2nd	Onne—2nd	Saouga
IV	Saouga	Onne—1st	Funtua
	Onne—1st	Funtua	
	Funtua		

Table 8. Seed yields of lines in International Trials (1978).

Line	Seed yield Mean kg/ha
Trial 1	
VITA-1	817
VITA-3	892
VITA-4	1,103
VITA-5	959
VITA-7	1,215
VITA-8	1,093
TVx 1948-01F	1,136
TVx 1999-1D	1,133
Local check	850
Trial 2	
VITA-6	1,334
TVx 7-5H	1,262
4R-0267-1F	1,208
Local check	1,125

ing lines were selected for large seeds in the first season and then evaluated for bruchid resistance. Only 33 of 1,397 selections produced bruchid resistant seeds while about 84 had been expected. Forty-two F_2 populations from four-way crosses, involving TVu 2027, thrips resistant lines and Advanced breeding lines, were selected for ethephon tolerance, and 754 plants were screened for bruchid resistance. Recovery was again low but may be from bad weather experienced at harvest. Plants from 246 resistant seeds will be reevaluated for bruchid resistance in 1980.

To combine the two mechanisms, crosses were made between TVu 2027 and Kenya and different Advanced breeding lines and virus/bruchid resistant segregants and TVu 625 and TVu 4200 which have shown pod resistance to bruchids. Genetic studies indicate that bruchid resistance is primarily an expression of the maternal genotype and is controlled by a recessive gene.

Resistance to pod sucking bugs. Resistance has been shown in laboratory tests to be associated with pod color with dark colored pods having the highest levels of resistance. Wide variation in pod color occurs among the Advanced breeding lines, which are now being selected for this character. TVx 3210-05E, TVx 3405-01E, TVx 3428-03E, TVx 7R-051D and VITA-7 and several Preliminary lines display good resistance. Reselections from them will be evaluated at different levels of pest infestation in the field in 1980.

A diallel set of crosses have been made among IRAT 146, TVu 2870, TVu 6507, TVu 1509 and TVu 7133, VITA-5 and TVx 2940-01D to study the inheritance of resistance to pod-sucking bugs and thrips and combine sources of resistance to the 2 pests.

Leafhopper resistance. Lines in Preliminary, Advanced and International Trials are being evaluated at IITA for resistance to leafhoppers. Two sets of crosses were made: the first for a genetic study and the second to transfer leaf pubescence from two accessions of *V. unguiculata* sp. *pubescens* to Advanced breeding lines. Although hairs occur only along the upper leaf midrib, they may interfere with oviposition, which is mainly into the midribs and leaf veins.

Aphid resistance. Entries in Advanced and International Trials were evaluated for aphid resistance, and crosses between susceptible and resistant lines were completed for genetic studies.

Breeding for seed characteristics

Large seeds with rough, white testa are preferred over a large part of the West African savanna. While such types are common, they tend to be adapted to traditional cropping systems and are photoperiod sensitive and low yielding. Large seeds with smooth, red, brown or black testas are preferred in other regions.

The F_5 generation of backcross three combinations of VITA-4 and VITA-5 with AC 70002, a large seed with rough, white testa, were yield tested at IITA and Gusau in the second season. Several lines with large seed and yields comparable to VITA-4 and VITA-5 are being multiplied for Advanced and International Trials in 1980.

The F_3 and F_4 generations of backcross one combinations between AC 70002 and various Advanced breeding lines plus VITA-4 and VITA-5 were screened for disease resistance in the first season before single plants were harvested and selected for large seeds. These 135 selections will be multiplied in the dry season and evaluated in Preliminary Trials in 1980.

The F_2 generation of double crosses between large-seed lines and Advanced breeding lines were bulk harvested and screened for seed size in the first season 1979. Selections were grown in the second season, and, despite poor establishment, single plants were selected for seed size and disease resistance. The F_3 and F_4 generations of similar crosses were also screened in 1979.

In addition, further crosses have been made between large-seed lines and Advanced breeding lines.

Population improvement

The population improvement system, involving back-up, disease and insect subpopulations, continued in 1979 with more specific and intensive selection strategies.

Back-up population. Seed from crosses between 23 Advanced breeding lines and male steriles constituted the 1979 back-up population. The F_2 bulk was sown in the second season and screened for thrips, principal diseases and agronomic type. The top 16 percent of the population was selected. They will be crossed with Advanced breeding lines in another cycle.

Single plants with dark colored pods and large seeds were selected. Forty-six fertile plant selections (0.05 percent) were reselected from a section of a field that had been rogued and a section that had a full plant stand to compare the effectiveness of the two methods of selection.

One hundred and fifty fertile plant selections (1.5 percent) from the 1978 second season population were reselected for disease resistance, agronomic type and seed size to provide 211 entries for the F_3 breeding nursery. The remaining entries were selections from the conventional crossing program.

The benefit of the more intensive selection strategy was demonstrated by the yield evaluations of current and previous populations. Bulk progeny of the 1978 second season populations gave a higher grain yield than earlier populations at Mokwa and Gusau and earlier populations, except the 1977 dry season population, at IITA in the 1979 first season (Fig. 1).

In 1980, two populations will be established, both of which will be selected at IITA and at a location in the dry savanna. These populations will undergo intensive selection and become an elite population, which will recombine genetic material and provide a gene pool for long-term selection.

Disease subpopulation. Seed from crosses between 25 multiple disease resistant lines and male steriles constituted the 1979 disease subpopulation. Seven of these lines were selections from the 1976 population, providing the first recurrent selection input. A divergent-convergent selection strategy was begun with the bulk being subdivided and grown at three locations in Nigeria in 1979. The top 10-25 percent of the population was selected. After single plant selections had been made, the entire population was harvested in bulk. The locations were the Onne substation first season for cowpea golden mosaic virus (CGMV) and web-blight; IITA first

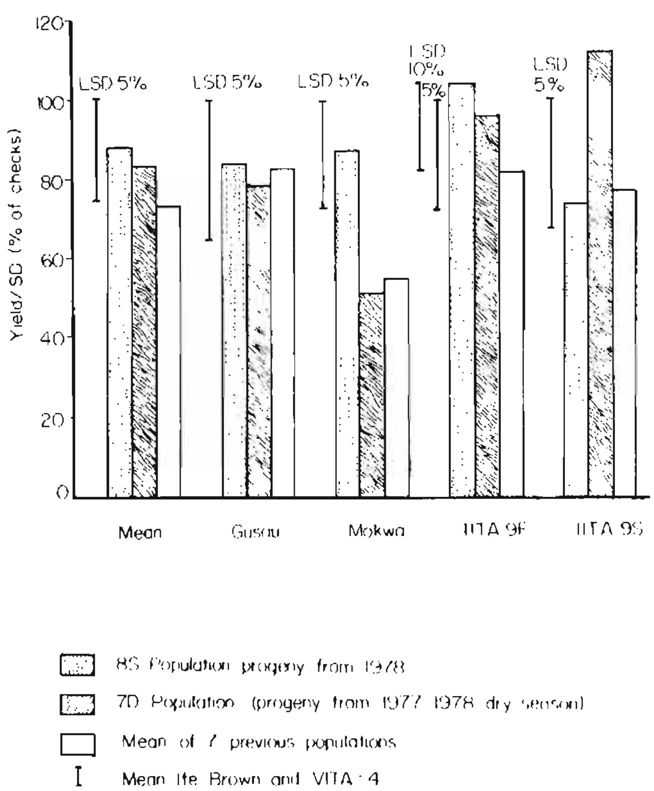


Fig. 1. Yield evaluation of back-up populations (1979).

season for CYMV, anthracnose, web-blight, bacterial blight and *Cercospora* sp., brown and pink rust and pod blotch; Daudawa for scab, pod blotch, bacterial blight and *Septoria* and IITA second season for virus and anthracnose. The harvest from these locations, except Daudawa, has been mixed and sown for intercrossing at IITA in the dry season.

Single plant selections were made at each location, and reselections were made at IITA and Daudawa in the second season. They are being multiplied for the pathology trials. Selections from the 1978 record season and bulks of the 1976-78 first and second seasons' disease subpopulations were compared with the 1974 back-up population, which had served as the original source of male steriles. Reselection in the 1978 record season progenies provided six sources of multiple disease resistance for the International Cowpea Disease Nursery. There was a linear improvement in CYMV resistance with time among the bulks (b 0.5, r^2 -- 0.89), but no improvement was indicated for other diseases.

In 1980, the strategy of intensive selection at locations where specific pathogens are most severe will be continued. Selected plants (convergent-divergent selection) will be bulked for recombination and further selection for specific disease complexes.

Insect subpopulation. The third introduction of new parental lines was carried out in 1978. The F_1's were grown in the dry season, and F;2's were bulked for selection at different locations. In the first season at IITA, thrips infestation was low, and the top 25 percent of the population was selected on the basis of pod color. The bulked progenies were then screened for pod bugs at Daudawa and bruchid, thrips and ethephon resistance at IITA in the second season.

An unselected bulk sown at Daudawa indicated that selection for pod color had increased the frequency of recovery of tolerance to pod bugs from 1.9 to 2.9 percent. From the separate screenings, about 200 single plants were selected for testing in 1980.

Thirty single plant selections from the 1977-78 subpopulations were further screened for resistance to thrips and pod bugs. Promising lines will undergo further screening for resistance to thrips, pod bugs and bruchids.

Eight subpopulations from the 1977 first season to 1978 first season were compared for thrips resistance at Gusau and pod bug resistance at Daudawa. Levels of resistance fell within the range of the resistant and susceptible checks, but the 1977 second season and 1978 first season populations for thrips and the 1977 dry season population for pod bugs lay at the resistant end of the range. To improve the effectiveness of selection in 1980, populations will be developed for resistance to single pests.

Intercropping subpopulation. Seed from crosses between different photoperiod sensitive lines, thrips resistant lines, Advanced breeding lines and male steriles in the backup population constituted the 1979 intercropping subpopulation. These lines were screened with sorghum at Kamboinse, maize at Daudawa and sole at IITA in the second season. Site specificity for flowering time and performance of the selections will be evaluated in a trial at the three locations in 1980.

Cereal-cowpea intercropping trials

For savanna areas, maize-cowpea relay cropping (30-40 days) offers a number of advantages over the traditional mixed cropping systems. Twenty-one Advanced breeding lines and four germplasm accessions identified as promising under direct or relay mixed cropping with maize in 1978 were grown as a sole crop and with maize at Kamboinse and Gusau. In the mixed crop, the cowpea and maize were sown in alternate rows 1 m apart. At Gusau, the cowpea was sown as the anthesis of the maize, but the overlap period was 75 days due to late removal of the maize. At Kamboinse, cowpea and maize were sown simultaneously. At both locations, the interaction between cultivars and cropping systems was significant, but performance varied with location. Nevertheless, TVu 4619, TVx 2783-02E and TVx 1948-01F were consistent in their tolerance of intercropping over seasons and environments.

Vegetable cowpeas

At IITA and the Onne substation, 268 F_4/F_5 lines and 46 single plant selections were grown in the first season with standard checks in every tenth plot for comparison of vegetable type pods and resistance to CGMV. The best 19 lines were included in replicated trials at IITA and the Onne substation and a further 187 lines in an observation nursery at Onne in the second season.

Nine entries from the yield trial and 14 from the observation nursery will be further evaluated for yield, vegetable characteristics and disease resistance in 1980 and used as parents in crosses for improved vegetable type and insect resistance.

Pathology

Field surveys and results from multilocational testing have provided information on the distribution and importance of cowpea pathogens across sites. Examination of such data provides information on pathogen ecology and the environmental indices that may regulate their occurrence Fig. 2). This leads to the definition of pathogen priorities of distinct ecosystems or pathosystems of relevance to possible stratification of the cowpea breeding program at IITA. During 1979, emphasis was given to the development of techniques for screening for resistance to some major diseases of the African savanna and forest.

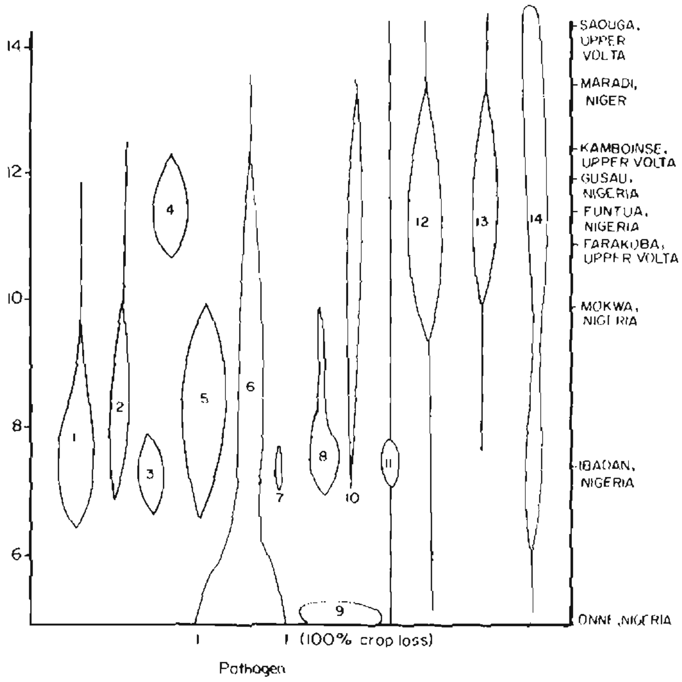


Fig. 2. Pathogen ecology: West Africa.

(1) Cercospora cruenta ***leaf spot; (2) Bacterial pustule; (3) Anthracnose; (4)*** Sphaceloma ***scab; (5) Cowpea yellow mosaic virus (CYMV); (6)*** Rhizoctonia ***web blight; (7) Southern bean mosaic virus (SBMV); (8) Cowpea mottle virus (CMeV); (9) Cowpea golden mosaic virus (CGMV); (10) Rust; (11) Cowpea aphid-borne mosaic virus (CAMV); (12)*** Colletotrichum ***brown blotch; (13)*** Septoria ***leaf spot; (14) Bacterial blight.***

Cowpea golden mosaic virus (CGMV)

A geminivirus associated with an isolate of CGMV obtained from the Onne substation was successfully purified, but it is yet to be established as the causal agent of CGMV. The virus was successfully purified, using buffers of low molarity for extraction and chloroform for clarification. Partially purified preparations were additionally absorbed with an antiserum prepared against phytoferritin and other host proteins. Double particles were revealed in electron microscopic plates made at Rothamsted Experimental Station, U.K.

Further investigation of the virus-vector relationship of CGMV has shown that *Bemisia tabaci* may acquire the virus within seven minutes with pre-acquisition and pre-inoculation starvation periods of three hours each; under these conditions, transmission efficiency was 10 percent. Transmission efficiency increased to 94 percent when the acquisition period was increased to 24 hours. An inoculation feed of two minutes was sufficient for virus transmisison (6 percent efficiency), following a 24-hour acquisition period and three-hour pre-inoculation starvation. Transmission efficiency increased to 82 percent when the inoculation period was increased to six hours (Table 9). The virus was retained for up to 21 days, following a 24-hour acquisition period (Table 10). While work is required on the latent period, available data suggest persistent transmission of CGMV by *B. tabaci*.

Table 9. CGMV-vector relationships: acquisition access and inoculation feeding periods relative to transmission efficiency.

Acquisition access period	Inoc. feed period	Transmission efficiency (%)
5 min)	24 h	0
7)		10
15)		16
1 h)		20
3)		40
12)		56
24)		94
24	(2 min	6
	(5	28
	(30	52
	(3 h	48
	(6	82
	(12	80
	24	82

Work on the artificial host range of CGMV confirms that the virus is essentially confined to the genus *Vigna*, including *V. lasiocarpa* and *V. oblongifolia* var. *parviflora* in addition to *V. unguiculata*.

Other notable susceptibilities included *Macroptilium erythroloma* and *M. bracteatum*. The host range of CGMV is distinct from that of LBGM and apparently also from mung bean yellow mosaic, which infects pigeon pea and soybean as well as mung bean in India. Proof of relationship with these viruses awaits the preparation of a specific antiserum. The search for possible natural host reservoirs of CGMV has, so far, been unsuccessful despite the finding of golden mosaic symptoms in wild legumes, including a species of *Dolichos*.

The first season at the Onne substation provided an excellent environment for CGMV resistance screening, using VITA-5 as the susceptible indicator variety. Field data from the Onne substation in 1979 indicate that VITA-1 and VITA-4, which usually remain symptomless in greenhouse inoculation tests, may develop mild golden mosaic under field conditions in some seasons (Table 11). While the pathogenic variation of CGMV at the Onne substation is unknown, it is evident that natural infection pressure is intense. Whitefly populations of 50-100 individuals per seedling may become established as early as two days after seedling emergence.

Rhizoctonia web blight

Repeatable differences in response to natural infection by *Rhizoctonia* were obtained between cowpea lines sown in the first season at the Onne substation in replicated single row plots, spaced 50 cm apart (Table 12). Using this system, there appears to be scope for selecting for moderate resistance among cowpea yield trial material, using VITA-1 as a resistant standard (Table 13).

Cowpea mottle virus (CMeV)

CMeV is known only in Nigeria where it is reported to be seed transmitted. Since previous results (IITA Annual Report, 1978) have shown that predominantly symptomless infection is common in resistant cultivars, the relative danger in utilizing tolerance as the chief means of controlling this virus disease is important to determine.

A trial was sown at IITA in the 1979 first season to investigate the field efficacy of greenhouse-identified tolerance in reducing natural infection and preventing seed transmission in four cowpea lines. Test plots were each bordered by an infector row of highly susceptible TVu 612, which was pre-sown and inoculated with a biologically purified isolate of CMeV. No insecticide was applied until 30 days after planting to permit beetle vector activity during early crop growth. Infection rates in the test cultivars were assessed by random collection of leaf samples (50 per variety) at 48 days after planting. The susceptible check and infector rows were 100 percent infected and severely diseased. The presence of CMeV in the samples was indexed both by greenhouse back tests and by serological means. Results (Table 14) indicate that, despite heavy infection pressure, the incidence of natural infection is much less in a highly tolerant line (TVu 3901) than in a susceptible cultivar (VITA-1), suggesting that there may be more than one resistance mechanism operating in certain cultivars.

CMeV seed transmission rates were measured in approximately 600 seedlings of each of the lines grown from seed harvested from infected plants. Owing to the risk of symptomless infection in the tolerant lines, Table 15 presents results only from the two susceptible varieties. Only one case demonstrated seed transmission so that seed transmission rates appear extremely low, helping to explain the local distribution of the virus. This investigation confirms that available sources of high tolerance to CMeV should be used.

Cowpea aphid-borne mosaic virus (CAMV)

An isolate of CAMV obtained from the Onne substation (CAMV-Onne) was characterized by the Virology Unit as more aggressive than an isolate of CAMV obtained from Ife, Nigeria (CAMV-Ife). Results (Table 16) indicate that

Table 11. CGMV resistance: field and greenhouse screening, scores (scale 1-9).

	Onne 1979 first season						IITA
	Prel. 1.	Prel. 2	Adv. 1	Adv. 2	Adv. 3	Mean	g'ho., 79F[2]
VITA-1	4.33	5.00	3.00	2.50	2.33	3.43	NS–
VITA-4	3.00	4.33	2.00	2.00	1.00	2.27	NS+
VITA-5	8.33	7.67	8.50	8.00	8.33	8.17	SS-3

[2]*NS = No symptoms.*
SS = Systemic symptoms.
–/+ = Without/with virus recovery.
1-3 = Mild-severe.

Table 12. Web blight screening.

	Onne 1979 First season					
	Prel. 1	Prel. 2	Adv. 1	Adv. 2	Adv. 3	Variety Mean
VITA-1	4.25	5.25	5.00	4.33	5.33	4.83
VITA-4	5.50	6.00	5.00	6.67	7.00	6.03
VITA-5	6.00	5.75	8.00	8.33	8.33	7.28
Ife Brown	6.00	6.00	6.00	8.00	8.00	6.40
Lowest	3.50	4.00	4.00	4.33	4.67	4.10
Highest	8.75	7.50	9.00	9.00	9.00	8.65
Trial mean	5.87	5.71	6.96	7.03	7.57	
SE	0.66	0.52	0.49	0.75	0.47	
CV %	15.87	12.94	12.14	18.45	10.78	

Table 13. Web-blight resistance: Advanced Trials.

	Adv. 1	Adv. 2	Adv. 3
VITA-1	5.00	4.33	5.33
TVx 3040-01E	4.00	-	-
TVx 3341-09E	4.00	-	-
VITA-7	4.67	-	-
TVx 3335-03F	-	4.33	-
TVx 3360-026E	-	-	4.67

Table 10. Whitefly retention of CGMV, pure and mixed with lima bean golden mosaic (LBGM).

Virus		No. insects tested[1]	Transmission[2]	Retention[3]
CGMV	Cowpea VITA-5	25	1116/367	21
LBGM	Lima bean TP1 250b	25	76/180	9
CGMV)	Lima bean TP1 250b	5	17/47	3
+)	Cowpea VITA-5	5	10/30	3
LBGM)				
LBGM)	Lima bean TP1 250b	5	11/40	8
+)	Cowpea VITA-5	5	11/17	3
CGMV)				

[1]*Pure and combined virus transmission tested in different experiments.*
[2]*No. test plants infected as a fraction of total exposed.*
[3]*Maximum no. days, following 24 hr. acquisition access periods.*

greenhouse inoculation with CAMV-Onne may lead to systemic infection in some lines (TVu 1948 and TVu 2480) previously reported as immune to CAMV-Ife, but symptoms are typically mild and transient. This underlines the value of measuring the severity of systemic symptoms in virus resistance screening, preferably conducted also in the field as an adjunct to greenhouse work.

Entries in the Preliminary, Advanced and International Trials were screened for resistance to CAMV-Onne in greenhouse tests and sources of resistance were found. Table 17 summarizes results from screening of the Advanced Trial lines against CAMV-Onne as well as CGMV (Onne, 1979 first season) and CYMV (IITA, 1979 first season), demonstrating that at least 10 lines possess combined resistance to these three viruses.

Scab

Scab, caused by the fungus *Elsinoe phaseoli* (conidial state: *Sphaceloma* sp.) is reported from Central America and eastern Africa where it may cause severe disease in cowpea and other legumes. A very similar disease of hitherto unknown etiology affects cowpea in the Guinea savanna belt (about 9-12°N in Nigeria) in West Africa. The causal agent of the latter has now been shown by the Institute for Agricultural Research at Samaru, Nigeria, to be *Sphacelom* sp., which has been obtained in pure culture.

However, owing to its very slow growth rate on potato dextrose agar and in the absence of an efficient, selective medium, the use of pure culture of *Sphaceloma* for field inoculation purposes is precluded. For this reason, IITA attention has recently been directed at developing alternative procedures of resistance screening.

It was found that infected plant material, bulked by presowing a scab susceptible line, IAR 74-23, under irrigation before the first season began was an effective inoculum. Dry, diseased stems, branches or pods were hung securely on branches in the center of the canopy of from 3 to 4 week-old seedlings on days when rain appeared imminent. Symptoms appeared about 1 week after inoculation on the young branches. The disease leads to flower abortion and to distorting and dropping of young pods though severe pod symptoms are not invariably associated with severe stem damage. Microscopic examination of infected plant debris revealed the presence of chlamydospores, but their role in seasonal

Table 14. CMeV resistance.

Line	Response to sap inoculation (greenhouse)	Field infection incidence (%) (back tests)	(serology)
VITA-1	Susceptible[1]	94	54
TVu 493	Tolerant[2]	56	56
TVu 2755	Tolerant	54	37
TVu 3901	Highly tolerant[3]	26	12

[1]*Pronounced systemic symptoms (SS 2).*
[2]*Predominantly symptomless infection (NS +SS-1).*
[3]*Symptomless infection (NS 1).*

Table 15. CMeV seed transmission in two susceptible varieties.

Variety	No. infected plants/ total tested	Transmission rate (%)
TVu 612	0/586	0.0
VITA-1	1/510	0.2

[1]*CMeV presence confirmed serologically.*

Table 16. CAMV resistance: International Cowpea Disease Nursery.

	CAMV-USA	CAMV-Kenya	CAMV-Tanz	CAMV-Ife	CAMU-Onne
TVu 410	1	(S)[1]	1	(S)	3
TVu 612	1	(S)	3	1	1
TVu 1185	2	2	1	3	1
TVu 1330	1	2	1	1	1
TVu 1948	1	(S)	1	1	3
TVu 2480	1	1	3	1	3

[1]*(S) = systemic infection, severity of reaction unknown.*

Table 17. Combined virus resistance: Advanced Trials, scores (1-9 scale).

	CGMV (Onne 1979 first season)	CYMV (IITA 1979 first season)	CAMV (IITA greenhouse 1979 second season)
Trial 1 (spreading)			
VITA-1	2.33	1.00	1.00
VITA-4	1.00	1.00	4.33
VITA-5	8.33	1.00	1.00
Ife Brown	3.00	5.33	9.00
7R-0189D	2.33	1.00	1.00
TVx 3040-01E	2.33	2.33	1.67
TVx 3341-09E	2.33	1.00	2.33
TVx 3368-021E	3.00	9.00	1.67
Trial mean	3.53	2.13	3.23
SE	0.74	0.47	1.22
CV %	36.39	37.87	65.69
Trial 2 (semi-erect)			
VITA-1	4.33	1.00	1.67
VITA-4	3.00	1.00	3.67
VITA-5	8.33	1.00	1.00
Ife Brown	4.33	3.67	9.00
TVx 3348-023D,	3.00	2.67	2.33
TVx 3385-029E	2.33	1.00	1.00
Trial mean	4.04	1.87	3.53
SE	0.54	0.60	1.15
CV %	23.35	55.60	56.50
Trial 3 (erect)			
VITA-1	5.00	1.00	1.00
VITA-4	4.33	1.00	1.00
VITA-5	7.67	1.67	1.00
Ife Brown	4.33	3.67	8.00
7R-051D	2.33	1.67	1.00
TVx 3360-026E	3.00	1.00	1.67
TVx 3428-08D	2.33	1.67	1.00
IAR 355	8.33	6.33	1.00
Trial mean	4.01	2.53	2.24
SE	0.54	0.54	0.91
CV %	23.11	37.03	70.58

[1]*Also has tolerance to CMeV (IITA greenhouse 1978 second season).*

Table 18. Scab resistance: International Cowpea Disease Nursery, scores (1-9 scale).

Line	Samaru 1976	Samaru 1977	Samaru 1978	Samaru 1979	Kampala 1977
			Location, season		
VITA-1	1	1	5.5	6	2
VITA-4	-	1	1	1.5	-
VITA-5	3	1	6	-	5
TVu 486	1	1	1	1.2	2
TVu 853	1	1	3	1.2	2
TVu 1017	5	4	7.5	-	7
TVu 1404	1	1	1	1	2
TVu 1433	1	1	1	1	2
TVu 2331	5	5	5.5	-	9
TVu 2897	8	1	8	-	5
Trial mean (2 reps)	1.6	1.3	4.2	-	3.8

Table 19. Scab resistance: Advanced Trials (Funtua, 1979), scores (1-9 scale, two dates of assessment).

	25/9/79	16/10/79
Trial 1 (spreading)		
VITA-1	2.00	5.00
VITA-4	1.00	2.67
VITA-5	1.67	5.00
Ife Brown	2.33	5.33
TVx 3339-03D	1.33	3.33
TVx 3363-01D	5.00	7.00
TVx 3380-042E	1.67	3.33
TVx 3381-2F	1.33	3.33
Trial mean	2.63	5.03
SE	0.41	0.44
CV %	27.13	15.06
Trial 2 (semi-erect)		
VITA-1	1.67	5.33
VITA-4	1.67	5.00
VITA-5	1.33	5.33
Ife Brown	3.33	6.00
TVx 3343-03E	1.33	5.00
TVx 3371-01F	5.00	9.00
TVx 3379-01F	1.00	3.67
TVx 3385-029E	1.67	4.00
TVx 3404-012E	1.33	3.67
Mean	2.65	5.95
SE	0.43	0.48
CV %	28.11	11.62
Trial 3 (erect)		
VITA-1	2.00	5.67
VITA-4	1.00	3.67
VITA-5	1.67	5.00
Ife Brown	2.00	6.33
TVx 3210-05E	3.00	8.67
TVx 3382-033E	4.00	7.33
TVx 3356-04F*	1.33	2.00
TVx 3360-026E	1.33	5.00
TVx 3394-01D**	1.00	3.67
Mean	2.45	5.63
SE	0.57	0.44
CV %	40.27	13.49

*Susceptible to Septoria leaf spot in the same trial.
**Susceptible to brown blotch in the same trial.

Table 20. Varietal differences in level of infestation of different plant parts by MARUCA larvae (IITA, 1979 second season).

Variety	Mean number of larvae per: Terminal shoot	Flower bud	Flower	Pod
TVu 946	0.05	0.13	0.22	0.04
VITA-5	0.13	0.77	1.26	0.03
Ife Brown	0.21	0.98	1.38	0.09
VITA-3	0.77	1.55	1.88	0.06
LSD (0.05)	0.23	0.48	0.65	0.06

carry-over is yet to be elucidated. A wild shrub, *Cassia* sp., often shows scab-like symptoms, but cross inoculation to cowpea was unsuccessful.

A field screening of International Cowpea Disease Nursery material was sown at Samaru where scab resistance was confirmed in at least three lines, TVu 853, TVu 1404 and TVu 1433 (Table 18). Similarly, a field screening of material at Funtua confirmed VITA-4 as a useful scab-resistant standard. At least nine Advanced Trial lines possess resistance levels equal to or better than VITA-4 (Table 19). Under the heavy infection pressure which developed, no line remained entirely scab free.

VITA-5 had the least number of larvae in the pods when compared to other cultivars, but the differences were not significant. The level of infestation of different plant parts by *Maruca* larvae in the different cowpea cultivars (Table 20) was identical to the comparative differences in resistance identified earlier in the respective cowpea cultivars (IITA Annual Report 1975).

In further field testing for resistance to *Maruca* during 1979, the field scoring technique for *Marcua* resistance was standardized. The scoring method is as follows:

1. **Injury to terminal shoots and stems.** One plant is selected per meter row at 35 (± 5) days after planting. The plant is carefully examined at the terminal shoots, axes, stem, etc., for signs of *Maruca* injury (entry or exit holes, frass and webbing). The number of injuries are totalled, and a score is assigned to the plant according to the scale shown in Table 21.

2. **Injury to flowers.** Flowers are scored at 40 (± 5) days after planting. Plants are selected as for terminal

shoots. On each plant, five peduncles, which are at least 8.0 cm long, are randomly selected. On each peduncle, the flowers are examined for entry or exit holes made by *Maruca* larvae. Entry holes of first-stage larvae are minute and may be unnoticed by the casual or untrained observer. A flower with one or more entry or exit holes is considered injured.
(See Number 3 under Entomology.)

Entomology

Insect pests are the main factor limiting cowpea yields in Africa. At least seven different groups of pests attack the plant at all stages, from seedling to harvest and beyond. Legume pod borer, *Maruca testulalis*, legume bud thrips, *Megalurothrips sjostedti* and coreid bugs, which include *Clavigralla tomentosicollis*, are the three major field pests and are either singly or collectively responsible for major losses in cowpea yield. Research at IITA has concentrated on identification of cowpea cultivars resistant to these pests.

Legume pod borer, *Maruca testulalis*

During 1979, cultivars that had indicated resistance to *Maruca* in previous studies (IITA Annual Report 1975, 1977) were further tested.

Tvu 946 and VITA-5 were selected based on comparatively less damage to stems or shoots. TVu 946, in addition, also had shown least damage to flowers, and VITA-5 had shown least damage to pods. These two cultivars, along with known susceptible check VITA-3 and local improved variety, Ife Brown, were tested in 1979 for varietal differences in level of infestation of different plant parts by *Maruca* larvae.

TVu 946, an early flowering type, was planted one week later than the other test cultivars to synchronize flowering (Table 20). TVu 946 had the least number of larvae on all the plant parts, except on the pods where VITA-5 had the least number. There was no significant difference in the number of larvae in the terminal shoots of TVu 946, VITA-5 and Ife Brown, but the number was significantly less in TVu 946 and VITA-5 compared to susceptible check VITA-3. The larvae in flowers were least in TVu 946 and varied significantly from the other test cultivars.

The injured flowers are then expressed as a percentage of the total present and scored as in Table 21. Flowers may either be closed or open but must still be intact on the peduncle.

3. Injury to pods. Plants are selected as described previously in 1 and 2 for pod scoring. For each plant selected, 5 peduncles are scored according to the method shown in Table 21. Injury to pod consisted of the presence of feeding activity of *Maruca* larvae, frass and entry or exit holes. One such indication was enough for the pod to be classified as injured. The percent injury per peduncle is based on the total number of pods carried on the peduncle.

Both the score and the number of pods are recorded. To minimize bias, the peduncle are selected from their point of attachment to the stem and then followed up to the tip where pods are located. One plant is sampled per meter row.

Flower buds are also scored at 40 (± 5) days after planting in the same way as for flowers during the initial evaluation. However, injury to flower buds, especially by first instar larvae is extremely difficult to recognize and require more expertise and time than for flowers. As a result, flower buds are not included in Table 21. Scoring for flower bud injury would be necessary in forecasting populations for control purposes, but this is not the objective of the method described here.

Data on the field screening for *Maruca* injury on the selected varieties is shown in Table 22. VICAM-1/SP, TVx 3122-06D, TVx 309-1G and TN-88-63 had low scores for terminal shoot and flower bud. All varieties had high scores for flower injury and all but four varieties showed low level of pod damage. The varieties showing low levels of damage will be further tested with VITA-5 and TVu 946, which showed low level of larval infestation and were earlier identified as resistant checks.

Legume bud thrips (*Megalurothrips sjostedti*)

To find out the distribution of legume bud thrips on cowpea plant, the different plant parts were sampled for the assessment of the thrips population. As earlier reported (University of Ibadan, 1977), thrips were found to be concentrated on the fruiting structure while only 28 percent are located on the vegetative parts of the plant. About equal numbers were found on flower buds and flowers (Table 23).

Comparison of sampling methods. Two different sampling methods were used to estimate thrips populations. Counting the number of thrips present in 10 flowers was as accurate as or required less time than a suction device

Table 21. Field scoring chart for MARUCA injury to cowpea.

A. Terminal shoot	
Number of shoots with *Maruca* injury	Score
0- 1	1
2- 3	2
4- 5	3
6- 7	4
8-10	5
Sample 1 plant at random/m-row at 35 ± 5 days after planting	
B. Flower	
Injury/Peduncle (%)	Score
0- 20	1
21- 40	2
41- 60	3
61- 80	4
81-100	5
Sample 5 peduncles/plant; 1 plant/m-row at 45 ± 5 days after planting.	
C. Pod	
Injury/Peduncle (%)	Score
0- 20	1
21- 40	2
41- 60	3
61- 80	4
81-100	5
Sample 5 peduncles/plant; 1 plant/m-row at 70 ± 10 days after planting.	

Table 22. Field scoring different larval feeding sites of selected cowpea cultivars for damage rating.

Variety	Score: Terminal shoot	Flower bud	Flower	Pod	Σ/n	Rank
VICAM-1/SP	1.0	2.0	2.5	2.0	1.9	1
TVx 3122-06D	1.0	2.0	2.5	2.0	1.9	1
TVx 309-1G	1.0	2.0	3.0	2.0	2.0	3
TVx 2713-2C/A	1.3	2.3	2.5	2.0	2.0	3
Wusi Local	1.3	2.3	2.5	2.0	2.0	3
TVx 1841-01E	2.0	2.0	2.5	2.0	2.1	6
TN-88-63	1.0	2.0	3.5	2.0	2.1	6
VITA-7 (TVx 289-4G)	1.7	2.3	2.5	2.0	2.1	6
5F-P1-186	1.0	2.7	2.5	2.7	2.2	9
5F-P1-188	2.0	2.3	2.5	2.0	2.2	9
TVx 3048-02D	2.0	2.3	3.5	2.0	2.5	11
VITA-1	2.3	2.7	3.0	2.7	2.7	12
TV 1839-02F	3.0	3.0	3.5	2.7	3.1	13
Mean	1.6	2.3	2.8	2.2	2.2	

Rating Scale: 0 1 resistant; 1 < 2 moderately resistant; 2 < 3 intermediate; 3 ≤ susceptible; 4 = highly susceptible.

Table 23. Number of thrips on various cowpea plant parts for a three-week sampling period on Ife Brown.

Plant part	No. thrips	Percent of total	SE
Foliage/stem	36	28	7.1
Open flowers	58	24	19.8
Unopened flowers	23	11	8.8
Large flower buds	28	21	9.5
Medium flower buds	10	8	4.6
Small flower buds	8	7	2.7

(D-vac). Utilizing the counting method, significant differences can be measured between insecticides, both dosages and interval of applications. This confirms earlier findings (IITA Annual Report 1978). The counting, therefore, should have application in evaluating cultivars being developed for insect resistance. Table 24 shows that differences were detected among trials, which is attributed to a resistant mechanism present in some of these strains. TVu 1509, TVu 946 and TVu 2870 as reported previously (IITA Annual Report 1976, 1977 and 1978) have measurable levels of resistance. VITA-1 was utilized as a standard for comparison.

The counting method was utilized to identify a few resistant lines from the insect subpopulation breeding trials.

Coreid bugs

Comparison of sampling methods. Two different sampling methods were evaluated that quantitatively measured populations of pod bug adults. The visual score counts detected more adults per unit of area than a suction device (D-vac). In addition the visual counts of pod bug adults and the number of feeding punctures are highly correlated.

Laboratory screening. A rapid screening technique to identify resistant lines was also developed. From 7- to 10-day-old pods are exposed to adult pod bug for 72 hours. The pod is split, seed removed and the inner wall of pod is scraped to remove the matrix which surrounds the seed. The feeding punctures are clearly visible when viewed under a low-power desk magnifier.

Utilizing this procedure, several hundred lines have been screened, and lines have been identified that have 60 percent less feeding punctures when compared to a commercial cultivar. Pod color is involved in this reduction in feeding. All these lines have dark green pods; however, not all dark green pods give this reduction in

Table 24. Evaluation of selected cowpea lines to estimate levels of resistance to thrips.

Strain	No. of thrips present in 10 untreated: flower buds	flowers	No. of open flowers 4m-row	Yield* (%) gain	Damage index (%)	Resistant** index	Resistant ranking
Ife Brown	37	81	73	50	53	28	5
TVu 1509	22	37	110	24	23	59	1
TVu 7274	14	111	42	10	27	42	4
TVu 2870	27	44	180	29	23	52	3
VITA 1	28	200	15	69	73	0	6
TVu 946	16	60	165	22	20	56	2
LSD (0.05)	8	40	26	-	10	-	-

*Difference between insecticide treated and untreated plots.

**Resistant index in calculated by computing differences in treated and untreated plots for thrips numbers, flowers and yield. The higher the number, the more resistant the line.

feeding. Cage and field tests are planned to determine if these lines exhibit similar reduction in damage to pod sucking bugs.

Integrated control of cowpea pests

Cropping systems and pest infestation. Replicated, large-plot farmer's field experiments (30 m × 30 m) were performed to compare differences in pest infestation of cowpeas grown under traditional unsprayed intercrop systems (maize/cowpea and sorghum/cowpea) and insecticide sprayed and unsprayed monocrops. Plots were planted and maintained by farmers. These studies were conducted in Nigeria from April-July, 1978, at Ofiki, Nigeria, and from September-November, 1978, at Yankari, Nigeria. The synthetic pyrethroid insecticide Ambush was sprayed against cowpea pests.

At Ofiki, flower thrips, *Megalurothrips sjostedti*, were significantly lower in maize cowpea intercrops (average of 3.1 per peduncle compared to 5.4 per peduncle in unsprayed monocrop). At Yankari, counts were consistently higher in maize and cowpea intercrops (average of 5.2 per penduncle compared to 3.8 per peduncle in unsprayed monocrop). However, the thrips populations did not differ significantly.

The predator complex associated with *M. sjostedti* on cowpea flower peduncle was dominated by the *Anthocorid* bug, *Orius albidipennis* and *Orius* sp.; larval *Mirid* bugs; the predatory thrips, *Frankliniella* sp. and *Haplothrips* sp.; predacious fly and beetle larvae; ants and adult *Staphylinid* beetles. No evidence of parasites was found. Predators, except thrips, were counted in the three treatments at Ofiki. Their numbers were lower in the intercrop, indicating that increased predator activity was not the factor reducing the thrips populations. These results suggest that thrips distribution was governed by differences in microclimate between farming systems in diverse environments and the appropriate choice of farming system could contribute to the integrated control of thrips on cowpea.

The pod borer, *Maruca testulalis*, infested monocropped and intercropped cowpea equally at Ofiki; *Maruca* populations at Yankari were too low to obtain reliable data.

Very high populations of pod sucking bugs, *Clavigralla tomentosicollis*, were encountered at Yankari. Ambush failed to control the pod bugs at these high densities, and the bugs were present in larger numbers on the sprayed plots where podding was superior due to protection from thrips and *Maruca*. At Ofiki, pollen beetles, *Meloidae*, were attracted to maize tassels just as the cowpea was flowering, and their numbers were highest on the smaller intercropped cowpea plants; however, there were no significant differences. At Yankari, where the maize plants were almost dry by the time the cowpea flowered, the pollen beetle population was low. These results suggest the desirability of intercropping schemes in which maize and cowpea do not flower simultaneously.

Ambush did not affect large beneficial species in Ofiki but diminished them by 45 percent in Funtua. There was no significant difference in *Maruca* parasite activity between sprayed and unsprayed fields at Ofiki. Apparently, the populations of these vagile predators and parasites were sufficiently replenished on sprayed plots from the surrounding bush. High population outbreaks of cowpea aphid, *Aphid craccivora*, occurred late in the season on insecticide sprayed plots at both localities. The corresponding relationship may not be favorable for the aphid natural enemy complex, and this aphid may become a potential secondary pest.

Table 25. Parasitism of pod sucking bugs by Tachinidae in Nigeria and Tanzania.

Host	Location	No. of bugs caged	No. of pupae recovered	Percent parasitism	Parasite
Clavigralla tomentosicollis Stal	Funtua, Nigeria Sept.-Nov., 1978	648	1	0.15	*Alophora nasalis*
	Funtua, Sept.-Nov., 1979	436	2	0.46	no emergence
	Ilonga ARI, Tanzania, June 1979	213	2	0.94	*Alophora nasalis*
Clavigralla elongata Signoret	Ilonga ARI	953	12	1.26	*Alophora nasalis*
Anoplocnemis curvipes F.	Funtua, Sept.-	247	32	13.00	*Clara magnifica*
	Ilonga ARI June 1979.	69	10	14.49	*Clara magnifica*
Mirperus jaculus Thumb.	Ofiki, Nigeria June-Aug., 1978	100	2	2.00	*Bogosia minor*
	Ilonga ARI, June, 1979	116	0	0.00	*Bogosia minor*
Riptortus dentipes F.	Ofiki, June-Aug., 1978	126	1	0.79	*Bogosia minor*

Particular attention was given to the study of the parasite complex of pod-sucking bugs, which are the major pests of cowpea in Nigeria. The parasitism of pod sucking bugs by *Tachinidae* in Nigeria and Tanzania is indicated in Table 25. *Tachinid* parasites, *Diptera,* were recovered by collecting adult bugs. The parasite complex was similar in Nigeria and Tanzania, including three of four species in common. All samples showed low rates of parasitism although they were taken when host populations were at their peak, and parasites should have increased accordingly.

Soybean

During 1979, continued emphasis was placed on combining good seed storability and the ability to fix N in association with rhizobia indigenous to Africa soils with high yields, resistance to lodging and shattering found in materials from the U.S.A. About 50,000 families derived from 43 crosses to combine seed longevity and yield were evaluated in 1979 along with about 100 more crosses to combine high yield and comparability with a range of rhizobia (promiscuity). Progress has been achieved in the selection for these qualities, and lines will be available for yield testing in the near future.

Genetic improvement

Yield trials

Uniform, Advanced and Preliminary Yield Trials were sown at two sites in Nigeria, IITA and Mokwa. Yields were low and coefficients of variation high at both sites. Heavy rainfall at IITA prior to harvest caused large losses due to seed rot while at Mokwa damage from pod-sucking bugs was severe.

The 1979 Uniform Trial consisted of two check varieties, TGm 80 (Bossier) and TGm 479 (Jupiter), and three lines, which had yielded well in the 1978 Advanced Trial and had above average seed storability. Line M-216, developed by the Institute for Agricultural Research, (IAR) Ahmadu Bello University, Nigeria, and line TGx 46-3C, developed by IITA, significantly outyielded both check varieties at IITA; M-216 also outyielded both checks at Mokwa (Table 26).

The 1979 Advanced Yield Trial consisted of 12 entries (Table 27), two high-yielding checks, Bossier and Jupiter, one check with superior seed storability, TGm 685, and nine IITA breeding lines, which gave reasonable yields and had better than average seed storability in the 1978 Preliminary Yield Trial. At IITA, TGx 17-2G, TGx 182-1D and TGx 187-2D gave yields comparable to the highest-yielding check variety, Bossier. Jupiter yielded best at Mokwa followed by TGx 47-3G and TGx 187-2D. TGm 685 gave low yields at both sites.

The 1979 Preliminary Yield Trial consisted of 30 breeding lines and two checks, Bossier and TGm 685. The breeding lines were derived from crosses, including one or more parents of Asian origin with good seed storability. The best lines (Table 28) will be advanced for further yield testing in 1980. The seed storability of all entries in all trials is being confirmed.

Seed storability

Methods of aging seed. To identify lines with good seed storability, rapid screening methods are being employed. One is based on accelerated aging for 4-6 weeks at high temperature and humidity; the other on immersion of seed for 70 seconds in hot water. Hot water immersion gave variable results (Fig. 3). For this reason, the accelerated aging procedure is now preferred (Fig. 4). From tests, it appears that there is no close relationship between seed size and longevity (Fig. 3 and Table 29).

Table 26. Soybean Uniform Trials (IITA and Mokwa, 1979). Yield kg/ha.

	IITA	Mokwa	$\bar{x}$
TGm-80 (Bossier)	519	463	491
TGm-479 (Jupiter)	612	832	722
M-216	1,480	1,038	1,259
TGx 12-4E	838	829	834
TGx 46-3C	1,134	563	849
Mean	917	745	831
CV %	37	13	
SE (D)	215	59	

Table 27. Soybean Advanced Yield Trials (IITA and Mokwa, 1979). Yield kg/ha.

Genotype	IITA		Mokwa		Mean
TGx 17-2G	1,434	(1)	713	(4)	1,074
TGx 187-2D	1,299	(4)	849	(3)	1,074
TGx 47-3G	1,057	(5)	885	(2)	971
TGx 182-1D	1,336	(3)	524	(8)	930
TGm 80 (Bossier) check	1,364	(2)	420	(11)	892
TGm 479 (Jupiter) check	632	(11)	1,032	(1)	832
TGx 124-3E	1,034	(6)	549	(5)	792
TGx 12-6H	892	(7)	623	(6)	758
TGx 174-5E	691	(10)	670	(5)	681
TGx 103-1E	839	(8)	492	(10)	666
TGx 226A-1-17	698	(9)	504	(9)	599
TGm 685 check	630	(12)	297	(12)	464
Mean	992		630		
CV %	39		32		
LSD P = 0.05	557		291		
SE (D)	273		143		

Table 28. Performance of best lines in Preliminary Yield Trial (IITA and Mokwa, 1979). Yield kg/ha.

Line	IITA		Mokwa		Mean
TGx 252A-2	1,519	(2)	1,347	(1)	1,433
TGx 250A-2	1,117	(16	1,023	(2)	1,071
TGx 226A-1-18	1,402	(3)	685	(3)	1,044
TGx 226A-1-17	1,538	(1)	433	(24)	986
TGm 80 (Bossier) check	1,157	(13)	243	(31)	700
TGm 685, check	887	(20)	364	(30)	262
No. entries	32		32		
Mean	1,044		585		
CV %	36		45		
SE (D)	310		213		

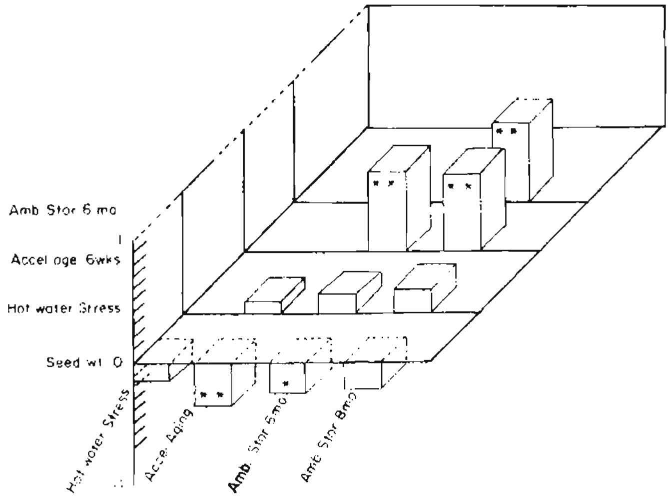


Fig. 3. Correlation matrix of seed weight and three storability tests based on emergence from sand box of 69 F_6 families from two crosses, TGx226 and TGx222, and four check lines.

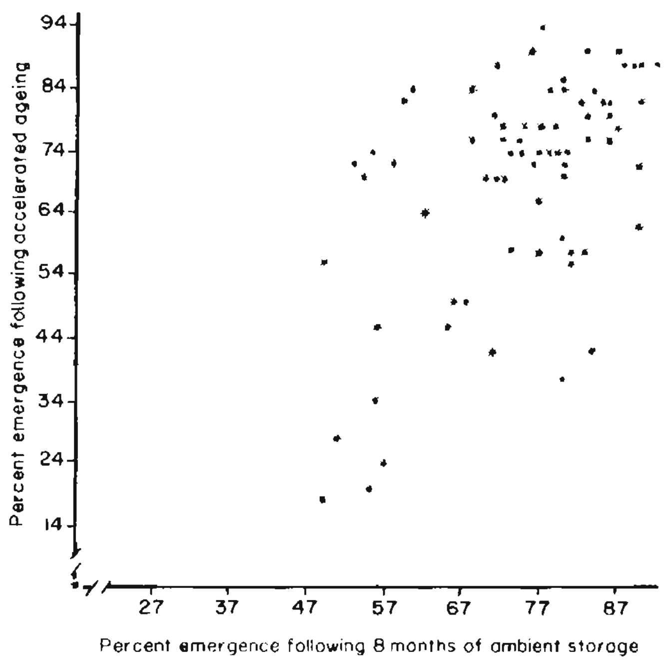


Fig. 4. Relation between effects of accelerated ageing and storage amount on percentage seedling emergence.

Heritability of seed longevity

Studies are not yet complete, but first evidence suggests that when crosses are made, the influence of the maternal plant is important. None of the F_1 seed from the cross Bossier × TGm 737 emerged while 25 percent of the seed emerged from the reciprocal cross (Table 30). Corresponding reciprocal differences were not observed among F_2 seed, which suggests that in the F_1 differences were attributable to a non-cytoplasmic maternal influence. If this is the case, segregation for longevity is delayed until the F_3 generation: the emergence of F_3 aged seed derived from an F_2 plant reflects the maternal influence of the F_2 plant.

Selection for seed storability

Approximately 50,000 F_3 families derived from 43 crosses to combine seed longevity and yield were evaluated in the field in 1979, and the best 4,000 were selected for further evaluation. Because aged seed is so sensitive to soil variability, tests at IITA in the future will be conducted in a screenhouse with uniform soil.

Resistance to field weathering

To test whether or not a hard coat (low permeability) influences deterioration of seed in the field before har-

Table 29. Correlation matrix of effects of seed weight and three storability tests on seedling emergence in the field.

	Seed weight	Hot water stress	Accelerated aging
Hot water stress			
##Expt. (a)	0.02		
Expt. (b)	0.14		
Expt. (c)	−0.32**		
Accelerated aging (4 wks.)			
Expt. (a)	−0.27**	0.25*	
Expt. (b)	0.27	0.35	
Expt. (c)	0.05	0.17	
Ambient storage (9 mo.)			
Expt. (a)	0.22	0.57**	0.35*
Expt. (b)	0.03	0.50	0.56*
Expt. (c)	−0.04	0.21*	0.32**

*,** *Significant at P = 0.05 and P = 0.01, respectively.*
Seedling emergence tested in field.
Experiment (a) consisted of 123 breeding lines.
Experiment (b) consisted of 15 entries of the 1978 Advanced Yield Trial.
Experiment (c) consisted of 169 entries in 1978 Preliminary Yield Trial.

Table 30. Percent emergence of parent, F_1 and F_2 seed of reciprocal cross of Bossier and TGm 737, after accelerated aging.

Origin of seed	Unaged seed	Accelerated 4 weeks (sown 5/9/79)	Aging 6 weeks (sown 13/11/79)
Parents			
TGm 80 (Bossier)	94	38	-
TGm 737	95	90	-
F_1 seed			
TGm 80 (Bossier)	-	-	0
TGm 737 x TGm 80 (Bossier)	-	-	25
F_2 seed			
TGm 80 Bossier x TG 737	-	54	-
TGm 737 x TGm 80 (Bossier)	-	62	-
TG 737			

vest, 28 lines with different degrees of seed permeability were examined. Hard seed coat tended to be associated with better emergence and smaller seeds (Table 31).

To compare methods of selection for resistance to deterioration in the field, two varieties were harvested in the rainy season promptly when pods began to change color or 2-4 weeks later. Comparisons were made of inoculation with *Phomopsis sojae* and spreader rows to provide a source of inoculum of the seed-borne fungi that cause deterioration. Harvested seed was divided; a sample was sown in a screenhouse to determine the effect of treatments on seedling emergence; another was surface sterilized and germinated in the laboratory to determine the incidence of seed-borne pathogens.

Spreader rows significantly reduced emergence from 37 to 29 percent (Table 32). The incidence of *Phomopsis* was high on seed not only from inoculated plots but also from uninoculated ones. There was a close correlation between the incidence of *Phomopsis* on seed and seedling emergence (r = 0.63). This confirms that *Phomopsis* is an important pathogen causing seed deterioration prior to harvest.

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Screening for promiscuous nodulation

By developing varieties capable of fixing N with a wide range of *Rhizobia* species, the need for treating soybean seed with a specific rhizobial inoculant may be circumvented. The lines identified for their promiscuity have consistently nodulated well across locations in Nigeria, and collaborators in other countries have reported similar results.

Numerous crosses to incorporate the promiscuous nodulation character into high-yielding backgrounds have been made, and in 1979, approximately 6 ha of F_2 and F_3 material was evaluated for compatibility with indigenous rhizobia at Mokwa. Plantings were made of fields low in N and with no history of inoculant application. Single plants were selected for agronomic characters and nodulation, which was determined by digging plants after

Table 31. Correlation matrix showing relationships between seedling emergence percent unimbibed seed, days to harvest and seed weight.

	Emergence, prompt harvest	Emergence, delayed harvest	Hard seed, prompt harvest, 1 hr soak (%)	Hard seed, delayed harvest 1 hr soak (%)	100 seed weight
Emergence, delayed harvest	0.86**				
Percent hard seed, prompt harvest, 1 h soak	0.69**	0.73**			
Percent hard seed, delayed harvest, 1 h soak	0.71**	0.75**	0.97**		
100 seed weight	0.59**	0.67**	0.62**	0.69**	
Days to prompt harvest	00.46*	0.33	0.27	0.21	0.09

*,**Significant at 0.05 and 0.01, respectively.

Table 32. Effects of varieties, spreader rows, *Phomopsis* ***inoculation and harvest date on seedling emergence of soybeans and incidence of seed-borne*** *Phomopsis.*

Treatment	Level	Emergence	Seed-borne *Phomopsis*, (%)
Variety			
	TGm 80 (Bossier)	41	56
	TGx 9-5H	25**	72**
Spreader Rows			
	with	29	65
	without	37**	63
Phomopsis inoculation			
	with	32	68
	without	34	60**
Harvest			
	prompt	55	44
	2 wk delay	33**	69**
	4 wk delay	8	79

**Significant main effects at 0.01.

seeds reached physiological maturity but before complete degeneration of the nodules. Parental lines, also grown in the test, nodulated or failed to nodulate as expected. In 3 F_2 populations, every plant was evaluated for nodulation regardless of its agronomic merit. About 10-15 percent of the plants were well nodulated in crosses (Bossier × Tgm 119 and TGm 344 × Bossier) between highly promiscuous and an intermediate parent (Fig. 5)

Although *promiscuous nodulation does not appear to be* simply inherited, well nodulated plants occur frequently.

Nondestructive assay of nitrogen fixation

A quick reliable method to identify nodulated plants in segregating populations would be useful, particularly if the plants could be identified before flowering in time to make crosses. An effort was made in 1978 and 1979 to determine whether or not the accumulation of a ureide compound, allantoin, would serve to identify plants fixing nitrogen. Results showed that nodulated plants accumulated 3-4 times more allantoin than N-fertilized *plants. However, the relationship* between ureide concentration and nodule mass was best when there was less than 1 g of nodules per plant. When there was more than 1 g of nodules, allantoin concentration reached a plateau, and the method became more qualitative than quantitative.

Although a clear relationship has not been established between allantoin accumulation and N fixation, the technique was used to evaluate 60,000 F_2 plants from crosses to incorporate promiscuity and high yield. At maturity, plants were dug up; the number and size of nodules were examined. The relationship between nodulation and allantoin accumulation does not appear to be simple. Although *all* plants there were *profusely nodulated* contained high levels of allantoin, not all high allantoin plants had nodules. This suggests that allantoin may be produced from processes unrelated to N fixation.

Photoperiod studies

The responses of soybean to changes in daylength are being studied to understand how latitude and date of planting can be expected to influence plant growth. The studies also provide information on the influence of the length of the reproductive periods on seed yield.

Ninety-three soybean lines were grown in both short days (SD ·· 12 hr) and long days (LD 13.5 hr). The duration

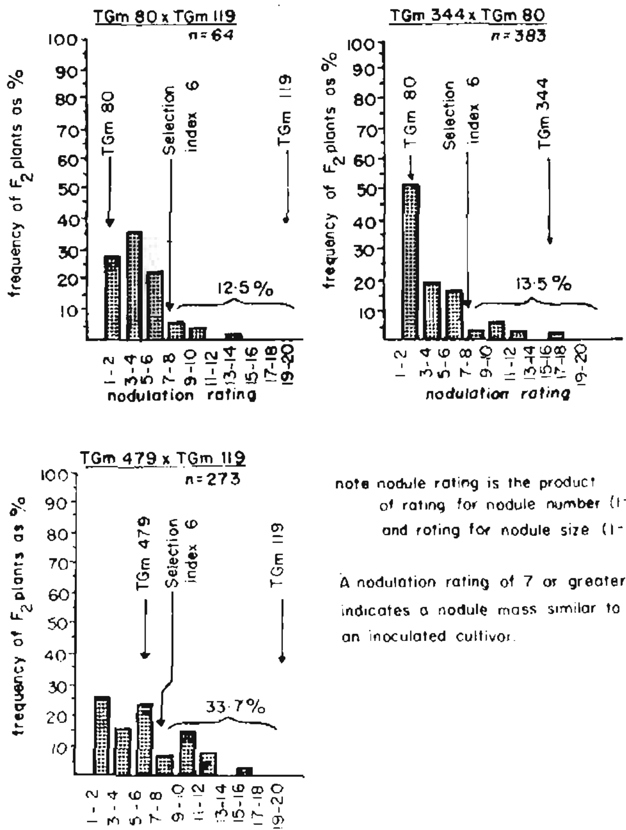


Fig. 5. Distribution of F_2 plants from three crosses of promiscuous and non-promiscuous soybean lines evaluated for nodulation in the field with indigenous rhizobia (Mokwa 1979).

of three growth phases was determined: the time from emergence to R1 (first open flower on the main stem), *time from* R1 to R5 (beginning of pod filling) and time from R5 to R7 (first mature pod on the main stem). From this study, six varieties with different responses to daylength were selected for further study. All showed delayed flowering in long days (Table 33), particularly varieties 1, 2 and 4. In varieties 1, 3 and 4, the period R1 and R5 increased while in varieties 5 and 6 the interval R5 to R7 increased.

Table 33. Effect of 13½ hr. vs. ~ 12 hr. photoperiod on days to first flowering, length of prepod-fill period and active pod-filling period for six soybean varieties (IITA, 1979).

	Days to flowering R1			Days from R1-R5			Active filling period, days R5-R7		
Variety no.	SD	LD	Diff.	SD	LD	Diff.	SD	LD	Diff.
1. TGm 294-4-4277	32	44	12	17	26	9	29	26	3
2. TGx 46-3C	34	49	15	25	23	-2	29	34	5
3. Hampton 393	29	35	6	16	24	8	29	31	2
4. TGm 693	38	54	16	14	27	13	23	22	-1
5. TGm 725	28	36	8	16	16	0	20	31	11
6. TGm 634	27	36	9	12	14	2	26	38	12
LSD (0.05)	2	4		3	5		2	2	
CV %	4	6		11	13		5	4	

Photoperiod had large effects on growth rate of individual seeds. For variety 1, long days increased the rate of seed growth from 5.4 to 6.2 mg of seed per day. For variety 5, long days decreased the rate of growth from 4.8 to 3.2. Faster growth rates of individual seeds were associated with shorter periods of active pod filling (R5 to R7) (Fig. 6).

The delay in flowering in long days resulted in larger plants (Table 34). The difference in plant weight became larger by R7 because long days always extend either the R1-R5 period or the R5-R7 period (Table 33).

Although long days consistently resulted in larger plants, there was not always a proportional increase in seed yield because the pod weight ratio decreased for all varieties under long days (Table 35).

Resistance to bacterial pustule

Bacterial pustle caused by *Xanthosomas phaseoli* var. *sojense* is the most commonly observed disease of soybean in West Africa. It occurs in nearly all climatically hot regions of the world. A backcross breeding scheme is being used to incorporate the single recessive gene for resistance into otherwise suitable varieties. The efficiency of such methods depends on accurate identification of resistant plants in segregating populations. A study to develop a screening method indicated that sowing alternate rows of a susceptible variety will lower the frequency of escape while inoculating with a knapsack sprayer will not.

Table 34. Total dry weight/p m² for 6 soybean varieties under short- and long-day conditions.

	Total dry wt., g/m²					
	At flowering		R-5		R-7	
Variety no.	SD	LD	SD	LD	SD	LD
1	150	282	367	442	419	683
2	137	311	405	423	456	561
3	109	196	304	369	386	475
4	276	291	323	454	385	471
5	89	186	317	338	257	468
6	115	204	290	331	292	501
LSD (0.05)	41	48	87	132	113	117
CV %	18.9	12.9	17.3	22.4	20.5	22.4

Table 35. Effect of short (12 hr) and long (13½ hr) daylengths on pod weight ratio and seed yield.

	Pod weight ratio[1]		Seed yield/m² g	
Variety no.	SD	LD	SD	LD
1	0.67	0.64	142	132
2	0.71	0.62	107	103
3	0.70	0.61	87	131
4	0.66	0.58	95	120
5	0.70	0.68	81	108
6	0.72	0.66	69	90
LSD (0.05)	0.07	0.06	46	45
CV %	7.2	5.9	31.2	26.0

[1]*Pod weight ratio = wt. of pods + pods + seeds/total dry wt.—(US + petioles at R7 stage).*

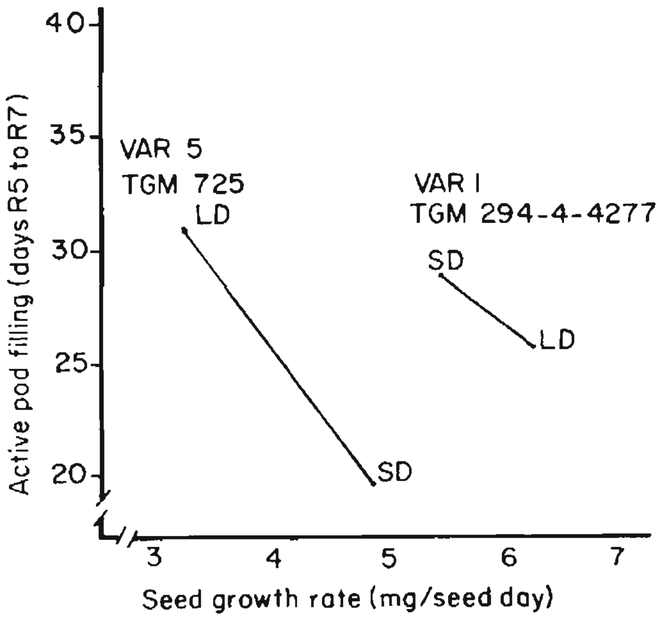


Fig. 6. Relation between seed growth rate and duration of pod filling as influenced by daylength.

Management trials

Variety management trials were conducted at three locations in Nigeria to determine the influence of environment and management practices on the growth and yield of soybean (Table 36).

At Yandev, the soil N and P status was adequate to support good growth without additional fertilizer. Consequently, the response to P and N were marginal. All the promiscuous genotypes nodulated with indigenous rhizobia; whereas, Bossier and Jupiter did not, and as a result, inoculation with *R. japonicum* improved nodulation, growth and yield of these two cultivars. TGm 618, a local cultivar from the Central African Republic, has a yield potential equal to Bossier and Jupiter. This cultivar is being used extensively as a promiscuous parent in the breeding program. Late-maturing cultivars such as Malayan and TGm 344 gave poor yields regardless of management practices, presumably due to drought in the late stages of growth. If late-maturing material is to be grown in Yandev, they should be planted in early June.

At IITA, lodging of the tall genotype was severe due to high fertility. Within-row spacing had little effect on yield for all the cultivars except Bossier. Bossier was the least able to compensate for reduced stands, and large yield reductions were observed when the within-row spacing increased from 5 to 15 cm. The highest-yielding cultivars at IITA were TGm 57G, TGm 618, Bossier and Jupiter. Most varieties produced seed yields of approximately 1,500 kg/ha.

At the Onne substation, the acid soils gave a complex of effects. The addition of lime influenced all measured parameters. Nodule mass of plants inoculated with *R. japonicum* was doubled by the application of 0.5 t lime/ha but was not further affected by 2.0 t lime/ha. These data supported by soil analysis indicate that 0.5 t lime/ha is sufficient to supply Ca as a nutrient in order to establish a symbiosis. The application of 2.0 t lime/ha decreased the soil exchangeable A1 from 1.1 to 0.5 meq/100 g and resulted in increases in growth and yield of acid sensitive cultivars. However, some genotypes appear to be more tolerant to A1 and did not respond to applications above 0.5 t lime/ha. The highest-yielding cultivars under Ca and A1 stress were TGm 618 and TGm 344. Bossier was very sensitive to both Ca defiency and A1 toxicity. These observations indicate that genotypes tolerant to A1 at levels of 1-1.3 meq/100 g can yield adequately provided sufficient lime is applied to satisfy the Ca required for nodule initiation. Also, taller genotypes appear to be more adapted to this stress environment.

Microbiology

In research on the cowpea *Rhizobium* symbiosis, the emphasis was on the ecology of rhizobia; whereas, in research on the soybean *Rhizobium symbiosis*, it was on seed inoculation and studies of the behavior of *Rhizobium japonicum* in acid soils.

Rhizobium culture collection

A collection of cultures of microorganisms represents a storehouse of information and a genetic resource base. In recognition of the importance of *Rhizobium* cultures in improving food crop production and soil fertility, a collection of these cultures was established at IITA in 1978. The rhizobial strains in the collection have been increased and a catalog of the strains has been prepared. The collection reflects the high priority placed on cowpea and soybean improvement; it includes 242 "cowpea miscellany" rhizobia, 82 *Rhizobium japonicum* strains and three other *Rhizobium* spp. A working collection that consists of the eight most effective cowpea and soybean strains has been established.

Rhizobia in acid soils

The most efficient N-fixing strains do not always persist in the field; studies of the persistence, competitive ability and effectiveness of two antibiotically labeled *R. japoni-*

Table 36. Soybean variety management trials (IITA, Yandev and Onne, 1979). Yield kg/ha.

Variety effects	IITA	Yandev	Onne I	Onne II
TGm 579	1,538 (1)	1,708 (5)	-	-
618	1,537 (2)	1,921 (1)	887 (2)	593 (3)
479 (Jupiter)	1,520 (3)	1,861 (2)	509 (9)	483 (6)
80 (Bossier)	1,502 (4)	1,797 (3)	522 (2)	489 (5)
577	1,438 (5)	1,779 (4)	-	-
119	1,401 (6)	1,456 (7)	919 (1)	464 (7)
120	1,206 (7)	1,456 (6)	623 (6)	303 (9)
344	1,160 (8)	1,090 (8)	809 (3)	687 (2)
107 (Malayan)	691 (9)	618 (9)	766 (4)	490 (4)
693	-	-	722 (5)	762 (1)
220	-	-	613 (7)	385 (8)
x̄ ± SE (x̄)	1,355 ± 94	1,521 ± 67	707 ± 80	517 ± 76
CV %	21	13	34	45
Management factor 1				
	Nitrogen	Nitrogen	Spacing	Nitrogen
Level 1	1,304	1,595	752	277
2	1,388	1,514	822	638
3	1,372	1,454	550	637
x̄ ± SE (x̄)	1,355 n.s.	1,521 ± 39	707 ± 46	517 ± 44
Management factor 2				
	Spacing	Phosphorus	Calcium	Calcium
Level 1	1,360	1,343	573	467
2	1,316	1,648	794	517
3	1,388	1,572	757	567
x̄ ± SE (x̄)	1,355 n.s.	1,521 ± 39	707 ± 46	517 n.s.

Significant interactions

V x N**
V x P*

Nitrogen: Level 1 = Nil; Level 2 = Commercial inoculant
Level 3 = 100 urea kg/ha at planting
Spacing: Level 1 = 75 cm x 5 cm; Level 2 = 75 cm x 10 cm;
Level 3 = 75 cm x 5 cm
Phosphorus: Level 1 = Nil; Level 2 = 400 kg single super/ha;
Level 3 = 800 kg single super/ha
Calcium: Level 1 = Nil; Level 2 = 400 kg hydrated lime/ha;
Level 3 = 1,600 kg hydrated lime/ha.

cum strains in two soils were started in 1978 to determine the need for periodic reinoculation. The strains were introduced through seed inoculation into the highly acid soil at the Onne substation (Oxic palendult, pH 3.7) and, for comparison purposes, into the slightly acid soil at IITA (Oxic paleustalf, pH 5.4); both soils contained fewer than 5 *R. japonicum* and over 10,000 cowpea rhizobia at planting. Two cultivars, Bossier (non-promiscuous) and TGm 294-4 (non-promiscuous), and 4 treatments were used in 1978: (i) uninoculated, (ii) inoculated with IRj 2101 spc (formerly IRj 101 spc), (iii) inoculated with IRj 2114 str (formerly IRj 114 str) and (iv) fertilized with 150 kg N/ha in 2 doses. Lime at 1 t/ha was applied to half of the plots in the Onne soil. The survival of strains was determined by rhizobial counts in the soil; competitive ability was by nodulation and effectiveness by shoot N content and grain yields. The first year results were presented as part of IITA's 1978 Annual Report. In 1979, uninoculated seeds were sown twice at both locations; TGm 294-4 was replaced with Malayan (promiscuous). Before each sowing, soil was sampled to count surviving inoculant rhizobia and to determine soil acidity, exchangeable A1, Ca and Mn.

The results of rhizobial counts showed that 10 times more rhizobia survived in inoculated Onne soil with lime. Results of nodule assays for antibiotic mutants are shown in Tables 37 and 38. Cross-contamination was higher at the Onne substation than IITA because much less control could be exercised on movement on plots in the former. Competitive ability in terms of nodulation decreased with time. The decrease was faster in the slightly acid IITA soil, particularly for Malayan inoculated with IRJ 2101 spc, than in the highly acid Onne soil. Of the two inoculum strains, IRJ 2114 str was more frequently found in nodules from uninoculated treatments than IRJ 2101 spc, indicating that it is more competitive for nodulation than IRJ 2101 spc in the presence of indigenous rhizobia. There were instances of double infection where IRJ 2114 str and indigenous rhizobia were found in the same nodule. Liming the Onne soil had a variable effect on competitiveness.

In the slightly acid IITA soil, Malayan responded to N fertilizer in terms of shoot N content (Table 39). There was no response to inoculation as was the case in 1978 in terms of grain yield; this is again attributable to effective natural nodulation of the hosts.

In the highly acid Onne soil, liming increased shoot N content of both hosts. In the second sowing, Malayan responded to N fertilizer without lime and Bossier responded to N fertilizer with lime (Table 39). Although soybeans responded to inoculation in 1978, no such re-

Table 37. Competition for nodulation of soybean by two antibiotic resistant mutants of** R. japonicum **with indigenous rhizobia in a slightly acid soil (IITA, 1979).

Treatment	Second sowing: Proportion of nodules SPC' and/or STR' (%) TGm 80 (Bossier)	TGm 51 (Malayan)	Third sowing: Proportion of nodules SPC' and/or STR' (%) TGm 80 (Bossier)	TGm 51 (Malayan)
Uninoculated	4.5	4.8	2.5	7.5
Nitrogen	9.7	3.3	5.0	2.0
IRj 2114 str	93.0	68.2	86.2	90.0
IRj 2101 spc	98.0	70.3	42.5	26.2

LSD 0.05 for the comparison of means between all groups is 19.2 for the second sowing and 17.4 for the third.

Table 38. Competition for nodulation of soybean by two antibiotic resistant mutants of** R. japonicum **with indigenous rhizobia in a highly acid soil (Onne, 1979).

Treatment*	Second sowing: Proportion of nodules SPC' and/or STR' (%) TGm 80 (Bossier)	TGm 51 (Malayan)	Third sowing: Proportion of nodules SPC' and/or STR' (%) TGm 80 (Bossier)	TGm 51 (Malayan)
IoLo	73.5	75.0	66.2	63.4
IoL1	100	101.1**	97.5	61.2
NLo	0	29.2	64.8	59.6
NL1	92.5	81.0	82.5	38.8
STR Lo	100	100	95.0	92.5
STR L1	100	97.3	98.8	83.8
SPC L	100	100	82.5	72.5
SPC L1	100	100	85.0	82.5

LSD 0.05 for the comparison of means between all groups is 36.6 for the second sowing and 37.9 for the third.
**I_0 = uninoculated; N = 150 kg N/ha split into three applications;*
STR = inoculated with IRj 2101 str in year of establishment; SPC = inoculated with IRj 2101 spc in year of establishment.
L_0 = no lime and L = 1.0 t/ha lime applied before crops I and II.
***Includes doubly infected nodules.*

sponse was observed in 1979, probably because of the presence of effective contaminating inoculum strains in uninoculated plots.

Grain yield of the third crop at IITA was less than the first but was unaffected by inoculation. The abundant and effective natural nodulation in uninoculated plots was probably the reason. At the Onne substation, all yields were low, owing to diseases, wet-stem rot and web-blight, and nutrient deficiencies, Mg and Zn. Lime was *the only treatment to affect yield. Lime also decreased* exchangeable A1 and total acidity (Table 40). Inoculation did not affect the level of exchangeable A1 or total acidity. A1 concentration was negatively correlated with shoot yields (r - 0.4932, significant at 1 percent level) and shoot N content (r -- -0.4346, significant at 1 percent level).

As expected, *nodule yield and the proportion of nodules* formed by the antibiotic resistance mutants were closely correlated. Also, the shoot N content was correlated with exchangeable Ca.

The survival and function of the two strains were adversely affected in the highly acid soil unless lime was added. The inoculant strains could eventually die out on such soils, necessitating reinoculation of seed. To obviate the need for lime, current research aims to identify indigenous strains tolerant of soil acidity stresses. The survival and function of the inoculant strains were less affected in the slightly acid soil.

Inoculation with *Rhizobium*

In the IITA Annual Report 1978, experiments were described showing significant increases in grain yield of soybean in response to inoculation with strains of *R. japonicum*. Of the 12 single strain inoculants tested, three strains, IRj 2123, IRj 2111 and IRj 2101, were rated superior in terms of symbiotic effectiveness expressed mainly *as plant growth and yield. Bossier and TGm 294-4 were* tested, and a yield increase of up to 100 percent was obtained. Orba (promiscuous) on the other hand, responded little to inoculation (25 percent yield increase).

This year, the three superior strains of *R. japonicum* were further tested in the field using four soybean cultivars; TGm 294-4, Jupiter (moderately promiscuous), Malayan and Orba to confirm last year's results and compare their effectiveness on a broader host range. A fourth *Rhizobium* strain isolated from Orba was also used in order to determine its potential as an inoculant, primarly on the promiscuous cultivars. This latter strain nodulates with cowpea effectively and differs in this regard from the other three.

N-deficiency early in the life of the plant impairs growth and symbiosis. To determine whether or not N fertilizer would alleviate this deficiency, inoculant treatments received either 0 or 25 kg N/ha as a starter dose. A treatment with 150 kg N/ha was included for comparison with the inoculated treatments.

The cultivars, TGm 294-4, Malayan and Orba, responded to inoculation with strains IRj 2123, IRj 2111 and IRj 2101, in terms of number and weight of nodules (Table 41). However, the inoculum derived from Orba, although nodulating with Malayan and Orba profusely, was incompatible with TGm 294-4 and Jupiter. The compatibility of Jupiter was specific even within *R. japonicum* strains. For example, IRj 2101 and IRj 2111 formed very few nod-

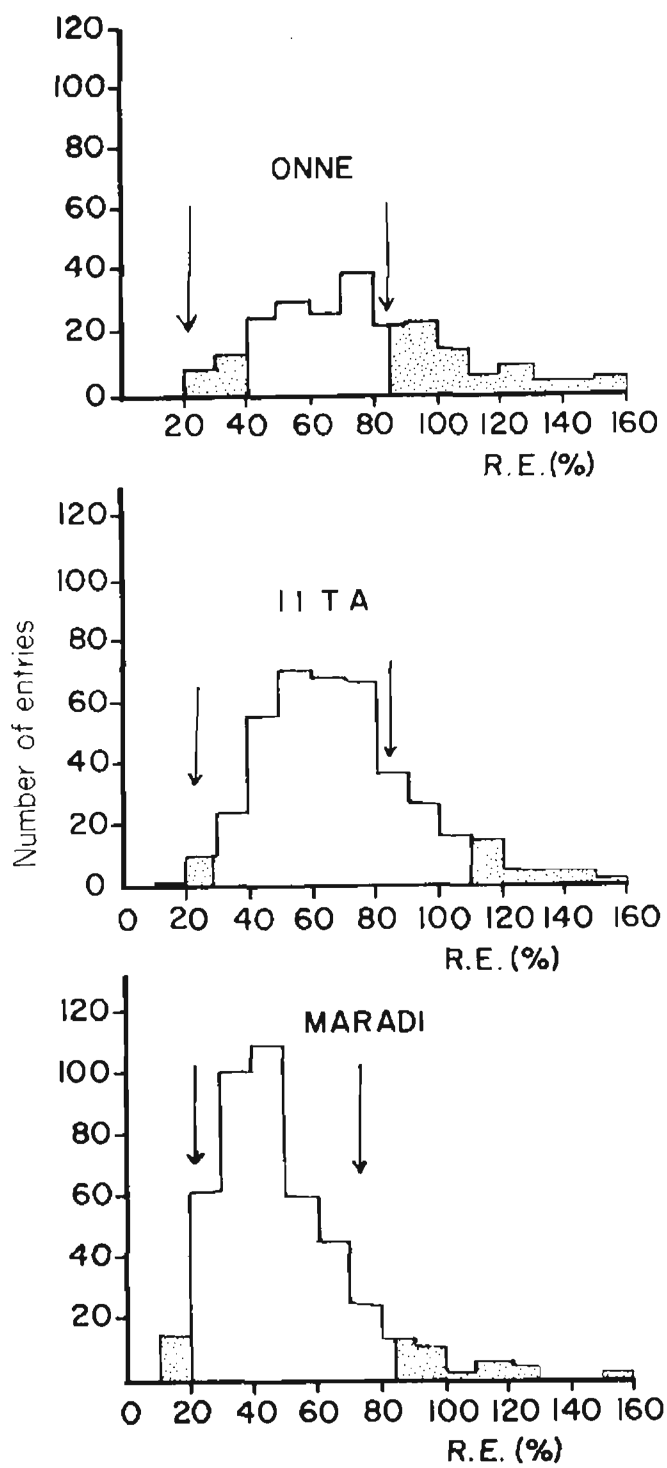


Fig. 7. Distribution of the R.E. of cowpea cultivars (IITA, 1979).

ules on Jupiter in contrast to abundant nodulation by IRj 2123. *It is, therefore, important to screen more R. japonicum* strains for compatibility and efficiency of symbiosis with Jupiter.

Although the field selected had been depleted of N by successive croppings of unfertilized maize, variation was large and even some uninoculated plants showed no signs of N-deficiency. The effect of starter N (on nodule number and dry weight) was consequently inconsistent. Further studies to determine the effect of starter N on symbiosis and growth are needed.

As expected, N fertilizer (150 kg N/ha) inhibited nodulation of the promiscuous cultivars Malayan and Orba but increased plant growth of all cultivars (Table 42). Inoculation with IRj 2123, IRj 2111 and IRj 2101 also increased the grain yield of TGm 294-4. The responses of other cultivars were small. The grain yield of Malayan was low, and there was no response to either inoculaton or N fertilizer. Promiscuous cultivars inoculated with Orba also showed marginal responses.

Environmental diversity in cowpea rhizobia

Rhizobia that are to be used as inoculants for cowpea production must be tolerant to adverse soil and climatic variables; they must be efficient N-fixing strains and good saprobes and competitors for nodulation. In order to identify rhizobial strains possessing these attributes, it is necessary to know the extent of diversity of the strains available, their symbiotic competence and their ability to withstand the selected environmental stresses.

To provide nodules for the isolation of the many diverse rhizobial strains required, close to 500 cowpea cultivars from the IITA Genetic Diverse Nursery and the International Cowpea Observation Nursery with local checks were sown at three sites, IITA, the Onne substation and Maradi, Niger, representing a range of environments from tropical forest to semi-arid sahel savanna. At the Onne substation (rainfall of 2500 mm), the soil is acid with high Al saturation and low Ca and contains 4.3×10^4 cowpea rhizobia/g soil. At Maradi (rainfall of 600 mm), the soil is sandy with low cation exchange capacity N, K and Ca and is subjected to extreme temperatures and drought and contains 4.9×10^2 cowpea rhizobia/g soil.

The cowpeas were sown in unreplicated trials with N (+N) and without N (−N) fertilizer. At Maradi, the +N consisted of a single dose of 50 kg urea-N/ha applied at emergence; at IITA and the Onne substation, 100 kg urea-N/ha was applied at emergence and again at three or four weeks after emergence. Plants were harvested before maturity, and the relative effectiveness (R.E.) of the biological combination in terms of N fixation was estimated.

$$R.E. = \frac{FW(-N)}{FW(+N)} \times 100$$

where FW (.) = fresh weight of 10 shoots in the appropriate block.

Cultivars were divided into three groups: good with an R.E. > 85 percent; intermediate with an R.E. < 85 percent but > 20 percent, and poor with an R.E. < 20 percent.

At IITA, most cultivars (161 entries) had an R.E. from 40 to 80 percent with a broad maximum from 50-80 percent (Fig. 7). At Maradi, the R.E. of most cultivars (332 entries) ranged between 20 and 60 percent with a sharp peak between 30 and 50 percent. At Onne, most cultivars (165 entries) had an R.E. from 40 to 100 percent with a narrow maximum from 50 to 60 percent. The results in Figure 7 suggest that on the basis of the distribution of R.E., the

Table 39. Shoot N content (Mg N/plant)* during two successive sowings of uninoculated seed in a slightly acid soil (IITA) and a highly acid soil (Onne). N was determined at 6 weeks, except for the second sowing at IITA when it was at 8 weeks.

		Second sowing		Third sowing	
Location	Treatment**	TGm 80 (Bossier)	TGm 51 (Malayan)	TGm 80 (Bossier)	TGm 51 (Malayan)
IITA	Io	548.6	364.1	205.7	156.0
	N	695.8	570.6	271.8	234.6
	STR	479.0	379.1	176.0	118.9
	SPC	495.0	258.6	187.2	160.3
Onne	IoLo	102.3	74.2	147.3	95.2
	IoL$_1$	149.4	121.8	218.3	196.7
	NLo	118.8	115.9	94.3	86.6
	NL$_1$	193.5	139.2	265.0	191.1
	STRLo	123.5	86.3	141.0	100.1
	STRL$_1$	171.4	156.5	233.6	235.0
	SPC Lo	95.2	91.2	146.0	135.3
	SPC L$_1$	158.1	105.5	214.4	167.9

**LSD 0.05 for the comparison of means between all groups at IITA are 198.4 and 74.5 for second and third sowings, respectively; and at Onne are 36.6 and 77.2 for second and third sowings, respectively.*
***See footnote to Table 39.*

Table 40. The effects of liming and cropping a highly acid ultisol on total acidity (Al + H) and exchangeable Al determined prior to each crop.

	Al + H, me/100g soil			Al, me/100g soil		
Treatment	Crop I	Crop II	Crop III	Crop I	Crop II	Crop III
No lime	1.40	1.84	1.68	1.20	1.22	1.36
With lime	1.40	1.35	0.49	1.20	0.76	0.21

Each value is a mean of 64 separate determinations.

cowpea rhizobia symbiosis is more adversely affected at Maradi than Onne. It also confirms the genuineness of limiting the R.E. of poor performers to below 20 percent and of good performers to above 85 percent.

For nodule collection, cultivars were selected at each location in the good and poor categories to provide a wide range of diversity. Table 43 shows the numbers of cultivars sown, harvested and selected.

Among the 214 cultivars selected in the trial, four performed well at all three locations (Table 44). Their R.E. determined on the basis of shoot weight at six weeks will be compared with shoot N content at six weeks and grain yield at harvest. If there is a direct correlation, these cultivars may be used to develop efficient lines of cowpea capable of more effectively utilizing indigenous strains and tolerating some important environmental stresses found at Onne and Maradi. TVu 179 performed poorly at all three locations: it had an R.E. of 27.7 percent at Onne, 38.6 percent at Maradi and 40.8 percent at IITA.

After scoring for nodule location, 10 nodules were picked from several plants of selected cultivars in the (–N) block

Table 43. Numbers of cowpea cultivars employed in the field trials on diversity of cowpea rhizobia.

	IITA	Maradi	Onne
Number of entries sown	450	485	400
Number of entries harvested	421	455	235
Number of entries selected	68	79	67

Table 44. Relative effectiveness of the most effective host-strain combinations.

Number and origin of cultivar	IITA	Maradi	Onne	Mean
TVu 113 (Uganda)	113	177	107	139.0
TVu 3945 (Nigeria)	119	130	94.7	114.6
TVu 205 (U.S.A.)	93.6	79.2	127	99.9
TVu 652 (South Africa)	80.9	76.7	105	87.5

Table 41. ***Rhizobium*** **inoculation and starter N effects on nodule numbers, nodule dry weights and shoot dry weights at nine weeks.**

Treatments		Nodule number				Nodule dry weights (mg/plant)				Shoot dry weights (g/plant)			
Inoculants	Starter N	294*	Jup*	Mala*	Orba*	294	Jup	Mala	Orba	294	Jup	Mala	Orba
Uninoculated	0	0.9	0.4	25	18	19	8	239	188	9	12	12	13
	25	2	0.6	27	25	36	12	114	234	12	17	19	21
IRj 2123**	0	76	36	36	36	457	311	288	327	10	13	14	16
	25	72	26	52	57	553	191	332	446	21	13	17	17
IRj 2111	0	69	15	17	24	304	126	132	277	12	14	13	12
	25	40	9	31	35	219	112	260	263	13	16	15	18
IRj 2101	0	43	8	31	33	343	109	210	284	13	14	8	13
	25	54	11	22	23	473	42	133	186	17	25	15	16
Orba	0	2	6	37	43	32	52	236	385	13	14	14	17
	25	5	6	17	33	72	49	118	276	16	12	15	11
Fert. N	150	1	0.8	10	15	7	15	78	165	17	18	15	26

*294 (TGm 294-4), Jup (Jupiter); Mala (Malayan); and Orba are the soybean cultivars.
**IITA accession numbers.
LSD for the comparison of means of nodule numbers of different treatments—28.7.
LSD for the comparison of means of nodule dry weights different treatments—171.
LSD for the comparison of means of shoot dry weights different treatments—6.

Table 42. ***Rhizobium*** **inoculation and starter N effects on grain yield (kg/ha) and yield increase over the uninoculated control.**

Treatments		TGm 294-4		Jupiter		Malayan	
Inoculants	Starter N		Yield increase (%)		Yield increase (%)		Yield increase (%)
Uninoculated	0	1,328		1,489		897	
	25	1,517	14	1,744	17	722	
IRj 2123	0	1,994	50	1,789	20	1,160	29
	25	2,390	58	1,912	10	847	
IRj 2111	0	1,758	32	1,551	4	905	
	25	2,146	42	1,906	9	644	
IRj 2101	0	2,188	65	1,605	8	841	
	25	2,225	47	2,016	15	676	
Orba	0	1,656	25	1,378	0	813	
	25	1,866	23	1,573	0	786	
Fert. N	150	2,354	77	2,000	34	696	

LSD for the comparison of means for different treatments—399.

and stored over silica gel for rhizobial isolations, following standard procedures. Three or four isolates were obtained from each cultivar. On a yeast-mannitol medium, the isolates were typically slow-growing. Some isolates formed, after seven days, very small (diameter < 1 mm) colonies, usually dry, non-confluent and glistening or opaque and sometimes sticky. Others developed large colonies, usually slimy, confluent and translucent. Isolates from the Onne substation and IITA showed all the colony types; those from Maradi formed small, dry colonies.

Purified cultures of rhizobia were authenticated by the plant infection test using cowpea cultivar ER-1. They were given IITA accession numbers, lyophilized for storage in IITA's collection of rhizobia, and duplicate ampoules of each lyophilized culture were sent to collaborators at Boyce Thompson Institute (BTI) and Cornell University at Ithaca, New York, for the studies on their diversity and other tests.

Research by BTI and Cornell collaborators

Relationships were studied among the rhizobia isolated from legumes grown at the three sites in West Africa. Three methods are being used: the enzyme-linked immunosorbent assay (ELISA) and other serological methods, antibiotic resistance patterns and two-dimensional gel electrophoresis. The suitability of the second method was established in a screen of eight "cowpea" strains and three *R. Japonicum* strains in which no two strains showed identical patterns of sensitivity to 25 different antibiotics. Antisera for the first method have been produced, and testing is in progress.

To test the reaction of rhizobia to edaphic factors, 42 slow-growing rhizobia (from the cowpea group, *R. japonicum* and *R. lupini*) were employed. Five soil stress factors were examined: acidity, Al, temperature, moisture-temperature interaction and desiccation. Marked differences in tolerance to aluminium and desiccation were observed, indicating the good prospects of identifying and selecting tolerant strains from the natural population. No statistical differences ($\alpha = 0.05$) were observed in the response to pH; the lower limit for growth was pH 3.9 ± 0.2. There was not much difference between strains in their tolerance to high temperatures — all strains tested grew at 31, 33 and 35° C but not at 40° C when soil moisture in the silt loam soil was 25 percent (w/w). The optimum temperature for growth decreased as the soil water content decreased.

The initial approach in the search for suitable methods for breeders and agronomists to measure N-fixation of legumes was to investigate compounds in shoots, which might reflect nodule activity. No nodule-dependent cytokinin or auxin-like compounds were detected as nodule products, which might affect root or shoot growth. The work has been discontinued.

Ureide export from nodules of nodulating and non-nodulating soybeans were examined in relation to acetylene reduction. Ureides can be detected in non-nodulating plants and are present in high levels if available soil N is very low. In the field, ureides are not exclusively related to N-fixation. A correlation with fixation was observed only with ureide concentration in the lower stem. Similar rankings for nitrogenase activity and ureide levels were observed.

Lima bean

Some of the rationale for beginning work on improvement of lima bean as a crop for humid regions is no longer sound. The incidence of disease is high, and the efforts made to introduce resistance to lima bean golden mosaic from wild forms and from interspecific crosses have not been as successful as was originally hoped. Lima beans are at least as susceptible as cowpeas to damage caused by thrips. The cost of staking the climbing forms make it unlikely that they will ever become widely grown as a field crop and although good bush types are available, lodging results in the loss of most of the yield that bush forms produce in humid environments. For these reasons and because of the recent progress made in overcoming some of the factors that limited production of cowpeas in humid environments and on acid soils, further work on lima bean will be discontinued.

Cooperative programs

USAID: Tanzania food crops research

Participation in this project supported by USAID permits IITA's Grain Legume Improvement Program to undertake crop improvement research in an area representative of a large part of East Africa. Since the initiation of the project in 1973, about 1,000 germplasm lines of cowpea and 100 lines of soybean have been collected and evaluated. All these lines are being maintained for use in breeding programs. The agronomically superior and disease resistant lines have been included in multilocational yield trials as well as used as parents in hybridization work.

Cowpea

Variety Trials. Seven different multilocational trials were conducted to identify high yielding and widely adapted varieties. Tanzania Cowpea Uniform Trials consisted of 16 entries, planted at nine locations and Tanzania Cowpea Uniform Trials consisted of 25 entries, planted at seven locations. The performance of varieties differed from location to location. On an overall basis, however, TVx 1948-01F gave the highest mean yield (1,482 kg/ha), closely followed by Tkx 9-11D (1,471 kg/ha) and Tkx 9-16D (1,424 kg/ha). These were better than the check variety SVS-3 at most of the locations. In addition, these varieties possess resistance to aphid-borne mosaic, which is a widespread disease in Tanzania. Other promising lines were TVu 1502, and TVx 33-1J. The mean yield of TVu 1502 and TVx 33-1J in all locations during 1977-79 were 1,476 kg/ha and 1,421 kg/ha, respectively, as compared to 1,346 kg/ha for SVS-3. Therefore, these have been included in the village trials of 1980 crop season.

In Tanzania, 280 newly developed breeding lines were evaluated in Preliminary Trials 1 and 2. The top 48 lines have been selected for further evaluation next season. The mean yield of the best breeding lines ranged from 2,500-3,100 kg/ha as compared to 2,000 kg/ha for SVS-3. These lines will be evaluated in multilocational trials.

Tanzania's early-maturing cowpea variety trials consisted of 16 entries, planted at 10 locations to identify high-yielding widely adapted short-duration cultivars, which would fit as catch crop in the short rains and also as a late planted crop in the main season. 4R-0267-1F gave the highest yield (1,956 kg/ha), closely followed by 12-2C (1,523 kg/ha), ER-1 (1,468 kg/ha) and 5/8/2/2 (1,467 kg/ha). The performance of 5/8/2/2 has been good in the previous years. These have been included in the village trials planned for 1980.

A total of 38 breeding lines were evaluated in IITA Uniform Trials 1 and 2 at Miwaleni. VITA-4, TVx 1948-01F, TVx 2394-02F and TVx 309-1G appeared to be most promising.

Evaluation of segregating populations. Forty-six F_2 populations, 20 F_3 populations and 280 F_4 and F_5 selections were evaluated. A total of 318 desirable individual plants possessing disease resistance and good agronomic characteristics were selected from these populations. These were multiplied in the dry season (July-October 1979) and reselected for agronomic characteristics. In addition, 184 individual plants selected from IITA disease subpopulations and 144 breeding lines selected from IITA Preliminary Trial 1 were also evaluated in the dry season. Based on disease resistance, maturity and yield potential, a total of 185 lines were selected for evaluation in initial yield trials in the 1980 crop season. Most of these selections possess multiple disease resistance.

New crosses. To combine disease and insect resistance with good agronomic characteristics, the selected breeding varieties were crossed with known sources of resistance to diseases and insects. TVu 3629 and TVu 410 were used as resistant sources for top necrosis and aphid-borne mosaic virus, respectively, TVu 7274, TVu 1509 and ER-1 for resistance to thrips and TVu 2027 for resistance to bruchids. A total of 56 types of new crosses were made, which included two- and three-way and double crosses. The F_1 plants are being grown in the screenhouse, and the F_2 populations will be evaluated in field in the coming crop season.

Crosses with wild cowpeas. These cowpeas have been noticed growing in abundance along the road sides in several parts of Tanzania. They show a great deal of diversity with respect to leaf type and shape, but all have very small pods and small seeds. It has been observed that despite heavy insect population in nature, these wild cowpeas thrive well and set numerous pods. They may have resistance or tolerance to insect pests. Because insect pests are major problems in cowpea production, a crossing program was initiated this year to transfer insect-resistant genes (if any) from the wild cowpeas. These are being screened for insect and disease resistance. Ten different types of crosses have been made, using wild cowpeas and promising varieties. The F_1 plants are being grown in the screenhouse where backcrosses and three- and four-way crosses are being made. The wild cowpeas freely crossed with the cultivated types and F_1 plants are fertile. The segregating populations derived from these crosses will be evaluated next season.

Soybean

Variety Trials. Tanzanian Soybean Uniform Trials consisting of 12 varieties and Tanzanian Soybean Advanced Trial consisting of 25 entries were conducted at several locations to identify suitable varieties of soybean. Considering the yield potential and susceptibility to bacterial pustule, nine varieties evaluated in the uniform trial were better than Bossier. However, several lines evaluated in the advanced trial were found superior to Bossier. 30295-13-6 gave the highest yield (1,444 kg/ha) followed by 30280-2-17 (1,411 kg/ha) and 30106-2-1 (1,366kg/ha) as compared to 943 kg/ha for Bossier. In addition to being high-yielding, these new lines were free from bacterial pustule and had better seed quality. These will be evaluated next season.

Hybridization program. Based on the data from soybean multilocational variety trials conducted during the past three years, Bossier has been identified as the best variety. It has also been recommended for cultivation. However, it suffers from poor quality seed and loses viability rapidly during storage. One of the local varieties, 3H/1, has yield potential and good seed quality, but it is later in maturity and susceptible to diseases. Therefore, several crosses were made between these two varieties to combine high yield and disease resistance of Bossier with good seed quality of 3H/1. The F_1 plants are being grown in the screenhouse, and the F_2 plants will be evaluated in field in the coming season.

IDRC: Upper Volta cowpea improvement

The Uppler Volta Cowpea Improvement Program began in 1977 with support provided by the government of Upper Volta and the International Development Research Center of Canada (IDRC). The project's research, concentrated at Kamboinse for breeding and at Saria for agronomy work in 1979, extends the range of environments sampled by IITA into the semi-arid savanna and serves the regional SAFGRAD program as well as the national program. Research is focused on the development of lines of cowpea that combine stable yield with resistance to insect pests, diseases and drought stress. Material originating from IITA, and consisting of On-farm, Upper Volta, International, Advanced and Preliminary Yield Trials has been the major source for selection of lines adapted to Upper Volta environments.

On-Farm Trials. Cowpea varieties were tested in 1979 on the basis of their performance in different ecological zones in 1978. In summary, the variation in yields of some varieties was shown to be dependent on rainfall during the growing season at the different sites. On the average over locations, TVx 289-4G was the highest yielder as in last year's experiments, and it was particularly good in wetter areas. Because of its consistently good yields, it has been recommended for release and is renamed Kamboinse Niebe-1 (KN-1) in Upper Volta. During 1979, it was included in the demonstration plots, and Upper Volta's Ministry of Agriculture has multiplied 1 ha of its seed during the rainy season for distribution next year. Based on its superior performance over a wide range of locations in IITA's International Trials, it has also been described as VITA-7.

Upper Volta Yield Trial. Lines which performed consistently well in 1977 and 1978 and others showing promise, were also included in Upper Volta Yield Trial in 1979. The main objective was to assess stability of yield and adaptability across ecological zones. The trial comprised several cultivars, six improved and one local. Among the improved cultivars, four were spreading and two erect types. The experiment was grown at 11 locations, three of which were at Kamboinse representing three soils on a catenary slope, a shallow soil at the top of the sequence with low fertility and poor water holding capacity, a soil on the middle slope, and a deeper, more fertile soil on the lower slope.

On the average over locations, TVx 289-4G produced the highest yield (1,642 kg/ha). The most suitable line for low-yielding environments appeared to be TVx 1948-01F. It combined good yield with consistently good performance. At Kamboinse, the highest yields were obtained on the middle slope, although plant growth, in terms of plant height and width, was better on the fertile deep soil at the bottom of the slope. The low yield of TVx 289-4G and other spreading varieties on the lower slope was the result of excessive vegetative growth on fertile soil with adequate water, which led to poor pod development.

The yield of the most erect variety, TVx 309-1G, was unaffected. A similar phenomenon was observed in management and advanced trials on the same site.

International Yield Trials. These are parts of IITA's series of Cowpea International Trials. There were two trials: Trial 1 consisted of 19 semi-erect and spreading types plus a local check; Trial 2 consisted of 9 erect lines plus a local check. They were sown at Farako-Ba, Kamboinse and Saouga.

Yields were highest at Kamboinse and lowest at Saouga. They were particularly low in Trial 1 at Saouga where a sand storm at the end of July retarded growth.

In International Trial 1, on the average over three locations, TVx 289-4G gave the highest seed yield (1,599 kg/ha). Its performance was particularly good at Kamboinse and Farako-Ba where there was adequate rainfall but poorer under the relatively dry conditions at Saouga, confirming observations of its performance in other trials.

TVx 1999-2E gave the second highest yield with 1,477 kg/ha, not significantly different from TVx 289-4G. TVX 1999-0F, a sister line of TVx 1999-02E, also produced a reasonably good yield and was the best yielder at Saouga. These two lines were the top yielders in Advanced Trial 1 in 1978. Because of their consistently good performance during the past two years, particularly in the dry areas, they appear to be potential new selections for distribution. They will be included in the 1980 Upper Volta Yield Trial and further tested in a wider range of environments.

In International Trial 2, TVx 1836-015J was the best yielder (1,514 kg/ha), ranking first at both Farako-Ba and Kamboinse and being not significantly different from the other improved varieties at Saouga. TVx 1193-7D and TVx 2394-02F also yielded well. TVx 1193-7D performed well in the last year's trials at different sites in West Africa, and based on its superior performance, has been described as VITA-6.

The best varieties produced significantly better seed yields than the local checks at Farako-Ba and Kamboinse but not at Saouga where only TVx 1999-02E and TVx 199-01F have equalled the local variety in this year's International Trials. Photoinsensitive IITA lines appeared to switch to reproductive growth too soon to accumulate sufficient vegetatively but switched to support high yields. Photosensitive lines grew well vegetatively but switched to reproductive growth too late to avoid moisture stress during pod filling. In the local variety, the phases are synchronized closely with the rainfall so that vegetative growth and reproductive growth are completed in time to make the best use of available soil moisture.

Advanced Yield Trials. These evaluate promising lines, selected on their preliminary evaluation, across a range of environments. Three trials, each including 25 varieties, were sown at Farako-Ba, Kamboinse and Saouga. In all trials, VITA-1 was poorest because of its sensitivity to photoperiod. VITA-4 and VITA-5 were better suited to favorable environments.

In Trial 1, Ife Brown was the highest yielder at Farako-Ba and Saouga, (1,669 kg/ha) and (1,358 kg/ha) but several lines were similar to it. TVx 289-4G was the highest yielder at Kamboinse, but not significantly different from the most promising lines. It did best in environments that favor high yield. Among the new lines, TVx 3381-02F was the highest yielder at Farako-Ba (1,633 kg/ha), and TVx 3405-014E was the highest yielder at both Kamboinse (1,952 kg/ha) and Saouga (1,244 kg/ha). On the average over the three locations, TVx 3381-02F was the highest yielder (1,566 kg/ha), and it was the most stable line across environments. Other high-yielding lines were TVx 3405-04E (1,542 kg/ha), 7R-0189D (1,487 kg/ha) and TVx 3385-027D (1,470 kg/ha). These varieties produced mean seed yields either similar to or better than the best standard check variety (VITA-4).

In Trial 2, no single line was the highest yielder at all three locations. TVx 3404-012E was the highest yielder at Farako-Ba (1,627 kg/ha), TVx 3391-014D at Kamboinse (2,081 kg/ha) and TVx 3343-03E at Saouga (1,198 kg/ha), but none of them was significantly superior to the best performing standard check variety. On the average over the three locations, TVx 3404-012E was highest yielder (1,477 kg/ha) followed by TVx 2724-01F (1,405 kg/ha) and TVx 3385-029E (1,399 kg/ha).

In Trial 3, no single line performed best at all locations as well. TVx 3428-03E was highest yielder at Farako-Ba (2,561 kg/ha) and was significantly better than the check variety (Ife Brown). TVx 3337-015E was best at Kamboinse (1,848 kg/ha), but not significantly different from the best check variety (VITA-4). At Saouga, TVx 3382-033E was significantly better (1,651 kg/ha) than the best check variety (Ife Brown). On the average over locations, TVx 3428-03E was the highest yielder (1,846 kg/ha), followed by TVx 3382-033E (1,786 kg/ha). Ife Brown was the best yielder among the check varieties (1,567 kg/ha)

There were differences among sites in days to flowering, number of pods/m^2, seed size and threshing percentage. Flowering at Kamboinse was 3-4 days earlier than at the other sites. Of the components of seed yield, the number of pods/m^2 accounted for most of the variation in yield between sites.

In extremely dry environment of Saouga, a drought from July 21 to August 7 and again during pod filling, combined with high temperatures contributed to the poor growth and yield. Other contributing factors were low fertility and water holding capacity of the soil. Soil analysis showed a very low level of P low organic C (0.28 percent) and a high proportion of sand to silt and clay. The water holding capacity of a soil is very critical, especially in areas where rainfall is limited and irregular.

Records of height and width did not adequately describe plant growth, especially for spreading type varieties in Trials 1 and 2 where plant width is restricted by between-row distance. Another method of assessing vegetative growth is needed. For erect varieties in Trial 3, the present measurements of growth serve to explain the yield differences, particularly between Farako-Ba and Kamboinse.

Preliminary Yield Trials. Three trials were sown at Kamboinse. Two were IITA Preliminary Yield Trials, each consisting of 144 entries, and one was the Upper Volta Preliminary Trial, including 256 entries. The trials compared selections from F_3 breeding nurseries with standard checks and a local variety.

In all three trials, several new lines produced yields similar to the best standard checks. TVx 3882-02E produced the highest yield (2,597 kg/ha) in Trial 1 TVx 1850-01H (2,343 kg/ha) in trial 2 and TVxUV-140 (2,260 kg/ha) in Upper Volta trial. Yield of these varieties were 8, 14 and 10 percent higher than the best check in the respective trials.

Improved varieties do not have the preferred large, white seeds, but crosses are now being made to combine large seed into the best lines.

IITA maize varieties carrying multiple resistance to maize streak virus, P. polysora, H. maydis ***and downy mildew.***

CEREAL IMPROVEMENT PROGRAM

Introduction

Maize and rice command high priority by many governments in Africa. Maize is the basic food in many parts of the continent, and it is grown both as a sole crop and as an intercrop with tuber crops, legumes and other cereals. Though not grown in large areas in Africa, rice is in rising demand and is of increasing importance in the production systems of a large number of farmers.

The Cereal Improvement Program pursued research on genetic improvement, crop management and analysis of insect and disease problems in maize and rice. The research is being conducted in collaboration with a number of African countries, International Rice Research Institute (IRRI), Centro Internacional de Mejoramiento de Maiz y Trigo (CIMMYT) and West Africa Rice Development Association (WARDA).

Maize

The primary objective of the maize improvement program is to develop high-yielding stable varieties for the different ecologies in Africa. The program emphasized the following areas of work in maize during 1979:

1. Improvement of yield potential and the level of genetic resistance in maize streak resistance populations.
2. Development of early-maturing maize varieties with resistance to maize streak virus and other tropical diseases.
3. Screening for maize borer resistance.
4. Combining streak and downy mildew resistance in tropical germplasm.
5. Initiation of multiple disease and insect resistant maize populations.
6. Continuation of the efforts to select improved maize plant type with adaptation to the tropics.
7. Production and evaluation of topcrosses.

Genetic improvement

Resistance breeding

Breeding multiple resistance in promising maize varieties was the major task in 1979. Maize streak virus, downy mildew, ear and stalk rots complex, leaf rust, blight and stemborer are the major constraints to tropical maize. Populations were initiated to breed against these constraints by crossing CIMMYT varieties and U.S.A. cornbelt or temperate varieties with TZSR, IB 32 and Asian downy mildew resistant composites. S_1 recurrent selection and full-sib breeding procedures were employed for improvement of these populations through multilocation testing.

In Nigeria, different ecological zones exist for screening against specific diseases, insects and drought tolerance. Research was carried out at locations ranging from savanna forest to high-rainfall areas and from low- to highland zones.

Maize streak virus. Backcrossing was employed to breed maize streak virus resistance into tropical maize inbred lines, IITA and CIMMYT composites, U.S.A. cornbelt inbred lines adapted to the tropics and African national maize program varieties. Four derived streak-resistant populations were compared to their original varieties in the 1979 first season (Table 1). This was also to confirm results of the 1978 third season and demonstrate a new vector distribution method in the field.

Individual plants were infested with viruliferous leafhoppers after 10 days of plant germination. The earliest streak symptoms on the plants were observed three days after release while the latest were observed 4½ weeks after release.

Results for streak incidence and grain yield of the two versions, artificial infestation and virus-free conditions, are summarized in Table 1. Streak-resistant populations were significantly lower in infection than normal populations. In disease situations, the streak-resistant populations were significantly higher in yield than normal populations. In disease-free situations, no significant differences in yield were noticed between resistant and normal populations. The results of these two trials clearly indicate significant improvement in streak resistance without losing yield potential.

Tables 2 and 3 give the general performance and yield of streak-resistant, full-sib families selected among six white and two yellow composites at IITA and Mokwa. The full-sib families were selected based on a minimum of 5 t/ha yield and foliar disease resistance.

In the 1979 third season, white and yellow full-sib families from the above populations were planted in two isolated

Leafhopper infestation in the field is accomplished with an improved method shown here. Leafhoppers in the plastic vials are anesthetized with passing CO_2 from the tube.

fields for recombination. Within-family and within-row selections were made to improve plant type. Two newly constituted high-yielding and streak-resistant white and yellow populations are expected to be ready by the end of 1980 for international testing programs.

During the 1979 first season, TZSR and early populations were crossed to combine early maturity with streak resistance and subjected to streak pressure. During the second season, the S_1 lines were developed from resistant plants by subjecting them to streak pressure in the screenhouse. The overall objective is to develop two new white and yellow streak-resistant early populations for the short-rainy season savanna areas and the mixed cropping areas in the humid and subhumid forest zones.

A number of exotic maize varieties, promising composites and Africa, Asia, Mideast and U.S.A. cornbelt varieties that carry resistant genes to diseases other than streak were challenged under screenhouses for maize streak virus reaction. Desirable traits from these materials were incorporated into the breeding stock while looking for new sources of resistance to streak.

Maize mottle virus. In the 1979 dry season, a virus disease tentatively identified as maize mottle was observed in severe form in a CIMMYT (EVT 12) trial. Poza Rica was the most sensitive variety.

Downy mildew disease. In the 1979 first season, a program was initiated in coooperation with the National Cereals Research Institute (NCRI), Nigeria, to breed against downy mildew, a fungus showing close relationship with *Sclerospora sorghi* and causing severe and widespread yield losses. In 1970, the disease was first observed in Nigeria in Samaru, Kaduna State. Then, in 1975, near Owo, Ondo State, it was found in severe form. In 1979, a survey revealed the wide spread of this disease from its original location. Downy mildew is in its severe form at Owo, Ikare and Ekiti, Ondo State; Okenne, Lokoja and Kabba, Kwara State; and Igara and Auchi, Bendel State. Losses are estimated at 75-100 percent.

Asian downy mildew resistant sources were screened with local checks in a naturally infected downy mildew area at Owo to determine whether or not they can hold their resistance in Africa. Downy mildew resistant sources were received through the International Downy Mildew Maize Nursery, Thailand. Results showed that they had a good level of resistance to Nigeria's *Sclerospora* sp. compared to the local checks, TZPB, TZE4, TZSR-W and TZB, which showed 72, 67, 61 and 45 percent infection, respectively (Table 4).

Two locations have been selected for further screening of downy mildew. Facilities in Nigeria at Owo are being developed by NCRI and at Kabba by IITA. Under such joint efforts, crosses of Asian downy mildew resistant materials with IITA streak-resistant lines and advanced generation materials will be tested for downy mildew reaction in May 1980.

Stemborers. Stemborers are one of the major constraints in maize production in Africa. One of the long-term solutions to this problem is the development of resistant varieties. To get a uniform infestation of borers in the field for screening, a borer-rearing unit is being developed. Until this is in full operation, work is going on to develop a method of distributing *Sesamia* in the field. The insects for these trials are reared on maize stalks.

Four different infestation techniques for *Sesamia calamistis*, either eggs or first instar larvae, were trialed with TZPB:

1. Egg-Brush Method (EBM). Separated eggs (15) were dropped by means of a brush into a whorl of the plant's leaves.
2. Egg-Agar Solution Method (EAM). Separated eggs were suspended in a 0.015 percent agar solution. The suspended eggs (10-15) were then distributed by a syringe into a whorl.
3. Larvae-Brush Method (LBM). First instar larvae (15) were dropped by means of a brush individually into a whorl.
4. Larvae Dispenser Method (Bazooka) (LDM). First instar larvae (10-15) were dispersed in a fine cop grid and then by a calibrated distribution mechanism onto a plant. This method was developed by CIMMYT.

Twenty plants per replication were infested by each technique at the early whorl stage (15-20 days). The treatments were randomized and replicated 10 times. The

Leaf samples of two segregating maize plants from the cross N28 X TZSR: left, multiple resistance to streak and P. polysora; ***right, resistant to streak but susceptible to*** P. polysora.

Table 1. Streak incidence and yield of streak resistant vs. original population with and without virus inoculation.

Variety	1978 Third season			1979 First season		
	Streak incidence (%)	Grain yield (t/ha)		Streak incidence (%)	Grain yield (t/ha)	
		Infested	Control		Infested	Control
TZPB	71	2.5	4.0	74	1.2	5.4
TZPB-SR*	9	3.6	3.8	16	6.8	5.9
TZB	68	2.1	4.1	79	1.0	6.7
TZB-SR	17	5.0	4.2	21	5.8	5.1
La Maquina 7422	78	0.7	4.6	86	0.4	4.4
La Maquina 7422-SR	15	3.4	4.0	16	6.4	4.8
096EP6	73	1.3	3.3	91	1.0	2.3
096EP6-SR	18	3.1	3.2	26	4.2	2.5
TZSR-Y (check)	9	4.1	4.5	17	4.9	5.5
TZSR-W (check)	8	3.0	4.7	27	5.3	4.4
LSD	12	1.8	1.7	3	2.3	2.5

**SR : streak resistant.*

Table 2. General characteristics of selected streak-resistant white full-sibs (IITA and Mokwa, 1979).

Pedigree	Full sibs tested	Full sibs selected	Days to flower	Yield (t/ha)	(1-5) blight score	(1-5) rust score
TZPB	30	10	58	7.59	1.5	1.6
TZB	86	9	58	8.64	1.5	1.6
Tlaltizapan 7322	40	7	60	9.12	1.4	1.3
Gemeiza 7421	26	5	59	7.81	1.6	1.5
Poza Rica 7422	20	3	60	8.53	1.5	1.5
La Maquina 7422	15	6	59	7.36	1.3	1.0

Table 3. General characteristics of selected streak-resistant yellow full-sibs (IITA and Mokwa, 1979).

Pedigree	Full sibs tested	Full sibs selected	Days to flower	Yield (t/ha)	(1-5) blight score	(1-5) score
Poza Rica 7428	30	6	58	7.28	1.5	1.6
096EP6	8	2	58	5.22	1.5	1.5

Table 4. Screening of Asian maize cultivars resistant to downy mildew (DM) (Nigeria, 1979).

Entry No.	Cultivars	Origin 1979	Total plants	Infected plants	DM (%)
1	Suwan 1 (S) C4 white	Thailand	7	0	0
2	Thai comp. 1 early DMR (S) (S) CS	Thailand	9	0	0
3	Thai comp. ¾ F_2	Thailand	9	1	11
4	Caripeno DMR (S) C2	Thailand	9	0	0
5	Yellow DMR source	Thailand	8	0	0
6	Thailand comp. E. DMR	Thailand	14	0	0
7	Suwan 2 x Medok	Thailand	11	0	0
8	Suwan x Penjalinan	Thailand	4	0	0
9	Suwan 1 x Genjah	Thailand	10	0	0
10	Suwan 1 x Indonesian early	Thailand	12	0	0
111	Suwan source 2	Thailand	13	0	0
12	Suwan source 4	Thailand	13	0	0
13	Suwan source 9	Thailand	12	0	0
14	Thai DMR 6	Thailand	13	0	0
15	Early DMR comp. 1	Thailand	9	0	0
16	Early DMR comp. 2	Thailand	7	0	0
17	Phil. DMR comp. 2	Philippines	5	0	0
18	D 744	India	10	0	0
19	EVA (MDR-1) 77-11	India	10	0	0
20	Harapan x Medok	Indonesia	2	0	0
221	TZSR white check	IITA	18	11	61
22	TZPB check	IITA	18	13	72
23	TZB check	IITA	11	5	45
24	TZE4 check	IITA	15	10	67

Table 5. Overall assessment damage of maize plants infested with S. calamistis, *using four infestation techniques.*

Infestation technique	Plants with leaf feeding (%)	Mean borer no. from 25 percent sampling	Mean borer no. from 2 DH/SB	Damage DH/SB (%)	Mean cob weight (kg)
EBM	53.6	2.9	5.5	22.4	1.2
EAM	38.7	2.5	4.2	20.1	1.2
LBM	47.1	4.3	6.9	50.0	1.1
LDM	86.6	8.9	12.9	72.6	0.7

DH – dead hearts.
SB = stalk breakage.

Sesamia calamistis ***infestation in the resistance breeding maize nursery at Umudike, Nigeria. (October 1979.)***

evaluation of the test was made by using the following criteria:

1. Leaf feeding, 1-9 rating scale.
2. Twenty-five percent random sampling of infested plants to determine number of borers.
3. Dead hearts, stalk breakage at weekly intervals and number of established larvae.
4. Yield.

Table 5 shows the overall assessment of damage of maize plants due to artificial infestation with *calamistis*. A comparison of the four different infestation techniques indicates that the LDM technique had the highest surviving number of larvae. The method does not damage the first instar larvae. It also has the highest number of plants with leaf feeding, which means that larvae established well. Also, dead hearts and stalk breakage results due to the high number of surviving larvae are highest with the LDM technique. The total number of infested plants with leaf feeding was 86.6 percent. This number should be increased at least above 90 percent to get sufficient uniform infestation.

Screening of large amounts of maize germplasm for resistance to the important stemborer, *S. calamistis,* has been conducted at Umudike, Nigeria, where severe natural infestation occurred during the 1979 second season; 724 different maize genotypes, including IITA-developed genotypes and newly introduced populations or lines, were screened in three different experiments.

In the first experiment, 65 genotypes were tested at two different sites at Umudike. Most of the genotypes were severely damaged by borer. However, the borer pressure was considered to be extremely high, and three genotypes with less damage were selected as tolerant (Table 6).

In the second experiment, 205 IITA newly developed genotypes were planted at Umudike in early August with 4 replications in a complete randomized block design. Each replication was a single row plot with 10 plants in 2 m. No chemicals were applied. Natural severe infestation occurred from the early stage.

Approximately 95 percent of the genotypes tested were rated as susceptible or highly susceptible with 11 genotypes selected as intermediate for resistance (Tables 7 and 8).

Three genotypes, (ECEM × E-573) × N3 × MAD × TZSR (B25), TZSR-W × ZUCA 11, and RB14AHT, A × REV, showed relatively uniform resistant reactions in all four replications. The other seven genotypes rated highly susceptible in at least one replication. Most of the selected lines in this experiment carry resistance to maize streak virus. Most lines or crosses in Table 8 were developed in Africa. Selected genotypes were sibcrossed or crossed with other selected genotypes for further improvement of resistance. Highly significant differences were found among genotypes. The coefficient of variation in this experiment was 17.6 percent.

In the third experiment, 454 genotypes from the U.S.A., Asia (S. Korea and Thailand), CIMMYT and IITA were planted in single-row plots having 20 plants. Two single cross hybrids were planted as checks around the field and also in two central straight rows across the field as an index of uniformity of infestation. Ratings were made one week after average flowering time. Insecticide, Kokotin, was applied two weeks after planting to control a high natural pressure. Although borer infestation was less than expected, differences of rating scores were clear. Ninety-one percent of the genotypes rated between intermediate for resistance and highly susceptible. Ratings of low susceptibility were given to 43 lines, which were significantly more tolerant than all other lines (Table 9). Three of these entries were TZSR-W inbreeding lines.

Table 6. Three genotypes surviving previous stemborer screenings considered tolerant at two sites (Umudike, 1979).

Genotypes	Ratings (1-5) Site A	Site B	Yield (kg/ha) (1978)
295 FS 1 ○ 3	3.5 b	4.2 b	4727
295 F 5 ○ 2	3.8 b	4.8 a	5038
S-1-13 ○ 1	5.0 a	3.8 b	-
LSD (0.05)	0.77	0.70	

FOR PASTE—

⊗ ⊗ ⊗

Table 7. Average frequency distribution of 205 maize genotypes to stemborers* (Umudike, September 1979).

Ratings	No. of genotypes	Percent of frequency/w 5% confidence limits
1 (81-100 percent survival) (resistant)	-	-
2 (61-80 percent survival)	-	-
3 (31-60 percent survival)	11	2.77- 5.4- 9.66
4 (11-30 percent survival)	95	38.02- 46.3- 52.18
5 (0-10 percent survival)	99	42.89- 48.3- 57.11
Total	205	100.0

**Essentially S. Calamistis. Overall average ratings: 4.5, based on 1-5 rating.*

Table 8. Eleven selected resistant genotypes of maize to stemborers (Umudike, 1979).

Genotypes	Ratings (1-5)
(ECEM × E-573) × N3 × MAD × TZSR	2.8
TZSR-W × ZUCA-11	2.8
(ECEM × E-573) × REV ○ S_1 bulk	3.0
IB 32 × REV-B8 × ECEM × E-573	3.0
RB14AHT, A × REV ○	3.0
IB 32 × REV-B8 × N# bulk	3.2
ZCA × TZSR-Y (1)	3.5
SC × REV ○ – (2)	3.5
REV, S_1 × B30 – (2)	3.5
TZSR-W × ECEM × E-573 – (3)	3.5
ZUCA × TZSR-Y - (2)	3.5

The information obtained in this experiment were used at IITA for recombining stemborer and maize streak resistance.

Population improvement

Three varieties that were developed during the years at IITA are TZB and TZPB, now widely grown in Nigeria, and TZo_2, still an experimental variety. These varieties are being further improved by the S_1 recurrent selection procedure.

TZB. A recombination plot of the seventh cycle of selection was grown during the 1978-79 dry season under irrigation. Ninety-three ears were selected for the next cycle of selection. A total of 288 S_1 ears were produced. These S_1 lines will be tested in the 1980 first season at several locations. The recombination will be made in the 1979-80 dry season.

TZPB. Three hundred and six S_1 lines and 135 full-sibs from selected populations for prolificacy were tested at IITA, Ikenne, Onne and Mokwa. Based on the results obtained in the four locations, 40 S_1 lines (13 percent) with a yield range of 5.8-7.0 t/ha and 24 prolific full-sibs (18 percent) with a yield range of 6.1-8.5 t/ha were selected. The average yield of the control TZPB population was 4.9 t/ha. Following the results of comparison trial of TZPB and TZPB prolific, it was decided to combine the two populations. The selected S_1 lines and full-sibs were recombined in the isolated field by the half-sib method.

TZo_2. At IITA and Mokwa, 320 S_1 lines were tested. The performance of these lines was relatively poor with low yield and high disease incidence. Two CIMMYT hard endosperm materials (OMPT IIA and EVT 15A) were tested in the 1979 first season. Several promising entries were found compared to TZo_2 (Table 10).

CIMMYT international testing. Five experimental variety trials, EVT 12, EVT 13, EVT 16 for normal and OMPT 11A and EVT 15A for hard endosperm o_2 maize were conducted at IITA, October 1979-February 1980. Promising experimental varieties are listed in Table 10.

Early-maturing variety testing. A number of early-maturing composite varieties were developed recently at IITA. A major emphasis during 1979 was to test them extensively and select the most promising ones. Eleven populations were evaluated at five locations in Nigeria in the

Table 9. Frequency distributions of 454 maize genotypes for stemborer ratings (Umudike, November 1979).

Ratings	No. of lines	Percent of frequency
1 (resistant)	7	1.5
2	36	7.9
3	151	33.3
4	144	31.7
5 (susceptible)	116	25.6
Total	454	100.0

Overall average rating – 3.7.
Average ratings of check : IB 32 × N3 = 2.9.
Suweon 19 = 3.1.

first season and two locations in the second season. Two varieties, TZE_4 and TZE_5 were the most promising. The best nine varieties were tested again in two population densities in three locations (IITA, Ikenne ad Mokwa) in the first season and in two locations (IITA and Ikenne) in the second season. A split plot design was used with population density as main plots and varieties as subplots. There were four replications with 4-row plots in every location.

The varieties were similar to each other (except variety Upper Volta that was used as a check) for flower date, plant and ear height and yield (Tables 11 and 12).

There were some differences in percent of ear rot and lodging. TZE_4, TZE_{15}, TZE_{16} and TZE_{17} showed lower damage from ear rot and TZE_4, TZE_{16} and TZE_{17} had better resistance to lodging. Lodging, as expected, was higher in the high-population density.

The average yield range was only 2.52-3.17 t/ha. Two varieties, TZE_4 and TZE_{15}, yielded more than 3.0 t/ha. They had also been the highest-yielding varieties in the 1978 trial. There is an interaction between these two varieties and the plant population even though the difference in yield between the two was very low. TZE_4 yielded more at the high-population density while TZE_{15} was better at the low-population density. Similar results were obtained in 1978 (Table 13). However, TZE_{15} was more sensitive to lodging than TZE_4. Therefore, TZE_4 is the most promising early variety and was selected for seed multiplication and distribution. TZE_3, which was the third highest yielding variety, was even more sensitive to ear damage and lodging than TZE_{15}.

The average yield in the high plant density (66,650 plants/ha) was 10 percent higher than in the low plant density. Similar results were also obtained in 1978 (Table 13). Higher population densities should be applied for testing of early-maturing varieties: it is intended to continue the selection cycles under high-population densities for early varieties.

Advanced varieties multilocation testing. Nine promising maize composites were tested during 1979 at IITA, the Onne substation and Ikenne, locations in the forest zone with high rainfall, as well as at Mokwa and Zarra, locations in the derived savanna zone in northern Nigeria (Table 14). The experiments had been initiated in 1978 at IITA, the Onne substation and Ikenne; the average yields of the medium-maturing varieties over location and years were very similar. Except the lower average yield at the Onne substation, average yields in the other four locations were similar. However, there were different variety × environmental interactions. TZPB and La Maquina 7422 showed the highest and lowest yields at the Onne substation, respectively, while La Maquina 7422 gave the highest yields in Mokwa and Zaria.

Similar results were obtained for TZE_3 and TZE_4. These two varieties had very similar yields over locations and years. But, TZE_3 yielded more than TZE_4 in the derived savanna zone while TZE_4 gave higher yields in the forest zone.

Topcross approach. Topcrosses (variety × line crosses) have some prospect in many African countries, that do not have an organized seed industry. Conventional single

Table 10. Grain yield (kg/ha) of some promising CIMMYT experimental varieties (IITA 1979-80 dry season).

Trial	Variety	Yield	Ear aspect[a]
EVT 12	Guanacaste 7729	3133	2.3
	Dholi 7622	3053	1.8
	Across 7622	2987	2.2
	Ferke (2) 7622	2880	1.8
	Kanima 7725	2787	2.8
	TZB (check)	2347	2.2
	TZPB (check)	2453	1.8
EVT 13	Across 7728	2507	1.8
	Across 7736	2373	2.2
	Sete Lagoas 7728	2373	1.8
	Across 7635	2227	2.2
	TZB (check)	2093	1.8
EVT 16	Tlaltizapan 7844	2867	2.1
	Across 7734	2573	2.0
	Tlaltizapan 7833	2560	2.2
	TZB (check)	2480	2.0
OMPT 11A	White o_2 pool (Flint Sel.)	3773	2.2
	Tuxpeno-1 H.E.o_2	3373	2.6
	Amarillo Dentado H.E.o_2	3173	2.0
	TZPB (check)	3360	1.8
	TZo_2 (check)	2560	2.0
EVT 15A	Across 7738	2493	3.0
	Ilonga 7740	2280	3.1
	TZB (check)	2560	2.3
	TZo_2 (check)	1933	3.1

[a]Ear aspect. 1 = excellent; 5 = very poor.

Table 11. Agronomic characteristics of TZE varieties at two plant population densities.

Variety	Days to silking	Ear rot (%)	Plant ht. cm	Ear ht. cm	Lodging percentage 66,650 pl./ha	Lodging percentage 44,450 pl./h.	Lodging percentage Average
TZE_2	48.2	11.6	163	79	27.6	12.8	20.2
TZE_3	47.5	14.6	164	84	44.6	33.3	39.0
TZE_4	47.5	7.0	166	85	12.9	10.5	11.7
TZE_8	47.2	12.9	168	80	39.5	28.6	34.1
TZE_{13}	47.5	10.1	164	82	29.8	16.8	23.3
TZE_{14}	49.0	14.7	170	85	45.5	40.7	43.1
TZE_{15}	47.7	7.9	162	79	32.0	20.5	26.3
TZE_{16}	48.2	6.4	160	78	23.2	13.7	18.5
TZE_{17}	47.3	8.6	159	78	20.2	17.6	18.9
Upper Volta	45.0	18.5	151	74	52.6	51.1	51.9

cross and double cross hybrids, even if proved productive, face difficulty in popularization. Therefore, IITA scientists have pursued the topcross approach to determine their yield advantage over the parent varieties.

Twelve varieties developed at IITA, CIMMYT and NCRI have been employed in the topcrosses (Table 15). The better among the topcrosses yield 30-87 percent over the parent varieties. In an observational trial hit by drought, the topcrosses have done even better.

The topcross approach seems to offer promise for reasons of relative simplicity in seed production. It is recognized that the topcrosses will perhaps be *inferior in* yield potential to the conventional double crosses but seem to offer a big improvement over the populations.

IITA intends to develop S_3-S_4 lines from diverse genetic backgrounds and with resistance to insects and diseases. These lines will be made available to several national programs in *Africa to evaluate the prospects for*

Table 12. Grain yields of TZE varieties at four locations with two population densities (1979).

	Grain yield (t/ha)										
	66,650 plants/ha					44,430 plants/ha					
Variety	IITA I	Ikenne I	Ikenne II	Mokwa	Average	IITA I	Ikenne I	Ikenne II	Mokwa	Average	Total average
TZE_2	3.20	2.70	2.27	3.40	3.14	2.95	2.60	1.57	2.65	2.44	2.79
TZE_3	3.71	2.38	2.27	4.76	3.28	3.05	2.36	2.09	2.88	2.60	2.94
TZE_4	4.57	3.19	2.76	3.40	3.48	3.27	2.79	2.30	2.83	2.80	3.14
TZE_8	3.24	2.48	1.95	3.72	2.85	2.90	2.33	1.59	3.32	2.29	2.57
TZE_{13}	3.08	2.71	1.64	3.75	2.80	2.27	2.62	1.64	3.35	2.47	2.64
TZE_{14}	3.31	2.55	2.21	2.86	2.73	2.70	2.57	2.60	3.15	2.76	2.75
TZE_{15}	3.52	3.10	3.09	3.50	3.30	3.46	2.71	2.58	3.38	3.03	3.17
TZE_{16}	3.19	2.89	1.30	3.71	2.77	2.52	2.17	1.30	3.06	2.26	2.52
TZE_{17}	3.58	3.19	2.36	3.43	3.14	2.48	2.76	1.60	2.46	2.33	2.74
Upper *Volta*	2.33	1.00	1.05	3.09	1.87	2.33	1.14	1.03	1.92	1.61	1.74
Average	3.37	2.62	2.09	3.56	2.91	2.79	2.41	1.83	2.81	2.46	

Table 13. Average grain yields of TZE varieties at two population densities (1978 and 1979).

	Grain yield (t/ha)						
	66,650 plants/ha			44,430 plants/ha			
Variety	1978	1979	Average	1978	1979	Average	Total average
TZE_{15}	3.56	3.30	3.34	3.38	3.03	3.21	3.32
TZE_4	3.65	3.48	3.57	2.98	2.80	2.89	3.23
TZE_{17}	3.33	3.14	3.24	3.17	2.33	2.75	3.00
TZE_{14}	3.05	2.73	2.89	2.85	2.76	2.81	2.85
TZE_3	2.85	3.28	3.07	2.50	2.60	2.55	2.81
TZE_{13}	2.86	2.80	2.83	2.74	2.47	2.61	2.72
TZE_2	2.71	3.14	2.93	2.55	2.44	2.50	2.72
TZE_{16}	2.88	2.77	2.83	2.72	2.26	2.49	2.66
TZE_8	2.70	2.85	2.78	2.26	2.29	2.28	2.53
Average	3.07	3.05	3.06	2.79	2.55	2.67	

Table 14. Grain yields (kg/ha) of nine promising maize composites tested at five locations (Nigeria, 1978 and 1979).

Variety*	*Maturity	Ibadan	Ikenne	Onne	Mokwa	Zaria	Average	Index
PR 7422	M	5861	5662	4380	6132	5485	5499	94
PR 7437	M	6248	6359	5002	-	-	5870	101
MMB	M	5747	6127	4557	6302	5640	5675	97
ICTA-B1	M	4655	5340	4184	5618	5689	5097	87
TZB	M	6515	5754	4913	6795	3538	5503	94
TZPB	M	6254	5860	5242	5864	5959	5835	100
La-Maquina	M	5754	6083	3084	9057	6430	6082	104
TZE_3	E	4250	3174	2546	3767	5420	3831	66
TZE_4	E	4425	3494	3141	3560	4360	3796	65
Average		5523	5317	4117	5887	5312	5231	

**PR = Poza Rica; MMB = Milho Maya Brazil; La Maquina = La Maquina 7422.*

M – Medium-maturity group (120 days).

E = Early-maturity group (90 days).

developing topcrosses with higher productivity than the varieties now being grown in these countries. The S_3-S_4 lines can also be used in the production of synthetic varieties.

Physio-breeding

The major objective of US × Tropical crosses is to introduce the efficient plant architecture of the U.S.A. cornbelt genotypes into adapted disease resistant tropical populations. In 1979, three different US × Tropical maize populations (1,043 lines) were tested at IITA, Onne, Ikenne, Mokwa and Umudike (Table 16).

US × Tropical A. These crosses consisted of 303 full-sib families described formerly as 104 full-sib families developed in 1978. The selected full-sib families were tested at IITA (two replications), Ikenne (three replications) and Mokaw (two replications) in the 1979 first season. Each full-sib entry was a single-row plot, 5 m long, planted at 75 cm × 25 cm spacing. At IITA and Ikenne, all entries were harvested for a yield estimate. At Mokwa, only superior entries were harvested based on visual observation for factors, including expected yield, lodging and leaf disease resistance. Each of the 40 most promising late (average 57 day to flower) and early (average 51 days to flower) families were selected.

Among the 40 selected early families (13.2 percent), 18 yielded more than 5.1 t/ha. Yields ranged from 4,055-6,722 kg/ha (avg. 5,095 kg/ha). Recombinations will be made with the selected 40 families in 1980. Among the 40 selected late families (13.2 percent), 25 yielded more than 5.2 t/ha. Yields ranged from 4,268-6,189 kg/ha (avg. 5,251 kg/ha). Recombinations based on individual plant performance will be made before and after pollination in 1980.

US × Tropical B. Three hundred and eighty-three S_1 lines developed in 1978 were tested at IITA (three replications) and the Onne substation (two replications), during the 1979-80 dry season. These S_1 lines were derived from the same original crosses as the US × Tropical A population. The objectives were to select the most promising lines for recombination by the S_1 recurrent selection procedure and develop the inbred lines. Forty-three promising S_1 lines (11.2 percent) were selected from both IITA and the Onne substation. Major consideration was given for yield, lodging and *Eldana* resistance at IITA and for yield and *H. maydis* resistance at Onne.

In addition, 45 lines (11.7 percent) were selected for resistance to *H. maydis* at Onne. Severe infection of *H. maydis* at Onne provided a good opportunity for this selection. The lines selected were significantly less susceptible than the majority of the lines.

US × Tropical C. These crosses consisted of Hawaiian supersweet corns and streak resistant composite, TZSR-yellow. The main objective of these crosses was to combine the plant type and *H. turcicum*, *H. maydis* and *P. sorghi* resistance and *P. polysora* and other fungal diseases resistance from African composites. F_2 populations were planted in the 1979 first season and selfed. A total of 357 pure starch selfed ears were selected from the F_2 population segregating for starch/supersweet. Seeds of these ears were planted in three replications in the field at IITA in October. They were planted also in the screenhouse under high virus incidence; 157 lines (44

Table 15. Grain yield of improved maize varieties and the best derived topcross from each variety.

Improved variety		Top-cross		
Variety	Yield (t/ha)	Variety × S_3 line	Yield (t/ha)	Percent increase over the variety
TZSR-W	3.2	TZSR-W × 105	6.0	187
TZE_3	3.1	TZE_3 × 279	5.7	184
TZE_{17}	2.8	TZE_{17} × 174	5.0	178
La Maquina 7422	3.4	La Maquina 7422 × 167	5.8	172
096EP6	2.7	096EP6 × 180	4.6	168
Tlaltizapan 7322	2.8	Tlaltizapan 7322 × 260	4.6	167
Poza Rica 7422	3.2	Poza Rica 7422 × 260	5.1	157
TZB	3.5	TZB × 167	5.5	156
TZE_{14}	3.7	TZE_{14} × 276	5.6	153
Obregon 7328	3.2	Obregon	5.3	150
TZPB	3.8	TZPB × 107	5.3	140
TZE_4	3.6	TZE_4 × 62	4.7	130

Table 16. Summary of selected US × Tropical maize lines (1979).

Population	Season	No. of lines	Test location	No. of lines selected	% selection intensity
US × Tropical-A	First	303	IITA	40 early	13.2
			Ikenne	40 late	13.2
			Mokwa		
US × Tropical-B	Second	383	IITA	43	11.2
			Onne		
US × Tropical-C	Second	357	IITA	34	9.5
			Umudike		

percent) were selected for tolerance to maize streak virus based on the average rating scores for each line.

In the field, 357 lines of one replication were infested with leafhopper five weeks after planting. A high mottle virus incidence and a low maize streak virus incidence was obtained in most lines with symptom severity correlating with the screenhouse maize streak virus ratings.

Thirty-four lines (9.5 percent) were selected for yield and resistance to viruses and stemborers (*Eldana* and *Sesamia*) based on their performance in the field. Average mottle incidence from the artificially virus-infested plots was 79.9 percent compared to only 29.0 percent for natural infestation.

More intensive US × Tropical crosses were made in 1979 between widely grown U.S.A. cornbelt germplasm and tropical disease and insect resistant populations of IITA, CIMMYT and Asian downy mildew resistant populations. Results of IITA physio-breeding maize work clearly indicate that high-yielding, early-maturing varieties with good plant architecture can be developed from the US × Tropical crosses.

Comparison of selection criteria in TZPB. Excessive plant height and leafiness and inefficient transfer of assimilates to the sink are considered to be 2 important limitations to yield in tropical maize. Two different selection criteria were initiated in 1976 in order to achieve more efficient plant type, using TZPB as a base population : selection for efficient plant type under low population density (TZPB-EPS) and selection for prolificacy (TZPB-Prolific) (Table 17).

The efficiency of the new selection criteria was tested during the 1979 first season at Ikenne. TZPB-EPS C_2 and a mixture of 138 full-sibs of TZPB-Prolific were compared with TZPB in two population densities of 53,000 and 35,000 plants/ha. A split plot design with six replications, 6 rows each, was used. Planting distance was 75 cm × 25 cm and (75 cm + 150 cm)/2 × 25 cm in the high and low densities, respectively. Only the two middle rows were harvested.

At harvest, the final stand was much lower than initially planted due to poor germination and bird damage, especially in the TZPB population. Therefore, the yield data were analyzed both as actual yield and corrected yield (adding 75 percent for missing plants to compare the variation on equal population numbers).

Table 17. Effect of selection under wide spacing and for prolificacy on plant and ear height.

Selection criteria		Plant height (cm) (%)	Ear height (cm) (%)
TZPB	53,000	213.6	108.2
	35,000	217.6	110.8
	Avg.	215.6 (100)	109.5 (100)
TZPB-Prolific	53,000	224.0	119.6
	35,000	220.0	112.6
	Avg.	222.0 (103)	116.1 (106)
TZPB-EPS	53,000	179.8	85.6
	35,000	184.4	89.6
	Avg.	182.1 (84)	87.6 (80)

The results obtained in this trial showed that after two cycles, the selection for prolificacy (Table 18) did not increase the average number of ears per plants even in the lower plant population. The same was observed in the TZPB-Prolific, full-sib trial. Also, no improvement in yield was obtained in this population compared to TZPB. On the other hand, lodging was more severe in the TZPB-Prolific than in the TZPB, especially in the higher population density. Plant and ear height were also higher than in the control. There is a possibility that by selecting mainly for one character, the other is lost.

The approach to select under wide spacing was even more disappointing. The main achievement was reduction in plant and ear height, which is a significant one for two cycles of selections. However, the yield of the TZPB-EPS population was significantly lower than the other two populations.

By reducing plant and ear height, the yield was expected to improve by increasing the planting density and improving lodging resistance. This was not found in the TZPB-EPS population. The relative decrease in yield in the TZPB-EPS population compared to the other two was greater in the higher population level. Also, the reduction in plant and ear height did not improve the lodging resistance. These results were not expected. The TZPB-EPS population is a recombined population of 22 selected families with a mean yield of 6,232 kg/ha from two locations, which was 48 percent higher than the TZPB composite. Since the selection under wide spacing was effective in reducing plant and ear height, further selection in the TZPB-EPS population will be done in the future to improve yield and lodging resistance.

Rice

Progress has been made in screening germplasm for drought resistance, the African specific rice yellow mottle virus and blast disease. Also, good results have been obtained in the identification and development of lines tolerant of Fe toxicity, culminating in the release through the Liberia program of a named variety, Suakoko 8. Progress has also been made in screening lines for high-yielding characteristics under different moisture conditions. In fact, some of the lines developed and screened for upland conditions are showing excellent potential and have been requested for further testing in Brazil as well as many countries in Africa.

Genetic improvement

Among the various factors affecting upland, hydromorphic and irrigated/swamp rice cultivation, the following were considered to be most important:

1. Biological factors.
   — Diseases such as blast, leaf scald, sheath blotch, glume discoloration and yellow mottle virus.
   — Insects such as *Diopsis* and stemborers.
   — Weeds, particularly grasses.
   — Birds and rodents.
2. Climatic factors.
   — Water, solar radiation and extreme temperatures.
3. *Cultivation practices.*
   — Date and method of planting.
   — Nutritional deficiencies/toxicities.

For upland rice, the development of semi-dwarf plant type, a long-term goal, demands several major changes in the African farming systems. As an interim measure, IITA rice scientists are selecting and developing improved upland varieties with intermediate stature (115-135 cm) that do not demand a high degree of weed management. Weeds are always a major production constraint in upland rice. Emphasis for upland rice is also on resistance to drought and blast disease and resolution of the etiology of the syndrome of glume discoloration, generally termed "dirty panicles."

For irrigated rice, tolerance to blast and yellow mottle virus diseases and stemborers together with superior grain quality characteristics are being incorporated with high-yield potential.

For swamp rice, tolerance to Fe toxicity is crucial. Much of the work on this ecology is being done at Rokupr, Sierra Leone.

It is recognized that costly chemical control of insects and diseases and soil amelioration practices are not in the reach of peasant farmers in Africa. IITA, therefore, emphasizes genetic resistance to the above constraints. The local African germplasm has some level of tolerance and is employed as the basis of improvement for productivity. The IITA breeding scheme involves a number of locations in Nigeria and Sierra Leone, each of which presents a production stress consistently.

Upland rice

Six hundred new crosses were made, and 210 F_2 and 515 F_3 and 1,340 F_4-F_6 lines were grown in 1979 for upland rice. The crosses combine a wide germplasm base, with single and multiple crosses of Africa, Asia, South America, IITA, IRAT, IRRI, WARDA and the All-India Coordinated Rice Improvement Project (AICRIP) varieties.

Organized testing of the IITA generated upland rice material and the exotic germplasm introduced was carried out in upland conditions at IITA, the Onne substation and Ikenne for yield and general performance in three stages — Preliminary, Advanced and Elite Yield Trials — based on the previous years' performances.

The locations were chosen to present different stresses. IITA experiences frequent drought (more than the Onne substation or Ikenne). Onne experiences severe leaf blast as well as leaf spot, sheath blotch and dirty panicles. Ikenne experiences leaf blast in the vegetative phase and leaf spot, sheath rot, neck blast, dirty panicles and some drought in the flowering and post-flowering phases.

Observational tests for F_4-F_6 lines from IITA and a large number of the introductions were carried out at the three locations as well as at Funtua, a savanna location in northern Nigeria, the Republic of Benin, Sierra Leone and Sao Tome. IITA also participated in the International Rice Testing Program (IRTP) of IRRI.

Superior material for the dryland-savanna and the dryland-forest ecologies was obtained from the new crosses. Many entries are as early as 90-105 days; others range to 135 days. Many are of intermediate stature and have long, fine, translucent grain. Many have narrow leaves and are glabrous, producing clean, well exserted panicles under upland conditions where other rices produce choked panicles and diseased spikelets. All have high horizontal resistance to blast. Two crosses, TOx 782 and TOx 1008, have bold grain from a Japonica parent but much larger grain and higher yield potential. Neither TOx 782 nor TOx 1008 carry the dwarf gene.

Improved intermediate- and short-statured cultivars for African uplands. Evaluation for yield superiority showed that IITA's TOx varieties often were better than OS6, the most predominant upland variety in Nigeria (Table 19).

Their selection was also based on their resistance to lodging, drought and diseases such as blast, sheath blotch and glume discoloration.

The selected varieties were intermediate statured (115-135 cm), except for the shorter TOx 356-1-1-1, TOx 490-3-108-1-1 and TOx 515-22-107-1. These shorter varieties, however, have a more moderate tillering habit, thicker and deeper roots and droopier lower leaves than the typical semi-dwarf varieties selected for irrigated conditions.

Table 19. Range of plant height, maturity and grain yield of some improved intermediate- and short-statured cultivars for African uplands.

Variety	Height range (cm)	Maturity range (days)	Yield range (t/ha)
TOx 504-21-120-1	136-149	120-128	4.3-6.0
TOx 490-3-108-1-1	84-100	112-118	4.0-5.4
TOx 504-14-7-1	119-135	110-115	3.8-5.2
TOx 356-1-1-1	90-115	100-118	3.5-5.5
TOx 340-1-5-1	110-125	112-116	2.9-4.6
TOx 475-1-1-1	115-125	110-120	2.8-5.3
TOx 86-1-3-1	115-129	113-122	2.8-4.8
TOx 494-1-1-1	122-135	110-115	2.4-5.0
TOx 502-46-4-1	95-110	110-112	2.4-4.6
TOx 515-22-107-1	81- 92	105-119	2.3-6.0
TOx 95-8-1-3-1	138-148	117-128	2.3-3.9
OS 6 (local check)	128-167	123-127	2.2-4.9

Table 18. Comparisons between selection criterias in the variety TZPB in two population levels (Ikenne, 1979 first season).

Selection criteria	Plant population/ha		Percent lodging	No. ear /plant	Yield (t/ha)	
	Planted	Harvested			Actual	Corrected
TZPB	53,000	36,267	12.9	1.03	6.11	8.18
	35,000	24,444	8.0	1.01	4.20	5.66
TZPB- Prolific	53,000	42,400	42.8	1.07	6.08	7.28
	35,000	32,178	13.8	1.04	4.77	5.11
TZPB-EPS	53,000	40,000	27.1	1.01	4.12	5.08
	35,000	29,778	9.9	1.04	3.82	4.33

TOx 86-1-3-1 was most distinctive in withstanding blast, leaf spot, sheath blotch and dirty panicles at the Onne substation. The only other materials that came close to the performance of this line were six from IITA and IR 5931-110-1, IR 8103-72-2, Pattambi 1737 and Pattambi 1751 from IURON. However, the IURON material was more affected by panicle and sheath diseases. In another screening test at Funtua, where severe drought stress occurred, TOx 86-1-3-1 was the highest yielder.

Among the selected elite lines tested in 1979, TOx 475-1-1-1 was superior to OS 6 in all the locations tested. At IITA and Ikenne, it averaged 4.4 t/ha compared with 3.4 t/ha for OS 6. This TOx line was also the highest yielder (1.9 t/ha) under the highly leached acid soils compounded with severe fungal diseases at the Onne substation.

TOx 494-1-1-1 has slender grains, tolerance to blast and rice yellow mottle virus and is being used in hybridization to further improve its yielding ability.

In toposequence transect screening (IITA Annual Report 1976), the advanced TOx lines were screened for drought tolerance. About 6-8 weeks after planting, the lines were compared to OS 6 for leaf-water potential during drought. TOx 515-22-107-1-1, TOx 490-3-108-1-1, TOx 356-1-1-1, TOx 504-14-7-1 and TOx 504-21-120-1 maintained a higher leaf-water potential. All these lines were initially selected for their yield and leaf blast resistant superiority.

Among the 90-110 day duration varieties, TOx 502-25-118-1-1, TOx 502-41-1-1-1, TOx 502-46-3-1, TOX 502-46-4-1 and IRAT 13 × Dourado Precoce #852 were higher yielders than 22 other selections tested. TOx 502-46-4-1 with 4.63 t/ha was the highest yielder while the others yielded 3.29-4.48 t/ha. The cross TOx 502 (63-83/Dourado Precoce) resulted in several promising early upland selections.

Promising upland rice lines for further tests. The multilocational yield tests of more than 200 selections resulted in identifying 24 new promising lines with a maturity range of 90-135 days. They were selected against the various upland stresses but need further confirmation for their yield superiority. Of these, 20 are TOx lines selected for their field tolerance to blast and drought. Their yielding capacity is comparable to OS 6, and they have large, well exserted panicles with good grain filling characteristics.

Four varieties — IR 45, IR 7760-4-8-2, IR 9575 and IR 9669 — from IURYN have yields that are slightly superior to OS 6 but only favorably comparable to TOx 515-22-107-1 and TOx 490-3-108-1-1, the local checks.

Exotic varieties and IITA breeding lines under upland conditions. A total of 120 varieties, including IITA breeding lines and several exotic semi-dwarf varieties were tested in three locations in northern Nigeria — Daudawa, Gusau and Malum Fashi. The cultivars encountered severe drought during their reproductive stage because of delayed planting, but blast was not prevalent. Therefore, the varieties *were selected based on their general perfor*mance. TOx 502-41-1-1, TOx 502-46-3-1, TOx 504-13-103-1 and TOx 504-14-106-1 gave good grain filling at all three locations and are worthy of further observation.

Coordinated variety trial: WARDA. Fifteen varieties, including TOx 502-41-1-1 as a local check, were evaluated at IITA in a short-duration trial under freely drained upland conditions. IRAT 109 (5.70 t/ha) and IRAT 110 (5.87 t/ha) were superior to the check TOx 502-41-1-1 (4.04 t/ha). However, the latter variety has long, slender grains, which are preferred in the region compared with the short bold grain type of the two IRAT lines. The mean grain yield of all the entries was 2.45 t/ha.

Also, 15 varieties, including TOx 515-22-111-1 as a local check, were tested in a medium-duration trial at IITA. The entries in general suffered more from drought at the grain filling stage resulting in a mean grain yield of only 1.36 t/ha for the trial. IRAT 13 (3.21 t/ha), IRAT 132 (2.42 t/ha) and variety 4418 (2.40 t/ha) were superior to the check variety (1.52 t/ha).

Further, 275 entries from WARDA's Initial Evaluation Trial were evaluated for general performance, and grain yields were recorded on 1 m length. OS 6 was used as a local check. Varieties that were resistant to blast and yielded 25 percent higher than OS 6 are presented in Table 20.

Mutation breeding. Recognizing that the African land varieties have adaptational advantages over exotic germplasm but are deficient in plant types and, thereby, low in yield potential, 16 local varieties were chosen for mutation breeding. The irradiation was done by the courtesy of FAO/IAEA, *Vienna*.

True breeding plant type mutants (semi-dwarfs) were obtained in OS 6, Ngovie, TD 58 and Khao Maleuh. No dwarf mutants could be obtained in LAC 23, TOx 502, Dourado Precoce and IAC 25. The dwarf mutants from OS 6 are indistinguishable in height from the original parents until flowering since the dwarf gene affects the elongation of internodes. This mutant, however, has its main defects in supernumerary late tillering and reduced panicle length. An adapted local variety, Moroberekan, was hybridized with an OS 6 dwarf mutant.

O. sativa × O. glaberrima. The F_1 hybrid of *O. sativa* × *O. glaberrima* is nearly self-sterile but partially fertile on out-pollination. Advantage is taken of this self sterility for population improvement by mix-planting African local upland varieties with the F_1 sterile hybrids and collecting the seed originating from outcrosses. The F_4 generation of such a natural hybridization scheme has provided a pool of variability for many attributes. Fertile progenies can be extracted out of this population in any advanced generation.

Table 20. WARDA upland initial evaluation test (IITA, 1979).

Variety	Plant height (cm)	Tillers/ m²	Grain yield (t/ha)
TOx 502-8-112-1	129	205	4.56
C 46-15/IR 24²	87	128	3.50
TOx 502-25-1-1	137	155	3.45
ART 9	126	168	3.29
IRAT 132	103	138	3.26
DJ 11-508-3	77	200	2.97
DJ 12-519-1-3	85	265	2.85
IRAT 194/1/2	104	145	2.84
ADNY 7	101	135	2.83
ART 40v	131	130	2.77
M 133/6/1/2	133	148	2.75
TOx 504-4-106-1	138	170	2.72
ART 117	134	168	2.53
OS 6	146	173	2.00

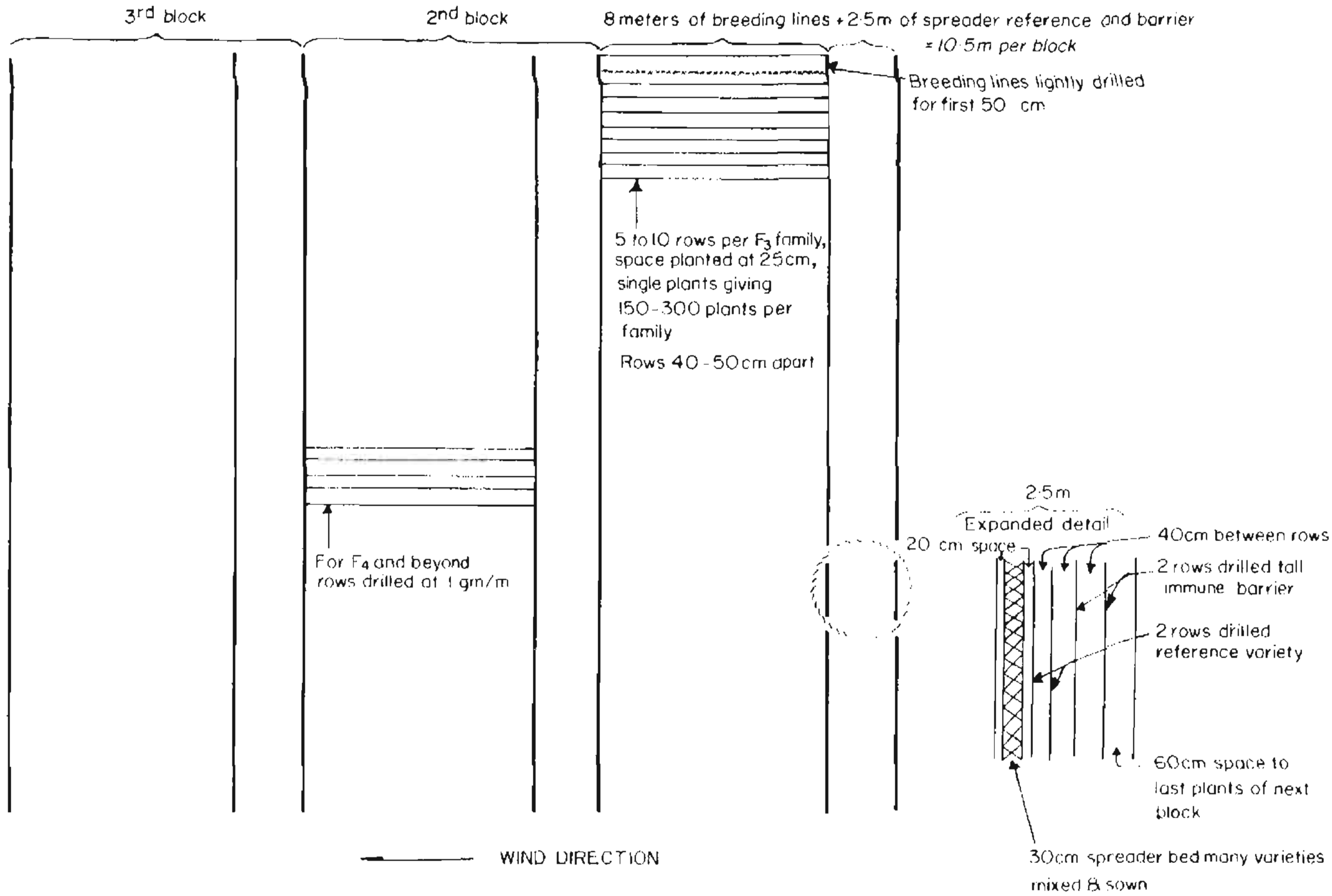


Fig. 1. Design for selecting for horizontal blast resistance combined with performance in F_3 and more advanced generations. Rice grown under dryland conditions.

Population improvement. A different approach to population improvement for upland rice is the use of interspecific crosses between *O. sativa* and *O. glaberrima*. The F_1 crosses of this species are self-sterile but partially fertile on out-pollination. Emasculation or floret clipping is not required, and out-pollination is provided by interplanting with a mixture of adapted upland *sativas*, differing in duration. This species cross has been brought to the PI_4 generation (fourth population improvement generation). Considerable diversity in many characters now exists with sufficient sterility present to ensure continued natural intercrossing. Individual plants with high fertility can be extracted from the population in any advanced generation.

Disease resistance/tolerance. An improved design has been developed that incorporates early generation selection for horizontal blast resistance into the normal pedigree breeding nurseries where selection is carried out for general performance (Fig. 1).

This improved design is used from F_3 onwards, and it is simple to layout and use. It enables simultaneous selection for horizontal blast resistance, early vigor, canopy cover, height × density interaction and single plant evaluation and selection for 'upland toughness,' morphology, panicle and grain characters and yield.

Disease of the spikelets, giving rise to the term "dirty panicles" is a common complex on unadapted material under upland conditions. Drought and nutritional stress accentuate the problem. Sheath diseases and *Rhynocosporium* are also important in upland rice culture. Brown spot occurs on some sites and genotypes. Selection against all of these problems is routinely conducted in breeding plots.

Panicle and sheath diseases are especially severe on most lowland-adapted semi-dwarfs when grown under dryland conditions and on many of their dwarf progenies. Many African land varieties and their intermediate-height progeny produce clean panicles even under stress conditions. Selection for clean panicles and sheaths and low brown spot appears to be straight forward in the populations. There appears less scope for selection for *Rhyncosporium* resistance in the existing genotypes.

Lowland rice

BG 90-2 is one of the highest yielding paddy rice in West Africa but requires improvement, especially in blast resistance and grain quality; 250 lines of BG 90-2 derivatiyes obtained from the Centro Internacional de Agricultura Tropical (CIAT), Columbia, were crossed with different blast resistant donors and backcrossed four times. These were evaluated in 1979 for horizontal blast resistance and high yield and long, translucent grains. Improved BG 90-2 is now available for wide-scale testing.

TOM 1-3, a dwarf mutant of OS 6 with slender, translucent grain, is another line which was found to be high-yielding under irrigated conditions.

Coordinated variety trial: WARDA. The WARDA coordinated trial for irrigated rice culture was in two maturity groups — early and medium duration — each of which consisted of 14 varieties. TOx 514-16-101-1-1, a semi-dwarf identified at IITA, was used as a check for both the groups, and the trial was conducted at IITA.

For the early-duration varieties, the experimental mean for the grain yield was 4,424 kg/ha. Three varieties, IET 1785 (6,679 kg/ha), ADNY 11 (6,159 kg/ha) and IR 3273-P339-2 (6,000 kg/ha), were significantly superior in yield to check variety TOx 514-16-101-1-1 (4,401 kg/ha).

For the medium-duration varieties, the experimental mean for the grain yield was 4,330 kg/ha. No variety was significantly superior to check variety TOx 514-16-101-1-1 (5,666 kg/ha). IET 2885 gave a 19 percent increase over the check, though statistically not significant. This variety gave good performance in the coordinated trials of WARDA in the previous years as well.

Disease resistance/tolerance. The approach was to include disease resistance/tolerance as an integral part of breeding and selection, without separate disease screening, as much as possible. This requires selection within areas where rice will be grown with normal disease development occurring naturally. The exception to this general approach is breeding for tolerance to rice yellow mottle virus (RYMV). Incidence is so erratic that artificial inoculation is required. However, since this is a systemic disease, selection for tolerance can be readily carried out following simple mechanical inoculation and judging symptom severity and measuring yield reduction.

Results of testing hundreds of lines from diverse sources confirm that high tolerance is common in old Africa upland land varieties and in many *O. glaberrima* lines. In addition, high tolerance has been found in some Southeast Asian upland types such as Khao Maleuh and Khao Ray and in Brazilian upland cultivars. Collection from African swamp and flooded rice ecologies, which differ in morphological characters from African upland types, also differ in RYMV tolerance — they are susceptible.

The 500 high-yielding paddy dwarfs tested from IRRI, AICRIP and CIAT are generally susceptible in varying degrees. Of this group, four lines have been detected with moderate tolerance levels: 6906 from CIAT (a Bahagia cross) and IET 2812, IET 3231, IET 5734 from AICRIP.

Many of IITA's TOx lines derived from simple crosses of tolerant African or Brazilian uplands × susceptible paddy dwarfs and selected for upland performance are highly tolerant. This is surprising since selection did not involve exposure to RYMV. Lines from such crosses (TOx 494, TOx 503, TOx 504, TOx 515, TOx 516) are being used to contribute RYMV tolerance to high yielding paddy dwarfs.

TOx 494-1011, which also has high horizontal blast resistance and long translucent grain, is the current source of major interest. From crosses of this parent, new lines may be obtained combining all these resistances with high yield and quality.

Insect resistance. In studies on resistance to *Diopsis thoracia* (Table 21a), the stalk eyed fly, the following has been found:

1. There is no direct relationship between tiller damage and yield loss among different cultivars.
2. Varieties with approximately equal tiller damage ranged in yield loss from 2 to 54 percent.
3. Low-tillering types such as OS6 and TOs 4121 has less compensatory ability, and their yield was reduced greatly (44 and 54 percent vs. 2 percent for Suakoko 8).
4. Even a high-tillering, high-yielding variety such as BG 90-2 suffered a 40 percent yield loss as against 2 percent for Suakoko 8 in spite of equal tiller damage. This was attributed to the inability of BG 90-2 to produce new tillers that would mature in time to be harvested with the original tillers. Thus, the slight photosensitivy of Suakoko 8 acts as a buffer on tiller damage.

In work with *Chilo zacconius*, the following points have been found:

1. With equal artificial challenge, Lac 23 had only 19 percent dead hearts compared with approximately 30 percent for 5 other varieties: Colombia 1, IR 4625 132-1-2, 139C MD-3-3, ADNY 2 and on irrigated saline/alkaline from Ghana (A).
2. Lac 23 exhibited negative effects on larval weight and suffered the least reduction in the percent of filled grains in infested stems. (5 percent vs. 17 and 33 percent for Improved Mashuri and ADNY 2).

Agronomy and physiology

Upland rice

Methods of planting for the evaluation of upland rice cultivars of different plant types. Interaction between the genotype and the environment determines the performance of a cultivar. Improved semi-dwarf rice cultivars are largely recognized to have ideal plant type for lowland rices; thus, their evaluation is simple. Culivation practices, which promote the high yield realization of semi-dwarf types, are being used in screening of lowland rice cultivars.

Opinions among researchers differ regarding appropriate plant type characteristics for upland rice. Further, planting methods vary greatly in upland rice cultivation. Also, the term "upland" covers a range of moisture regimes that again affect the varietal performance. These factors contribute to the difficulty in determining the appropriate cultivation practices for the selection of upland rice.

During 1979, the objective was to identify appropriate methods of planting for the evaluation and selection of high-yielding cultivars under varying moisture regimes. ADNY 11, an improved lowland, semi-dwarf, panicle-number type and Os 6, were evaluated under four moisture regimes: irrigated paddy, valley bottom hydromorphic condition without standing water on drought stress, dryland without drought stress with sprinkler irrigation twice a week and dryland with drought stress with sprinkler irrigation once a week. N, P and K were applied at the rate of 90:45:0 kg/ha. Three plant spacing simulating dibbling (30 cm × 30 cm), space planting (30 cm × 10 cm) and row drilling (45 cm × 3.3 cm) were used. However, the seed rate was kept constant by adjusting the number of seedlings per hill, six seedlings per hill at

30 cm × 30 cm, three seedlings at 30 cm × 10 cm and one seedling at 45 cm × 3.3 cm.

Except for ADNY 11 under drought stress, row drilling resulted in the highest yields under all the moisture regimes for both cultivars (Table 21b), and ADNY 11 outyielded or equalled OS 6 under all moisture regimes and methods of planting. The lower grain yields of ADNY 11 at 45 cm × 3.3 cm in dryland conditions under drought stress was because of excessive tillering, which had a detrimental effect on grain filling (Table 22).

Among the different methods of planting, drilling in rows appears to be suitable for the evaluation of cultivars with different plant types. Also, row drilling either by tractor or hand is a convenient method of planting. However, appropriate method of seeding to ensure a uniform stand and establishment coupled with effective weed control measures, particularly within the rows, are essential factors for the use of drilling methods to evaluate different varieties.

High soil temperature tolerance. Among the most desirable traits that contribute to drought tolerance in upland rice are deep and thick root systems that explore a large volume of soil to the deeper layers for water and nutrients and appropriate growth duration to suit the rainfall pattern of the region. Upland rice totally depends on rainfall for its water requirements; planting early in the monsoon would increase its probability of escaping drought towards the end of the growing season.

IITA scientists have observed that in parts of West Africa, soil temperatures reach above 40°C before the rains stabilize. This necessitates having rice with high soil temperature tolerance at germination if it is to be sown early. A preliminary test was, therefore, conducted to study the seed germination at a near optimum temperature (28.0 ± 0.90° C) and a high (40.0 ± 0.90° C) temperature of 7 rice varieties. As shown in Table 23, some varieties appear to be able to withstand a high temperature at the time of germination as expressed by the rapidity and percentage of germination. TOx 95-8-1-5 was found to have greater tolerance to a high temperature than adapted upland types such as OS 6 and Moroberekan.

Rice varieties and water stress

Response of BG 90-2, IR 442-2-58, IR 2035-120-3, IR 2071-586-5-6-3 (IR 42) and TOx 504-14-14-1-1 to water stress at

Table 22. Panicle number per m² and 1,000 grain weight of ADNY 11 in dryland without drought stress.

Method of planting	Panicles/m²	1,000 grain weight
Dibbling (30 cm × 30 cm)	215	22.9
Space planting (30 cm × 10 cm)	246	22.4
Drilling (45 cm × 3.3 cm)	451	19.6

Table 21a. Effect of Diopsis on yield and yield components among 10 varieties.*

Variety	Change** in no. of healthy tillers (%)	Change in no. of mature panicles at harvest (%)	Change in no. of mature grains per panicle (%)	Change in total grain lot (%)	Damaged tillers in infested plots (%)
IRRI 12682	+18	19	12	10	15
OS6	15	38	9	−44	19
ADNY 11	+11	9	5	11	14
BG 90-2	+19	31	16	40	11
IR8	+15	18	12	22	23
SD27	+32	+5	11	15	9
TOS 4121	+14	46	17	54	14
GH 106-76	+13	4	18	23	21
IR 5	+17	11	22	28	19
Suakoko 8	+15	4	1	2	13

*Data calculated from comparison between protected and unprotected replicated plots of 0.72 M^2.
**In infested plots, compared with uninfested.

Table 21b. Grain yield (t/ha) of OS 6 and ADNY 11 under different methods of planting and moisture regime.*

Methods of planting	Dryland (Drought stress)		Dryland (No stress)		Hydromorphic		Paddy	
	OS 6	ADNY 11	OS 6	ADNY 11	OS 6	ADNY 11	OS 6	ADNY 11
Dibbling (30 cm × 30 cm)	1.7	2.6	3.2	3.7	3.5	5.4	3.8	6.3
Space planting (30 cm × 10 cm)	1.9	1.9	2.5	3.3	4.6	5.7	4.9	6.7
Drilling (45 cm × 3.3 cm)	2.4	1.5	3.5	6.8	5.1	6.9	7.7	8.4
Average	2.0	2.0	3.1	4.6	4.4	6.0	5.5	7.1

*Same seed rate was used to plant all the different spacings by adjusting the number of seedlings per hill.

flowering stage was studied. Leaf water potential, stomatal resistance and the degree of leaf rolling were recorded at 3, 5, 7 and 9 days after moisture stress.

Response of the cultivars markedly varied in their ability to maintain high leaf-water potential even days after water stress. TOx 504 and IR 42 maintained higher water potential and lower stomatal resistance and stomatal densities (Table 24, 25 and 26). Stomatal lengths are not significantly different. Their critical water potential for stomatal closure seem to be lower, which is desirable for the maintenance of photosynthesis under moderate water stress conditions. However, it appears that rice is not escaping drought by closing stomata since no differences for stomatal resistances between varieties were observed nine days after stress.

The ability of the varieties to maintain high leaf water potential is associated with a leaf rolling mechanism. TOx 504 is characterized by rolling the leaves upside down when no stress is occurring. In drought conditions, it reversed the way of rolling. Other mechanisms such as deep roots, stomatal adjustment and desiccation tolerance contributing to drought resistance need to be explored.

Table 23. The rate of germination of upland rice cultivars at near optimum and high temperatures.

	Percent germination					
	28.0 °C ± 0.9 °C			40.0 °C ± 0.9 °C		
Cultivar	48 hr	72 hr	96 hr	48 hr	72 hr	96 hr
TOx 95-8-1-5	100			80	95	100
Moroberekan	100			40	40	80
OS 6	90	100		25	55	60
TOx 475-1-1-1	80	90	90	15	35	35
IR 1416-131-5	85	100		70	80	80
IR 2035-120-3	70	95	95	50	55	55
BG 90-2	80	95	95	10	25	30

Cooperative programs

USAID: SAFGRAD

The Semi-Arid Food Grains Research and Development Project (SAFGRAD) is funded by the U.S. Agency for International Development (USAID) in collaboration with the Organization of African Unity's Scientific, Technical and Research Commission (OAU/STRC). In addition to IITA's work in grain legumes and maize, SAFGRAD involves the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) for work on sorghum, millet and groundnuts and the University of Purdue, Indiana, U.S.A. for work on farming systems as well as economic and social research. Under SAFGRAD, IITA conducted its maize research in 1979 in cooperation with international, national and regional agencies.

Genetic improvement

The work done toward accomplishing SAFGRAD's objectives of developing high-yielding early- and medium-maturing maize varieties tolerant of environmental stresses commonly encountered in the semi-arid tropics can be grouped under two major activities: regional effort and on/site experiments at research stations in Upper Volta.

Regional efforts

Uniform Variety Trial-1 (RUVT-1). *This trial consisted of* early varieties (80-90 days maturity) that have been found

Table 24. Comparison of leaf-water potential of five cultivars under drought conditions (S) and well-watered conditions (C) from day 0.

Days			IR 442	IR 2035	IR 2071	TOX 504	BG 90-2	F. Test VAR.	F. Test STR.	LSD (0.05)
	M	S	5.2	4.3	4.7	4.0	5.5	N.S.	N.S.	-
		C	5.7	7.5	7.5	4.8	6.3			
3										
	A	S	11.3	10.0	11.0	9.0	11.0	N.S.	N.S.	-
		C	9.8	8.5	8.3	6.8	10.7			
	M	S	8.2	6.0	8.3	5.0	6.0	XXX	N.S.	1.7
		C	8.0	6.3	6.0	6.8	6.8			
5										
	A	S	12.3	10.8	12.8	9.5	11.5	XXX	N.S.	2.5
		C	12.3	11.3	12.3	8.8	9.7			
	M	S	15.7	-12.0	-13.5	-9.3	-13.8	XX	XX	4.3
		C	9.2	7.8	11.8	8.0	8.8			
7										
	A	S	-20.5	-15.5	14.7	12.8	-17.7	XX	XX	5.1
		C	12.5	14.7	15.0	11.8	15.8			
	M	S	-33.0	30.3	21.8	-20.3	-25.7	XX	XXX	6.1
		C	11.8	-10.5	-13.0	-9.5	-10.3			
9										
	A	S	-32.0	-30.3	-24.0	-23.8	-30.0	XX	XXX	4.9
		C	-15.0	13.3	17.0	11.3	-14.5			

Days: Number of days without watering. M: Measurements in the morning.
A: Measurements in the afternoon. S: Stressed plants. C: Control plants.

to be promising in different national programs. Twelve varieties were tested in randomized block design trial with four replications. The plot size was 4 rows, 5 m long. This trial was sent to the Republic of Benin, Cameroon, Mauritania, Ghana, Mali, Ivory Coast, Senegal, Sudan, Guinea and Upper Volta.

There were considerable differences in the performance of varieties, including TZE_3 and TZE_4. Considering the average performance of these varieties across all the locations, it was seen that IRAT 100 (hybrid) was the highest yielding entry (3,023 kg/ha) followed by BDS III (2,970 kg/ha). IRAT 100 took 57 days to flower while BDS III took 53.

Regional Uniform Variety Trial-2 (RUVT-2). Twelve medium maturing varieties nominated by various national and international institutions on the basis of earlier performance in their national programs were tested in this trial. Randomized block design with four replications was adopted to conduct the trial. The plot size was also 4 rows, 5 m long. The trial was conducted in the Republic of Benin, Ivory Coast, Senegal, Mauritania, Mali, Ghana, Gambia, Sierra Leone and Upper Volta. Data were recorded on the same characters as indicated earlier in RUVT-1.

Significant differences among varieties, including TZSR(W), TZPB and TZB, were found for grain yield at all the locations. On the basis of average performance across all the locations, IRAT 102 (hybrid) gave the highest yield (3,398 kg/ha), closely followed by TZB (3,192 kg/ha) and N.H. 2 (3,169 kg/ha). IRAT 102 and TZB took 62 and 64 days to flower, respectively.

Family Testing Trials. Four base populations — TZE_3, TZE_4, TZB and TZPB — were identified to be the promising materials to initiate the population improvement program through the SAFGRAD network. Full-sib families in all four populations were developed at Saria, Upper Volta, during the 1978 season. In the 1979 SAFGRAD workshop, it was decided to test these full-sibs in some countries having a stronger national program.

Trials RFTT-1 and RFTT-2 consisted of 140 full-sib families of TZE_4 and TZE_3, respectively, sent to Senegal, Upper Volta and Nigeria. Trials RFTT-3 and RFTT-4 consisted of full-sib families of TZPB and TZSR, respectively, sent to the Republic of Benin, Ivory Coast and Upper Volta. Four check varieties were included in each trial making a total of 144 entries; 12 × 12 simple lattice design with two replications was utilized for all the RFTT trials. The plot size was one row, 5 m long.

In RFTT-1, the full-sib families tested at Bobo, Upper Volta, yielded 667-4,806 kg/ha. These families, in Senegal, yielded 748-4,138 kg/ha. Mean grain yield of all the families averaged over both the locations was 1,976 kg/ha while mean grain yield of selected families was 2,559

Table 26. Stomatal density (N MM ^{2}) and stomatal length (L, UM) of the five cultivars of rice.

	Stomatal density (N MM ^{2})		Stomatal length	
Cultivar	Upper face	Lower face	Upper face	Lower face
IR 442	210	259	20.4	21.2
IR 2035	231	257	20.8	20.8
IR 2071	155	206	21.6	22.0
TOx 504	153	176	22.0	22.0
BG 90-2	206	261	21.1	20.8
	Var.	Face	LSD 0.01	
F Test N	xxx	xxx	38.9	
L	N.S.	N.S.		

Table 25. Diffusive resistance (Scm ^{1}) of upper (U) and lower (L) leaf surface of the five cultivars subjected to water stress treatment from day 0.

Day			IR 442	IR 2035	IR 2071	TOX 504	BG 90-2	F. test Var.	F. test Face	LSD (0.05)
3	M	U	2.8	2.5	2.2	4.8	2.4	XXX	X	1.08
		L	2.8	2.5	2.8	2.9	2.4			
	A	U	1.2	1.1	1.1	1.5	1.2	XXX	XXX	0.19
		L	1.4	1.2	1.5	1.5	1.3			
5	M	U	2.0	1.8	1.7	3.1	2.0	XX	XX	0.54
		L	1.3	1.8	2.2	1.9	1.9			
	A	U	1.3	0.8	0.7	1.2	1.00	XX	N.S.	0.38
		L	1.4	1.1	1.1	1.1	0.9			
7	M	U	4.0	2.1	1.5	2.0	2.4	XX	N.S.	4.11
		L	7.8	2.7	1.9	1.9	2.5			
		U	5.6	6.1	2.3	2.7	7.1	XX	N.S.	3.51
		L	10.1	9.2	5.3	2.7	9.6			
9	M	U	3.7	4.9	3.3	2.2	4.5	N.S.	XXX	4.67
		L	8.4	10.4	12.5	8.9	9.7			
	A	U	3.6	5.1	3.9	3.3	5.1	N.S.	XXX	4.43
		L	11.5	12.8	8.5	8.5	9.7			

M: Morning.
A: Afternoon.

kg/ha (29 percent higher). In RFTT-2, mean grain yield of the TZE_3 families was 2,588 kg/ha while mean grain yield of selected families was 3,081 kg/ha (19 percent higher). Grain yield varied from 213-2,248 kg/ha in Senegal and 1,640-5,566 kg/ha at Kamboinse, Upper Volta. In RFTT-3, grain yield of TZPB families varied from 4,685-12,567 kg/ha at Fereke, Ivory Coast, and 1,258-4,743 kg/ha at Saria, Upper Volta. The average yield of selected families was 6,151 kg/ha, which was 19 percent more than the population mean (5,160 kg/ha). In RFTT-4, full-sib families yielded 3,408-10,330 kg/ha at Fereke, Ivory Coast, 2,300-6,326 kg/ha at Kamboinse, Upper Volta. Mean grain yield of all the families tested in this trial was 5,329 kg/ha, and the average yield of the selected families was 6,052 kg/ha, which is about 15 percent higher than the population.

On-site experiments in Upper Volta

The SAFGRAD research trials in Upper Volta were conducted at three locations, Kamboinse, Saria and Bobo-Dioulasso. In all, 10 varietal trials were conducted: RUVT-1, RUVT-2, RFTT-1, RFTT-2, RFTT-3, RFTT-4, country trial-1, PET-1, PET-3 and TZPB (EPS) full-sib family trial. The results from two RUVT trials and four RFTT trials have already been presented in this report under regional activity. Results of the other trials are summarized below.

Country trial-1. In 1978, more than 100 varieties, composites and populations were evaluated at Saria in observation plots. Based on these results, 49 cultivars were selected and evaluated in 7 × 7 lattice design with 2 replications at Kamboinse, Saria and Bobo, in 1979. Plot size was 4 rows, 5 m long.

Significant differences in grain yield were observed among the varieties at the three locations. On the basis of average yield over the three locations, H 763 was the highest-yielding entry (4,590 kg/ha) followed by BDS III (4,306 kg/ha), Phil DMR comp I (4,280 kg/ha) and BIU yellow (4,170 kg/ha). TZPB on an average yielded 3,693 kg/ha. IRAT 100, IRAT 80 and Massayomba yielded 3,494, 3,021 and 3,329 kg/ha, respectively. Among the early-maturing varieties tested in this trial TZE_4 yielded 3,370 kg/ha.

Preliminary Evaluation Trials (PET-1 and PET-3). PET-1 and PET-3 were received from CIMMYT, and both the trials were conducted at Kamboinse in 1979. PET-1 consisted of tropical early-maturing populations, and PET-3 consisted of temperate or temperate × tropical populations. There were 10 entries in PET-1 and 18 in PET-3. Both trials were laid out as randomized block design with four replications. Plot size was four rows, 5 m long.

Significant differnces in yield among varieties were observed in PET-1 but not in PET-3. None of the varieties tested in PET-1 was significantly superior to the highest-yielding check variety, IRAT 102.

TZPB (EPS) full-sib family trial. Full-sib families developed in TZPB (EPS) population at IITA in 1978 were tested in randomized block design with an objective to select the most promising families for reconstituting the population adapted to semi-arid environment. On the basis of grain yield and other agronomic characters, 50 families have been selected and will be utilized for recombination in 1980 season.

Agronomy

The semi-arid tropics do not only have the problem of low and erratic rainfall, but the areas also have soil conditions such as crusting and soil management practices such as crop residue removal that lead to reduced water infiltration and increased runoff.

Further, research during 1979 showed that a dry spell during the growing season may be a more important factor than the length of the growing season for raising a successful maize crop in Upper Volta. Early varieties will not necessarily outyield late ones, depending on when the crop is subjected to moisture stress. In Saria, for instance, in a Plant Density Trial, IRAT 80 (60 days to 50 percent silking) yielded as well as Jaune Flint de Saria and TZE_3 (both about 50 days to 50 percent silking) in spite of a late planting date (July, 7) and the limited useful rainfall after 80 days after planting. In Saria, in a Regional Uiform Variety Trial (RUVT-1) late varieties outyielded early ones.

Indeed, the erratic occurrence of the dry spells during the growing season poses difficult crop management problems. Even though August is generally the wettest month (in both total precipitation and number of rainy days), it was a dry month for Saria and Farako-Ba in 1979. The variability in precipitation pattern occurs not only from year to year but also from location to location and even from field to field.

Also, risks for growing maize were found to be reduced by management practices such as planting maize on deeper soils or on soils situated in the lower parts of the toposequence. Other management likely to increase water infiltration in the soil and/or to reduce water losses will also reduce the risk factor for growing maize, e.g. depth of soil preparation, cultivation, additions of organic residues and manure and mulching, but there is clearly a need to quantify these effects to determine their cost-benefit ratio.

The lowest mean grain yields per trial were obtained in Saria (1,810 kg/ha) on a shallow soil while the highest were obtained at Kamboinse (3,800 kg/ha) on a deep soil. The highest yielding treatments for the same trials gave 2,080 and 4,420 kg/ha, respectively (Table 27).

The results of 1979 showed that the linear model postulated by Duncan to relate the yield per plant to plant density can also be used in the semi-arid tropics. By having only two plant densities, the optimum density and the grain yield can be calculated at the optimum density. For medium-maturity varieties (about 60 days to 50 percent silking), the optimum densities were between 30,000-70,000 plants/ha. For early-maturity varieties (about 50 days to 50 percent silking), the optimum densities were between 60,000-80,000 plants/ha. The optimum densities tended to increase with the fertilizer level.

In spite of large differences in depth of soil preparation between bullock and tractor plowing, there were no differences in grain yields between both methods in a trial planted on a shallow soil. Both methods gave yields 40-50 percent superior to those obtained with the farmer's conventional daba (hoe) soil preparation. No-till with paraquat weed control was no better than the farmer's conventional method. There was no difference in grain yield between planting on a flat seedbed and planting on ridges. Planting on tied ridges and also planting on a flat seedbed with ridging and tying 4 weeks after planting tended to give higher yields than those obtained with plain ridges because of increased water reserves in the soil.

At a low plant density (about 50 percent of optimum plant population), there was no effect of row spacings (37.5, 75.0 and 112.5 cm) on grain yields. At a density close to the optimum, however, the widest row spacing (112.5 cm) gave significantly lower yields because of too high inter-plant competition. Growing a maize crop at very high plant densities up to 31 days after planting and then cutting half of the plants for mulch *in situ* gave yields that were comparable to or higher than those of plots grown at the same (as above) final plant densities since planting time (control). When the cutting of the excess plants was delayed until 45 days after planting, grain yields were decreased in relation to the control.

Based on 1979 results, TZE_3 and TZE_4 appear to offer no grain yield advantage over Jaune Flint de Saria (a local population improved by IRAT through mass selection) nor over two local Kamboinse materials. All these materials are of similar maturity (around 50 days to 50 percent silking). TZE_3 and TZE_4, however, have more resistance to lodging and also more resistance to foliar diseases.

Planting depth was an important factor affecting the yield of a local variety but not that of TZE_4 or Jaune Flint de Saria. At a shallow planting depth (3-5 cm), all three varieties had similar yields, both under ridges and a flat seedbed. At a deep planting depth (8-10 cm), the yield of the local variety was sharply reduced. The local variety has more difficulty to emerge through deep planting depths and variability in emergence increases interplant competition in a way such that final grain per unit area is decreased.

Entomology

Since little information was available on the insect complex of the maize crop in Upper Volta, SAFGRAD's first year research efforts into maize entomology was to find out the insect and non-insect pests associated with this crop. Studies were carried out to assess avoidable loss by insecticide treatments on important pests that feed at different stages of crop growth.

Insects associated with maize. Seventeen pests were found feeding on maize crop at different stages of crop growth. Out of these, millipedes (a non-insect pest), termites and armyworm were very important. At times, they can substantially reduce yields. Borers, *Sesamia calamistis* and *Eldana saccharina*, were observed on early planted maize. The percent of infestation, planted in early June, ranged from 5.9-46.3 in Jaune Flint de Saria and 30.4-45.1 in Jaune de Fo. The two improved local varieties planted in late June or July had no borer infestation. Armyworms, an important leaf-feeding insect, were also observed. A number of infested plants varied from 5.9-12.4 percent in Jaune Flint de Saria and 6.0-16.5 percent in Jaune de Fo in early June planting, and 3.7 and 5.0 percent in late June planting, respectively.

Estimation of yield loss due to insect pests of maize. To determine the yield loss due to insect pests, an experiment was planted on 15 July 1979, in a split plot design. The whole plots were insecticide treatments: untreated (WP1) vs. treated (WP2); subplots were four varieties of maize, Jaune Flint de Saria (JFS), TZE_3, IRAT 102 and TZPB. Plot size was 6 rows, 5 m long. Plant spacing was 75 cm × 25 cm. Plants were thinned to two per hill. Before planting, heptachlor at 0.5 kg/ha a.i. was mixed with the fertilizer and applied in the soil to check infestation by millipedes. Basal doses of 108 kg of N was applied, split two times after 21 and 42 days after planting.

Grain yield varied significantly in treated and untreated plots and also among varieties. In untreated plots, TZE_3 yielded significantly less than JFS and IRAT 102, but there was no difference in yield between TZE_3 and TZPB. In treated plots, TZPB gave the lowest grain yield, and there was no difference among other varieties. IRAT 102 gave the highest yield of 4,820 kg/ha. TZE_3 produced 806 kg more yield per ha in treated plots than untreated. No other variety had such a big difference. JFS and IRAT 102 also produced higher yield in treated plots, and the dif-

Table 27. Maize agronomy trials, overall averages and best treatment grain yields (1979).

Trial	Location	Overall avg. kg/ha	Best treatment* kg/ha	Remarks
1. Plant density	Farako-Bâ	2447	4341	IRAT 100 (110 days), at 67,000 plants/ha)
				IRAT 80 (110 days), at 66,000 plants/ha
	Saria	2706	3741	
2. Soil preparation methods	Saria	2129	2447	Bullock plowing, shallow soil
3. Seedbeds	Kamboinsé	3706	4471	JFS (90 days); ridging 4 WAP (tied)
4. Spatial arrangements	Kamboinsé	3294	4329	Planted at 133,000 plants/ha; every other row was then cut 31 DAP
	Saria	2918	3835	
5. Mulching	Kamboinsé	2965	3459	TZE3 (90 days)
	Saria	2141	2800	TZE3 (90 days); shallow soil
6. Rotation	Saria	2729	2929	120-69-42 kg N-P_2O_5-K_2O/ha
7. Phosphatic rock	Saria	2235	3153	100 kg P_2O_5/ha; source single superphosphate
8. Planting depths	Kamboinsé	4471	5200	JFS (90 days); deep soil

*These are the treatments with the highest grain yields, but treatment differences were not always statistically significant.

An IITA agronomist (lower right) discusses with village farmers results of a high-yielding rice variety selected and developed by the Sierra Leone/IITA/UNDP/FAO Project in cooperation with the Rokupr Rice Research Station. Varieties are tested on farmers' fields before being recommended for widespread adoption.

ferences were 447 and 480 kg/ha, respectively. There was very little difference in yield between treated and untreated plots for TZPB.

From yield data, insects were found to cause significant losses in yield. Infestation of termites would have been more if a basal dose of heptachlor had not been given. Similarly, *Eldana* sp., which survives on organic matter in the soil, might also have attacked the crop if insecticide had not been applied.

In this experiment, no borer infestation was observed from sowing till harvest.

UNDP: Sierra Leone Rice Project

This is a UNDP-funded FAO field project in support of the Rice Research Station at Rokupr, as sub-contracted to IITA. Participation in this project enables IITA to undertake research in rice pathology and agronomy and test improved rice varieties on farmers' fields.

Rice pathology

High-yielding varieties with disease and insect resistance have been identified and are available for the different ecosystems of Sierra Leone. Several of these cultivars, which possess horizontal resistance to blast and pale yellow mottle virus, were incorporated in the 1979 yield trials. Twenty-six advanced lines for upland and 11 lines for irrigated and shallow swamp were selected for their superior performance, including good resistance to blast.

In disease surveys, blast continues to be the most important disease in upland rice, which occupies about 70 percent of the area under rice in Sierra Leone. At the newly cleared upland experimental site at Sendugu, several cultivars suffered from severe brown spot, particularly where grass was the predominant vegetation prior to clearing. "Dirty panicles" were rampant among several brown spot affected plants. Scald was common, although it appeared later compared with previous years. Sheath rot was found in several cultivars; sheath blotch was not as common. Crinkle, pale yellow mottle and false smut were sporadic. In shallow irrigated swamps, blast and brown spot were the most common diseases. The occurrence of brown spot disease was in the new site and was perhaps due to soil mineral imbalance. Blast was damaging on a few varieties promoted by the Ministry of Agriculture in the Eastern and Northern Provinces.

An inland swamp in the Eastern Province (Bala town) was found severely affected by pale yellow mottle. This swamp harbors ratoon from previous years crops; at the same time, it is planted to new crop from year to year. It is likely that such situations account for the relatively high incidence of pale yellow mottle among rice fields in the Eastern Province.

In bolilands, farmers' plots were found generally free of serious diseases. A few isolated patches among rice fields in the Northern Province were desiccated due to brown spot. In experimental plots in Gbomsamba, some test cultivars were severely affected by brown spot and "dirty panicles."

Rice agronomy

During the 1978-79 dry season, nine experiments were conducted in irrigated rice at Mange. The important findings from these experiments are summarized below:

Yield maximization. Rectangular transplanting under a moderate level of fertility ($N_{80}P_{40}K_{40}$) with manual weeding gave a higher yield (2,021 kg/ha) than random transplanting under similar fertility but without weeding (1,784 kg/ha). All other treatments gave yields ranging from 1,651 to 1,253 kg/ha.

International trials on nitrogen fertilizer efficiency in rice. Plow sole application (by means of a drilling hoe) of sulfur coated urea (54 kg N/ha) and urea (87 kg N/ha) applied in three splits gave the highest yield (2,364 kg/ha). Second best was ammoniun sulfate applied in three splits at the rate of 120 kg N/ha with a yield of 2,207 kg/ha, followed by broadcasting and incorporation of ordinary sulfur coated urea at the rate of 87 kg N/ha with a yield of 2,106 kg/ha. However, broadcasting and incorporation of the same at the rate of 54 kg N/ha gave almost similar yields (2,101 kg/ha). All sources increased the yield over the no-fertilizer control, which gave the lowest yield (1,466 kg/ha). There was no significant difference among the treatments.

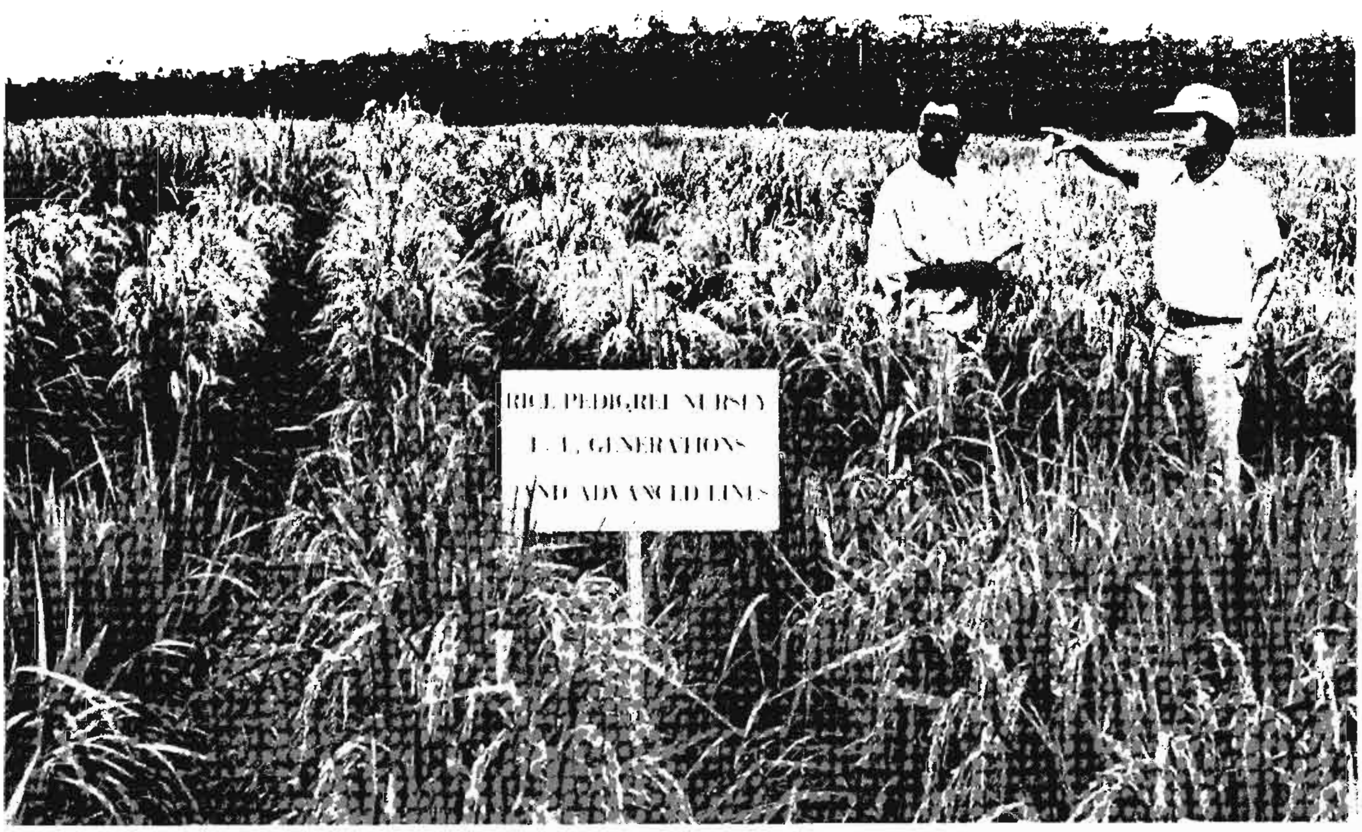
International long-term fertility trial. This experiment was initiated in the 1976 wet season. $N_{60}P_{40}K_{40}$ was found to give consistently the highest yield; the yield in the 1978-79 dry season was 2,636 kg/ha.

$N_{60}K_{40}$ was second best (2,593 kg/ha), followed by $N_{60}P_{40}K_{40}$ + Mn (2459 kg/ha) and $N_{60}P_{40}K_{40}$ + Mo (2,289 kg/ha), $N_{60}P_{40}K_{40}$ + Mn + Zn + Mo and $N_{60}P_{40}$ (2,215-2,208 kg/ha); all other treatments gave less than 2,000 kg/ha, and the control gave 1,563 kg/ha. The differences among treatments were not significant.

Direct, residual and cumulative effects of P and K. Phosphorus (P_2O_5) and potassium (K_2O) applied at 60 kg/ha either alone or in combination, applied fully in wet or dry season or half in the wet and half in the dry season did not show any significant difference among treatments.

Nitrogen × variety interaction. Significant interaction between N levels × variety interaction was observed. Without N, varieties, PN 623-3, PN 390 SLR2 and PN 6-11-1, gave yields between 1,532-1,607 kg/ha only. At 40 kg N/ha, 529 CMD 10-3-6, TOx 502-6-NK12-NIDI, PN 6-11-6 and PN 623-3 gave the best response; the yields ranged between 1,954-2,202 kg/ha. At 80 kg N/ha, TOx 502-6 NK12-NIDI gave 2,639 kg/ha; the yields of all other varieties gave less than 2,200 kg/ha. At 120 kg N/ha, PN 623-3 (2,381 kg/ha), BPI 76 (NS) (2,163 kg/ha) and 529 CMD 10-3-6 (2,222 kg/ha) gave the best response; all other varieties gave less than 2,000 kg/ha.

Cassava, cowpea and maize production potential. Besides rice, other crops (cereals, grain legumes and root and tuber crops) studied in the 1978-79 wet and dry sea-



General view of new F_3 and F_4 families of high-yielding upland breeding lines of rice being developed at IITA.

sons without resource constraint but affecting economy of water in the dry season, showed that cassava gave the highest income. Groundnut is promising in the dry season with good yields and high returns, followed by maize, which gave better yields in the dry season than in the wet season when waterlogging affected the crop. Cowpea is also promising and gave better returns than rice.

Rice extension

The objective of the project's extension work is to place increased emphasis on applied research adapted to the farm situation, on technology transfer to Sierra Leonean farmers and on the generation of feedback from the farm to guide further applied research and field extension operation. Extension activities were intensified in the 1978-79 dry season, five each of type 'A' and type 'B' 'on farm' trials were conducted in the inland valley swamp ecology at Sendugu village with the farmers of the village actively participating in all field operations.

Type 'A' trials. The variety BS SID-28-2 gave the highest yield of 4,387 kg/ha, followed by 2,246 with a yield of 3,675 kg/ha. Rok 12, Rok 14 and the local variety gave yields of 3,196, 2,796 and 2,706 kg/ha, respectively.

Type 'B' trials. Rok 14 with a balanced application of $N_{60}P_{30}K_{30}$ gave the highest response of 2,195 kg/ha over the control yield of 895 kg/ha. $P_{30}K_{30}$, P_{30} and K_{30} gave responses of 965, 500 and 480 kg/ha, respectively, which comfirm the earlier finding that when only one or two nutrients are applied to rice in the IVS, the choice should be P and/or K.

F_3 families of TOx 1369 rice line possessing desirable characters for dryland conditions such as upright narrow leaves, medium-quantity tillering and strong leaves.

TRAINING PROGRAM

Necessity for additional trained agricultural research and extension personnel is a felt need of African governments and institutions which work with IITA. Working to increase the number of scientific, technical and extension personnel who are equipped and motivated to contribute to the development of food production in the tropics, training continued to be an integral part of IITA in 1979. The program offers several categories and levels of training to cope with the challenge. Through training activities, participants contribute to the transfer of IITA technology and provide valuable feedback to the Institute's research programs.

While planning any training initiative, the following criteria are ensured:

1. That the program represents a need at the national level and has the capacity to contribute at the Institute level.
2. That it makes a definite contribution both to the Institute and to the national program.
3. That it does not stand isolated by itself but is fully integrated into the overall program of the Institute.
4. That priority is given to the food production benefits within the geographic area over which IITA has a mandate.
5. That it catalyzes a relay effect on training at the national levels.
6. That the facilities and funds assigned to the program are efficiently utilized so as to produce a substantial pay-off.

Training services

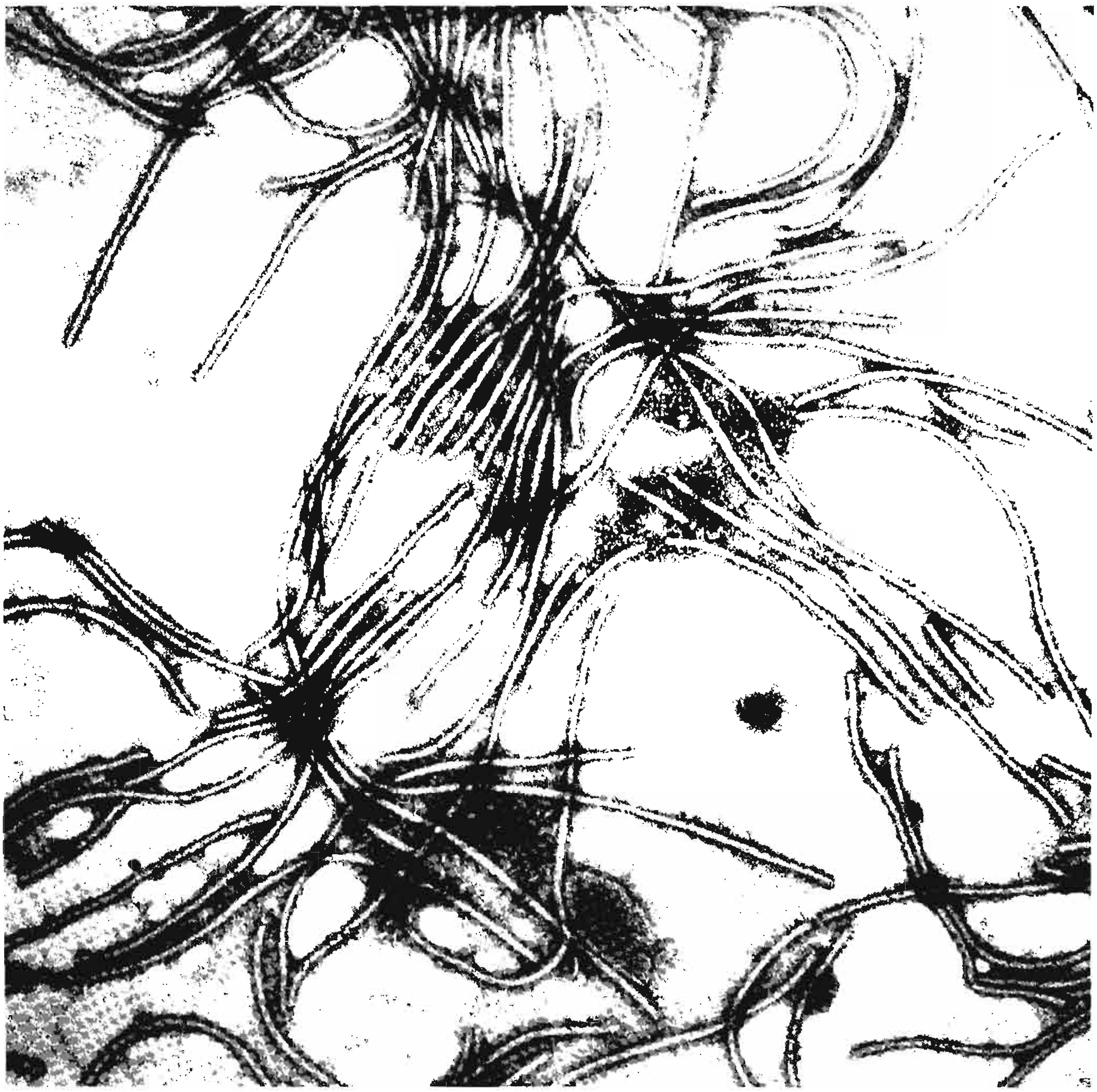
IITA is able to receive more than 250 participants each year. Its training services are organized into the following categories:

Degree-related research training program. This program provides for the supervision of students working on the research portion of their degrees. Over the years, the Institute has received 134 postgraduate degree candidates from 33 universities of Africa, Australia, Europe and North America for supervision of the research portion of their degrees. During 1979, 35 Master students and 26 Ph.D students, representing 17 countries (11 in Africa), were engaged in research.

Non-degree-related research training program. This program provides for training for employees of departments and ministries of agriculture, universities, experiment stations, research institutes, international organizations and private agencies who need to acquire additional technological research or production skills. Each program is individual in nature and is planned for specific participants. During 1979, 163 persons were at IITA in this category.

Vacation student research scholarships. Summer scholarships have been awarded to 144 final year students of faculties and schools of agriculture in West and Central Africa since 1971. The program is designed to establish relationships with universities of Africa and to identify young people who are attracted to careers in agricultural research. Ten students were received in this program in 1979.

Group courses program. This program provides for the training of groups of agricultural technicians, research workers and extension supervisors. The courses, many of which are bilingual (English/French), are in research and extension, covering subjects of soil microbiology, soil and water conservation, genetic resources conservation and soil and plant analyses. About six of these courses are coordinated each year. Over 800 agricultural technicians, research workers and extension supervisors from 52 countries have participated in the Institute's group courses program. About 200 participants were received through this program in 1979.



One of the support services for the research programs includes the Virology Unit and the electron microscope. This photo shows a purified preparation of sweet potato virus as seen in the electron microscope. (Photo magnified 100,000 times.)

RESEARCH SUPPORT

Introduction

Research support units provide essential services to the research programs — developed land and field services at IITA's two sites (Ibadan and the Onne substation), as well as planting material services through the Genetic Resources Unit. Support facilities also include the Virology Unit, Library, Conference Center, Communications and Information Office and Physical Plant Services. The latter enables the Institute to be largely self-sufficient for the needs of water, electricity, construction and required maintenance.

High-rainfall substation

The Onne substation continued research in crop improvement and farming systems in its high-rainfall environment. Granted to IITA by Rivers State in 1974, the Onne substation is an 80-ha site in the humid coastal zone of Nigeria (Table 1), to assist specifically the four major research programs of IITA. The Onne substation placed emphasis in 1979 on cassava, cowpea, maize, rice and plantain as well as weed science and soil chemistry and fertility research, the highlights of which are contained in the following reports.

Farming systems

Weed science. A long-term trial continued on the performance of sole and mixed crops under various weed control regimes. Information from this experiment will be useful for commercial farmers looking for an economic optimum for weed control, without losing yield. A newly established trial is designed to study the persistence of herbicides under heavy leaching and freely drained soil conditions at Onne.

Soil chemistry and fertility. A long-term trial, now in its sixth season, is showing valuable trends; the experiment is looking at the leaching rate of exchangeable cations and the residual effect of lime. Maize is grown in the first season and cowpea in the second. However, soybean will be substituted for cowpea in 1980 because soybeans are more sensitive to soil acidity.

The first season saw the cropping of a clearing/residue management trial. Maize was the test crop. Whole plot treatments consisted of hand cleared plots, either burnt or mulched with brushwood. Fertilizer levels were studied in subplots including a non-fertilized control plot.

Two trials were conducted to investigate the response of cassava to K and the interaction of K with Mg.

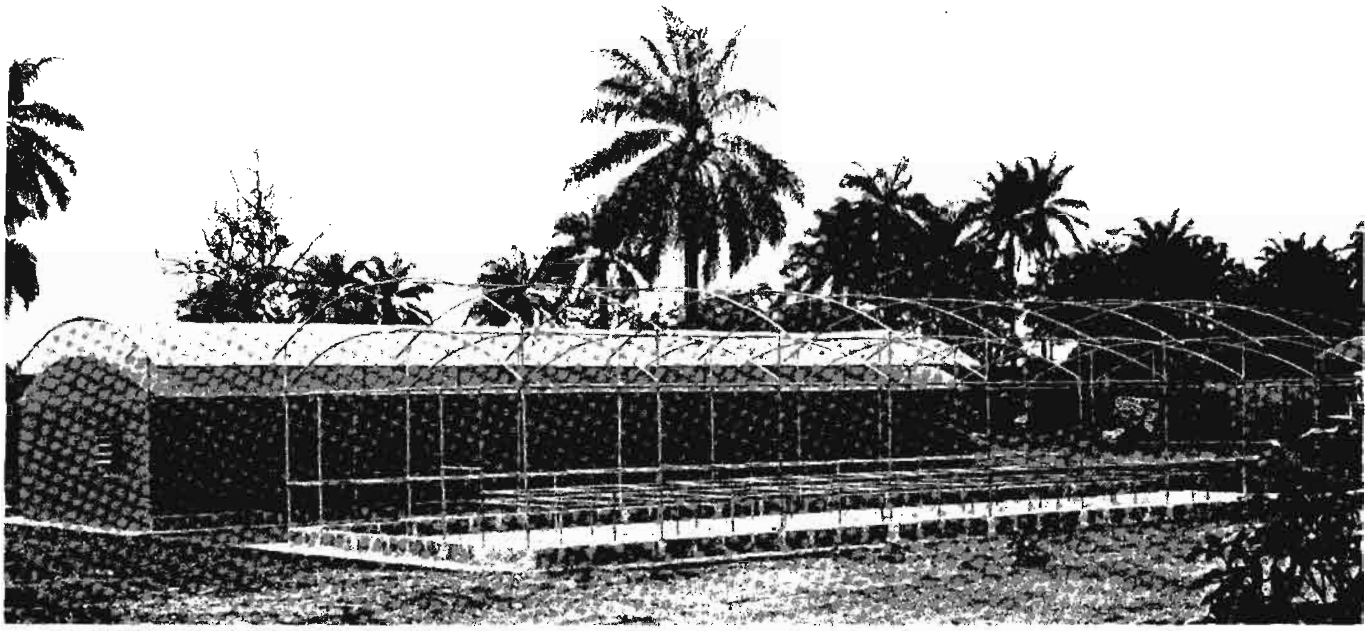
Plantains. An evaluation of the response of plantain to micro-nutrients continued. The collection of plantain varieties was maintained with some new varieties added. An intercropping trial involved plantains with rice and sweet potato. The rice and sweet potatoes were catch cropped before the plantain grew too tall and light became limiting. This demonstrated an efficient way of utilizing land before the plantain crop matures.

Root and tuber improvement

The recent identification of two new pests of cassava in Nigeria — the green spider mite (*Mononychellus*) and the cassava mealybug (*Phenacoccus*) — has emphasized the importance of the Onne substation as a source of disease-free material for planting. Continued yield trials of improved cassava varieties showed that two clones, TMS 30572 and TMS 30555, are capable of a respectable performance under Onne's soil and climatic conditions.

Table 1. Monthly temperature and rainfall recorded at the Onne substation during 1979.

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Year
Average max. temp. (°C)	32.9	33.1	32.6	31.8	30.7	29.2	28.4	28.1	29.1	29.5	30.4	32.7	30.7
Average mean temp. (°C)	27.8	27.9	29.0	27.8	26.9	25.8	25.6	26.0	26.0	26.0	26.7	26.6	26.7
Average min. temp. (°C)	22.7	22.7	23.4	23.8	23.2	22.4	22.8	23.1	22.9	22.6	23.1	20.6	22.8
Monthly rainfall (mm)	0.0	176.0	117.8	175.5	223.0	412.2	378.2	220.0	392.4	353.8	163.8	1.3	2614.0



Pre-cut virology screenhouses with good temperature control under construction at IITA.

Multiplication of selected clones of cassava has expanded to maintain a stock of disease-free material and to release some of these clones to progressive farms and allied industries for further evaluation. Cassava cuttings from Onne were supplied to the Cross River Agriculture Ministry and Imo State's Nigeria Starch Mills. Twenty-seven clones of sweet potato were assessed in yield trials with promising results.

Grain legume improvement

In both first and second seasons, grain and vegetable cowpeas were evaluated for yield. The first season plantings were attacked, by *Maruca*, but the second season trials, although planted late, were successful. Screening trials for cowpea and soybean lines, capable of fixing N and tolerating soil conditions of high Al saturation and low Ca levels, showed good results. Three management trials, covering 1.5 ha, investigate the performance of soybean and cowpea lines under spacing and applied N vs Innoculant and K applied lime combinations. Finally, some disease screening work on a small scale was carried out with a view to expanding next year.

Cereal improvement

Maize lines were screened for tolerance to high rainfall and acid soil conditions. Also, rice was grown successfully in both seasons despite army worm (*Pseudoletia*) in the first season.

Trials included: Breeding trials for selection of improved material; international varietal performance trials, yield trials, screening for resistance to blast, and selection of radiation induced mutants for breeding.

Research station operations

Farm Management provides field support for scientific programs at IITA and the Onne substation. At IITA, 300 ha of land have been developed for research including 40 ha in 1979. This area has been provided with an adequate network of access roads and has been protected by soil conservation measures where necessary. All fields have been identified and marked, and 90 ha of overhead irrigation has been installed. The irrigated area carries three crops per year while the remaining area carries two. Development of the high-rainfall substation at Onne commenced in 1976 and to date 41 ha have been developed for research. In addition, buildings have been erected to house stores, workshop, offices and laboratories, and adequate farm equipment has been purchased.

Screenhouses

With the aim to develop a greenhouse suitable for the hot and humid tropics and not dependent on air-conditioning, three screenhouses were built according to the design of an experimental unit at IITA (IITA Annual Report 1978). The construction of these screenhouses consisted of assembling a pre-cut pipe framework by means of clamps. Benches were provided within the framework by the same pipe and clamps covered with aluminum sheets. For cladding, U.V. stabilized polythene fine mesh screen and heavy-duty roofing sheets were chosen. These materials are comparatively inexpensive and last at least two years.

Screen and roofing sheets were attached to the pipe framework by means of aluminum strips, which made cladding simple and enables rescreening in a comparatively short time. The temperature regime inside these screenhouses also approaches environmental conditions, which is considered to be largely due to the independent roofing principle, enabling efficient natural ventilation through the screen top.

Screenhouses of this type, not requiring much expertise in terms of construction have a proven purpose : experimentation under adequate insect proof and temperature controlled conditions at a low cost.

An IITA plant explorer samples the genetic diversity of cowpeas in a Nigerian market.

Genetic Resources Unit

In the four years since IITA's Genetic Resources Unit (GRU) was established, its plant collectors have gathered 16,500 germplasm accessions, most of them food legumes and rice. These genetic resources come mostly from the great diversity to be found within the ancient traditional crops of peasant farms in sub-Saharan Africa.

When the various collections and donations of germplasm that are still in transit to IITA from outside Nigeria reach the Institute, the Genetic Resources Unit will hold more than 27,000 accessions in its germplasm banks. This bank has 75 plant species, among them food legumes, rice, yams (and some of the wild relatives of these crops) and African cassava clones. Already the bank has 20,129 items of which the largest crop collections are of cowpea (10,364), lima beans (1,421), African land races of Asian rice (2,706), African rice (1,307) and yams (508 clones).

The unit continued to pursue its objective to collect, preserve and promote the use of crop genetic resources from sub-Saharan Africa. In six exploration missions, 3,244 accessions were gathered, 950 from Nigeria, 307 from North Sudan, 1,287 from Cameroon, 646 from Tanzania and 54 from Kenya. Collaborators from many countries and research institutions donated a further 1,009 samples, bringing the total of acquisitions in 1979 to 4,253.

The use of germplasm was promoted during the year by the distribution to many parts of the world of 6,073 samples of legume seeds and 5,878 samples of rice from the Genetic Resources Unit germplasm bank (Table 2). But the preservation and distribution of viable seed are alone not enough to promote and expand the use of crop germplasm. The study and documentation of the large collections is essential to their subsequent use by crop improvement scientists.

More than 5,500 items of food legume and rice germplasm were studied and evaluated for numerous traits, either by the pathologists of the crop improvement programs or Genetic Resources Unit scientists. The data gathered in these studies as well as information about the source of new germplasm were added to the unit's computer data banks for storage and quick retrieval.

In genetic resources management, 5,745 items of germplasm were grown for seed increase and maintenance in 1979, and the unit continued to manage short- and medium-term seed stores for the Institute. Installation of a −20° C, long-term seed store (84 m^3) began at the end of the year. It will be used to preserve IITA's world collection of cowpea germplasm and African rice though both of these important collections will be kept at other genetic resources centers as well.

Among the other activities of the Genetic Resources Unit were various studies on rice and an assessment of the effects of nematode control on the storage life of yam germplasm tubers.

Oryza spp.

Seed dormancy in *Oryza* spp. In termination tests with fresh seeds at 29° C, seed dormancy was retained longer in *O. glaberrima* (60 days) and *O. barthii* (80 days) than in *O. sativa* (10 days). Seed of *O. glaberrima* held its dormancy longer at 5° C than at 16-20° C; at 5° C, seed with about 12 percent moisture content held its own dormancy in storage longer than seed dried to 7 percent moisture.

Photoperiod response in *O. glaberrima*. Seven hundred accessions of *O. glaberrima* and 480 of *O. sativa* from the germplasm collections were sown in April and again in November. Differences between sowing dates in number of days to flowering suggested that most of the African rices are photosensitive with a short-day requirement for flowering. Sowing dates had much less effect upon days to flowering in the Asian rices (which were collected in Africa). The results also indicated a correlation between *O. glaberrima* ecotypes and response to photoperiod; varieties adapted to swamps and deep-flooded ecologies were strongly photosensitive compared with most upland varieties, which flowered sooner and in longer days.

Drought tolerance in *O. glaberrima*. In a simulated drought stress experiment, 250 *O. glaberrima* varieties were found to be more drought tolerant than a susceptible *O. sativa* control (Moroberekan). None of the *O. glaberrima* types was superior to the *O. sativa* drought tolerant control (IRRI 6495), but half of them were at least as tolerant.

Blast disease in *O. glaberrima*. Of 401 *O. glaberrima* accessions, only 8 percent showed blast disease symptoms in a field screening test, which included a blast susceptible *O. sativa* control (OS 6) and 13 *O. sativa* varieties susceptible to a range of blast races. Six of the latter expressed disease symptoms, but it was not possible to identify the races of blast involved.

The inheritance of rice blast disease tolerance. In crosses between varieties of *O. glaberrima*, tolerant and susceptible to blast disease, all F_1 plants were tolerant. The study of large F_2 populations continues (1,500 plants from each cross). Hybrids were also made between *O. sativa* and *O. glaberrima* not only to study blast disease inheritance but also to assess the possibility of gene transfer between the species. All of seven cross combinations were successful, but all of the F_1 plants were male sterile (0-10 percent pollen fertility). Backcrosses to both parental species were successful, and the backcross seed was sown in the field at the end of the year.

Nematode control and the storage of yam tubers. A field trial with white guinea yam (*Dioscorea rotundata*, variety Egbe) was conducted to see if the control of nematodes with nematocide during crop growth would influence subsequent losses of rotten tubers in storage. This is highly relevant to the maintenance of yam germplasm as vegetatively propagated clones.

There were two species of nematodes present in the field, the root-knot nematode *Meloidogyne javanica* and the lesion nematode *Pratylenchus brachyurus*. Populations of both species increased markedly during crop growth in plots without nematocide, but 6 kg/ha a.i. of oxamyl gave good control. A granular formulation applied to the soil was most effective in the control of *M. javanica* while the foliar application of liquid formulation was most effective in the control of *P. brachyurus*. In storage for 4 months after harvest, 53 percent of the tubers from the untreated control plot rotted compared with 39 percent from the best nematocide treatment. The nematocide had no effect on tuber sprouting in storage nor after they were planted. The plants grown from treated tubers were normal.

Virology Unit

To facilitate the control of virus diseases causing economic loss in the crops under investigation at IITA, the Virology Unit continued studies of the etiology of virus diseases in cassava, sweet potato, cocoyam, yam, cowpea, lima bean, soybean, maize and rice. In addition, epidemiological studies as well as studies on resistance screening and indexing methods are aspects of the work covered by this unit.

Cassava

African cassava mosaic is currently the only virus disease known in this crop in Nigeria. The Geminivirus consistently isolated from infected plants has not yet been transmitted back to cassava. The isolated virus reaches high concentrations in its primary isolation host, *Nicotiana benthamiana*. Since it was consistently isolated from symptom plants collected from all over Nigeria and never from symptomless plants, this isolated virus is assumed to be the causal agent of the disease.

The virus was purified from infected tissues of *N. benthamiana, N. glutinosa, N. tabacum* "Samsun NN" and *N. clevelandii*. Initial purification attempts using different

Table 2. Numbers of samples of legume and rice germplasm distributed by the Genetic Resources Unit in 1979.

Destination	Cowpea	Lima bean	Winged bean	Pigeon pea	Soybean	Other legumes	Rice	Total
Africa	2066	40	201	17	3	71	38	2436
Asia	591		7	1		29		628
Europe	217	387	46	3				653
America	20	400	4			43	30	97
IRRI							585	585
WARDA							666	666
IRAT							666	666
IITA	1717	35	42	17	3	113	3893	5820
Total	4611	862	300	38	6	256	5878	11951

buffers showed that 0.05 *M* phosphate buffer (pH 7.8) containing 0.1 percent of 2-mercaptoethanol gave good results as evaluated by virus yield and infectivity on *N. benthamiana.*

Also, the effect of organic solvents on infectivity and virus yield was tested by adding:

1. n-butanol at 8 percent (v/v),
2. Chloroform ¼ volume,
3. Chloroform/n-butanol (half volume of 1:1 mixture), or
4. Chloroform/carbon tetrachoride (25 ml each for every 100 ml juice).

Treatment with chloroform gave better infectivity although the chloroform/butanol treatment yielded preparations most free of plant protein contaminant, but virus infectivity was lower.

The virus was further concentrated either by precipitation in 8 percent polyethylene glycol 600 (PEG) and 0.25 *M* NaC1 or by direct centrifugation for 4 hours at 29,000 rpm in a Beckman 30 rotor. Since centrifugation yielded higher amounts of virus, it was adopted as the standard purification procedure. The preparation was further purified by differential centrifugation and subject to rate-zonal centrifugation on a linear gradient of 10-40 percent sucrose in 0.05 *M* phosphate buffer (pH 7.2) for 4 hours at 25,000 rpm in a SW-27 rotor. Gradients gave 2 ultraviolet absorbing regions when monitored at 254 nm, and both were infective when tested on *N. benthamiana*. The peaks are thought to represent singlet and doublet particles. Similar purification procedures, using healthy leaves, yielded no virus peaks.

The virus was also purified from infected cassava leaves producing identical peaks in the sucrose gradient. When *N. benthamiana* was inoculated with samples from these peaks, symptoms were produced identical to the ones described earlier. However, the virus yield from cassava leaves was only about 1/100 of the yield from *N. benthamiana* by comparing the peaks as monitored by ISCO density gradient fractionator as well as by judging infectivity by using dilution series.

Cleaner preparations were obtained when partially purified preparations were absorbed with an antiserum prepared against plant proteins from healthy plants. After absorption and low-speed centrifugation, the virus is pelleted by high-speed centrifugation followed by density gradient centrifugation.

Sweet potato

A virus was transmitted consistently to *N. benthamiana* by sap inoculation from sweet potato plants with a great variety of virus-like symptoms. The virus on back tests to *Ipomea setosa* induced the same characteristic symptom as earlier described for the aphid-transmitted component of the sweet potato virus disease complex (IITA Annual Report 1975).

The isolated virus proved to reach high concentrations in *N. benthamiana* but could not be further transmitted to *N. tabacum* "Samsun NN," *N. glutinosa* or *N. clevelandii*. On testing seedling populations of the sweet potato clones Tlb 8 and Tlb 10 by sap inoculation from *N. benthamiana*, no symptoms could be induced with 2 different isolates in any of 20 seedlings after each received 3 consecutive inoculations. On electron microscopic examination of these seedlings as well as by back tests to *N. benthamiana*, presence of latent virus could also not be established.

After testing a few purification schemes, the following procedures were adopted for purification of this virus : infected leaves of *N. benthamiana* were homogenized in 0.1 *M* phosphate buffer (pH 7.7) containing 0.001 *M* cysteine plus 0.01 *M* ethylene diamine tetraacetate (EDTA) and 0.1 percent of 2-mercaptoethanol. The juice was passed through cheese cloth and then clarified with 8 percent n-butanol. The virus was further concentrated by centrifugation at 20,000 rpm for 90 minutes in a Beckman R-30 rotor. After resuspending the pellet in 0.01 *M* phosphate buffer (pH 7.7), the virus was further purified by 1 cycle of differential centrifugation followed by sucrose density gradient centrifugation. The virus peak was collected, diluted in buffer and concentrated by centrifugation. Electron microscopic examination revealed numerous filamentous particles that were highly infective on testing on *N. benthamiana*. Electron microscopic examination of ultrathin sections revealed pinwheel formation, indicating that this virus belongs to the potyvirus group. An antiserum with a titer of 1/256 was produced.

Cowpea, soybean and lima bean

Five different sap-transmissible viruses from cowpea have been isolated at IITA, four of which can cause economically important diseases in this crop. Two of these four diseases, cowpea yellow mosaic virus and cowpea mottle virus, have been studied in detail in the past, and relevant information has been collected to enable reliable and efficient indexing and resistance screening with well characterized and pure isolates.

An isolate of cowpea yellow mosaic virus used in resistance screening was increased in cowpea and ground in a 0.1 *M* phosphate buffer (pH 7.0) containing 0.1 percent of 2-mercaptoethanol. The juice was passed through cheese cloth, and 70 percent chloroform-butanol (1:1) was added. After low-speed centrifugation, the supernatant was removed, and the virus was precipitated in 4 percent PEG and 0.25 *M* NaC1. The precipitate was removed by centrifugation and the pellet was resuspended in 0.05 *M* phosphate buffer (pH 7.4). After centrifuging in a sucrose density gradient, the virus was injected into a rabbit at weekly intervals. An antiserum with a titer of 1/2048 was produced.

As isolate of cowpea mottle virus, originally obtained from cowpea and used in resistance screening, was increased in cowpea, and infected leaves were used for purification. The infected leaves were homogenized in 0.1 *M* phosphate buffer (pH 7.4) containing 0.1 percent 2-mercaptoethanol and clarified with 50 percent chloroform-butanol. The virus was concentrated by centrifugation for 3 hours at 29,000 rpm in a Beckman R-30 rotor and further purified by 2 cycles of differential centrifugation followed by sucrose density gradient centrifugation for 4 hours. The virus peak was collected, concentrated and injected into a rabbit. An antiserm with a titer of 1/2408 was produced.

The two other viruses — a cucumber mosaic-like virus (cowpea cucomo-virus) and cowpea aphid-borne mosaic (CAbMV) — have been subjected to further characterization. The cowpea cucumo-virus showed, though remote, a relationship to cucumber mosaic virus both by serological means as well as in host range studies where *N. glutinosa* and a certain cucumber variety were infected developing characteristic symptoms. Three pathogenically different isolates are maintained as pure isolates in *N. glutinosa* for use as inocula for resistance screening.

Cowpea cucumo-virus, besides having occasionally been isolated from cowpea, also proved to be responsible for a rather serious disease in lima bean, including the accessions selected for resistance to lima bean green mottle and lima bean dieback diseases (IITA Annual Report 1977), both caused by poty-viruses resembling cowpea aphid-borne mosaic virus.

The cowpea cucumo-virus was purified using infected *N. glutinosa* leaves. The tissue was homogenized in 0.1 *M* phosphate buffer (pH 7.4) containing 0.0005 *M* $MgC1_2$ and 0.01 percent cysteine. Further, 50 percent chloroform was added and the emulsion was broken by low-speed centrifugation. The supernatant was dialyzed overnight. After low-speed centrifugation, the virus was pelleted by high-speed centrifugation for 3 hours at 29,000 rpm. After one more cycle of both low- and high-speed centrifugation, the preparation was layered on top of a 10-40 percent sucrose gradient. A good yield of purified virus was obtained by this method.

Several isolates of cowpea aphid-borne mosaic virus (IITA Annual Report 1978) including the one from dieback diseased lima bean, proved to be very similar in host range studies, particularly in *N. benthamiana*. All the isolates, except one obtained from a seed-borne infection in TVu 22, induced characteristic green vein-banding in this test plant species.

The pathogenicity of the isolate from TVu 22 behaves differently in both *N. benthamiana* and cowpea varieties. For instance in VITA-7, which was otherwise found to be resistant to CAbMV, the TVu 22 isolate induces symptoms. Purification and subsequent antiserum development is in progress and will permit comparative serology of Nigerian and other isolates of CAbMV.

The last sap-transmissible virus isolated from cowpea, belonging to the carla-virus group (IITA Annual Report 1978), had long been overlooked since it apparently occurs only latently in cowpea. A similar virus was earlier isolated from lima bean, and it has now been identified as the possible causal agent of a rather common and prominent disease in soybean. This disease reached epidemic proporations at IITA this year. In contrast to earlier findings, a strong, positive reaction was obtained when a soybean isolate was tested with an antiserum to cowpea mild mottle virus (CMMV). In Ghana, CMMV has been described as causing disease in cowpea as well as in soybean.

The virus, isolated from soybean in one of Nigeria's soybean growing areas near Abuja, Nigeria (IITA Annual Report 1978), was multiplied in *N. benthamiana* and infected leaves were used for purification. Two methods of clarification were tried:

1. Infected tissues were found in a 0.1 *M* phosphate buffer (pH 7.4) containing 0.1 percent mercapto-ethanol and up to 50 percent chloroform.
2. The tissues were ground in a 0.18 *M* phosphate-citric acid (pH 8.0) containing 0.1 percent thioglycollic acid and further clarification was done by 8 percent n-butanol.

Both procedures resulted in good virus yield.

In sucrose density gradient centrifugation, two nucleoprotein components were consistently observed. The exact nature and role of these components is not yet known, but first indications are that they play a complementary role. An antiserum with a titer of 1/2408 was produced.

Maize

Maize streak virus (MSV) was purified using a 0.01 *M* phosphate buffer (pH 7.4) and 50 percent chloroform. Electron microscopic examination revealed doublet particles. After sucrose density gradient centrifugation, two extra ultraviolet absorbing bands thought to represent singlet and doublet particles were obtained with preparations from diseased plants compared to preparations from healthy plants. By using a sensitive serological technique (ELISA), the streak disease from rice (IITA Annual Report 1977) and maize were found to be identical.

Further work on maize mottle/chlorotic stunt and maize stripe/hoja blanca diseases (IITA Annual Report 1978) has mainly concentrated on studies of their epidemiology. Maize mottle, which shows characteristic mottle only in the early phase of symptom expression, and maize stripe were also found in the Onne substation and Mokwa experimental sites and some farmers' fields. However, incidence was usually very low. In contrast, both diseases were found to be epidemic on the island of Sao Tome, where exotic maize varieties were wiped out.

Initial purification of maize mottle/chlorotic stunt virus was attempted as follows: infected leaves were homogenized in a 0.05 *M* phosphate buffer (pH 7.4); the juice was passed through cheese choth and the fibers were re-extracted once more. Further clarification was achieved by 50 percent chloroform. After low-speed centrifugation, the supernatant was dialyzed overnight, and the virus was concentrated by centrifugation for three hours at 29,000 rpm. After two cycles of both low- and high-speed centrifugation, the preparation was then layered on a 10-40 percent sucrose gradient. Gradients were fractionated by upward displacement and scanned at 254 mm in a ISCO density gradient fractionator. Two suspect virus bands were observed in the gradients. Further work is in progress to elucidate the nature of these bands and to prove that they are representing the causal agent of this disease.

The maize dwarf mosaic virus (MDMV) (IITA Annual Report 1977) was compared with other types of this virus both from sugarcane (sugarcane mosaic virus, SCMV) and sorghum (sorghum red stripe virus, SRSV) by testing the MDMV isolate on a set of sorghum lines developed for virus strain differentiation. The isolate resembles SCMV as concluded from these experiments, and it may represent an occasional escape from sugarcane since so far no further infections of maize with this virus have been found.

Two hybrid lines of maize developed for resistance to this virus in Australia were evaluated for resistance to the IITA isolate and found to be highly resistant. In a collaborative program the University of Wageningen, The Netherlands, also tested these lines with isolates of sugarcane mosaic virus and sorghum red stripe virus. One was found to be segregating and the other highly resistant which means that it is resistant to a fairly broad spectrum of strains of MDMV.

MDMV was purified, using 0.25 *M* phosphate buffer (pH 8.5) containing 0.01 *M* EDTA and 0.001 *M* cysteine and 0.5 percent mercaptoethanol. After homogenizing the tissues in the buffer, chloroform and carbon tetrachloride (25 ml each for every 100 ml buffer) was added. The emulsion was broken by low-speed centrifugation. The virus was concentrated by centrifugation for 90 minutes at 20,000 rpm. The pellet was suspended in 0.01 *M* phosphate buffer (pH 7.7) containing 0.01 *M* EDTA and 0.001 *M* cysteine. After one cycle of both low- and high-speed centrifugation, the partially purified preparation was layered on top of a 10-40 percent sucrose gradient and centrifuged for three hours. A clearly visible band was observed, which proved to be highly infectious on mechanical inoculation to maize.

Rice

Rice yellow mottle virus (RYMV) in West Africa may differ in pathogenic properties from this virus in East Africa. Three *Oryza glaberrima* accessions, found to be highly tolerant to a Kenyan isolate of this virus, were found to be susceptible to an IITA isolate.

For purification, 100 g of young leaf tissue infected with RYMV was homogenized in 200 ml of 0.1 *M* phosphate buffer (pH 7.0) and 0.5 percent of 2-mercaptoethanol. Clarification with chloroform, chloroform/butanol or chloroform/carbon tetrachloride did not show any marked difference in virus yield. The virus was further concentrated either by precipitation in polyethylene glycol (PEG-6000) or sedimentation in ultracentrifugation. After two cycles of both low- and high-speed centrifugation, the pellet was resuspended into a 0.05 *M* phosphate buffer (pH 7.4). After low-speed centrifugation, preparations were then layered on a 10-40 percent sucrose gradient in 0.01 *M* phosphate buffer (pH 7.0). The virus sedimented as a single peak and electron microscopic examination revealed numerous spherical particles.

An antiserum with a high titer was prepared by injecting a rabbit with purified virus at weekly intervals. Also, the ELISA technique was developed for RYMV.

Analytical Services Laboratory

During 1979, the Analytical Services Laboratory conducted a total of 197,800 assays. These included the analysis of 8,294 soil samples, 15,200 plant tissue samples, 1,420 water samples and 3,898 seed, root and tuber samples.

A specific method was developed using the Technicon Autoanalyzer for quick assay of allantoin content in cowpea and soybean. The assay is important to the Institute's biological N-fixation research. As a result of the automated technique, the laboratory was able to assay 6,256 plant tissue samples for allantoin content, during one cropping season.

A second Technicon Autoanalyzer and a new Perkin-Elmer Model 703 atomic absorption spectrophotometer were added to the unit during the year to cope with the increasing demand for soil and plant analytical services from the Institute's research program.

Conference Center

Conferences. The following were held during 1979:

Feb. 19-23 Workshop on Rhizobium Survival and Testing in Africa.
Feb. 26-28 Orientation for FDRD Directors on Minimum and Zero Tillage.
March 19-23 Nitrogen Fixation Advisory Committee Meeting.
July 2-6 Regional Seminar for FAO Field Staff and Counterparts.
Oct. 15-19 First Annual Research Conference.
Nov. 20-24 Watershed Management and Development in the Tropics.

The Conference Center also hosted more than 200 other groups, ranging from primary school through university level students, professional associations, voluntary organizations and local cooperative farmer groups in 1979.

Visitors. More than 500 invited visitors came to IITA this year and in many different categories. All invited visitors were assisted from arrival to departure, and a program was set up outlining their appointments with staff members. When prior advice was received, overseas visitors were sent a letter of invitation and a general information sheet covering travel to and from the Institute and information about the Institute.

The Conference Center began a weekly seminar series, and it assures the publicizing of these seminars both within the Institute and to relevant institutions in Ibadan.

Library and Documentation Center

The Library and Documentation Center added about 2,000 volumes of books and 1,700 volumes of periodicals to its collection during 1979. The collection in December consisted of 15,800 books, 19,950 volumes of periodicals, about 3,000 pamphlets and reprints, 3,414 microforms, 1,587 slides and 33 cassettes.

Use of the library by IITA staff and trainees as well as by people not associated with the Institute increased during 1979. Lectures, students and research fellows from universities and agricultural research institutes in and around Ibadan became frequent users of the library.

Publication. The Center published bibliographies on farming systems, sweet potato (*Ipomea batatas*) and cowpea (*Vigna unguiculata*) during 1979. The latter documents cowpea literature, 1900-49, and joins a previous volume, 1950-73, as well as other publications on grain legumes published by the library during the first phase of its International Grain Legume Center Project. Funded by the International Development Research Center (IDRC), the library produced through this project 4 issues of the Tropical Grain Legume Bulletin, numbers 11 and 12, 13 and 14 and 15 and 16, during 1979. Also, abstracts of the world's literature on winged bean (*Psorphocarpus tetragonolobus*) and on Bambarra groundnut (*Voandzeia subterranea*) compiled by the library in 1978 were printed and distributed in 1979. The International Grain Legume Center Project will be in its second phase during 1980, and plans are to publish another volume on cowpea literature, 1974-78, and to continue with the Tropical Grain Legume Bulletin.

The library will also publish abstracts of literature in yams (*Dioscorea* sp.), updating a bibliography it published in 1976, and a guide to its French language scientific literature.

Training. At the request of the Department of Library Studies, University of Ibadan, the library gave practical training to four postgraduate and five undergraduate students during 1979.

Communications and Information Office.

Publication, translation and audio-visual support services continue to be the activities of the Communications and Information Office.

Media Services

Publications. During 1979, publications that were edited include the IITA Research Briefs, Annual Report 1978 and Research Highlights 1978.

Major IITA publications printed during the year at IITA are:

1. Soil Erosion Problems on an Alfisol in Western Nigeria and Their Control (reprint).
2. The Soils of IITA (reprint).
3. Integrated Approaches to Improving Cowpeas — *Vigna unguiculata*, (L.) Walp. (reprint).
4. Bambarra Groundnut (*Voandzeia subterrana* Thouars) Abstracts of World Literature 1900-78.
5. Winged Bean — *Abstracts of World Literature* 1900-77.
6. Sweet Potato — *Ipomea batatas* (L.)
7. Cowpeas (*Vigna unguiculata* L. Walp) Abstracts of World Literature — Vol. 2 1900-49.
8. Tropical Grain Legume Bulletin Nos. 12-16.
9. Soil Tillage and Crop Production.

Major IITA publications printed abroad during the year are:

1. IITA Research Highlights 1978.
2. Le Point de la Recherche à l'IITA 1978.
3. IITA Annual Report 1978.
4. Rice in Africa.
5. Farming Systems in Africa — A Working Bibliography, 1930-78.
6. Pests of Grain Legumes: Ecology and Control.
7. Soil Physical Properties and Crop Production in the Tropics.

Translations. The office handled three major translation jobs:

1. Selected Methods for Soil and Plant Analysis — French.
2. Research Highlights 1978 — French.
3. Cowpea Pests and Diseases — French and Spanish.

As usual, several letters, documents, handouts and pamphlets were translated from English into French and vice versa.

Distribution. Requestors from tropical and non-tropical regions expressed interest in IITA publications. A total of 9,100 publications were sent to approximately 4,000 persons in 126 countries.

Audio-visual. The Institute's slide set was updated and a new set is scheduled for 1980. The exhibits in the Conference Center also have been updated, and all programs are given a balanced representation.

Training. Three photographers from two agricultural research institutes were trained in the office while one agricultural information officer and nine graduate students came for various periods to study at the Communications and Information Office.

SPECIAL PROJECTS

Special projects are extra-core funded, medium-term projects (1-5 years), which contribute to the achievement of the Institute's research goals. These include cooperative programs and training and collaborative research projects.

Cooperative programs

IITA's cooperative programs involve the cooperation between IITA, a national government or regional body which requests the Institute's involvement, and, when necessary, a funding agency. During 1979, IITA was involved in eight such programs.

IDA: Eastern Cameroon farming systems research. This project is designed to describe within the Zapi-Est area of Eastern Cameroon the food crops farming systems and to plan on-going food crops research. To start the project, field work on an agro-economic survey was completed in December 1979. IITA's Farming Systems Program will be able to conduct research in farming systems with crop combinations, including tree crops, in an area representative of the African humid tropics with an annual bimodal rainfall of about 1800 mm. A long-term, food crops research plan is to be prepared for the area.

Data are not available now, but the general purpose of the agro-economic survey was to investigate existing farming systems in the area, to gather information on existing patterns of agricultural production and resource use, to identify major production constraints and to collect relevant information on marketing and input supplies. The survey involved personal interviews of randomly selected farmers in all of the 5 Zapi-Est zones, N-ka, Doume, Angossas, Diang Belabo and Mbang. In all, 432 farmers responded. The data provided by the survey will assist agronomists in the selection of improved lines of food crops for the area, groundnut, maize, plantain, cassava, cocoyam, cucumber, melon and rice, and in the development of appropriate methods of crop and land management to enable sustained production of the selected improved lines.

IDRC, IDA, Belgian Government: Cameroon root crops and farming systems. This project, through cooperative research and training, has the objective of improving root crops and production systems over a wider range of elevations than is possible in Nigeria and providing IITA an opportunity to focus on a disease that causes severe yellowing of cocoyam leaves, a serious problem in the Cameroons.

USAID: Zaire's PRONAM. Programme national du Manioc (PRONAM) enables IITA's Root and Tuber Improvement Program to extend its cassava research, particularly on the mealybug and green spider mite, into an environment distinctly different from Ibadan but representative of a large area of Central Africa. The project's objective is to build, through research and training, a national organization devoted to developing cassava production packages in Zaire — packages that are acceptable to local farmers.

IDRC: Upper Volta food legumes. This project emphasizes the testing of IITA cowpea varieties in single and mixed cropping systems in the Sudanic and Sahelian environments of Upper Volta. Also, with the initiation of the SAFGRAD project, research has been extended with additional responsibility for research on cowpeas for the neighboring semi-arid regions. The additional responsibility involves establishment of regional variety trials in collaboration with SAFGRAD member countries, supplying improved cowpea varieties and meeting some of the needs for logistic support.

USAID: SAFGRAD. Under the Semi-Arid Food Grains Research and Development project (SAFGRAD), IITA conducts, in cooperation with international, national and regional agencies, regionally oriented research aimed at developing improved cowpeas and maize and improved cultivation practices that are compatible with African small farm semi-arid farming systems. IITA also develops and implements short-term training for prospective African grain legume and cereal research workers.

USAID: Tanzania food crops research. This project provides assistance in crop improvement research on cowpea and other grain legumes and maize. It expands IITA's research into a geographically large area of East Africa. Evaluation of the project is based on improved varieties and farming practices accepted by the Tanzanian Ministry of Agriculture for promotion to farmers.

USAID, Technical Aid: Sao Tome. This project provides IITA an opportunity to conduct trials of its cowpea, maize and rice varieties on an island with many different ecosystems, including environments of high and low rainfall, soil imbalances and epidemics of diseases. Its objective is to assist the Republic of Sao Tome and Principal Ministry of Agriculture, through training and technical guidance, in testing crop varieties and cultural practices on the island.

UNDP: Sierra Leone. This project tests improved rice varieties and cultural practices suitable for small-scale rice farming systems in Sierra Leone. Participation in the program enables IITA to test its research on farmer's field in upland, inland valley, irrigated, boliland and mangrove swamp ecologies and to design and organize minikit and demonstration kit trials. Also, candidates are selected in consultation with the government, for training in rice research.

IDA: Liberia. Considering the magnitude of adaptive research work needed to support the rice development programs in Liberia, IITA initiated the project in December, 1973, in cooperation with the Central Agricultural Experimental Station (CAES), Suakoko. This arrangement continued until 1975, and subsequently, on March 31, 1979, IITA concluded its rice research program in Liberia.

Training and collaborative research

These projects established training and collaborative research programs for IITA with other research institutes, scientists and universities. Since 1973, the Belgian Government has been providing funds for training both Belgian nationals and Africans in aspects of tropical agriculture. In addition, the Belgian Government has been providing funds to support collaborative research projects with Belgian universities having special expertise and facilities required for special short-term projects. The Netherlands Government has been providing funds for the training of West African research and production agriculturalists, and the Ford Foundation has been providing similar support for East African agricultural scientists.

PERSONNEL

ADMINISTRATION

W.K. Gamble, *Ph.D., director general*
B.N. Okigbo, *Ph.D., deputy director-general*
M.A. Akintomide, *B.S., director for administration*
S.V.S. Shastry, *Ph.D., director of research*
J.E. Haakansson, *M.B.A., controller/treasurer*
D.C. Goodman Jr., *M.B.A., assistant to the director general (special projects)*
R. Jacob, *assistant to the director general**
C.A. Enahoro, *assistant to the director general*
K.A. Aderogba, *D.P.A., principal administrative officer*
P.C. Duffield, *Ph.D., IITA/USAID/Tanzania Project, coordinator*
S.J. Udoh, *A.M.N.I.M., accountant*
F.O. Ogunyemi, *A.C.A., accountant*
M.E. Olusa, *assistant to the director for administration*
R. Vick, *M.S., data processing manager*
D.J. Sewell, *dormitory and food service manager*
R.O. Shoyinka, *B.S., personnel manager*
E.A. Onifade, *security superintendent*
O.O. Ogundipe, *M.D., medical officer*
A. Yusuf, *B.S., controller of stores*
M. Boshoff, *B.A., conference coordinator and head, visitors' center**

FARMING SYSTEMS PROGRAM

I.O. Akobundu, *Ph.D., weed scientist*
A.A. Ayanaba, *Ph.D., soil microbiologist***
C.D.S. Bartlett, *Ph.D., agricultural economist, NAFPP*
W.H. Boshoff, *Ph.D., FAO project manager, agricultural engineer**
R.D. Bowers, *M.S., FAO project manager, agricultural engineer*
F.E. Caveness, *Ph.D., nematologist***
C. Garman, *M.S., agricultural engineer*
A. Getahun, *Ph.D., systems ecologist, agro-forestry project*
B.T. Kang, *Ph.D., acting program leader and soil fertility specialist*
T. Kaufman, *Ph.D., entomologist*
H.C. Knipscheer, *Ph.D., agricultural economist*
A.S.R. Juo, *Ph.D., soil chemist*
R. Lal, *Ph.D., soil physicist*
T.L. Lawson, *Ph.D., agroclimatologist*
K.M. Menz, *Ph.D., agricultural economist*
N.C. Navasero, *B.S., associate agricultural engineer*
C.L. Padolina, *M.S., associate agricultural engineer**
S.J. Pandey, *Ph.D., inputs coordinator, NAFPP*
B.R. Singh, *M.S., agro-service management specialist*
E.W. Sulzberger, *M.S., communications specialist, NAFPP*
K.V. Vanek, *Ph.D., FAO agricultural engineer*
P.R. Wijewardene, *M.S., agricultural engineer*
L.B. Williams, *M.S., coordinator and planning economist NAFPP**

Visiting Scientists

A. Agboola, *Ph.D., agronomist*
W.F. Buchele, *Ph.D., agricultural engineer*
L.L. Harold, *Ph.D., soil physicist*

Post-Doctoral Fellows

E.A. Atayi, *Ph.D., agricultural economist*
J. Braide, *Ph.D., plantain agronomist*
H. Maduakor, *Ph.D., soil physicist*
R.W. Michieka, *Ph.D., weed scientist*
D. Oben, *Ph.D., agricultural economist*
J.L. Pleysier, *Ph.D., soil chemist**
R. Rao, *Ph.D., soil microbiologist***

Associate Experts

P. Rosseau, *Ir., FAO associate expert, soil physics*
R. Swennen, *Ir., FAO associate expert, agronomy*

Research Associates/Assistants

A.M. Adejumo *agricultural engineering*
J.O. Adesina, *soil fertility*
K.L. Akapa, *agronomy*
A.O. Dabiri, *soil chemistry*
M.O. Ikhane, *agricultural engineering*
B.U. Ikhile, *soil chemistry*
M.A.O. Nwaogwugwu, *agronomy*
K.O. Oduro-Afriyie, *agroclimatology*
S.O. Olubode, *agronomy*
R.A. Raji, *weed science*
O. Yaya, *agricultural engineering*

ROOT AND TUBER IMPROVEMENT PROGRAM

S. Anderson, *M.S., agronomist, Programme National Manioc (PRONAM), Zaire*
F.E. Caveness, *Ph.D., nematologist*
W.N.O. Ezeilo, *B.S., coordinator, cassava center, NAFPP, Nigeria*
H.C. Ezumah, *Ph.D., project leader and agronomist, PRONAM, Zaire*
S.K. Hahn, *Ph.D., program leader and breeder*
H.R. Herren, *Ph.D., entomologist (biological control)*
G. Heys, *B.S., production agronomist*
K. Leuschner, *Ph.D., entomologist (host plant resistance)*
R. Pacumbaba, *Ph.D., pathologist, PRONAM, Zaire*
H.J. Pfeiffer, *Ir., production agronomist, Cameroon National Root Crop Improvement Program (CNRCIP), Cameroon*
T.P. Singh, *Ph.D., breeder, PRONAM, Zaire*
K.G. Steiner, *Ph.D., project leader and pathologist, CNRCIP, Cameroon*
E.R. Terry, *Ph.D., pathologist*
J.E. Wilson, *Ph.D., breeder*

Visiting Scientist

R.B. Volin, *Ph.D., pathologist*

Associate Expert

E.R. Frison, *Ir, FAO associate expert, tissue culture and virus indexing*

Research Associates/Assistants

M.O. Akoroda, *M.S., research associate*
E.M. Chukwuma, *breeding*
J.O. Kalabare, *research assistant*
S.Y.C. Ng, *M.S., tissue culture*

GRAIN LEGUME IMPROVEMENT PROGRAM

V.D. Aggarwal, *Ph.D., plant breeder, Upper Volta*
D.J. Allen, *Ph.D., plant pathologist*
A.A. Ayanaba, *Ph.D., soil microbiologist*
F.E. Brockman, *Ph.D., agronomist, SAFGRAD, Upper Volta*
P.R. Goldsworthy, *Ph.D., program leader*
E.A. Kueneman, *Ph.D., plant breeder*
M.J. Lukefahr, *Ph.D., entomologist*

M. Price, *Ph.D., Tanzania*
E.L. Pulver, *Ph.D., physiologist/agronomist*
V. Ranga Rao, *Ph.D., soil microbiologist*
R.J. Redden, *Ph.D., plant breeder*
J.B. Smithson, *Ph.D., plant breeder*
B.B. Singh, *Ph.D., Tanzania*
S.R. Singh, *Ph.D., entomologist*
E.E. Watt, *Ph.D., plant breeder, Brazil*

Post-Doctoral Fellows

S. Asanuma, *Ph.D., soil microbiologist*
L.E. Jackai, *Ph.D., entomologist*
P.C. Matteson, *Ph.D., entomologist*
K. Mulongoy, *Ph.D., soil microbiologist*
B. Ndimande, *Ph.D., pathologist**
H.J. Vetten, *Ph.D., pathologist**
H. Woesten, *Ir., physiologist*

Associate Expert

P. Homble, *Ir., FAO associate expert, lima bean project*

Research Associates/Assistants

T.N. Emelfeogwu, *microbiology*
A.L. Wong, *microbiology*

CEREAL IMPROVEMENT PROGRAM

A.O. Abifarin, *Ph.D., IITA liaison scientist, WARDA*
K. Alluri, *Ph.D., agronomist/breeder*
V.L. Asnani, *Ph.D., SAFGRAD project team leader*
I.W. Buddenhagen, *Ph.D., pathologist*
Y. Efron, *Ph.D., acting program leader from October*
F.H. Khadr, *Ph.D., NAFPP coordinator and maize specialist*
S.K. Kim, *Ph.D., maize breeder*
N.S. Jodha, *Ph.D., agricultural economist, Tanzania*
D. Mahapatra, *M.S., extension specialist, Sierra Leone*
I.C. Mahapatra, *Ph.D., rice agronomist, Sierra Leone*
F.M. Quin, *Ph.D., physiologist*
Y.S. Rathore, *Ph.D., entomologist, SAFGRAD*
S.A. Raymundo, *Ph.D., rice pathologist, Sierra Leone*
M. Rodriguez, *Ph.D., agronomist, SAFGRAD*
S.V.S. Shastry, *Ph.D., acting program leader to September*
S.S. Virmani, *Ph.D., rice breeder, Liberia**
J.H.R. ter Vrugt, *Ir., agronomist**
Kaung Zan, *Ph.D., IRRI liaison scientist, IITA*

Visiting Scientists

C. Renard, *Ph.D., physiologist*
T.E. Srinivasan, *M.S., rice breeder*

Post-Doctoral Fellows

S. Sarkarung, *Ph.D., rice breeder*
J. Singh, *Ph.D., maize pathologist*
Y. Tanaka, *Ph.D., rice pathologist*

TRAINING PROGRAM

L. Babadoudou, *Ing. Tech., production training officer (francophone)*
G. Cambier, *Lic., translator/interpreter*
W.H. Reeves, *Ph.D., assistant director, head of training*
D.W. Sirinayake, *production training officer (anglophone)*

FARM MANAGEMENT

P.D. Austin, *B.S., assistant farm manager, Onne substation*
S.L. Claassen, *M.S., assistant farm manager*
D.C. Couper, *B.S., farm manager*

GENETIC RESOURCES UNIT

A.T. Perez, *Ph.D., plant explorer*
S.D. Sharma, *Ph.D., plant explorer**
W.M. Steele, *Ph.D., coordinator*

Post-Doctoral Fellows

T. Badra, *Ph.D., plant explorer*
N.Q. Ng, *Ph.d., plant explorer*

Research Associates/Assistants

A.O. Oshunmakinwa, *B.S.*
M.O. Otunsanya, *B.S.*

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G.O. Ibekwe, *B.A., principal librarian*
S.M. Lawani, *M.S., head*
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COMMUNICATIONS AND INFORMATION

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J.C.G. Isoba, *M.S., communications officer, publications*
J. Loudon, *M.S., editor**
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PHYSICAL PLANT SERVICES

D. Antcliff, *refrigeration/air-conditioning*
A.C. Butler, *buildings and grounds services*
J.G.H. Craig, *assistant director*
O.O.A. Fawole, *light automotive*
J.M. Ferguson, *fabrication services*
G.D. Garrity, *electrical services*
N. Georgallis, *scientific/electronic services*
E. Magnani, *heavy equipment*
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*Left during the year.
**Transferred to other programs during the year.

COLLABORATORS AND TRAINING

FARMING SYSTEMS PROGRAM

Collaborators

Dr. O.E. Aduayi, *University of Ife, Nigeria*
Prof. A. Cottenie, *University of Ghent, Belgium*
Prof. M. De Boodt, *University of Ghent, Belgium*
Prof. E. De Langhe, *Catholic University of Leuven, Belgium*
Institute of Meteorological Research and Training, *Nigerian Meteorological Service*
National Meteorological Service, *Ghana*
National Meteorological Service, *Togo*
Mr. J.C. Okafor, *Forestry Commission, Enugu, Nigeria*
Prof. R.H. Rust, *University of Minnesota, U.S.A.*
Prof. R. Soper, *University of Manitoba, Canada*
Volunteers for International Technical Assistance (VITA) *U.S.A.*
Prof. A. Wild, *University of Reading, U.K.*

Research Fellows and Scholars

T. Adegboyega, *agricultural engineering*
J.K. Adewunmi, *agricultural engineering*
K. Akapa, *agronomy (b)*
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ROOT AND TUBER IMPROVEMENT PROGRAM

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Dr. D.B. Williams, *Team Leader, FAO Root Crop Development Project in the South Pacific*

Research Fellows and Scholars

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N.K. Idumbo, *breeding (b)*
B.B. Ifefo, *breeding (b)*
A.M. Kankolongo, *plant pathology (b)*
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Z.M. Mahungu, *breeding (b)*
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M. Msabaha, *breeding (a)*

GRAIN LEGUME IMPROVEMENT PROGRAM

Collaborators

Dr. M. Alexander, *Cornell University, U.S.A.*
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Dr. D.S. Jenkinson, *Rothamsted Experimental Station, U.K.*

Research Fellows and Scholars

A.E. Aboul-Ata, *pathology*
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B. Asafo-Adjei, *pathology (b)*
G. Atiri, *pathology (a)*
P.A.S. Awogbami, *pathology (b)*
I. Drabo, *breeding (c)*
C. Nebane, *pathology (b)*
B. Ntare, *breeding (a)*
J.A. Raji, *pathology (c)*
M. Ta'ama, *entomology (a)*
C.V. Udosen, *entomology (b)*
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CEREAL IMPROVEMENT PROGRAM

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Dr. N.L. Dhawan, *CIMMYT*
E. Fado, Projet Action Rurale, *Save, Rep. Pop. du Benin*
Dr. S. Fagade, Dr. J. Olufowote and Dr. J. Fajemisin, *National Cereals Research Institute, Nigeria*
B.O. Muoghereh, *Ubiaja, Bendel State, Nigeria*
Dr. B.L. Renfro, *The Rockefeller Foundation, Bangkok, Thailand*
Dr. G. Riley, *University College of Wales, Welsh Plant Breeding Station, U.K.*
Dr. E.W. Sprague, *CIMMYT, Mexico.*

Research Fellows and Scholars

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A.M. Alghali, *rice entomology (a)*
G. Ngala, *rice pathology (a)*
K. Nwosu, *rice entomology (a)*
S.Z. Morris, *maize breeding (a)*
W.A. Tairou, *rice breeding/pathology (a)*
M. Ukwungwu, *rice entomology (a)*

GENETICS RESOURSES UNIT

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F. Attere *(c)*
M. David *(b)*

(a) Research Fellow (Ph.D. candidate)
(b) Research Scholar (M.S. candidate)
(c) Research Scholar (M.Phil. candidate)

PUBLICATIONS

FARMING SYSTEMS PROGRAM

Akobundu, I.O, 1979. *Weed control in Nigeria.* PANS 25(3): 287-298

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Getahun A. *Ecological aspects of agro-forestry in the highland ecosystems of tropical Africa.* International Conference on International Cooperation in Agro-Forestry, Nairobi, July 16-22, 1979.

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Kang B.T. *Soil fertility management for maize production in the humid and sub-humid regions of West Africa.* First Annual Research Conference, IITA, Ibadan, October 15-19, 1979.

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Lawson, T.L., J.S. Oguntoyinbo, B.O. Ojo. *Agroclimatic conditions of West Africa.* Annual Research Conference on Soil and Climatic Resources and Constraints in Relation to Food Production in West Africa, IITA, Ibadan, October 15-19, 1979.

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Lawson, T.L. *Agroclimatic constraints to upland rice production in West Africa.* WMO/IRRI Symposium/Planning Meeting on the Agrometeorology of the Rice Crop, IRRI, Los Banos, December 3-7, 1979.

Okigbo, B.N. *Impact of agricultural systems and rural development on Nigerian forest systems.* MAB Conference, University of Ibadan, January 24-26, 1979.

Okigbo, B.N. *Increased food production through plant protection.* Ninth Annual Conference of the Nigerian Society for Plant Protection, University of Ibadan, February 21-23, 1979.

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Okigbo, B.N. *Inter-relationships among physical, biological and socio-economic factors in rural development.* Ford Foundation Workshop, Dakar, April 29-May 1, 1979.

Okigbo, B.N. *Evaluation of plant interactions and productivity in complex mixtures as a basis for improved cropping systems design.* International Intercropping Workshop, ICRISAT, Hyderabad, January 10-13, 1979.

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Okigbo, B.N. *Interface between nutrition policy and its implementation: Nigeria's experience with programs aimed at expanding small farm agricultural production.* Workshop on Nutrition Policy and its Implementation, Massachusetts Institute of Technology, Boston, Massachusetts, November 5-8, 1979.

Okigbo, B.N. *Meeting the demand for forest resources in the 80's: the challenge to Nigerian forestry.* Conference of the Forestry Association of Nigeria, Forest Research Institute of Nigeria, Ibadan, November 29, 1979.

Pandey, S.J. *Field program for the farmers education at the agro-service centers.* Third NAFPP National Cassava Workshop, Umudike, January 14-20, 1979 and Third NAFPP National Sorghum, Millet and Wheat Workshop, Zaria, April 9-11, 1979.

Pandey, S.J. *Methodology of conducting field demonstrations.* First Training Workshop for Agro-Service Agronomists, IITA, Ibadan, June 4-15, 1979.

Pandey, S.J. *Theory and practice of fertilizer calculations.* First Training Workshop for Agro-Service Agronomists, IITA, Ibadan, June 4-15, 1979.

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Singh, B.R. *Input Distribution and Logistics.* Training Seminar, IITA, Ibadan, April 6, 1979.

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Sulzberger, E.W. *The NAFPP — A new dimension for Nigerian agriculture.* Peace Corps Training Course, IITA, Ibadan, March 14, 1979.

Sulzberger, E.W. *NAFPP and communications.* Nigerian Institute of Journalism, Nigerian Institute of International Affairs, May 2, 1979.

Sulzberger, E.W. *Communications and agriculture development.* Maize-Cowpea Training Courses, IITA, Ibadan, May 16, 1979.

Sulzberger, E.W. *Communication for the NAFPP.* Assistant Agro-Service Managers Training Course, IITA, Ibadan, June 13, 1979.

Sulzberger, E.W. *Communication for the NAFPP.* Third NAFPP Sorghum and Millet Workshop, Zaria, April 11, 1979.

Sulzberger, E.W. *The NAFPP — A new dimension for Nigerian agriculture.* Western Group of Coordinators, Catholic Archdiocese of Ibadan, May 14, 1979.

Williams, L.B. *The NAFPP delivery system.* Rice and Maize Production Training Course for Peace Corps Volunteers, IITA, Ibadan March 21, 1979.

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Williams, L.B. *A review of the functions of the agro-service system.* Third National Sorghum, Millet and Wheat Workshop, Zaria, April 9-11, 1979.

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AGRICULTURAL ECONOMICS

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Diehl, L. and F.E. Winch. *Yam based farming systems in the South Guinnea Savannah of Nigeria.* Discussion paper No. 1/79.

Flinn, J.C. and P.S. Zuckerman. *Resources use, income and expenditure patterns of Yoruba smallholders.* Discussion paper No. 9/79.

Hoyoux, J.M. *Sole and mixed cropping patterns in a maize production area: Oyo State of Nigeria.* Discussion paper No. 5/79.

Hoyoux, J.M. *A manual: measuring the size of small farms.* Discussion paper No. 6/79.

Knipscheer, H.C., K.M. Menz, D.U. Oben and E.A. Atayi. *Agricultural economics within farming systems program at IITA.* Status report, December, 1979.

Okali, C.D., Oben, T. Ojo-Atere and T.L. Lawson. *An evaluation of the farmer's knowledge and use of hydromorphic toposequences in the Western State of Nigeria: findings from selected areas in the Oshun River Basin.* Discussion paper No. 4/79.

Zuckerman, Paul S. *A micro-level farm management study in Western Nigeria: field work design and application.* Discussion paper No. 7/79.

Zuckerman, Paul S. *A micro-level farm management study in Western Nigeria: some results and experiences with questionnaires.* Discussion paper No. 8/79.

GRAIN LEGUME IMPROVEMENT PROGRAM

Allen, D.J. *Cowpea improvement at IITA.* Symposium on Grain Legume Improvement in Eastern Africa, Nairobi, August, 1979.

Eaglesham, A. Ayanaba, V. Ranga Rao and D.L. Eskew. *Assessing nitrogen contribution of cowpea and soybean crop to soil.* Seventy-first Annual Meeting of the Agronomy Society, Fort Collins, Colorado, August 5-10, 1979.

Ranga Rao V., A. Ayanaba and A.R.J. Eaglesham. *Response of soybean to seed inoculation with* Rhizobium *in humid tropical conditions.* Seventh North American *Rhizobium* Conference, College Station, Texas, June 17-21, 1979.

CEREAL IMPROVEMENT PROGRAM

Alluri, K., I.C. Mahapatra and T.L. Lawson. *Production constraints for upland rice in West Africa.* First Annual Research Conference, IITA, Ibadan, October 15-19, 1979.

Buddenhagen, I.W. *Rice breeding for tropical African conditions and problems.* First Annual Research Conference, IITA, Ibadan, October 15-19, 1979.

Lawson, T.L. and K. Alluri. *Maximum water requirement of upland rice variety OS6 in the humid/subhumid zone of West Africa.* WHO/IRRI Symposium/Planning Meeting on the Agrometeorology of the Rice Crop, IRRI, Los Banos, December 3-7, 1979.

GENETIC RESOURCES UNIT

Perez, A.T., K. Alluri, and J. Ter Vrugt. *Highlights of the IITA rice varietal improvement work: 1977-78.* 1979 Rice Breeders Workshop, NCRI, Ibadan.

VIROLOGY UNIT

Thottappilly, G. *Virus research at IITA. Central Tuber Crops Research Institute,* Trivandrum, July 30, 1979.

Thottappilly, G. *Important virus diseases of food crops in Nigeria.* ICRISAT, August 7, 1979.

COMMUNICATIONS AND INFORMATION

Oyekan, J.O. *The IITA and Nigerian agriculture.* National Conference of the Nigerian Institute of Journalism, Lagos, May 1, 1979.

Oyekan, J.O. and R. Cowan. *Meeting communication training needs of national programs for production and crop improvement specialists.* Paper delivered at the Conference on the Communication Responsibilities of the International Agricultural Research Centers, IIRI, Los Banos, May 14-19, 1979.

MAJOR SEMINARS

(Given at the Institute by IITA scientists or by visiting scientists during 1979)

12 Jan	*Soil Evaluation for Liquid Waste Disposal*	**E.J. Tyler.**
19 Jan.	*Rice Disease Problems in Sierra Leone*	**S. Raymundo.**
26 Jan.	*Plant Type and Adaptability to Different Rice Growing Conditions*	**K. Alluri.**
2 Feb.	*Soybean Yield Response to Rhizobium Inoculation at IITA*	**V. Ranga Rao.**
16 Feb.	*Watershed Hydrology*	**L.L. Harrold.**
23 Feb.	*Current Status of Cocoyam Breeding*	**J. Wilson.**
2 Mar.	*Some Selection Criteria for Optimising Productivity of Cassava Under Cassava Mosaic Disease Stress*	**E.R. Terry.**
16 Mar.	*Measurement of Nitrogen Fixation in Cowpea*	**A. Eaglesham.**
20 Mar.	*Ecology of Rhizobium in Soils*	**M. Alexander.**
21 Mar.	*Research on increasing the production of Vicia faba in the U.K.*	**R.J. Roughley.**
22 Mar.	*Weak Links in the Chain of Rhizobium Research*	**C.A. Parker.**
23 Mar.	*New Maize Populations and Experimental Varieties*	**V. Asnani.**
23 Mar.	*Managing Acid Soils in the Tropics*	**A.S.R. Juo.**
30 Mar.	*Diseases of Tropical Food Crops and Their Control*	**J.A. Meyer.**
4 May	*Soybean Breeding in the Tropics — Problems and Prospects*	**B.B. Singh.**
11 May	*Newly Discovered Virus Diseases in Target Crops at IITA*	**H. Rossel.**
16 May	*Growth Regulators in Cover Crop Management*	**L. Ebner.**
18 May	*Wild Rices — Their Scope and Limitation as Genetic Resources*	**S. Sharma.**
1 June	*Cassava Research Program in India*	**N. Hrishi.**
6 July	*Society Relevant Plant Virology*	**L. Bos.**
13 July	*Weed Science Research Strategies at IITA*	**I.O. Akobundu.**
20 July	*The Role of a Statistics Department in Agricultural Research*	**B. Gilliver.**
20 July	*The Post-Harvest Component in the Work of IITA*	**W.H. Boshoff.**
27 July	*Nematology at IITA*	**F.E. Caveness.**
31 Aug.	*Water Relations in Plants*	**C. Renard.**
7 Sept.	*Drought Resistance and the Rationale for Crop Improvement in the Arid Zone*	**A. Blum.**
21 Sept.	*Plantain Research at IITA*	**J.O. Braide.**
5 Oct.	*Cowpea Production and Importance in Brazil and the IITA/EMBRAPA Improvement Program*	**E.E. Watt.**
12 Oct.	*Energy-Food Production and Soil Erosion*	**Buchele.**
19 Oct.	*Role of Agroclimatology in Farming Systems Research*	**S.M. Virmani.**
22 Oct.	*Weed Control in No-tillage Maize.*	**R. Michieka.**
27 Oct.	*Some Ideas on Induced Mutations for Crop Improvement*	**C.A.T. Gustafsson.**
2 Nov.	*Fallows in Cropping Systems of the Humid Tropics*	**G.F. Wilson.**

9 Nov.	*Review of Results of Cassava Intercropping Experiments at Ikenne 1976-77: Effects of Crop Species Patterns of Cropping and Cassava Lengths of Cutting*	**B.N. Okigbo.**
30 Nov.	*Improving the Storability of Soybean Seed*	**E.A. Keuneman.**
7 Dec.	*Present Status of Virus Research at IITA*	**G. Thottappilly.**
14 Dec.	*Research on the Engineering Aspects of Maize Production*	**Buchele.**

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