International
Institute of
Tropical
Agriculture

annual
report

About IITA

The International Institute of Tropical Agriculture (IITA) was established on July 27, 1967, as an autonomous, nonprofit corporation by a decree of the Federal Military Government of Nigeria. It formally organized at the first meeting of the Board of Trustees in Ibadan during July, 1968. The 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 1980 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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INTERNATIONAL INSTITUTE OF TROPICAL AGRICULTURE

Contents

Board of Trustees

Foreword

The year 1980 was one of financial uncertainty for the International Institute of Tropical Agriculture. A high rate of inflation, a doubling of the minimum wage, and a strengthening of the Nigerian naira against the American dollar had a very serious and negative impact on the real research capacity of IITA.

Research program budgets and staff had to be reduced, and a general belt tightening left the remaining scientists with insufficient supporting staff and operating allocations to enable them to work in a fully effective and productive manner.

It was through a very generous special contribution of 1 million naira, equivalent to 1.9 million U.S. dollars, by the Federal Republic of Nigeria in December 1980 that this precarious financial situation could be redressed.

Despite the disruptive economic conditions, IITA's research community produced a scientific product of commendable quality and quantity as reflected in this Annual Report.

As in previous years, the 1980 Annual Report is a compendium of salient research conducted in cereal, root, tuber, and grain legume improvement programs, and in farming systems for the humid and subhumid tropics. This report and its sister publication, 1980 Research Highlights, together provide a comprehensive summary of findings for both the scientist and the generalist.

This year also marks the first time the Annual Report is being published in French. Long overdue, we are confident it will be enthusiastically received by our French-speaking colleagues.

The structure of the Institute's research program remained unchanged in 1980, but the focus of the work was somewhat modified.

Farming systems research was reorganized to focus on three major components—land clearance and development, post-clearance management, and cropping systems. The maize improvement program included some exploratory work on the development of hybrids. The development of lowland rice varieties and the problems of production in central and eastern Africa were given greater emphasis. Breeding for resistance to insect pests of cowpeas was intensified, and cassava research was concentrated on host plant resistance to the green spider mite and mealybug.

In the resolution of the etiology of virus diseases, techniques of indexing the presence of sweet potato virus was developed. As a result, it is now possible to export virus-free sweet potato clones in tissue culture form internationally.

Previously, the Institute's research was almost exclusively pointed toward the small, traditional, resource-poor African farmer. But because of increasing interest in commercial farming in many African countries, the Institute is devoting a greater share of its research effort toward the solution of problems encountered by medium and large-scale farming enterprises.

We are sure you will find this Annual Report informative, and we will be pleased to respond to all requests for additional information about on-going research at the Institute. A listing of journal articles and IITA's scientific staff is appended to this report to assist you.

Hartmans

Dr. E. H. Hartmans
Director General

Farming Systems Program

Introduction

A primary goal of the Farming Systems Program is the development of methods of land use and crop management that will enable efficient, economic and sustained production of food crops for the humid and subhumid tropics. Research is directed primarily at problem solving the constraints of small farmers, many of whom still rely on bush fallow systems for producing the bulk of the food in the humid and subhumid tropics of Africa and elsewhere. Emphasis is given to developing technologies that are scale neutral so that they can be used by a range of farmers.

Because of the wide range of farming system forms in the humid and subhumid tropics, the program will not develop specific local blueprints for improved methods of land, soil and crop management; rather, the program's concern is to develop and make available preliminary technologies and subsystems that can be modified and adapted by national and regional organizations to the agronomic and economic as well as political conditions of their own areas. Considering the diversity of the farming systems in the Institute's mandate area, baseline data collection and analysis are undertaken to better delineate the major benchmark areas with relevant bioclimatic and soil parameters in relation to prevailing cropping systems. The benchmark sites will be used for determining typologies and testing principles of land and soil management and cropping systems.

The research emphasis of the program is on assisting farmers in the move from the subsistence shifting cultivation and particularly bush fallow systems, to more continuous and productive systems of cultivation with appropriate land and soil management practices, which will maintain soil productivity and minimize soil erosion and soil degradation.

To achieve more impact in the immediate future, the program focused its activities in the following research areas: baseline data collection and analysis, land and soil management and cropping systems.

Cooperative programs have been established in Cameroon and Ghana. Reports of these projects are included in cooperative projects, and individual reports are available from the respective organizations.

Baseline data collection and analysis

Research on baseline data collection and analysis includes the following areas: agroclimatology, soil and land characterization and evaluation and socioeconomic analysis.

Research in 1980 emphasized crop water requirements as well as the development of a soil evaluation system for highly weathered soils in West Africa and studies of soil erodibility. Socioeconomic analyses included food crop and agro-forestry farming systems surveys.

IITA general weather conditions

The nonoccurrence of the late July-August dry season was the dominant feature of the weather in 1980. As with similar cases in 1973 and 1979, the only other 2 of the decade, this feature was again associated with a general shift in rainfall pattern; the second rather than the first season constituted the major rainy season. There were consonant departures in insolation, the heavy rainfall period generally receiving less than normal global radiation. The mean temperatures were comparatively high along with the mean relative humidity while the evaporative demand was lower than the long-term mean. A summary of the main variables is given in Table 1.

Rainfall and evaporation. A streak of rainless days extending back to November, 1979, was broken with a 26.2 mm rain on 14 February. There were 4 other rains before the end of March (Table 1, Fig. 1), and the first quarter of the year was, thus, marked by a pronounced moisture deficit with a −44 percent departure in cumulative rainfall in conjunction with a −7 percent difference in cumulative evaporation.

No rain of substance fell in April, and total rainfall was fully 66 percent below normal. It was a clear case of a "false start" in the rains, causing most of the late March plantings to succumb to drought stress (Fig. 2). Favorable water balance was first established at the beginning

Table 1. Summary of climatic data (IITA, 1980).

Month	Total rain-fall mm	Total evapo-ration mm	Solar radiation G^m-cal/cm²/day	Temperature °C Min.	Mean	Max.	Relative humidity % Min.	Mean	Max.
Jan.	0	121.22	391.90	23.3	27.8	32.2	46	71	96
Feb.	26.2	150.51*	504.14	23.8	28.9	33.9	39	68	39
Mar.	52.0	174.22	513.70	24.3	28.7	33.0	46	72	98
Apr.	50.1	164.70*	490.16	23.8	28.4	33.0	49	72	95
May	193.0	126.17*	401.85	23.3	26.7	30.1	61	79	97
June	132.2	129.50	421.16	23.2	26.3	29.4	64	80	95
Jul.	203.8	88.04*	318.53	22.2	24.6	27.0	72	84	96
Aug.	367.8	92.07*	325.16	22.4	24.9	27.3	73	85	97
Sept.	248.9	104.10*	384.56	22.3	25.5	28.7	67	83	98
Oct.	208.4	107.88	418.96	22.5	26.0	29.4	64	81	97
Nov.	66.7	107.10*	408.28	22.5	26.3	30.0	56	76	97
Dec.	0	117.58	386.25	20.1	25.3	30.5	41	67	92

**Values adjusted for days with missing data.*

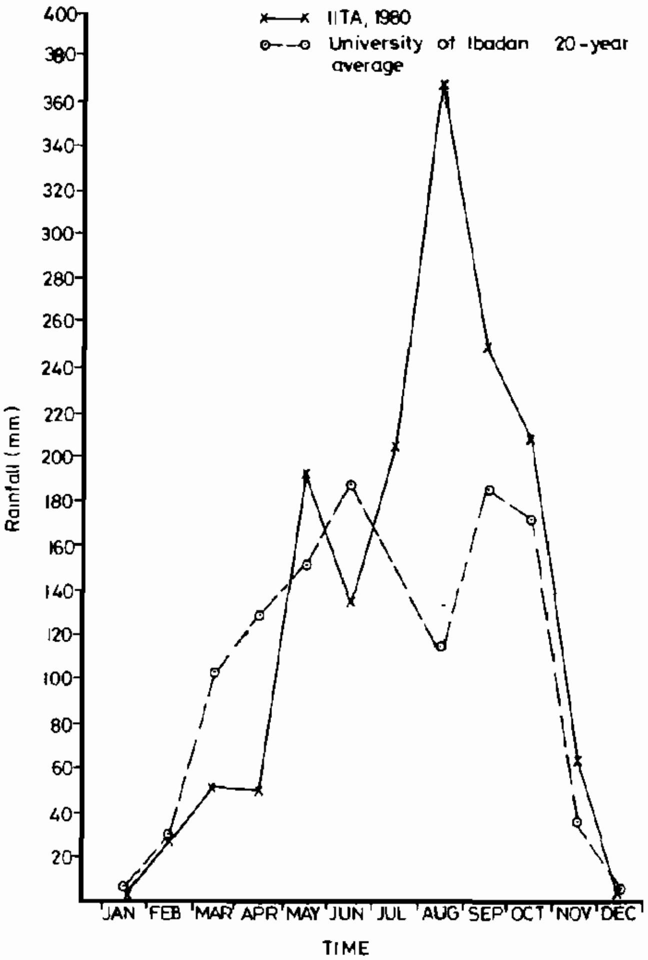


Fig. 1. Mean monthly rainfall.

of May, about a full month later than normal (Fig. 2) with a corresponding delay in the start of the first cropping season.

Precipitation remained quite regular through the first 2 weeks of June but tapered off again in the last third of the month and continued so through the first of July.

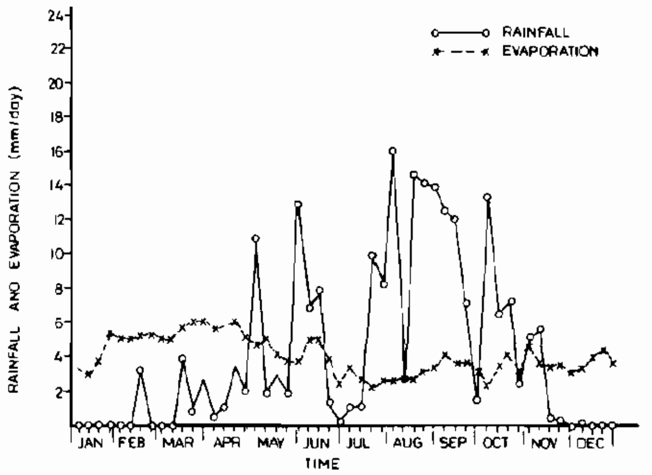


Fig. 2. Weekly mean rainfall and evaporation (IITA, 1980).

This spell of moisture deficit was followed by a period of excessive and persistent rainfall, which culminated in the highest monthly peak for the year and the third highest on record (367.8 mm for August). A singular rain incidence on 31 August resulted in an unprecedented and catastrophic flood in the general area.

With the failure of the 'normal' August break in the rains, first-season crops, with potential yields already depressed, suffered further damages through lodging, improper drying and delayed harvesting. The excessive moisture also caused considerable delay in land preparation and second season planting and persisted through September and October. The rainy season ended in early November. The cumulative total for the year was 1,549 mm or 22 percent above the long-term mean. Pan evaporation, on the other hand, was 7 percent less than its mean, totalling 1,483.09 mm.

Sky conditions and solar radiation. January and February were unusually cloudy, but solar radiation (Table 1, Fig. 3) was higher than normal. Cloudiness increased, particularly in the second half of April, in spite of the limited rainfall.

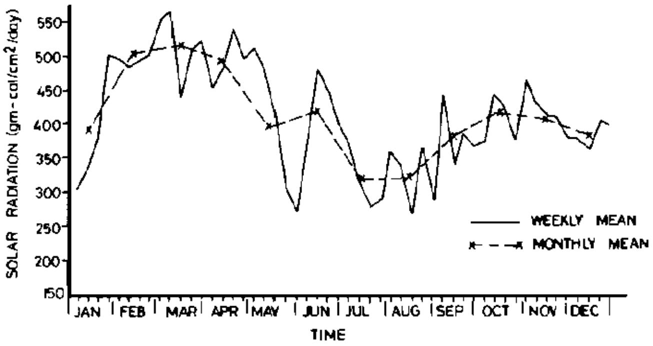


Fig. 3. Weekly and monthly mean solar radiation (IITA, 1980).

During the period May through August, which in effect covers the first cropping season, incident radiation dropped to a mean of 363.7 g-cal cm-2 day-1 or 6 percent less than the multiannual mean for these 4 months. The rest of the year, except for the month of November, saw a return to higher than normal insolation regimes.

Temperature and relative humidity. Higher temperatures prevailed on the average, mainly as a result of higher night-time temperatures, an apparent result of the more humid and cloudier conditions (Fig. 4). Monthly average minimum temperatures were record-high in many cases.

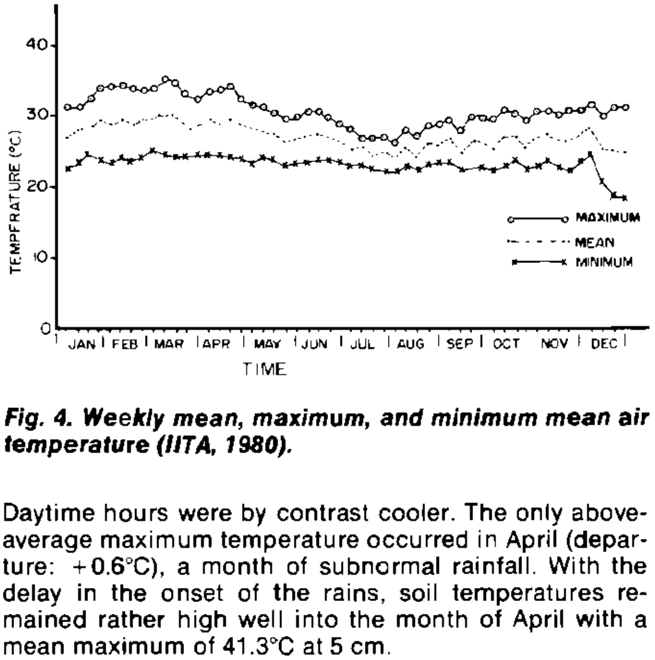


Fig. 4. Weekly mean, maximum, and minimum mean air temperature (IITA, 1980).

Daytime hours were by contrast cooler. The only above-average maximum temperature occurred in April (departure: +0.6°C), a month of subnormal rainfall. With the delay in the onset of the rains, soil temperatures remained rather high well into the month of April with a mean maximum of 41.3°C at 5 cm.

Observed relative moisture contents of air were also higher than normal, except for April (Fig. 5). These higher humidities evidently account, in part, for the lower values of evaporative demand.

An unusual prevalence of southerly and southwesterly winds in January and February constituted the basis for the observed cloudiness noted earlier. In general, wind speeds also remained above average throughout the year. The incidences of gusts during the wet period, particularly in late July and in August, account for the con-

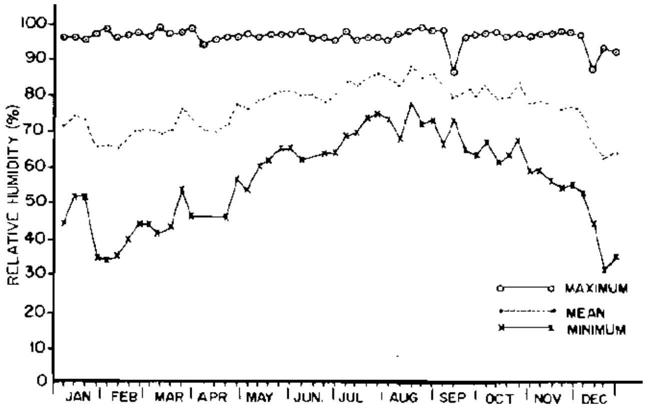


Fig. 5. Mean, maximum, and minimum relative humidity (IITA, 1980).

siderable lodging and stalk breaking observed during the period.

Dew/light precipitation. The contribution of dew to the water budget was much less than in the previous year. This is not surprising in view of the record high minimum temperatures and the high incidence of rainfall. The measured total for the year was 11.59 mm, ranging from a monthly maximum of 1.57 mm in November to 0.48 mm in August.

Agroclimatic analysis

Agroclimatic zones of West Africa

To provide a uniform framework for research to facilitate the choice of priority areas and determine the range of applicability of research results, an agroclimatic zonation of West Africa was undertaken. It is based on the concept of water-balance and Franguin's method of interception of rainfall potential evapotranspiration cure.

Months of positive water balance were defined as months with rainfall greater than or equal to potential evapotranspiration. On the basis of the number of the months determined for the network of approximately 88 stations over the region, 7 generalized agroclimatic zones were defined (Fig. 6).

Commonly used terminologies were retained in describing these zones. It is believed that the basic definition used in this classification is not only more meaningful from the cropping point of view but also avoids complex indices and is, thus, easier for the user to follow.

Crop water requirements.

There is a scarcity of research information regarding the water requirements for tropical food crops. It is important, therefore, to define the optimum water requirements of these crops to maximize their productivity under different ecological conditions.

Evapotranspiration and cowpea yields. Many studies on a variety of crops have tended to show a linear relationship between actual evapotranspiration and, more particularly, actual transpiration and yield. Using cowpea, TVu 3629 and TVu 4557, yield figures from a series of

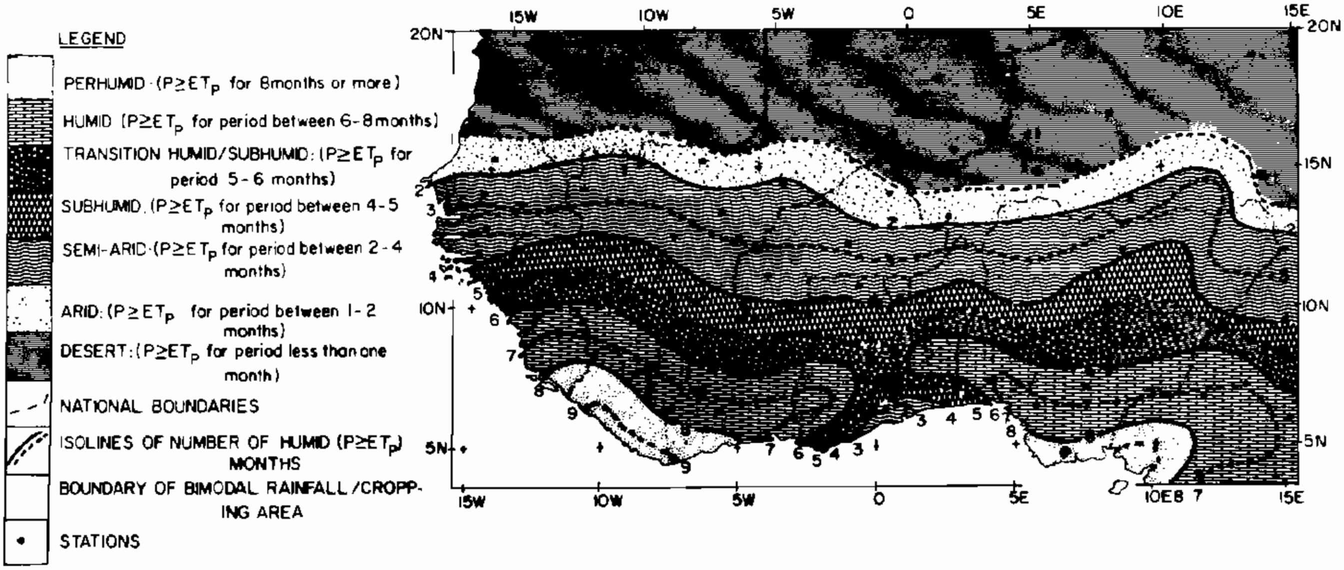


Fig. 6. Generalized agroclimatic map of West Africa. (Source: T. L. Lawson, IITA, 1979).

previous sequential planting experiments (IITA Annual Report, 1976), a preliminary attempt was made to model cowpea yield using estimated evapotranspiration.

Evapotranspiration estimates were obtained by assuming that the potential evapotranspiration is equal to Class A pan evaporation, and the actual mean weekly evapotranspiration is proportional to the ratio of the actual available soil moisture to the available soil moisture at field capacity. The 1976 results show a much better relationship than the 1977 results between the estimated evapotranspiration and cowpea yields (Figs. 7 and 8).

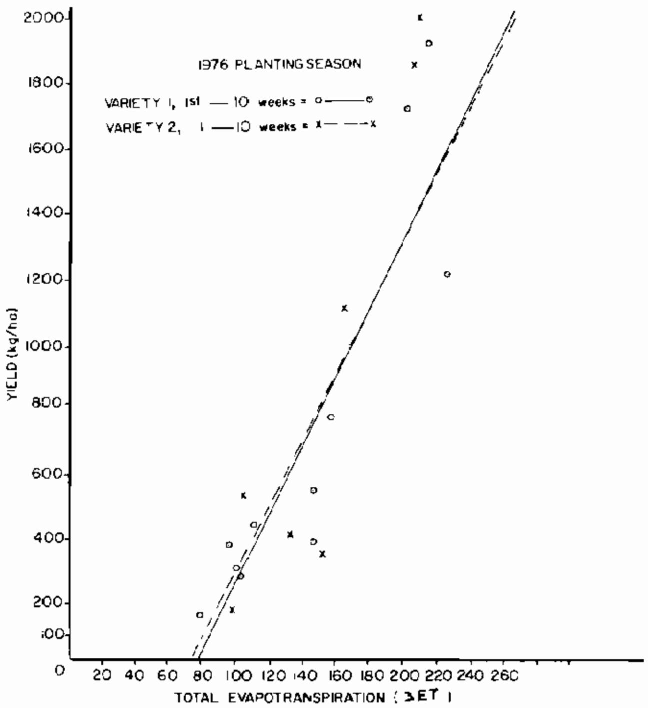


Fig. 7. Cowpea yield vs. evapotranspiration (1976).

Pest and disease problems are believed to be partly responsible for this. Possible inaccuracies in the evapotranspiration estimates may be equally important.

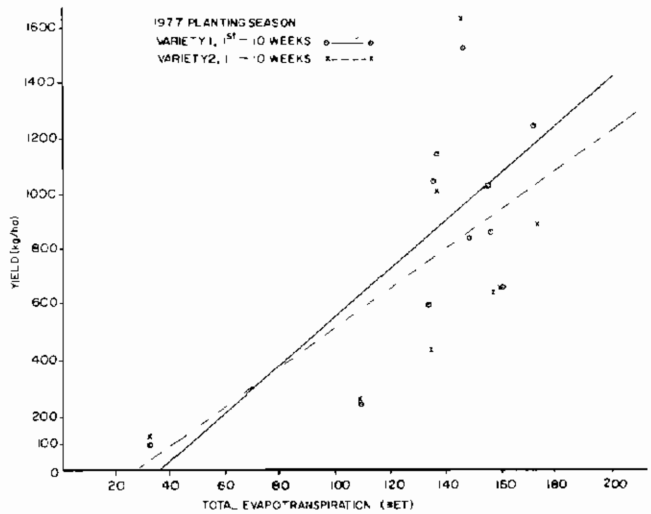


Fig. 8. Cowpea yield vs. evapotranspiration (1977).

Dry season evaporative demand and cassava yields. Cassava planted in a given year normally grows through the dry season and is harvested at the beginning of the rains the following year or thereafter. Although the plant reduces its canopy during the intervening dry season, no sign of wilting is observed on the leaves of the remaining foliage. On the hypothesis that the plants probably achieve this only by drawing on reserve resources, it would appear that yields might tend to decline in proportion to the length and severity of the dry season. Using cumulative Class A pan evaporation (Ep) as a measure of the intensity of the dry season, an analysis was made to relate the reported decline in the average yield of the 10 most promising cassava clones at IITA between 1973/1974 and 1977/1978 (IITA Annual Report 1977). The results, indeed, show a negative and highly significant linear relationship between the cumulative pan evaporation from 1 December through 28 and 29 February (the dry season for IITA) and the cassava yield. The relevant equation is as follows: $Y = 176.69 - 0.342I$, $r = -.978^{**}$, where Y is the yield of cassava and $I = \sum_{1}^{n} (Ep)$ (1 = Dec., n = Feb. 28/29). This relationship could prove useful in estimation of the performance of cassava across climatic zones.

Soil and land characterization and evaluation

Technical soil evaluation system based on soil mineralogy

Two distinctive approaches have evolved in recent years regarding the management of tropical soils for higher agricultural productivity. The high-energy input, extensive food and cash crop production systems are well suited for the fine-textured oxidic Oxisols, Alfisols, Ultisols and Inceptisols; whereas, agroforestry and low-energy input, food crop production systems are more suitable for the kaolinitic and siliceosis Alfisols, Ultisols and Inceptisols.

A key factor differentiating these 2 major categories of soils and their response to agricultural exploitation is soil mineralogy. A technical soil evaluation system using mineralogical characteristics as the main criterion is being developed at IITA with the primary objective to provide agricultural planners in the tropics with a set of simple guidelines for agricultural soil utilization. It is intended to provide supplementary information to the established soil classification systems with special reference to agricultural soils in which variable charge colloids dominate. Vertisols, Alfisols, Ultisols and Inceptisols dominating in high activity clays or constant charge minerals are excluded from this system since the agricultural soil evaluation systems for such soils are well established for the temperate and subtropical regions.

The proposed system may be briefly summarized as follows:

Soil group	Sub-group	Condition modifiers (or soil fertility limitation)	
		Physical	Chemical
Kaolinitic soils	Eutric	w, r, c	t*, (m*)
	Dystric	w, r, c	t, k, a, (m)
Siliceous soils	Eutric	w, c	t*, k*, (m*)
	Dystric	w, c	t, k, a (m)
Oxidic soils	Eutric	w	i
	Dystric	w	i, t, k, a
Allophanic soils	Eutric	-	i
	Dystric	-	i, t, k

The eutric subclass refers to high "base" status, and dystric to low "base" status. The soil fertility limitations in the last 2 columns refer to:

Physical condition modifiers:
w —low available water reserve
r —high soil erosion hazard
c —high soil compaction hazard
Chemical condition modifiers:
k —low potassium reserve
i —high phosphate fixation
t —secondary/micronutrient deficiencies and/or imbalances
a —aluminum toxicity for most legume crops
m —manganese toxicity to most legume crops
** —potential soil toxicity and/or secondary and micronutrient deficiencies and imbalance due to continuous cultivation with conventional chemical fertilization.*

Tentative quantitative limits of the "soil condition modifiers" have been defined, and refinement of these can be introduced in the future on the basis of further research information.

It is proposed to integrate this soil evaluation system in the land types and agroclimatic information so as to establish comprehensive guidelines for land clearing and management for different regions of the tropics. Close collaboration with FAO and other development agencies and interested national soils research institutions will be fruitful in further development of the system.

Soil erodibility characterization

Field experiments have been established to directly monitor soil erodibility at 3 locations in Nigeria—Onne, Ikom and Jos. In addition, soil detachability and transportability measurements on 20 soils collected from different parts of Nigeria are being made with a laboratory rainfall simulator. The accumulative infiltration measured for 3 locations prior to establishing the runoff plots are described by the following equations:

$I = 30.8t^{1/2} + 26.1t$ . . . Onne
$I = 16.0t^{1/2} + 93.3t$ . . . Ikom
$I = 2.1t^{1/2} + 6.3t$ . . . Jos

Where I is the accumulative infiltration in centimeters, and t is the time in minutes.

Field measurements of soil bulk density for 20 soils indicated a range of 0.70g cm^{-3} for Ikom to 1.5g cm^{-3} for Bakura and Tumu, Nigeria. Similarly, the soil-water transmissivity ranged from 236 cm/hr for Ikom to 1.4 cm/hr for Samaru, Nigeria. A plot of the accumulative infiltration vs. time for some Nigerian soils is shown in Fig. 9. Estimates of erodibility for some Nigerian soils by using the USDA Nomogram indicate a range of 0.05 t/acre/foot-ton for Ikom to 0.56 t/acre/foot-ton for steep lands near Abakaliki, Nigeria. A majority of the soils, however, have a low erodibility of about 0.1.

Hydromorphic soils in West Africa

A study was carried out to assess the quality and distribution of hydromorphic soils in various wetland areas in West Africa and their suitability and limitations for rainfed and irrigated rice production.

Hydromorphic soils could be defined simply as those soils where water can gather in sufficient volume and time to produce the effects of gleying or reducing re-

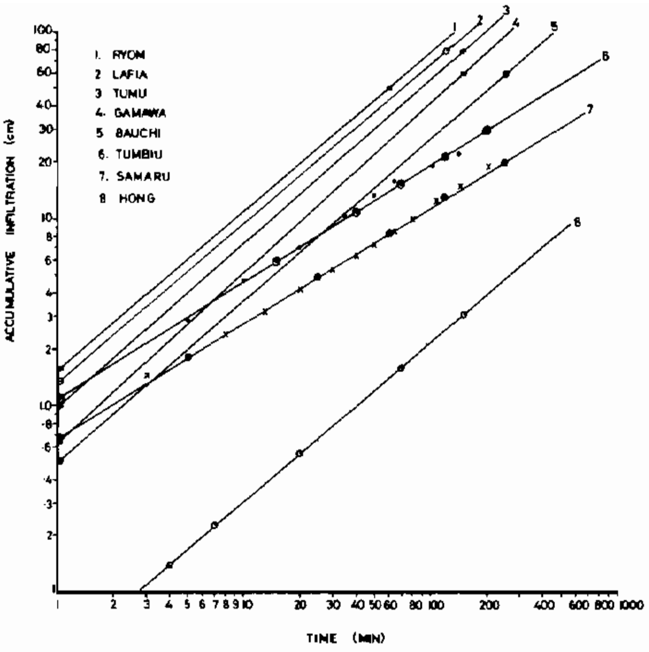


Fig. 9. Accumulative infiltration for some Nigerian soils.

gime. While hydromorphic soils mean the same to all soil scientists in terms of morphological and chemical properties, the different soil classification systems are still not very interchangeable because their respective concepts are based on different premises.

According to U.S. Soil Taxonomy, hydromorphic soils have an aquic soil moisture regime, and they appear under the suborder as well as the subgroup levels of classification. The FAO/UNESCO soil classification emphasizes the concept of gleization, and Gleysols and the "gleyic" subunits constitute the major hydromorphic soils of the "FAO Soil Map of the World." For both the French and Belgian classification systems, the processes of gley and pseudogley play prominent parts in the definition of hydromorphism. Moreover, Vertisols in West Africa are also subjected to seasonal waterlogging (pseudogley) and should come under the realm of hydromorphic soils. From the agronomic viewpoint, wherever excess soil moisture is the most important feature in land use for crop production, soils in such areas will come under the realm of hydromorphic soils.

An approximate correlation of the hydromorphic soils among the 3 international soil classification systems has been prepared at IITA.

A preliminary inventory of some chemical and physical properties of hydromorphic soils from Nigeria, Sierra Leone and Liberia may be summarized as follows:

Forest zone (Liberia, Sierra Leone and southern Nigeria). Hydromorphic soils occur in coastal, fresh-water swamps, inland swamps and small river valleys. Some areas are subject to deep flooding during the rainy season.

Approximately 80 percent of the hydromorphic soils (excluding acid sulfate soils in this region) are acidic (pH below 5.0) and coarse-textured (loamy sand and sandy loam) with low P and K reserves and low clay activity (Tables 2 and 3). Such soils would require high fertilizer inputs and good water control for intensive wetland rice production. More fertile rice soils in terms of soil-texture and nutrient status comprise about 15-20 percent of the 37 soils studied (Tables 2 and 3). Wetland areas with such soils may be developed into productive rice land. More detailed and systematic soil surveys by national organizations are needed in order to determine the extent and distribution of the more fertile wetlands and their feasibility for rice production.

Table 2. Texture, organic C and pH of 37 hydromorphic soils from the forest region of West Africa (southern Nigeria, Sierra Leone and Liberia).

Properties and range	Distribution, %	
	Surface soil	Subsurface soil
pH (H_2O, 1:1)		
4.0-5.0	78	73
5.1-5.5	14	22
5.6-6.0	8	5
Organic C, %		
0.5-1.5	38	97
1.6-2.5	24	3
2.6-5.0	30	0
> 5.0	8	0
Clay content, %		
0-15	46	19
16-25	19	35
25-35	14	16
35-45	8	16
45-55	5	3
55-65	8	11
Silt content, %		
0-10	16	24
11-20	22	24
21-30	16	14
31-40	24	19
41-50	12	14
51-80	10	5

Source of Data: IITA Soil Information Bank, Njala University College and University of Illinois Soil Survey Report for Sierra Leone (1974), Ministry of Agriculture and USAID Soil Survey Report for Liberia (1977), Manor River Union Soil Survey Report, Liberia (1979).

Forest/savanna transition zone (southern Nigeria). Hydromorphic soils in the forest/savanna transition zone occur mainly in inland valleys and depressions. As the region is characterized by a rolling topography and quartzose-rich basement complex rocks, the wetland valleys or depressions are generally small, and the soil depths are shallow. All the same, they occupy about 10-15 percent of the total land surface. Most of the hydromorphic land in this region presently is not used for food crop cultivation.

An extensive study on the soil and land characteristics of several inland valleys in the region was completed in 1979. In this study, groundwater regime throughout the year was used as an important criterion for the hydromorphic land quality evaluation. N deficiency and Fe toxicity associated with groundwater or seepage water were

Table 3. Nutrient status of 37 hydromorphic soils from the forest region of West Africa (southern Nigeria, Sierra Leone and Liberia).

Properties and range	Distribution, %	
	Surface soil	Subsurface soil
Exch. Ca, meq/100g		
0-0.50	41	59
0.51-2.00	35	22
2.01-4.00	5	5
4.01-8.00	11	8
> 8.00	8	5
Exch. Mg, meq/100g		
0-0.50	70	78
0.51-1.50	11	5
1.51-2.50	8	5
2.51-3.50	8	3
> 3.50	3	8
Exch. K, meq/100g		
0-0.05	24	65
0.06-0.15	35	22
0.15-0.25	30	14
0.25-0.35	11	0
Extractable P (Bray 1), ppm		
0-5	51	89
6-15	35	8
16-25	8	0
25-35	0	3
> 35	5	0

Source of Data: IITA Soil Information Bank, Njala University College and University of Illinois Soil Survey Report for Sierra Leone (1974); Ministry of Agriculture and USAID Soil Survey Report for Liberia (1977), Manor River Soil Survey Report. Liberia (1979).

also stressed. Utilization of these lands at traditional and improved levels of management for year-round crop production using wetland rice as the main season crop was proposed.

Further inventory of properties of 17 selected soils from the region are given in Table 4. Again, the predominant hydromorphic soils in this region are coarse and medium textured, but their chemical quality is slightly better than their counterpart in the high-rainfall region in terms of available Ca, Mg and K in the surface horizons. Available P status is invariably low although these soils have very low P fixation capacity.

Savanna zone (central and northern Nigeria). Hydromorphic soils in the savanna zone occur in a wide range of land forms such as inland depressions, river valleys and ancient and recent flood plains. The sedimentary plains of the Niger and Kaduna Rivers and their tributaries comprise a significant portion of potential rice land in central Nigeria, which is yet to be fully developed and utilized.

The inventory of hydromorphic soils in this region is exploratory due to lack of soil survey information. A preliminary inventory of soil properties of 10 selected sites in central Nigeria (excluding Vertisols) is given in Table 4. Hydromorphic soils at these locations show wide variability in texture, organic matter and soil reaction. Mineralogical studies showed that many hydromorphic soils in this region are montmorillonitic and, thus, of high clay activity. Hydromorphic soils with more favorable clayey and silty texture are found in some extensive areas in the river basins of central Nigeria. But, because of generally low nutrient status and seasonal flooding, effective water management and fertilization are required in order to develop such areas for rice production.

Table 4. Properties of 27 hydromorphic soils from the savanna zone and the forest/savanna transition zone of Nigeria.

Properties	Surface soil		Subsurface soil	
	Range	Mean	Range	Mean
Forest/savanna transition zone (17 soils)				
pH (H_2O, 1:1)	4.7-6.4	5.6	5.0-6.5	5.8
Organic C. %	0.37-1.96	0.91	0.07-1.36	0.42
Clay, %	4-68	15	3-70	21
Silt, %	4-51	21	5-53	18
Sand, %	13-89	64	10-84	61
Exch. cations, meq/100g				
Ca	0.67-12.83	3.48	0.47-11.13	3.34
Mg	0.29-7.40	1.53	0.21-7.89	1.67
K	0.03-0.26	0.13	0.02-0.46	0.11
ECEC, meq/100g	1.51-23.60	5.99	1.06-21.26	6.14
Bray P1, ppm	2-14	5	0.2-4	2
Savanna zone (10 soils)				
pH (H_2O, 1:1)	4.2-6.1	5.3	4.6-7.4	5.7
Organic C, %	0.29-2.70	1.04	0.07-0.75	0.42
Clay, %	6-50	22	5-70	28
Silt, %	8-51	37	6-55	29
Sand. %	4-82	42	5-89	43
Exch. cations, meq/100g				
Ca	0.55-7.94	3.50	0.40-6.84	3.34
Mg	0.20-3.36	1.32	0.06-3.25	1.30
K	0.04-1.92	0.40	0.04-0.29	0.14
ECEC, meq/100g	1.73-11.31	6.26	0.99-10.61	6.13
Bray, P1, ppm	2-39	9	0.4-5	2

An estimate is being made of the distribution of hydromorphic soils of selected areas of West Africa using LANDSAT imageries and a few large-scale soil maps that are available. The selected study areas include the wetland tracts along rivers of West Africa and inland swamps, such as those in Liberia and Sierra Leone and the wet sedimentary belts of southern Nigeria. Vertisols and the vertic subgroups are widely scattered but not fully documented on a national and regional basis.

Socio-economic analysis

Labor utilization

Literature was reviewed on labor utilization in cassava, yam, maize and upland rice production. Additionally, from short regional crop production surveys—preliminary labor utilization data were derived for cocoyam and soybean production in Nigeria (Table 5).

In 1980, further progress was made in the collection of time series data for food crop prices in West African countries. In addition to food crop prices in Nigeria and Cameroon, market prices were obtained from Ghana, Ivory Coast and Togo.

Table 5. Estimated average labor utilization for different food crops per operation in Nigeria.

Crop	From literature sources mandays/ha		From field surveys mandays/ha			
Operation	Maise	Yam	Cassava	Upland rice	Cocoyam	Soybean
Land preparation	24	95	40	55	36	35
Planting	10	35	13	30	14	15
Fert. application	15	15		5		12
Weeding	25	70	45	50	38	28
Harvesting	16	60	70	35	60	35
Totals	90	275	168	175	148	125

Agroforestry surveys

An agroforestry field survey was undertaken in southern Nigeria to identify major types of landuse in traditional farming systems and establish the degree of integration between (a) forest and tree crop plantations and small holder tree crop farming and (b) traditional arable crop farming and livestock production systems. Economic woody species, both cultivated and noncultivated, and their association with traditional arable crop farming received particular emphasis during the survey. The 6 survey locations—Ezzamgbo, Umudike, Onne, Ikom, Akamkpa and Uyo—are in the humid tropical zone, except Ezzamgbo, which is in the transition from the tropical wet to the tropical wet-and-dry climatic zone.

Landuse in traditional farming systems. Both traditional agriculture and rural settlements are largely confined to uplands with bottomlands seldom used for agriculture. All farmers in the survey areas have rain-fed upland farms. Only 23, 13 and 23 percent of the farmers in the derived savanna, lowland forest and coastal lowlands, respectively, have additional farms located in bottomlands. Permanent compound farm plots, common in the central zone of the region and in the settlement sites, are typically located on uplands or well-drained sites. The most common type of settlement is the dispersed homestead type, which is also correlated with the prevalence of permanent compound farms.

Major types of traditional systems of agriculture and their landuse. The dominant and most widespread types of traditional farming systems are permanent compound farming, rudimentary sedentary agriculture (with or without short fallow periods), bush fallow cultivation and traditional permanent tree crop farming. Shifting cultivation hardly exists, and taungya is hardly used in the region. Livestock is relatively insignificant. The bush fallow cultivation and the rudimentary sedentary agriculture are the most widespread systems of land use. Permanent compound farming is comprised of tree and arable crop farming enterprises with livestock as a third and minor activity. Land allocation is essential for homesteads, and tree and arable crop farming with livestock is confined to homesteads and villages.

Outside the permanent compound farms, except for retained (wild) economic tree crops such as oil palm, planted tree crops and arable crop farming are not spatially integrated. Hence, tree crops, once planted, occupy the land permanently while the arable crops are largely grown in the traditional bush fallow and/or rudimentary sedentary agriculture with a land use factor for uplands ($L = \frac{C+F}{C}$) ranging from 2.5 to 3.6 (Table 6). Thus, outside the permanent compound farms and traditional permanent tree crop farms, the land use ratio ($R = \frac{C}{C+F} \times 100$) in eastern Nigeria is less than 34 percent for uplands and 51 percent for bottomlands (Table 6).

In terms of land allocation, planted tree crops (including plantains and bananas) accounted for about 67 percent of the cultivated land; tree and arable crops mixture for 7 percent; and arable crops for only 25 percent (Table 7). About 76 percent of the farmers had arable crop farms under 4 ha, 45 percent of which were under 2 ha. Similarly, about 56 percent of the farmers had tree crop farms under 4 ha. Tree and arable crop mixtures were largely confined to farmers with the smallest amount of cultivated land.

Cultivated areas devoted to the important tree and arable crops grown were assessed for each survey location. Tree and arable crops most frequently grown with considerable acreage, in the order of importance for each group, were (a) oil palm, cocoa, plantain/banana, kola, rubber and citrus and (b) cassava, yam, maize and rice.

Table 6. Small holder land use in eastern Nigeria: Type of land cropped and cropping/fallow duration (1980).

	Derived Savanna				Lowland Forest				Coastal Lowland			
	Ezzamgbo		Ikom		Umudike		Akamkpa		Onne		Uyo	
Enterprise/Farmer	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	2	1.5	1.8	-	2.20	1	2.10	1	2	1.3	2.15	-
Cropping year, range	1-5	1-8	1-3	-	1-3	1	2-3	1	1-3	2-8	2-3	-
Fallow year, average	3.2	1.3	5	-	4.9	1.25	4.9	1.35	4.9	1.3	4.1	-
Fallow year, range	2-5	1-3	3-7	-	5	6	3-7	1-5	2-7	1-8	2-7	-
Land use factor ($L = \frac{C + F^{1}}{C}$)	2.5	1.9	3.6	-	3.25	2.25	3.33	2.35	3.45	2.08	2.9	-
Frequency of upland and bottom lands (% of farmers using)	100	35	100	-	100	5	100	20	100	50	100	5

[1] *(See Okigbo and Greenland, 1977 for classification)*

Table 7. Small holder land use in eastern Nigeria: Land allocation to enterprises per farmer (1979-80).

	Derived Savanna		Lowland Forest		Coastal Lowland		Row Total	
Enterprise	Ezzambgo	Ikom	Umudike	Akamkpa	Onne	Uyo	Av.	%
Average No. of plots	4.5	3.7	5.20	4.95	4.45	5.50	4.91	-
Area under Tree Crops (ha)[1]	1.34	7.10	15.05	13.79	6.30	11.87	9.24	67.0
Area under Arable Crop (ha)[1]	3.00	4.43	2.30	2.47	5.00	3.78	3.50	25.0
Area under Tree/Arable Crop (ha)[1]	0.12	1.01	0.56	0.81	3.03	0.51	1.01	7.0
Av. total Cult. land (ha)[1]	4.46	12.54	17.81	17.07	14.33	16.16	13.75	-

[1] *Fallow periods are often short and contain some cassava resulting in some short fallows being considered as cultivated plots by farmers. This has tended to put the total cultivated land slightly higher along with the problem of double counting of same plots due to intercropping and relay cropping.*

Small ruminant (goats and sheep) and poultry production is common with a general trend of more small ruminant production in areas of higher demographic densities where goats are more common and important in both humid and subhumid zones, while sheep and poultry are more important in the subhumid (derived savanna) zone. The number of domestic animals kept by each family is small.

Resource allocation to enterprises and production contraints. Family labor and arable land are the 2 principal resources. Farmers are dependent on family labor and only use hired labor during labor peak periods. A cropping calendar of the 13 most important tree and 18 arable crops showed that upland tree and arable crop farming, as parallel systems of production, compete for farm labor during land clearing, preparing and weeding. It was observed that there is a better utilization of family labor by having both tree and arable food crops than by either alone, and the 2 enterprises fulfill both cash and food needs of the family. The competition for labor between the tree and arable food crop enterprises could be reduced, if not eliminated, if both are integrated on the same land and, when possible, simultaneously operated. However, the practice of burning the bush in land preparation induces the physical or spatial separation of the 2 enterprises and causes arable crops to be grown in distant farms away from the homesteads (Table 7).

State of tree and arable crop farming. In general, there appears to be less expansion of tree crops on new lands. Any increase, especially in cocoa, kola and citrus, is due to rehabilitation and an increase in density of tree crops. Most farmers in the drier savanna and coastal lowlands, particularly under high-population conditions, thought tree crop farming to be declining. Major constraints to tree crop replanting and expansion were credit and lack of production inputs.

Farmers' view toward farming. Many traditional farmers themselves view farming as a nonprofitable enterprise and will abandon it if given other options. Eighty-six percent of the farmers stated that they will continue farming. Of these, 68 percent stated that they will continue because they have no other option available to them, 12 percent stated that they have great family responsibility that requires them to continue farming and 6 percent stated that they do not wish to buy foods from the market. Only 14 percent stated that they will continue farming because it is profitable. Those wishing to discontinue farming, especially arable crops farming, often gave old age as their main reason.

Proposed agroecological regions of the survey area: a synthesis. A map at a scale of 1:3,000,000 delineating agroecological regions has been prepared using the data of this survey (Fig. 10). Climate, geomorphology and soils, agricultural land use (farming systems), demographic conditions (density and settlement patterns) and the interaction of these have been considered in identifying these regions.

Accordingly, 5 major agroecological regions were identified:

I. Basement complex (cocoa/forest) with 4 subregions.
II. Sandstone and coastal sand complex (oil palm/root crop) with 5 subregions.
III. Niger delta and coastal swamp complex with 2 subregions.
IV. Upland moist savanna complex with 4 subregions.
V. Mangroves and coastal sand complex.

Region V was not surveyed, for it is considered a nonagricultural zone. Similarly, region III was not included in the survey because it is nonzonal in that land use is governed by the Niger River as the environmental factor. Only the lower part of Region IV was included in the survey, the derived savanna part, and this region, often referred as the middle belt is agriculturally (crop and livestock) important and is currently experiencing increased agricultural developments with a corresponding increase in population.

Region I and II are the most important for rain-fed traditional farming. The major distinction between these is their difference in geology and soils. In general, soils of Region I are geologically better soils (mostly Alfisols) and can support both tree and arable crop farming. The zone is currently used for cocoa, kola, citrus, etc., and a great variety of food crops is grown. On the other hand, Region II has soils that are chemically poor but with good physical properties (mostly Ultisols) that make tillage easy. Both soils are erodable and easily degradable with intensive cropping, particularly soils of Region II where the situation is already serious.

The agroforestry potentials (alley or strip cropping, planted fallows or taungya, multi-storey farming and agro-silvo-pastoral) are higher for Regions I and IV where such new or improved systems of land use may not be difficult to adopt. But, the same cannot be said for Region II.

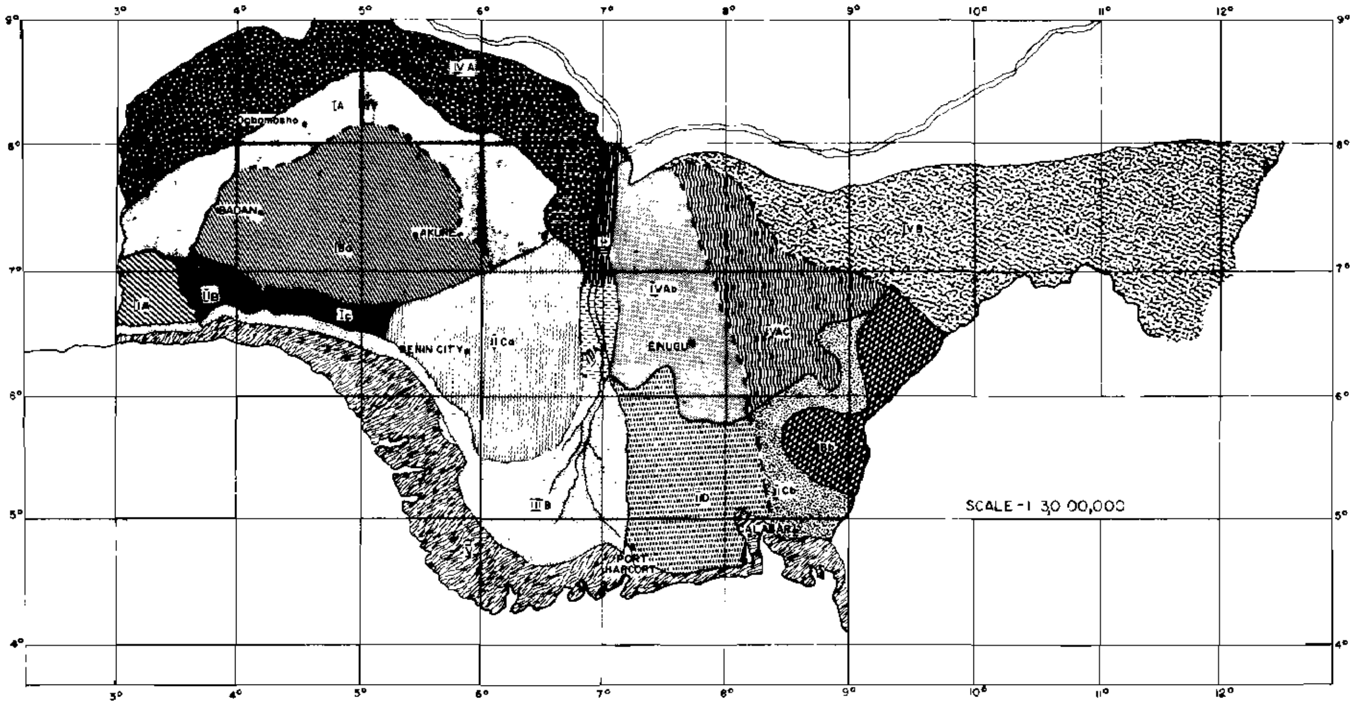


Fig. 10. Agro-ecological regions in the humid and sub-humid zones of Nigeria.

I. Basement Complex Regions (Cocoa/Forest)
- *IA* — *Northern sub-humid zone (W. Nigeria)—pop. high*
- *IBa* — *Central Humid, Sub-humid Uplands—(W. Nigeria)—pop. high.*
- *IBb* — *Eastern Humid Uplands (E. Nigeria) basement complex/volcanic—low pop.*
- *IC* — *Southern Humid Lowlands (W. Nigeria)—basement complex/coluvial, alluvial deposits —high pop.*

II. Sandstone and Coastal Sand (Oilpalm/Root Crops/ Forest Complex)
- *IIA* — *S.W. Sub-humid lowlands—sandy lowlands —medium pop.*
- *IIB* — *Lagos and Adjacent Lowlands—sedimentary sands—high pop.*
- *IICa* — *Benin Lowlands—Sedimentary sands—medium to low pop.*
- *IICb* — *Cross River Basin—sedimentary sands—low pop.*
- *IID* — *(Coastal) Sedimentary Sandy Plains—(E. Nigeria)—high pop.*

III. Niger Delta and Coastal Swamps
- *IIIA* — *Middle-Upper Delta—medium to high pop.*
- *IIIB* — *Lower Delta and Coastal Swamps—low pop.*

IV. Upland Moist Savanna
- *IVAa* — *Western Moist Savanna—mostly Basement Complex, medium—high pop.*
- *IVAb* — *Eastern Moist Savanna (sandstone hills)—high pop.*
- *IVAc* — *Eastern Moist Savanna—medium pop.*
- *IVB.* — *North Eastern (Guinea) Savanna—Sandstone medium to low pop.*

V. Mangroves/Coastal Sands

Land and soil management

Research on land and soil management includes the following areas: land clearing and development, tillage systems and small tools development and management of kaolinitic Alfisols and siliceous Ultisols.

Land clearing and development

Hydrological investigations and characterization of soil physical properties as influenced by methods of land clearing and post-clearing soil management were continued in 1980 for cassava planted in the 1979 second season and harvested toward the end of 1980.

Effect on soil bulk density. Deforestation resulted in a significant increase in soil bulk density (Table 8), and there were slight differences in bulk density among various methods of land clearing. Maize, being an open-row crop grown immediately after deforestation, increased soil bulk density (data of 1979), while cassava, being a close canopy crop, decreased soil bulk density. Moreover, tuber development just beneath the soil surface may have contributed to decreasing the bulk density of the layer above the tuber and increasing the bulk density of the layer below the tubers. Differences in soil bulk density were also reflected in the infiltration rate and penetrometer resistance.

Effect on total water yield. Water yield from the cleared watershed treatment was 259 mm while the forested treatment was only 2 mm. Deforestation contributed to a significant amount of seepage or ground water flow. The intermittent stream with only traces of flow during periods of heavy rains is now a perennial stream with measurable flow throughout the year. The maximum surface runoff was observed in September; the subsurface flow in October was almost equal to surface runoff. Continuing flow through the dry season also indicates the possibility of sizeable ground water storage that may be important at least in analyzing the hydrological balance of a cleared watershed.

Table 8. Effects of land clearing methods on soil bulk density in g/cm³ for the 0-5 cm depth (IITA, 1978-80).

Treatment	1978[1]	1979	1980
Traditional farming	0.64	1.06	1.07
Manual clearing—no tillage	0.68	1.14	1.05
Manual clearing—conventional tillage	0.68	1.20	1.29
Shear blade	0.70	1.19	1.37
Tree pusher—no tillage	0.66	1.25	1.37
Tree pusher—conventional tillage	0.53	1.22	1.32

Mean of 25 replications.
[1]1978 data prior to clearing.

Effect on surface runoff and erosion. Soil erosion and water runoff were lower for cassava than maize. Moreover, there were no significant differences among treatments either for runoff or erosion, except for the tree pusher—conventional tillage treatment. In spite of the protective cover of the cassava canopy, this treatment had 48 mm of water runoff and 4.2 t/ha/annum of soil erosion (Table 9). In comparison to this, runoff and erosion from the shear blade—no-tillage cassava was 5.0 mm and 0.08 t/ha. On the contrary, runoff and erosion from the shear blade—no-tillage maize treatment was 53 mm and 1.9 t/ha/annum, respectively. These results on the effects of methods of land clearing and post-clearing soil management have important practical agronomic implications. It seems that, in the long run, post-clearing soil management has the most important effect on soil erosion, runoff and decline of soil physical and chemical properties. This is not to say that the methods of land clearing are not important because a combination of harmful land clearing and post-clearing soil management methods, such as land clearing with tree pusher/root rake followed by conventional plowing and harrowing, results in the most losses in water runoff and soil erosion and in rapid degradation of soil physical and chemical properties.

Table 9. Effects of land clearing methods on surface runoff and erosion (IITA, 1980)

Treatment	Run-off, mm	Ero-sion, t/ha
Traditional farming	0	0
Manual clearing—no tillage	0.2	0.001
Manual clearing—conventional tillage	6.0	0.06
Shear blade—no tillage	5.0	0.08
Tree pusher—no tillage	3.0	0.04
Tree pusher—conventional tillage	48.0	4.2

Effect on cassava growth and yield. Seedling mortality was about 50 percent in these treatments because of shading by trees in the traditionally managed plots and by maise in the no-tillage plots (Table 10). Since cassava was planted in no-tillage treatments through 6-8 week-old maize, row spacing was often more than 1 m (sometimes 1.5 m), which also contributed to a low plant population. Cassava tuber yield varied by a factor of 2-2.5 among treatments with the lowest yield in the traditionally managed plots. Conventional tillage plots were planted at least 6 weeks later and harvested about a month after no-tillage plots. Tuber yield in conventional tillage plots would have been even more if they had been harvested 2-3 months later. Nevertheless, tuber and stalk yield from the no-tillage plots were comparable with those from the plowed and ridged plots.

Table 10. Effects of land clearing methods on cassava growth and yield (IITA, 1980)

Treatment	Plants/ha	Tubers/ha	Yield t/ha	
			Tubers	Stalks
Traditional farming	4,540	31,570	7.7	14.6
Manual clearing—no-tillage	5,230	36,640	15.0	22.4
Manual clearing—conventional-tillage	4,850	36,180	11.7	26.1
Shear blade—no-tillage	5,420	30,550	14.1	14.6
Tree pusher—no-tillage	5,800	39,580	20.2	16.8
Tree pusher—conventional-tillage	12,700	59,940	17.5	23.0

Tillage systems and small tools development

Effects of tillage methods on maize production. No-tillage methods with residue mulch have proven useful for some row crops in kaolinitic Alfisols in the forest zone of Western Nigeria. However, long-term studies at IITA have indicated that soil compaction can be a problem in no-tillage plots within 3-4 years. Moreover, soil compaction is more severe on mechanized than manually cultivated plots. Crop residue mulch is needed for many other uses (fodder, buliding houses and fences, fuel, etc.) and, therefore, may not be always available in the quantity required for effective soil and water conservation. Chiseling in the row zone rather than plowing the entire field, which makes the soil vulnerable to erosion, may be an alternative to ameliorate the soil of the compaction hazard. Plowing at the end of the rainy season may be another method. With this background, an experiment was carried out at IITA with the following treatments:

A. No-tillage with residue mulch.
B. No-tillage with chiseling in the dry season.
C. Moldboard plowing followed 2 harrowings (residue plowed in).
D. Disc plowing (residue disced).
E. No-tillage with residue removed.
F. Moldboard plowing at the end of rainy season and harrowing at planting.

G. Moldboard plowing followed by 2 harrowings (residue on the surface).
H. Moldboard plowing followed by 2 harrowings, followed by ridging (residue plowed in).

The effects of these treatments were investigated for soil physical properties and crop response. Preliminary results indicated that for a sandy loam soil, tillage methods had no significent effects on grain yield (Tables 11 and 12). However, it will be useful to conduct a similar study for different soils and ecological conditions to provide guidelines for appropriate tillage methods.

Table 11. Effects of tillage methods on grain and stover yield (IITA, 1980 First season).

Treatment	Grain yield t/ha	Stover yield t/ha	Harvest index %
A	2.52 A	6.3 AB	39.8 A
B	2.00 A	5.2 B	39.8 A
C	2.69 A	7.7 A	35.0 AB
D	2.41 A	6.7 AB	36.0 AB
E	2.14 A	5.9 AB	36.2 AB
F	2.62 A	7.3 AB	36.5 AB
G	2.07 A	7.7 A	27.0 B
H	2.25 A	6.9 AB	33.0 AB
LSD (5%)	0.82	2.1	10.5

Table 12. Effects of tillage methods on grain and stover yield (IITA, 1980 Second season).

Treatments	Grain yield t/ha	Stover yield t/ha	Harvest index %
A	2.40 A	4.80 A	51.8 A
B	1.81 A	4.32 A	43.5 A
C	2.00 A	3.65 A	53.3 A
D	2.12 A	3.53 A	60.2 A
E	1.80 A	4.22 A	42.3 A
F	1.81 A	3.58 A	49.9 A
G	1.97 A	4.54 A	43.6 A
H	2.05 A	4.27 A	49.3 A
LSD (5%)	1.01	1.81	17.7

Maize grain yield declined sharply in a field with its twelfth continuous crop of maize (2 crops per year). However, the rate of decline was much greater in conventional than in no-tillage plots (Fig. 11). Soil erosion has been a severe problem for yield decline in conventional-tillage plots while soil compaction has been a severe problem in no-tillage plots.

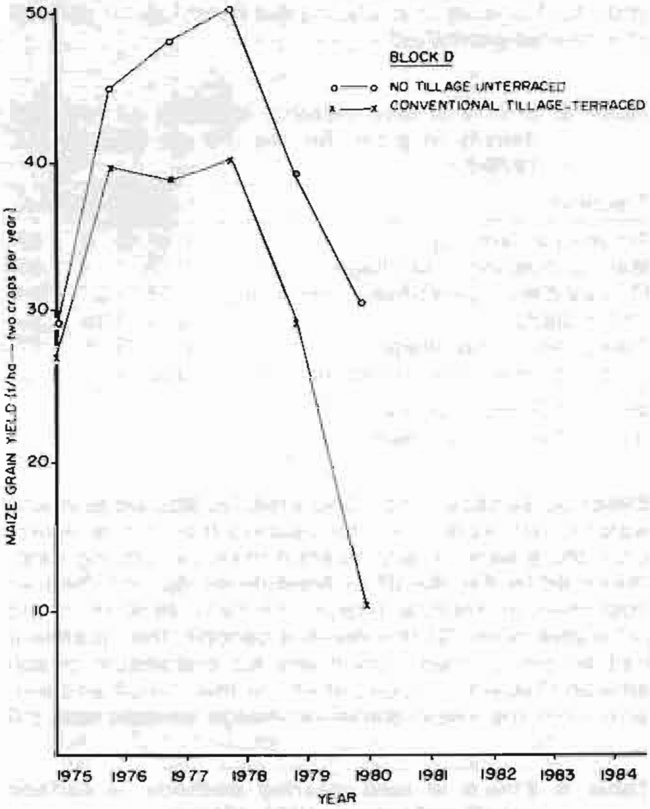


Fig. 11. Maize grain yield (Cv TZPB) under conventional and no tillage on a kaolinitic Alfisol cleared from secondary forest.

Poor stand in conventionally tilled maize with water standing for up to 2 weeks after rain because of compaction and low permeability.

Maize planted at the same time as the conventionally tilled maize, it has a good crop stand and compaction was not severe enough to reduce infiltration.

Effect of tillage methods and mulches on crop production in heavy-textured soils in Zanzibar. In collaboration with the University of Morogoro, Tanzania, tillage studies were conducted in Zanzibar to investigate the effects of methods of seedbed preparation and mulching on crop growth. Different treatments investigated were black and white polythene mulch, no tillage, ridges and bare flat surface. Differences in plant growth among different treatments were attributed to differences in soil temperature and moisture regimes. These soils have high clay content and low permeability. High soil moisture content and poor aeration were more serious in no-tillage and mulched plots during periods of frequent and heavy rains; consequently, crops were more chlorotic than in conventional-tillage plots. Effects of different treatments on crop yield indicate that the highest maize yield was obtained under white polythene mulch treatments and the lowest under no-tillage treatments (Table 13). These differences in grain yield were attributed to the number of grains per row and the unit grain weight. The yields of cowpea and soybean also observed a similar trend.

Table 13. Effects of seedbed preparation on soybean grain yields in Zanzibar.

Treatment	Grain yield t/ha 1979	1980
Black polythene	0.8	1.1
White polythene	1.5	1.0
No-tillage	0.5	0.4
Ridges	0.6	0.5
Bare	0.8	0.6
LSD (5%)	0.4	0.2

Effect of tillage on paddy rice production. In 1976, grain yields of rice were similar in conventional and non-tillage methods. Yields were significantly affected only by the level of N application. The yields were not affected by the tillage treatments for about 3 years. Since 1979, the plant height, tillers and grain and straw yield have been less in conventional-tillage than no-tillage for sandy soils (Table 14). In clayey soil, the differences due to tillage treatments were not pronounced (Table 15). Comparisons of rice yield in Tables 14 and 15 indicate that an optimum level of N for rice for a clayey soil is about 60 kg N/ha; whereas, the effect of N on rice yield in a sandy soil was not significant. The adverse effect of no-tillage on rice may be due to many factors, including nutrient imbalance. In a sandy soil, leaching losses of applied fertilizer on an untilled paddy may be more than in a puddled soil.

Table 14. Effects of tillage methods and N on rice grain yield (IITA, 1980 First season).

Fertilizer	Grain yield t/ha No Tillage		Conventional Tillage
With	2.50		3.82
Without	1.98		3.13
LSD (5%)		1.00	

Table 15. Effects of tillage methods and N on rice grain yield (IITA, 1980 Second season).

N rate kg/ha	Grain yield t/ha No Tillage		Conventional Tillage
0	1.99		3.75
30	2.94		4.79
60	3.59		4.54
90	4.02		5.05
LSD (5%)		0.82	

Effects of tillage methods and mulches on yam production. An experiment was initiated at Onne to investigate the effects of tillage methods and mulches on yam production. Treatments consisted of planting on either the flat or ridge with and without residue mulch. Observations were made for soil temperature, moisture and bulk density and root and shoot growth and tuber yield. Leaf area was generally more in mulched than unmulched plots with the least leaf area measured in the unmulched

No-till rice (top) had a poor stand and low yield after 6 consecutive crops compared to good stand and high yield in conventionally puddled paddy (below).

ridged treatment. Table 16 shows that 20 percent more yam tubers were produced in mulched than unmulched plots with least tuber yield measured in the unmulched ridge treatment. The beneficial effects of residue mulch may partly be attributed to favorable soil temperature and moisture regimes. Observations on soil moisture content made 40 and 90 days after planting indicated that unmulched ridges had the least soil moisture reserves.

Table 16. Effects of tillage methods and mulches on yam production (Onne, 1980).

	Ridge no mulch	Flat no mulch	Ridge plus mulch	Flat plus mulch
Length of tuber cm	20.7	20.7	23.5	21.7
Diameter of tuber cm	13.3[a]	13.9[a]	16.7[b]	17.1[b]
Yield t/ha	14.1	16.3	19	18.9

Effects of soil bulk density on root and shoot growth of cassava. A root-box study was conducted to investigate the effects of 3 soil bulk density treatments, 1.4, 1.6 and 1.8 gcm^{-3}, on cassava root and shoot growth. Cassava was grown in collapsable boxes 48 cm x 46 cm x 100 cm, with sides that could be removed for monitoring root growth at different stages. Measurements on root growth were made for cassava cultivar TMS30572 at 48, 78, 108, 132 and 185 days after planting. Root density, measured as length and dry weight, was not significantly affected by the soil bulk density treatments investigated. Neither were there significant differences in plant height, leaf area nor shoot dry weight. Cassava can withstand soil compaction more than grain crops such as maize, cowpea or soybean. Nevertheless, the shoot: root ratio was generally higher at soil bulk density of 1.6 gcm^{-3} than other densities (Table 17). The optimum density for the high feeding: tuberous root ratio was 1.6 gcm^{-3}. These results imply that effects of soil compaction on cassava may be highly dependent on soil texture as the latter affects both the intensity and capacity factors for nutrient and water availability.

Effects of tillage methods and mulches on soil temperature regime and its effects on crop production. Thermal diffusivity, the ratio of thermal conductivity and volumetric heat capacity, generally increases with an increase in soil moisture content up to a certain value. The exact relationship depends on soil texture. Thermal diffusivity measurements were made for 20 different soils, and the relationship between soil moisture content and thermal diffusivity for some soils is shown in Fig. 12. In general, thermal diffusivity is higher in coarse-textured sandy soils than heavy-textured clayey soils. The regression equations between sand, silt and clay on thermal diffusivity are given in Table 18.

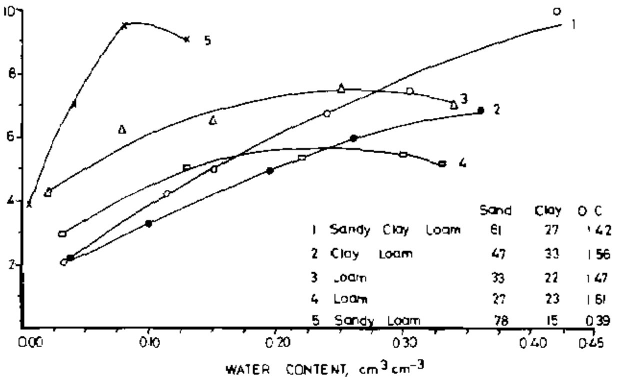


Fig. 12. Thermal differsivity of various soils as a function of the water content. Size of glass beads used 50-75 U.

Table 18. Regression equations relating thermal diffusivity, D ($cm^2\ sec^{-1}$) to percent sand, silt, clay or organic matter in a soil sample.

Simple

1. $D = 0.0103 - 0.000148\ cl$ $\quad r = 0.788^{**}$

Multiple

2. $D = 0.01182 - 01099 \times 10^{-3}\ cl - 0.1680 \times 10^{-2}\ cm$ $\quad r = 0.844^{**}$
3. $D = 0.0121 - 0.3066 \times 10^{-4}\ Si - 0.1104 \times 10^{-3}\ ci - 0.1479 \times 10^{-2}\ Om$ $\quad r = 0.860^{**}$
4. $D = 0.001025 + 0.1104 \times 10^{-3}\ Sa + 0.798 \times 10^{-4}\ Si - 0.1479 \times 10^{-2}\ Om$ $\quad r = 0.60^{**}$

Sa = Sand, Si = Silt, Cl = Clay, and Om = Organic matter.

Table 17. Effects of soil bulk density on cassava's shoot: root ratio and feeding root: tuberous root ratio.

Days after planting	Bulk density 1.4: Shoot dry wt / Root dry wt	Bulk density 1.4: Root dry wt / Tuber dry wt × 10^{-4}	Bulk density 1.6: Shoot dry wt / Root dry wt	Bulk density 1.6: Root dry wt / Tuber dry wt × 10^{-4}	Bulk density 1.8: Shoot dry wt / Root dry wt	Bulk density 1.8: Root dry wt / Tuber dry wt × 10^{-4}
48	134.72	-	58.89	-	50.00	-
77	188.24	84.53	258.89	305.08	126.04	185.90
106	140.13	67.47	128.55	70.40	110.4	98.81
134	150.17	42.44	267.41	41.90	348.91	12.60
185	401.96	299.79	249.39	537.66	200.01	329.94

A knowledge of the thermal diffusivity is necessary in predicting the temperature profile of a soil under different systems of management. Soil temperature affects crop growth directly as well as indirectly through its interaction with soil moisture regime and its effects on root growth, biotic activity and plant nutrients. Soil temperature measurements at different depths and times can be cumbersome. With the knowledge of soil thermal properties, moisture regime and boundary conditions, the temperature profile of a soil can be predicted with a reasonable degree of accuracy. An attempt was made to compare the measured soil temperature with that estimated by the Fourier series solution and the Hanks model. The initial and boundary conditions were measured for the following treatments: bare flat, flat mulched with crop residue @ ut/ha, ridged and flat surface covered with transparent polythene.

Soil temperature measurements were made for maize, cowpea and soybean. The predicted soil temperature at 20 cm depth under maize and cowpea was within 0.6°C of the measured soil temperature. Soil temperature can also be predicted from the air temperature (Table 19). The effect of canopy cover on diurnal fluctuations in soil temperature at 29 and 37 days after planting for a sunny and a cloudy day, respectively, is shown in Fig. 13. The higher temperature under soybean compared to the lower temperature under maize and cowpea is partly attributed to poor stand because of a supraoptimal temperature regime during the periods of seedling emergence and establishment.

The values of amplitude and phase angle for the first 3 harmonics of the temperature wave for different surface conditions and crop covers are shown in Table 20. It is

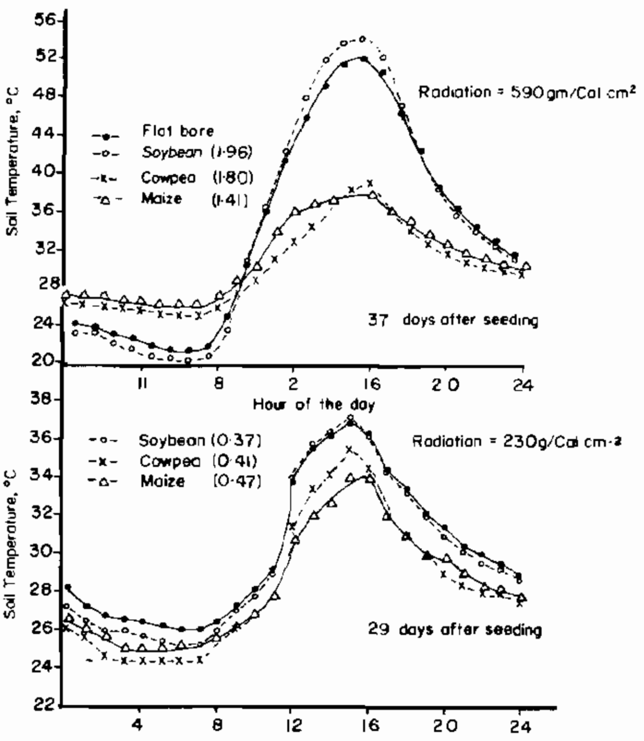


Fig. 13. Diurnal temperature variation at 5-cm depth in a flat base soil under 3 crop canopies at 2 occasions following seeding. Numbers in the brackets denote leaf area index on the day of temperature measurements.

Table 19. Calculated and measured soil temperature in control (bare flat) treatment.

Date	Soil depth (cm)	Air-temperature at 1 m height (°C) Maxi.	Mini.	Soil temperature (°C) Maximum Meas.	Maximum Calc.	Minimum Meas.	Minimum Calc.	Mean Meas.	Mean Calc.	Difference
4.12.80	1	34.3	22.9	44.2	47.8	26.7	26.0	35.4	36.9	1.5
	15	-	-	35.5	34.2	29.5	30.0	32.5	32.1	0.4
8.12.80	1	35.5	23.2	45.8	49.2	27.2	26.3	36.5	37.7	1.2
	15	-	-	35.6	34.4	29.6	30.3	32.6	32.3	0.3

Maxi. = maximum; Mini. = minimum; Meas. = Measured; Calc. = Calculated.

Table 20. Total variance (°C) of the soil temperatures at various depths under different crops grown on bare flat, mulched flat or bare ridged soil surface and its percentage accounted for by different harmonics.

Harmonic Number	Cover Crop→ Soil → depth (cm)	No Crop 5	No Crop 20	No Crop 35	Soybean 5	Soybean 20	Soybean 35	Cowpea 5	Cowpea 20	Cowpea 35	Maize 5	Maize 20	Maize 35
						BARE FLAT							
Variance (°C)		115.53	19.90	4.45	140.83	28.75	6.45	19.30	3.49	0.56	18.12	3.20	0.57
1		94.8	95.6	92.6	93.2	96.0	93.3	92.3	94.0	91.1	94.4	95.3	89.5
2		3.8	2.1	4.5	5.3	1.7	4.2	4.4	4.3	5.4	3.2	2.5	7.0
3		0.5	0.7	0.7	0.6	0.8	0.5	1.3	0.3	0.4	0.9	0.9	1.2
Total 1 to 3		99.1	98.4	97.8	99.1	98.5	98.0	98.1	98.6	96.9	98.5	98.7	97.7

(Percentage of variance accounted for by the harmonic) obvious that 90-95 percent of the variability in soil temperature regime under bare, maize, cowpea and soybean covers can be explained by the first harmonic while 97-99 percent of the variability can be explained by the first 3 harmonics (Table 20). In general, the second and third harmonics represented 1.2-7 percent and 0.1-3.8 percent of the total variance, respectively. This implies that the first 2 harmonics alone can explain the diurnal fluctuation in soil temperature up to about a 30 cm depth. The third harmonic explains about 1 percent of the total variance.

Runoff and erosion under root crops. Table 21 shows the effects of canopy cover of tropical root crops at different growth stages on runoff and erosion. Cassava, although a closed canopy crop, takes a relatively longer time to provide a complete ground cover than maize or cowpea. Staked yams leave the ground surface exposed to raindrop impact even when the canopy is fully developed and, therefore, renders the soil more susceptible to erosion. Sweet potato, with quick and effective ground cover, is a soil-conserving cover since it results in minimal runoff and erosion compared to cassava and yam (Table 21). Mixed croppings of maize with cassava, cassava with melon and maize with yam resulted in a significant decrease in both runoff and erosion. Simultaneous measurements of canopy cover made at different growth stages will provide necessary information for computing "C" values that can be used in the "Universal Soil Loss Equation" for predictive purposes.

Table 21. Effects of crop cover on runoff and erosion.

Crop cover	Runoff (mm)	Erosion (t/ha)
Maize with sweet potato	154	2.2
Cassava with melon	380	3.7
Yam with melon	314	4.0
Sweet potato	223	4.4
Maize	197	4.4
Melon	303	6.3
Weed fallow	251	4.4
Yam	186	2.0
Cassava with maize	457	9.2
Cassava	462	8.0

Weed control in no-tillage system

The effect of residue management and tillage on maize production using chemical weed control was investigated on a 1-year *Eupatorium odoratum* fallow. (Tables 22a and 22b). Maize yield was significantly lower in the no-tillage plot than conventional (plow and harrow) and reduced tillage (disc harrow) plot. Also, significantly more weeds grew at 4 weeks after planting where the residue was burnt off than where the residue was retained or raked off. The method of weed control affected grain yield but not lodging in maize. The maize yield was significantly lower in the unweeded than weeded plots (Table 23a). When plots were hand weeded, the crop yield was identical in the 3 tillage practices. However, when a preemergence herbicide was used for weed control, the yield was significantly higher in conventional than no-tillage plots (Table 23b).

Weed control in conventional and no-tillage cassava was evaluated in an Alfisol in a subhumid climate. The vegetation was a 2-year fallow consisting of perennial grass, *Panicum maximum;* and broad leaves, *Eupatorium odoratum, Alchornia laxiflora* and *Ficus* spp. The fallow vegetation was first slashed in late February before the onset of rains, and its regrowth was then sprayed in April with 3.0 kg glyphosate/ha a.i. In the conventional-tillage section, the fallow vegetation was plowed under. and the cassava was planted at 1.0 m × 1.0 m spacing on the flat after harrowing. In the no-tillage section, the cassava was planted directly into sprayed regrowth. Cassava

Table 22a. Effect of residue management and tillage practices on maize yield and crop performance (Ikenne, 1980).

Management practice	Plant Ht. cm	Lodging %	Weed F.W. g/m²	Grain Yield t/ha
Residue present	81.4	33 a	6.1	2.06 a
Residue removed	81.7	29 a	6.7	2.06 a
Residue burnt	87.9 a[1]	35 a	12.2 a	1.98 a
Plow and harrow	86.7 a	41 a	8.5 ab	2.12 a
Disc harrow	89.8 a	34 a	11.4 a	2.20 a
No tillage	74.5	22	5.0 b	1.78

[1] *Means followed by the same letter in the same column are not significantly different at the 5% level of Duncan's New Multiple Range Test.*

Table 22b. Effect of residue management and tillage practices on maize yield and crop performance (Ikenne, 1980)

Residue Management	Tillage Practice	Plant ht. cm.	Lodging %	Weed F.W. g/m²	Grain Yield t/ha
Residue present	Plow and harrow	83.8 ab[1]	45 a	5.8 b	2.13 ab
	Disc harrow	88.7 ab	31 abc	7.2 b	2.20 ab
	No tillage	71.7 c	24 bc	5.2 b	1.84 ab
Residue removed	Plow and harrow	87.0 ab	38 ab	8.8 b	2.17 ab
	Disc harrow	86.3 ab	32 abc	7.0 b	2.34 a
	No tillage	71.9 c	18 c	4.2 b	1.68 b
Residue burnt	Plow and harrow	89.3 ab	41 ab	10.8 ab	2.07 ab
	Disc harrow	94.3 a	39 ab	20.2 a	2.05 ab
	No tillage	79.9 bc	25 bc	5.7 b	1.83 ab

[1]*Means followed by the same letter in the same column are not significantly different at the 5% level of Duncan's New Multiple Range Test.*

Table 23a. Effect of tillage and weed control on maize yield and crop performance (Ikenne, 1980).

Treatment	Stand count (× 10³ pl/ha)	Lodging %	Grain yield t/ha
Plow and harrow	25 a[1]	40 a	1.91 ab
Disc harrow	25 a	37 a	2.06 a
No tillage	18	21	1.81 b
Herbicide	22	33 a	2.03 a
Hand weeding × 2	25 a	34 a	1.99 a
Unweeded check	20	32 a	1.76

[1]*Means followed by the same letter in the same column are not significantly different at the 5% level of Duncan's New Multiple Range Test.*

Table 23b. Effect of tillage and weed control on maize yield and crop performance (Ikenne, 1980).

Tillage practice	Weed Control	Stand count (× 10³ pl/ha)	Lodging %	Grain yield t/ha
Plow and harrow	Herbicide	26 a[1]	41 a	2.12 a
	Handweeding × 2	27 a	40 a	1.96 abc
	Weedy	22 bc	40 a	1.66 c
Disc harrow	Herbicide	25 ab	34 a	2.20 a
	Handweeding × 2	27 a	39 a	2.08 ab
	Weedy	22 bc	39 a	1.92 abc
No tillage	Herbicide	16 e	22 b	1.78 bc
	Handweeding × 2	20 cd	23 b	1.94 abc
	Weedy	18 de	19 b	1.71 c

[1]*Means followed by the same letter in the same column are not significantly different at the 5% level of Duncan's New Multiple Range Test.*

storage root yield was significantly depressed by tillage (Tables 24a and 24b). However, preemergence herbicides were more effective in conventional than no-tillage cassava. Crop yield was significantly higher in the hand weeded than in the chemically weeded plot under no-tillage. The hand weed plot under no-tillage compared favorably with the preemergence herbicide treatments under conventional-tillage. This is an indication that good cassava yield is possible under no-tillage conditions provided that weeds are controlled. The best weed control in cassava was obtained when a mixture of metolachlor and fluometuron was used. This yield did not differ significantly from that of the formulated mixture of atrazine and metolachlor, which has previously been shown to be safe for maize/cassava intercrops.

Table 24b. Effect of weed control on weed biomass and cassava root yield in an Alfisol (IITA, 1980)

Weed control	Weed D. Wt. t/ha	Cassava root yield t/ha
Atrazine plus metolachlor	3.18a[1]	19.53 b
Fluometuron plus metolachlor	3.88 a	20.89 b
Diuron plus paraquat	3.97 a	19.58 b
Weed free	0	31.79 a
Unweeded check	3.39 a	12.27 c

[1]*Means followed by the same letter in the same column are not significantly different at the 5% level of Duncan's New Multiple Range Test.*

Small tools development and evaluation

Rolling injection planter. The rolling injection planter was modified to improve its performance in both the conventional and no-tillage systems. First, it was provided with a small metal cover to hold the seed on the metering wheel to prevent uneven distribution of seed. This cover holds the seed in the metering wheel until the seed is just over the opener, and the seed is dropped almost directly on the ground through the opener (Fig. 14). Previously, the cutoff device on the rolling injection planter had a tendency to pinch maize seeds in such a way that the seeds jumped out of the seed hole in the metering wheel. This happened just as the seed had almost completely passed under the cut-off device. Also, the vibration of the machine had a tendency to shake seeds out of the metering wheel prematurely. This

Table 24a. Effect of tillage and weed control on weed biomass and cassava root yield in an Alfisol (IITA, 1980).

Treatment Tillage	Weed control	Weed D. Wt. t/ha	Cassava root yield t/ha
Conventional tillage	Atrazine + metolachlor 3.0 kg/ha	1.85 de[1]	25.08 b
	Fluometuron + metolachlor 2.0 + 2.0 kg/ha	1.94 de	28.62 ab
	Diuron + paraquat 3.0 kg/ha	2.71 bcd	27.27 b
	Weed free —	0 e	35.83 a
	Unweeded check —	2.13 cde	16.43 c
	Mean	1.73	26.65
No tillage	Atrazine + metolachlor 3.0 kg/ha	4.51 abc	13.98 cd
	Fluometuron + metolachlor 2.0 + 2.0 kg/ha	5.81 a	13.17 cd
	Diuron + paraquat 3.0 kg/ha	5.24 ab	11.90 cd
	Weed free —	0 e	27.75 b
	Unweeded check —	4.65 abc	8.10 d
	Mean	4.04	14.98

[1]*Means followed by the same letter in the same column are not significantly different at the 5% level of Duncan's New Multiple Range Test.*

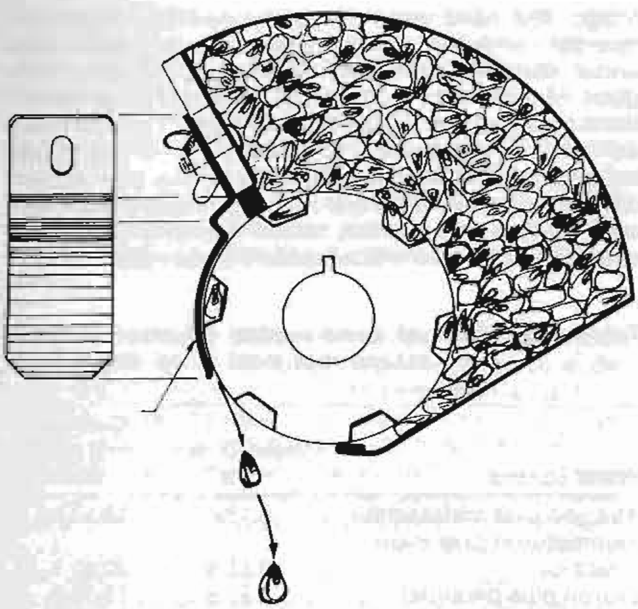


Fig. 14. Two-view drawing of the metering wheel cover for the rolling injection planter.

caused increased numbers of seeds in some hills and none in others. For crops requiring 3 or 4 seeds to be planted per hill, the small metal plate is not necessary. The seeds distribute themselves fairly evenly between the hole openers giving good crop stands.

A simple guard was designed that covers the opening between the opener lever and the injection wheel to prevent trash from passing between. The guard does not add significantly to the cost or weight of the machine. Previously, the small pieces of wood left in the field after clearing fallow were found to catch in the hole opener lever and wedge between the injector wheel and the handles. This makes the planter almost impossible to push.

The solution to the planter sinking in soft soil was to fit a wider hole opener lever. This lever is 5 cm wide, adding 3 cm to the width of the previous hole opener lever. The extra width provides for more contact with the soil, thus, distributing the weight over a greater area and keeping the planter from sinking. Finally, the requirement of planting in the row at other than 250 mm spacing has partially been solved. Seed rollers were made that give 2 and 3 seeds per revolution of the rolling injection wheel. This will give seed spacing of 500 mm (3-hole roller) and 750 mm (2-hole roller). A single hole roller could be made to give 1,500 mm spacing. This development brings a much wider range of activities for the rolling injection planter, giving it adaptability to various crops.

In an attempt to increase the rate of planting, different configurations of planters and fertilizer band applicators were also designed and tested as follows:

(a) A 2-row rolling injection planter was designed to increase the field capacity and make a more stable planter by eliminating the sideways tipping of the machine.
(b) A 2-row rolling injection planter with a fertilizer band applicator attached behind it acting as a press wheel worked very well, buf lumpy fertilizer slows down the planting operation as the lumps must be broken up before being used.
(c) A single-row rolling injection planter with a fertilizer band applicator attached behind it is too heavy to balance.
(d) A single-row rolling injection planter with a fertilizer band applicator attached beside it acting as a row marker as well as placing basal fertilizer works very well and eliminates using strings or poles for marking the rows. This system does not work well on heavy mulch, which contains a lot of fine grasses or weeds and hides the fertilizer.

Neither the single-row rolling injection planter with a fertilizer band applicator nor the 2-row rolling injection planter are able to work on traditionally cleared land that has stumps left standing more than 15 cm in height. This is because the amount of deviation from the row to be able to go around the stump is too great.

The working rates of these machine combinations are shown in Table 25. Table 26 gives the amount of time to move row marker stakes when planting or spraying.

Table 25. Rate of work of planter combinations (IITA, 1980).

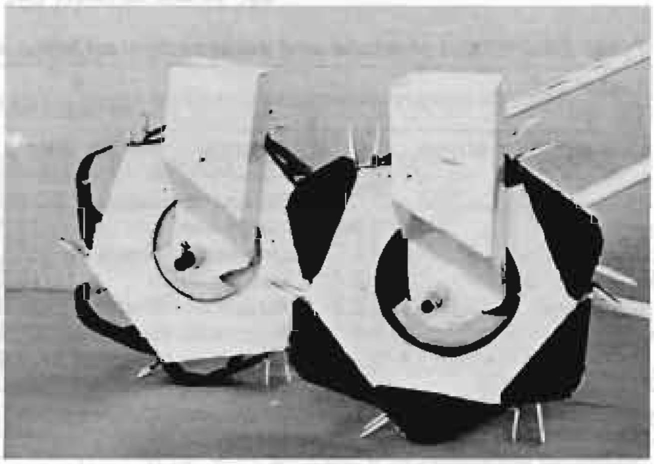
Machine	Man-hr/ha*
Single row rolling injection planter	10
Single row rolling injection planter plus fertilizer band applicator	13
2-row rolling injection planter	6
2-row rolling injection plus fertilizer band applicator	9
Single row rolling injection with fertilizer band applicator row marker	13

**These times to not include time to move row marking stakes.*

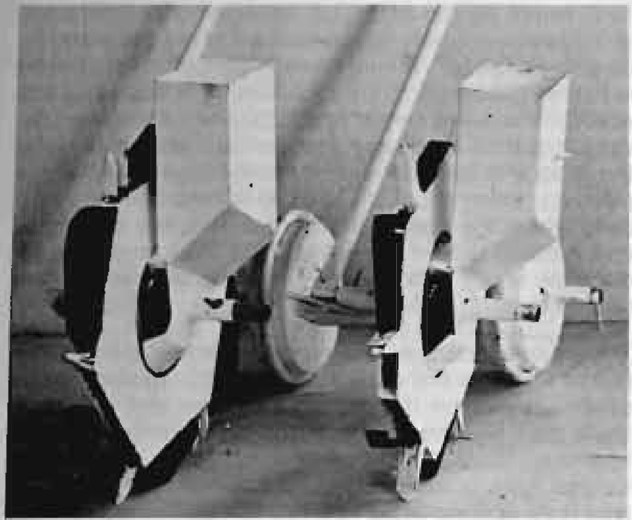
Table 26. Time for machine operator to move row marker stakes per hectare (IITA, 1980).

Width of machine	man-hr/ha
0.75 m	5
1.5 m	4
2.0 m*	3

**Estimate.*



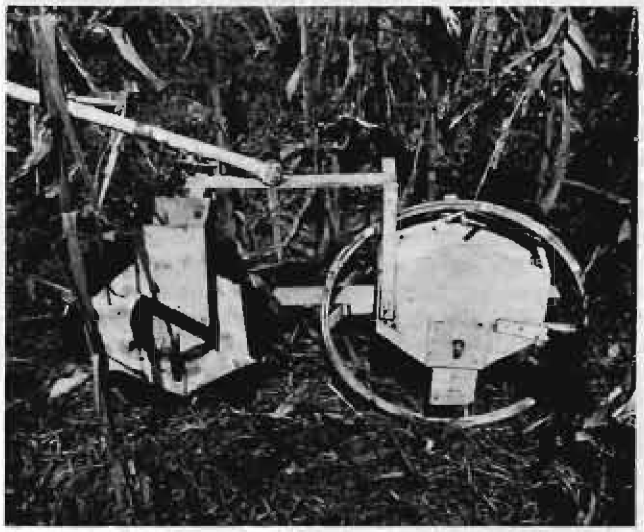
Guard on opener lever. Planter on right has guard installed.



Hole opener lever. Planter on left has 50 mm wide lever, planter on right a 25 mm wide lever.

Two-row rolling injection planter.

Two-row rolling injection planter with the fertilizer band applicator attached.



Single-row rolling injection planter with the fertilizer band applicator attached.

Single-row rolling injection planter with fertilizer band applicator row marker.

All machines were designed to either push or pull. Operators generally chose to pull. When conditions made penetration a problem, it was improved if the planter was pushed. Other trials were carried out to judge the variability of the rolling injection planter in stand establishment with no tillage. This variability may be caused by the amount of mulch cover on the soil or by how well the seeds are covered. To determine whether the planter was covering seeds well enough, maize was planted with no tillage. Ten pairs of rows were selected at random. One of the pairs of rows was carefully dug up and the seeds counted, then carefully replaced in their holes and covered with soil. The next row was left and not counted. Out of the total number of rows tested, the average stand count for the seeds dug up was 82 percent. The count for the rows left alone was only 51 percent. It is clear from this test that more work is required on seed covering. It was also noted that the heavier the mulch cover, the lower the stand count when using the rolling injection planter. A test to determine the effect of the amount of mulch cover on the effectiveness of the rolling injection planter was carried out on small plots with maize and cowpea, separately, replicated 20 times.

Tables 27 and 28 show that there is a consistent reduction in stand establishment as the amount of mulch cover increases for both maize and cowpea. This reduction in stand as mulch weight increased could be attributed to greater bird and rodent activity on the heavily mulched fields and/or shading from the mulch.

Table 27. Percent stand of maize on varying mulch weight per hectare (IITA, 1980).

Mulch t/ha	Stand percent
0 (Control)	74.4*
0	47.4
4	35.2
6	32.4
8	23.2
10	22.1

**The control seeds were planted by hand and well covered between the rows planted and the rolling injection planter.*

Table 28. Percent stand of cowpeas on varying mulch weight per hectare (IITA, 1980).

Mulch t/ha	Stand percent
0 (Control)	84.0*
0	84.4
4	59.7
6	52.9
8	51.5
10	41.1

**The control seeds were planted by hand and well covered between the rows planted by the rolling injection planter.*

In the cowpea plots, no mulch treatments were rotovated before planting. The control seeds, which were well covered, had the same germination rate as the seeds planted with the rolling injection planter. In the maize plots, the no mulch treatments were not rotovated before planting. The control seeds had 27 percent more germination than the seeds planted with the rolling injection planter.

The results on the no mulch treatments for both maize and cowpea support the conclusion of the earlier test on covering of seed. When the seeds are well covered, there is higher germination. During planting, it was noted that seeds are covered better when planting on soil with conventional than no-tillage. The soil falls back better onto the seed with conventional than no-tillage. On no-tillage planting, there is usually a small indentation above the seed where the opener is inserted. This may allow birds and rodents to find the seeds more easily and, thus, reduce the stand establishment. Further tests will be conducted to determine the causes of lower stands.

The hole openers of the rolling injection planter were tested to know the maximum speed for pushing before seeds are left on the ground's surface and the advantages and disadvantages of the different types of hole openers. Table 29 shows the maximum speed for a formed hole opener, a wedge hole opener and a split type hole opener. (Also see Fig. 15.) Both wedge and the split hole openers had a maximum speed of 3.4 kph while the formed hole opener had only 2.6 kph. This lower speed for the formed hole opener was because a small cup near the end of the opener held the seed after it was opened causing a delay before the seed was dropped.

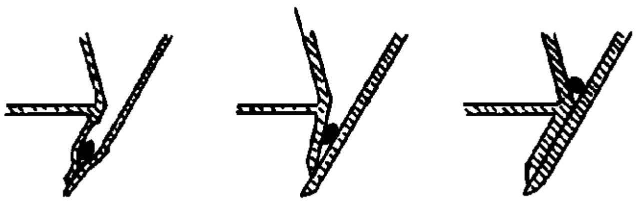


Fig. 15. Side view of different hole openers for the rolling injection planter; left to right, formed, wedge and split.

Table 29. Performance test of 3 types of hole openers at different speeds of planting.

	% of Seed placement[1]			
Kph	Cup type[2]	Wedge[3] Type	Split[4] Type	Remarks
1.69	100	100	100	
2.14	100	100	100	
2.61	100	100	100	
3.00	75.02	97.85	100	
3.43	50.07	98.60	97.37	Limiting
4.00	37.42	80.66	83.31	speed
4.29	13.05	15.00	17.00	

[1]Percentage (%) seeds deposited inside the hole.
[2]Formed hole opener carries the seed out, harder to penetrate the soil; clogged with soil very often.
[3]Wedge hole opener frequently clogged with soil.
[4]Split hole opener; split opener squeezes out dirt.

CDA sprayer. A 2 head, hand-carried sprayer, which had been built previously at IITA, was modified to give more even flow between the heads. The original sprayer had 1 feed line from the bottle to the cross supporting the heads. The tube had a T placed in it at the cross support to feed each of the heads (Fig. 16). The combination of low pressure in the spray bottle and the resistance to

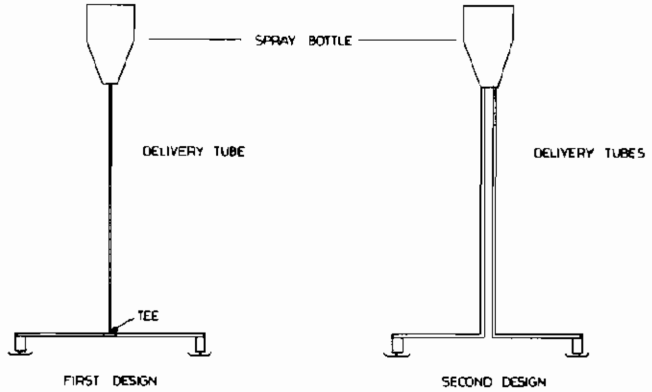


Fig. 16. Schematic diagram of delivery tubes for 2 head CDA sprayer.

flow in the 6 mm tubing would at times allow 1 head to take all the flow, leaving the other with no flow at all. This would happen normally when 1 head was higher than the other. This was mostly overcome by having a separate tube for each head coming from the spray bottle. The sprayer was set up with the spray heads 0.75 m apart to match the row width when working on standing maize stubble. This 2 head sprayer was used in conjunction with the 2-row planter with every other row of maize stover knocked down. The time required for using the 2 heads was approximately 0.6 of the single head. This increase in the rate of work would probably justify the extra expense of the 2 head machine, approximately 1.5 times the price of a single head machine.

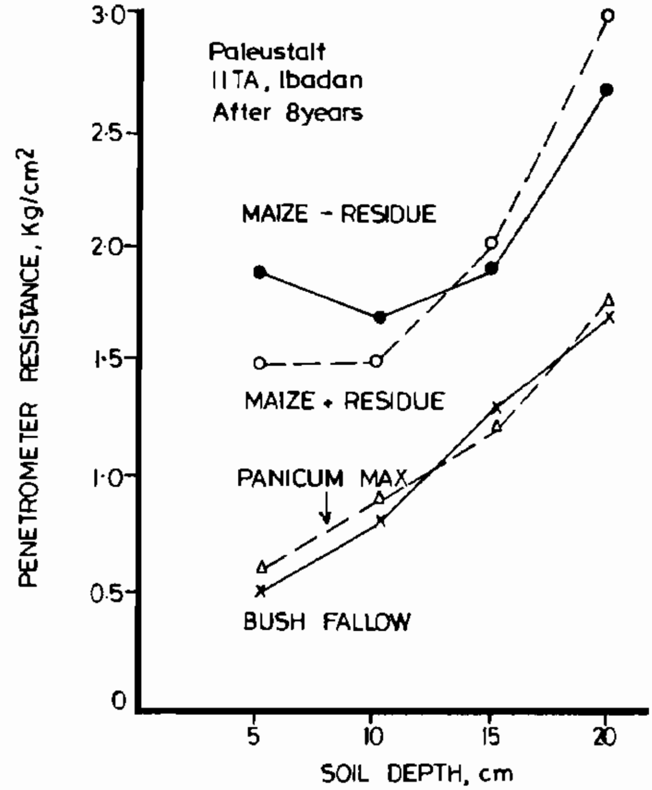


Fig. 17. Penetrometer readings of the surface layers of kaolinitic Alfisols under fallow and after 8 years of continuous cultivation.

Management of Kaolinitic Alfisols

A long-term experiment established at IITA since 1972 shows that fallow remains a vital component in maintaining the soil productivity of the highly erosive kaolinitic Alfisols on a predominantly rolling topography in the forest/savanna transition zone of West Africa. This is, in part, demonstrated by the alarming decline of some chemical and physical properties of the soils after 8 years of continuous cropping compared to those under natural and planted fallow.

Effect on soil chemical and physical properties. Continuous cropping for 8 years with insufficient amounts of crop residue return resulted in an increase in soil bulk density and acidity and a decrease in soil organic matter levels, and, consequently, a reduction in CEC and exchangeable Ca and Mg status in the soil (Table 30). Penetrometer readings of the cropped plots after 8 years indicated a severe compaction of the surface horizons compared to the soils under grass and bush fallow (Fig. 17).

Continuous no-tillage maize with crop residue returned as surface mulch twice a year was able to maintain soil organic matter (i.e., total N) levels comparable to that of bush fallow. But, the decline in soil pH, CEC, exchangeable Ca and Mg levels and the increases in soil bulk density and penetrometer readings were considerable

Table 30. Properties of surface soil (0-15 cm) under 8-year continuous cultivation and fallow after clearing of secondary forest (Oxic Paleustalf, Egbeda Series, IITA, 1980).

Treatment	pH (H_2O)	Total N %	ECEC meq/100g	Exch. cations, meq/100g Ca	Mg	K	Bulk density (Fine earth) g/cm³ 0-5 cm
Continuous cropping with minimum tillage							
Maize, residue returned	5.0	0.18	3.23	2.19	0.41	0.35	1.20
Maize, residue removed	4.7	0.11	1.81	1.13	0.24	0.11	1.31
Maize/Cassava	5.6	0.15	3.40	2.04	0.42	0.32	1.25
Soybean, residue returned	5.0	0.11	3.05	1.65	0.42	0.28	1.23
Natural and planted fallow							
Natural regrowth	6.5	0.19	5.14	3.53	0.91	0.41	0.88
Guinea grass	6.7	0.26	7.69	4.75	1.28	0.91	1.01
Pigeon pea	6.0	0.23	3.42	2.18	0.64	0.32	1.10

although to a much lesser extent compared to the no crop residue plots (Table 30). Moreover, properties of soils under continuous mulch, no-tillage maize for 8 years were by no means comparable to that under bush and grass fallow. Planted fallows such as *Lucaena* with both leaves and branches returned as surface mulch compared favorably to that of natural bush fallow; whereas, results of pigeon pea (bush type) were inferior. The latter result is mainly due to severe disease problems that cause the crop to die off after 1 year. Lack of effective ground cover during or before the reestablishment of the new crop may have caused the loss of Ca, Mg and K from the surface soil by eroding and leaching.

Effect on earthworm activity. There was a remarkable difference in earthworm activity between the fallow and cultivated plots. Earthworm activity monitored during a 4-day period in July, 1980 (Table 31), showed that the natural bush fallow plot had a significantly higher *Hyperiodillus* activity (columnar casts) than the 2 planted fallow plots (*Leucaena* and Guinea grass). The extremely low earthworm activity in the continuously cropped plots (8.5 years) is apparently due to many factors. Soil compaction, continued use of pesticides and herbicides and the decline in soil organic matter are probably among the important ones. The results of *Eudrillus* activity (granular casts) taken during the same period were less indicative. Although the difference among the fallow and cropped plots was not statistically significant, the *Eudrillus* activity under *Leucaena* was considerably greater than that under bush and Guinea grass as well as the cropped plots (Table 31).

Role of crop residue mulch on maize yield under no-tillage system. Respectable grain yields under a mulch-no-tillage system on manually cleared land were maintained up to 4 years; but yield declined steadily, thereafter, despite adequate fertilization and plant protection (Fig. 18). The reason for the yield decline is a complex one. The decline in soil biomass activity due to cultivation, soil compaction and possible Mn toxicity due to soil acidification are probably among the more important growth-limiting factors that cannot be simply remedied by conventional fertilization. The beneficial effect of crop residue mulch in the no-tillage maize system is evident, particularly in areas of ustic soil moisture regime and frequent incidences of dry spells during the early cropping season. These results suggest that to avoid permanent degradation of the "superficially" fertile Alfisols in the forest/savanna transition zone of West Africa, cultivated land needs to be returned to an effective fallow or resting period after 4-5 years of cropping under recommended soil management practices, i.e., the mulch no-tillage system.

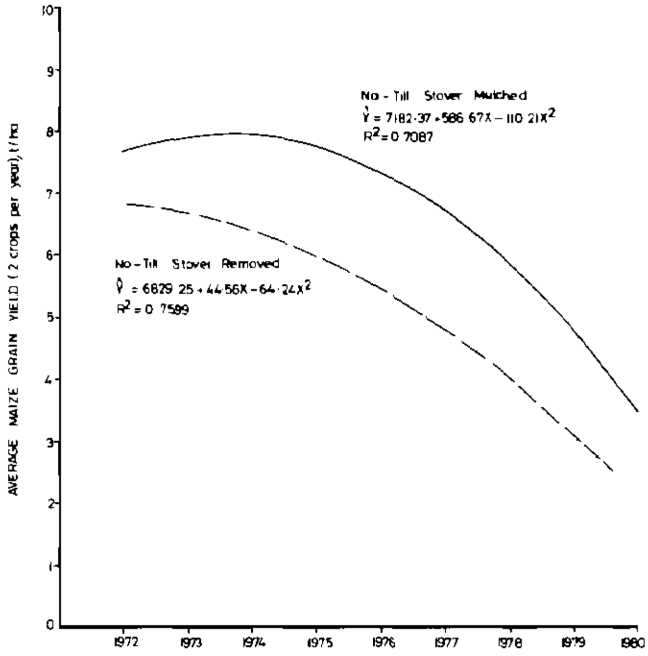


Fig. 18. Calculated yield curves of maize for a period of 9 years under no-tillage with and without stover mulch on a kaolinitic Alfisol.

Mineralization of soil organic matter.

A small-scale, manual, land clearing project (0.25 ha) was carried out to study the soil organic matter decomposition and nutrient release after forest clearing. A secondary objective of the experiment was to demonstrate whether improved soil and crop management practices at the small farmer's level could, in fact, increase the length of the period under cultivation before the land is returned to bush fallow. The improved practices included no burning, no tillage and the use of mulches, fertilizers, preemergence herbicides, pesticides and an improved crop variety. Soybeans were planted immediately after land clearing during the 1979 second season followed by maize during the 1980 first season. Fertilizer was not applied to either crop. Excellent growth of both the soybean and maize was observed, and tissue analysis indicated no nutrient deficiency. Results of weekly monitoring of NO_3-N and NH_4-N in the surface (0-10 cm) soil are given in Figure 19. Substantial amounts of soil organic N were mineralized during the onset of the rainy season. These data further suggest that, in spite of risking a drought stress, early planting of maize is preferred so that the crop can effectively utilize the high levels of mineralized N in the soil during the second season, both

Table 31. Earthworm activity in fallow and cropped plots taken during a 4-day period in July, 1980 (IITA).

	Hyperiodillus (columnar cast)		Eudrillus (granular cast)	
Treatment	g/250 cm²	No./250 cm²	g/250 cm²	No./250 cm²
Natural bush	10.46 a	12.98 a	0.01 a	7.66 a
Guinea grass	7.83 ab	10.02 ab	0.04 a	3.22 a
Leucaena	3.98 bc	6.85 abc	2.36 a	29.30 a
Maize/Cassava	2.15 c	5.78 abc	0.01 a	8.48 a
Maize + residue	0.60 c	1.79 c	0.02 a	2.35 a
Maize − residue	0.004 c	0.02 c	0.00 a	2.67 a

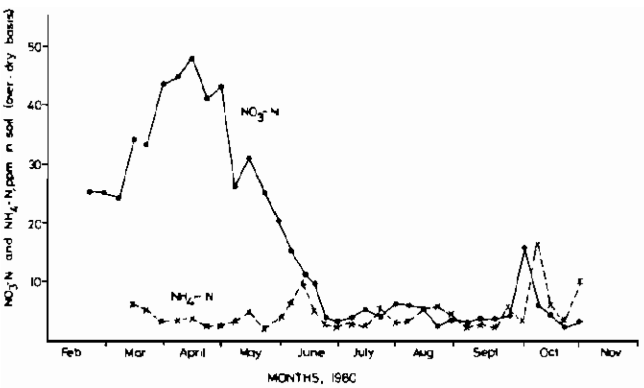


Fig. 19. Seasonal fluctuation of nitrate and ammonium -N in a newly cleared forest Alfisol (0-10 cm).

the NO_3-N and NH_4-N content in the soil were low, indicating that a higher rate of N fertilization would be required for the second maize crop. There were significant changes in soil organic C, N and P as well as bulk density 1 year after clearing (Table 32). The decline of soil organic C, N and P is primarily due to mineralization as soil erosion and surface run-off on this carefully cleared plot (64 subplots) are minimal. The second season maize, however, suffered severe streak virus disease.

Grain and dry matter yields of soybean and first season maize are given in Table 33. The grain yield of the first season maize was considerably lower than would be predicted from its early growth condition. This is probably because of the long dry spell during the grain-filling stage that severely affected the grain yield of the 1980 first season crop without supplementary irrigation.

Table 32. Changes in soil properties of a forest Alfisol 1 year after forest clearing (0-10 cm) (IITA, 1979-80).

Property and standard error	At clearing (1979)	After one year # (1980)
Bulk Density, g/cm	1.04 ±0.05	1.22 ±0.02
Organic C, %	1.55 ±0.07	1.24 ±0.06
Total N, %	0.171±0.007	0.146±0.007
Organic P, ppm	194±7	160±7

#Crop residues were removed after each harvest.

Table 33. Average grain and dry matter yields of soybean and maize from 32 subplots (IITA, 1979-80).

Crop	Grain Yield (12% moisture) kg/ha	Dry Matter (Oven Dry) kg/ha
Soybean (TGM 294) (2nd season, 1979)	1759±5	4605±202#
Maize (TZPB)	2639±183	4709±20**

#Total dry matter yield sampled at maturing stage.
***Stover yield only at harvest.*

Continuous fertilization and cropping

The long-term fertility trials initiated in 1972 on an Alfisol (Egbeda Series, Oxic Paleustalf) and Entisol (Apomu Series, Psammentic Usthorthent) to investigate the long term N, P, K, Mg, S and Zn responses of these soils following land clearing were continued in 1980. Maize

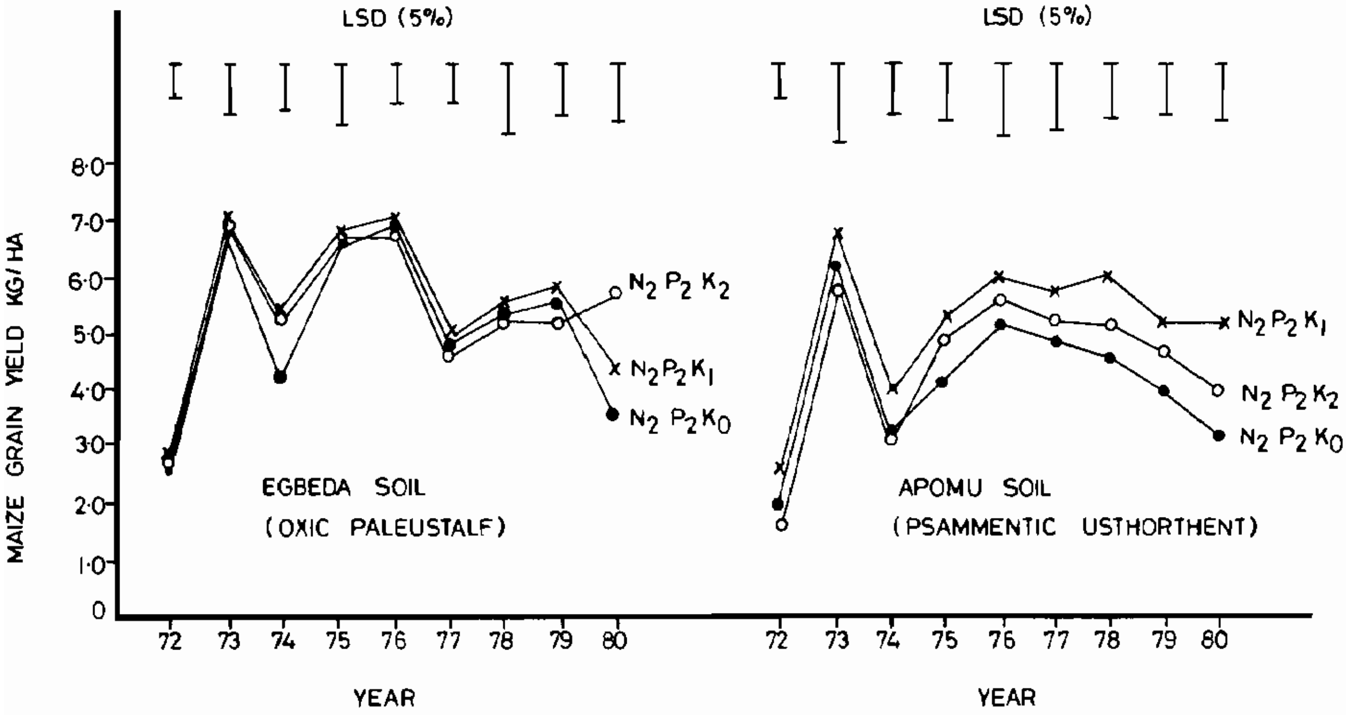


Fig. 20. Potassium response of maize grown on Egbeda and Apomu soils in long-term fertility trials at Ibadan, Nigeria (K-rates; K_0 = 0; K_1 = 40 and K_2 = 80 kg K/ha).

(main season crop) followed by cowpea (minor season crop) annual rotation was practiced during the last 6 years. Though P and N responses on the sandy loam Egbeda soil were observed, respectively, since the first and third years following land clearing, a significant response to K application on the maize crop was not observed until 1980, the ninth year after land clearing (Fig. 20).

The significant response to an annual application of 40 kg K/ha was rather unexpected since the soil K-status with this treatment at the start of the trial in 1980 was more than adequate at 0.32 me K/100g soil (Fig. 21). This may result from an early drought affecting the crop, which may have less effect on the crop receiving the higher K application.

On the sandy textured Apomu soil, where significant K response was observed already in the fourth cropping year, the main yield response was observed to be consistently higher at 40 kg K/ha than 80 kg K/ha. Though no definite explanation can be given for this observation, it may in part be due to the higher acidity build up with the higher K rate, which could have an indirect negative effect on the maize crop.

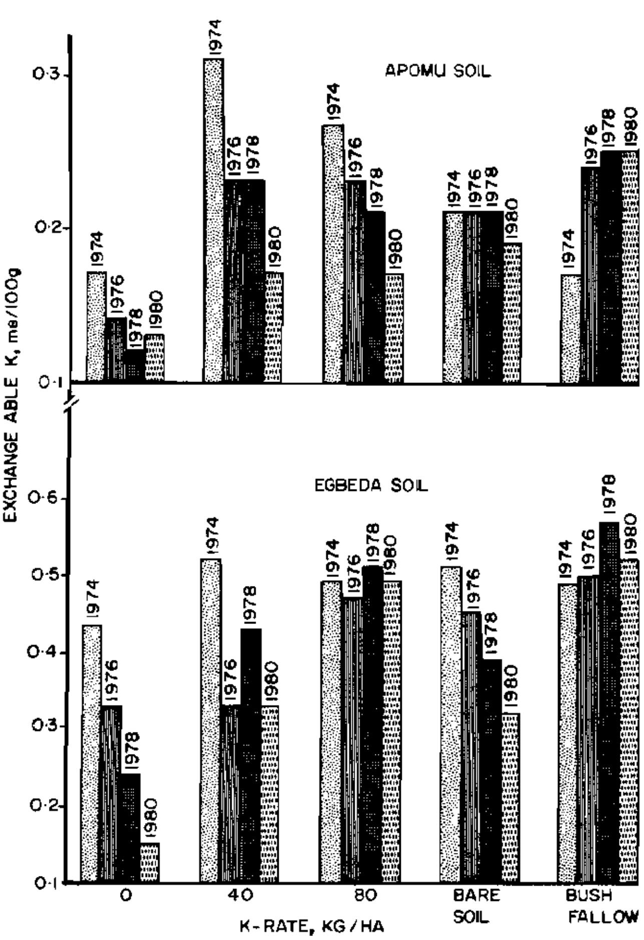


Fig. 21. Changes in soil potassium status of Egbeda (Oxic Paleustalf) and Apomu (Psammentic Usthorthent) soils in long-term fertility trials at Ibadan, Nigeria, with K application (K_0 = 0; K_1 = 40 and K_2 = 80 kg K/ha) and without cultivation.

Data on the soil K-status with K application and cropping showed significant changes on both soil types (Fig. 21). The soil K-status showed faster depletion with continuous cropping compared to a bare uncultivated treatment, particularly on the Egbeda soil. Annual application of 80 kg K/ha was able to maintain the soil K-status of the Egbeda soil at a level comparable to that observed under bush fallow. However, on the Apomu soil, the K-status was observed to be lower than that observed under bush fallow even with an annual application of 80 kg K/ha.

The effect of maize crop residue retention and removal with and without fertilizer application in this long-term trial, which initially did not show any particular trend on the maize grain yield in the last few years began to result in definite effects (Fig. 22). On the Egbeda soil, removal of the maize residue, particularly without fertilizer application, significantly reduced maize grain yield. On the Apomu soil, removal of maize residue significantly reduced maize grain yield, particularly with fertilizer application.

The detrimental effect of continuous removal of maize crop residue with continuous fertilizing and cropping was observed to be more pronounced with the cowpea crop. In 1980, the cowpea variety used in the experiment was changed from VITA-4 to VITA-5. VITA-5 gave a lower yield (Fig. 23) and is apparently more sensitive to Mn toxicity. With continuous application of NPK fertilizers, there was a significant soil pH depression with both the Egbeda and Apomu soils. The lower pH resulted in higher mobilization and extractable Mn levels, particularly on the Apomu soil, resulting in lower cowpea yields mainly due to Mn toxicity combined with K deficiency.

Plant residue management

Despite the importance of maintaining adequate soil organic matter under the traditional techniques of shifting cultivation or bush-fallowing, the plant residue during seedbed preparation is commonly burnt off. The long-term effect of this practice compared to plant residue management has not been adequately studied. A trial was, therefore, initiated on an Alfisol at Ikenne, Nigeria, to study the effects of burning and mulching of plant residue in relation to fertilizer application on the performance of maize. Results of the trials during 1978-80 are shown in Table 34. Though some responses to N and P were observed following land clearing from fallow, significant responses to P and N were only observed, respectively, in the second and third years following clearing. The main response was to P application.

Though the mean maize grain yields do not show any significant differences between burning and mulching of the plant residue during the 3 cropping years, some effects were observed among the various fertilizer treatments. Without fertilizer application, PK, NP and NPK treatments combined with mulching gave a higher maize yield, particularly in the third cropping year. However, with the NK treatment, burning gave a higher maize yield, which may be attributed to a quick release of P from burning of the plant residue.

Nitrogen-tillage interaction on maize

Despite the importance of no-tillage systems in soil conservation, little information is available on the best nutrient management aspects of the no-tillage system of

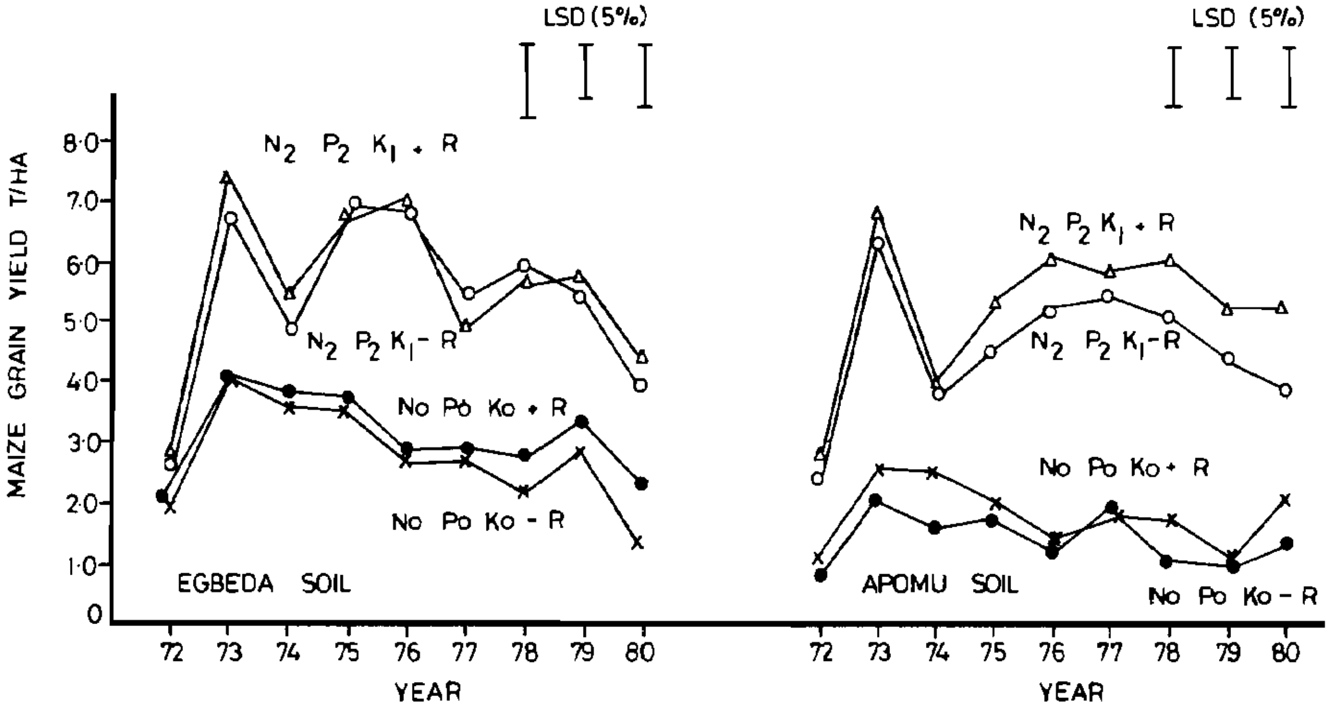


Fig. 22. Effect of continuous removal of maize crop residue and fertilizer application on maize grain yield in long-term trial on Egbeda (Oxic Paleustalf) and Apomu (Psammentic Usthorthent) soils.

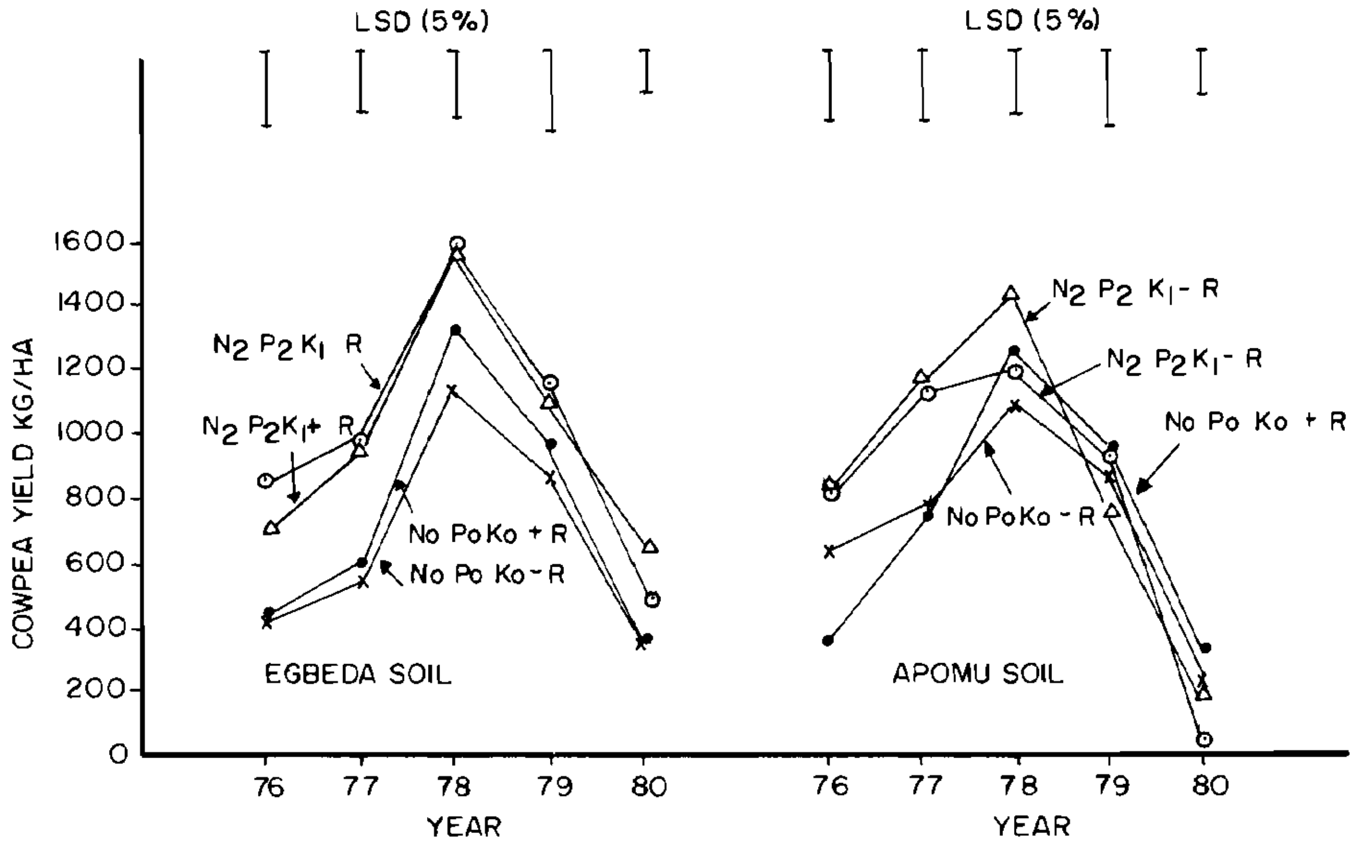


Fig. 23. Effect of continuous removal of maize crop residue and fertilizer application on grain yield of cowpeas in long-term trial on Egbeda (Oxic Paleustalf) and Apomu (Psammentic Usthorthent) soils.

Table 34. Effect of plant residue management and fertilizer application on main season grain yield of maize variety TZPB grown on Alfisol (Oxic Paleustalf), Ikenne, 1980.

Fertilizer treatment	1978 M*	1978 B**	1979 M	1979 B	1980 M	1980 B
	kg/ha					
Control	4228	3706	2864	2675	2841	3055
PK	5069	4830	4493	4386	4341	4080
NK	4939	4812	3016	3385	3243	3601
NP	5205	4720	4360	4526	5378	4857
NPK	5327	5275	4454	4448	5289	4936
NPK Mg Zn	5838	5824	4316	4509	4968	4724
Mean	5101	4861	3852	3988	4343	4208
LSD (5%) (I)***	835		612		567	
(II)	822		536		802	
(III)	738		764		1263	

**M = Plant residue applied as mulch.*
***B = Plant residue burnt before each cropping.*
****LSD (I) = Between plant residue management means.*
LSD (II) = Between fertilizer treatments within residue management.
LSD (III) = Between any two fertilizer treatments with different residue management.

maize production. Most of the fertilizer trials carried out in the tropics have dealt with conventional tillage. Studies were, therefore, carried out on an Alfisol (Alagba series, Oxic Paleustalf) at Ikenne and on an Entisol (Apomu series, Psammentic Usthorthent) at Ogbomosho, Nigeria, to determine the N requirements for maize production under conventional and no tillage. At both locations, maize yields from the control plots without N application were higher with conventional tillage than no tillage. this was also observed during the first cropping year in 1979 (Fig. 24). However, maize yields with N application, particularly at high N rates, were higher with no tillage than conventional tillage.

Planted fallow as an alternative N source

Use of *Leucaena* prunings. In looking at low cost alternatives to N sources, experiments were carried out using *Leucaena leuocephala* top prunings. *Leucaena* not only can serve as a potential N source but also can supply fuel wood. In a trial carried out on an Apomu soil series at IITA, the effects of rate and placement methods of the *Leucaena* top prunings were compared to urea. *Leucaena* top prunings were banded or broadcasted once at maize planting, while urea was banded twice, one-third N at maize planting and two-thirds N at 4 weeks after maize planting. Figure 25 shows that banding the *Leucaena* top prunings at 25 cm widths was most effective, and banding at rates of 5t or 10t was, respectively, 52 and 67 percent as effective as urea. Though the prunings can be used as an N source, application at planting time only was apparently not too effective.

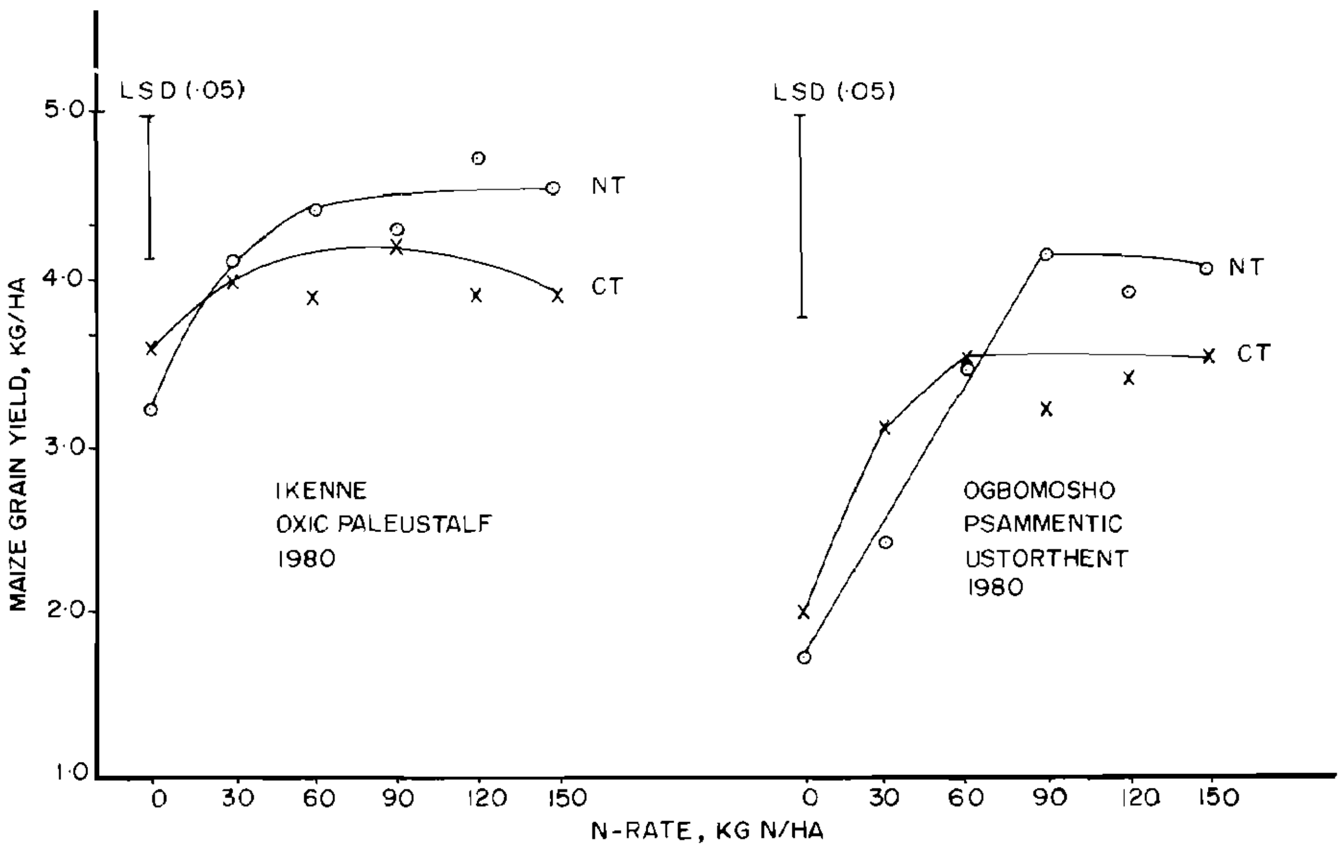


Fig. 24. Effect of tillage and N rates on maize grain yield.

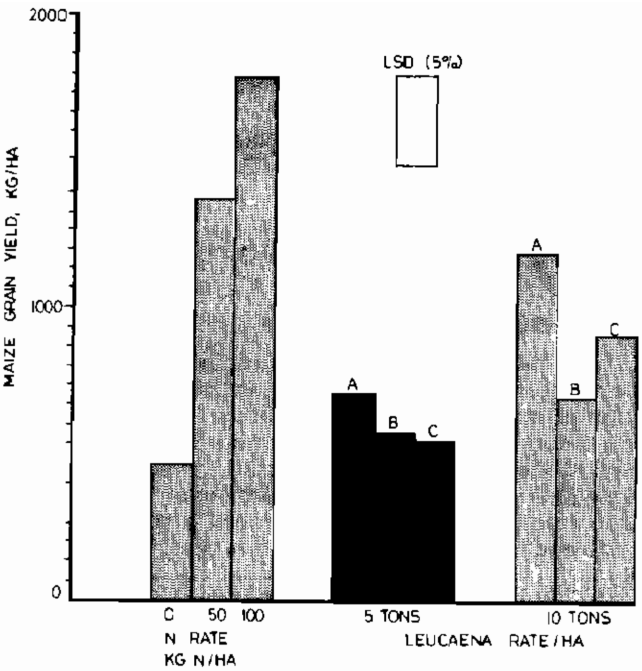


Fig. 25. Effect of N and **Leucaena** ***rates and application methods (A and B*** **Leucaena** ***tops banded at, respectively, 25 and 50 cm width and C*** **Leucaena** ***tops broadcasted) on maize grain yield on Apomu soil series (Psammentic Usthorthent).***

In-situ mulch from cover crops and fertilizer levels on maize yield. In-situ mulch from cover crop residue has been found to be a feasible method of establishing mulch for effective no tillage or mulch-conventional tillage production. Using *Mucuna utilis* as the cover crop, the effect of fertilizer and preemergence herbicide on maize yield in mulch-conventional tillage was evaluated. The design was a split plot in which main plots were (a) no herbicide and (b) a basal application of 60 kg N/ha, 60 kg P/ha and 60 kg K/ha with a side dressing of 30 kg N/ha at 4 weeks after planting; (ii) a basal application of 60 kg P/ha with a side dressing of 30 kg N/ha; (iii) a side dressing of 30 kg N/ha only and (iv) no fertilizer. The cover crop was killed with 2.0 kg glyphosate/ha a.i. Side dressing alone and no fertilizer were found to produce significantly lower yields than a full application of basal with a side dressing and a basal application of P with a side dressing (Table 35). The preemergence herbicide had no significant effect on yield. The results indicate that some fertilizer is needed in mulch-conventional tillage with in-situ mulch from a leguminous cover crop. A preemergence herbicide is not necessary as weed suppression by the mulch is an effective weed control (Table 36).

Nutrient requirement of crops on Alfisols

N and K responses of cassava. The N and K response study of cassava conducted on an Alagba series (Oxic Paleustalf) was initiated in 1978 at Ikenne. The 1979-1980 cropping season results are shown in Table 37. On this plot, which is in the second cycle of continuous cropping, the fresh tuber yields of both varieties, TMS 30555 and TMS 30572, showed a significant response to K application at the rate of 60 kg K/ha. N application only slightly increased tuber yield. TMS 30572 also gave higher tuber yield than TMS 30555 at this particular location. There is no difference in the percentage dry matter yield between the 2 varieties.

Differential P response of cowpea and soybean varieties. Investigations were carried out at Ikenne in the humid region of Nigeria to determine differences in the internal and external P requirements of 4 cowpea vari-

Table 35. Effect of fertilizer and preemergence herbicide on maize grain yield (IITA, 1980).

	kg/ha
Full basal & side dressing with Primextra	3333 a*
Basal P only and side dressing with Primextra	2970 a b
No fertilizer and No Primextra	2727 b c
Side dressing alone—No Primextra	2545 b c
Full basal & side dressing without Primextra	2303 c
Basal P only & side dressing without Primextra	2182 c d
No Fertilizer and with Primextra	1727 d
Side Dressing alone with Primextra	1091 e

**Means having common letters are not significantly different at 5% level according to Duncan's Test.*

Table 36. Effect of fertilizer and preemergence herbicide on weed weight at maize harvest (IITA, 1980).

	kg/ha
No fertilizer with Primextra	1803 a*
Side dressing alone with Primextra	1741 a
Basal P only and side dressing with Primextra	1437 a
Full basal & side dressing—No Primextra	1144 a
Basal P only and side dressing alone—No Primextra	1112 a
Side dressing alone—No Primextra	1061 a
No fertilizer and without Primextra	1032 a
Full basal & side dressing with Primextra	877 a

**Means having common letters are not significantly different at 5% level according to Duncan's Test.*

Table 37. Effect of N and P application on tuber yield of cassava cultivars TMS 30555 and TMS 30572 on an Alfisol (Oxic Paleustalf), Ikenne, 1980.

Fertilizer Treatment		TMS 30555		TMS 30572	
kg/ha		Tuber yield t/ha			
N	K	Fresh	Dry	Fresh	Dry
0	0	19.52	8.42	19.50	8.02
0	120	21.48	9.42	23.85	9.51
60	120	23.29	9.39	21.14	9.07
120	120	21.35	9.60	25.42	9.95
120	0	18.29	8.47	21.83	9.79
120	60	21.56	9.78	26.92	11.68
Mean		20.92	9.18	23.11	9.67

LSD (5%) Variety means fresh tuber 3.08; dry tuber 1.85.
Between fertilizer treatments within variety: fresh tuber 3.09; dry tuber 2.11.
Between fertilizer treatments among variety fresh tuber 4.37; dry tuber 3.74

eties with different growing habits. The relationship between adjusted P concentrations in the soil at planting time and cowpea yields is shown in Figure 26. The 4 varieties showed distinct differences in their external P requirement. Without P, a local variety, Shaki, gave the highest yield and has an external P requirement of about 0.06 ppm P while with P application, TVx 1193-7D, an improved erect variety, gave the highest yield and has the lowest external P requirement of about 0.016 ppm p. Ife Brown and VITA-4 gave the lowest yields, and Ife Brown has the highest external P requirement of about 0.10 ppm P while VITA-4 has an external P requirement of about 0.06 ppm P. From these results, it thus appears that though variety TVx 1193-7D is quite efficient in utilizing applied P in low P status soil, the local variety Shaki does better.

The differential phosphate requirements of 2 soybean varieties, TGM 51 × TGM 344 and TGM 479, were compared in a field experiment conducted on an Alfisol at Mokwa in the subhumid region of Nigeria. Results of the trial as shown in Fig. 27 clearly indicate that variety TGM 479 has a significantly lower yield than variety TGM 51 × TGM 344. Despite their differences in yield, both varieties have similarly low external P requirements of about .018 ppm P in soil solution. These low external P requirements may be attributed to other growth-limiting factors as indicated by grain yields. In spite of the low yield, data in Fig. 27 indicate the relatively higher efficiency of P utilization by variety TGM 51 × TGM 344 over variety TGM 479.

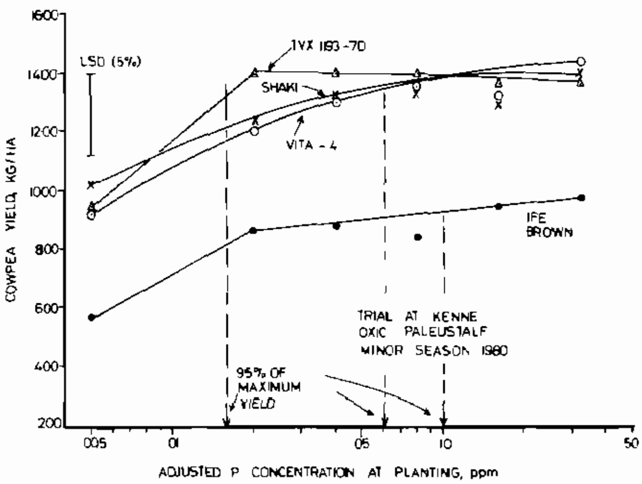


Fig. 26. Relationships between adjusted P concentrations and cowpea yield.

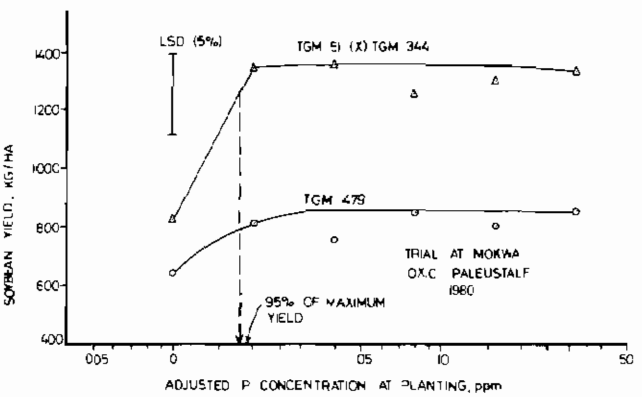


Fig. 27. Relationships between adjusted P concentrations and soybean yield.

Management of siliceous Ultisols

Maize-cowpea rotation

A 5-year management trial at Onne shows that a productive maize-cowpea rotation system is possible on coarse-textured deep and permeable Ultisols (Typic Paleudult) on a predominantly flat to gently undulating coastal land form. Maize was sown in early March and cowpea in late September or early October. Maximum grain yield throughout the 5 years ranges from 3.5 to 4.5 t/ha for maize and from 1.3 to 1.5 t/ha for cowpea.

A well-balanced fertilization scheme is required for the maize crop, N, P, K, S, Mg and Zn, and fertilization is generally not needed for cowpea in the second season as the residual fertility from the maize crop with residue return as surface mulch is adequate to support the cowpea crop. Reduced tillage with residue mulch is recommended because the coarse-textured, kaolin-dominated soil may be easily compacted.

It is important to point out that the maize, TZPB, and cowpea cultivars, VITA-1 and VITA-4, tested are fairly tolerant to soil acidity. The critical level of exchangeable Al saturation, i.e., a level required to attain 90 percent of maximum yield, for the maize cultivar ranges between 30-45 percent depending upon the rate of chemical fertilizer used (Fig. 28). The critical level of Al saturation for

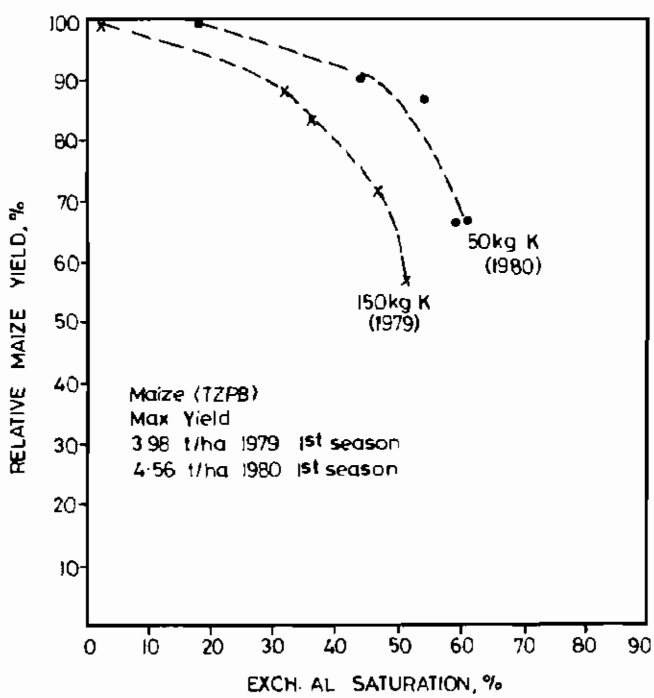


Fig. 28. Relative yield of maize as affected by percent exchangeable Al saturation in the soil.

both cowpea cultivars is as high as 60 percent when chemical fertilizer is not applied in the second season (Fig. 28). But, with moderate rate of fertilization, the critical level of Al saturation is reduced considerably, and the 2 cowpea cultivars show differential response to soil acidity, i.e., 30 percent for VITA-4 and 43 percent for VITA-1 (Fig. 29).

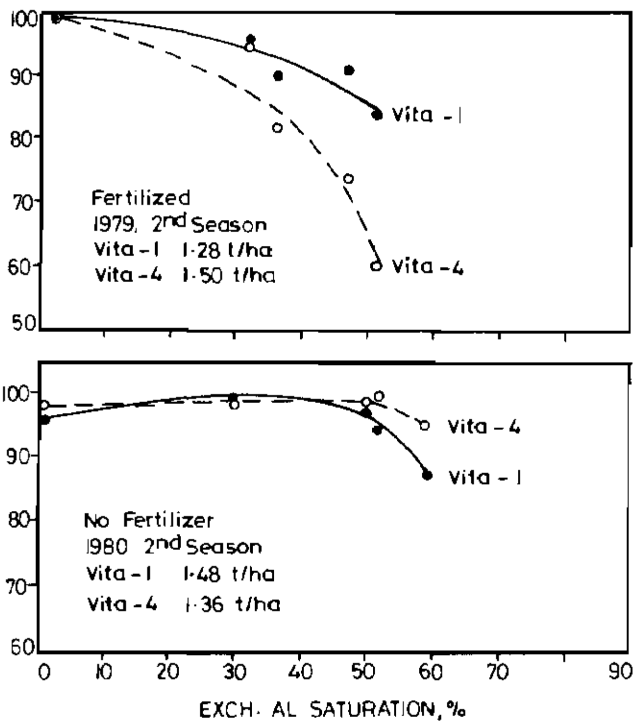


Fig. 29. Relative yield of cowpea as affected by percent exchangeable Al saturation in the soil.

Thus, liming is not necessary unless the exchangeable Al saturation of the soil has reached a level beyond the critical level of the crop to be grown. The critical level of exchangeable Al saturation in such coarse-textured, kaolinitic Ultisols depends to some extent upon the rate of fertilizer to be applied. The variability in the critical level of exchangeable Al saturation is because of the large increase in soluble Al in the soil solution after fertilization. Such effects have not been taken into account because soil sampling is normally done before planting. The effect of fertilizer salts on soil solution Al is shown in Table 38.

Residual effect of lime

Because lime is scarce in many parts of the humid tropics such as southeastern Nigeria, it is necessary to know what minimum rates of lime are needed for optimum crop production and what residual values may be expected. Results from an Onne trial are summarized as follows:

Relatively low rates of lime would be adequate to sustain crop yields under a maize/cowpea rotation system. It is interesting to point out that with balanced fertilization, respectable levels of maize and cowpea yields were maintained for 5 years in the unlimed plots (pH 4.3) where no severe Al toxicity effects were observed. Both cowpea cultivars nodulated well with indigeneous acid-tolerant rhizobia, and nodulation was only slightly reduced without liming.

Applied Ca in the form of lime leached readily from the surface layer, which is accompanied by the subsequent reappearance of exchangeable Al (Table 39). The increase in CEC values due to liming is also short-lived. The downward movement of Ca has little effect on the subsoil pH and exchangeable Al, suggesting that Ca leached in the form of neutral salts. The vertical distribution of exchangeable Ca in the field profile measured 3 years after lime application follows the theory and formulation of ion-exchange chromatography (Fig. 30). This is in agreement with a previous laboratory leaching study using undisturbed soil columns. Over 90 percent of the applied Ca may be found between 0-90 cm depths 3 years after liming because of the strong subsoil acidity (pH 4.3 and greater than 50 percent Al saturation). Recovery of the subsoil Ca, however, would require deep-rooting species tolerant to high exchangeable Al levels.

Moreover, because a high lime rate in the surface soil has little effect on the subsoil acidity, there would be no advantage of applying a rate of lime more than required to reach the exchangeable Al levels for the crop to be

Table 38. Concentration of Al in soil solution of a Ultisol (Typic Paleudult) as affected by fertilization (Onne, 1980).

	Soil pH (H_2O)	Exch. Al saturation %	Al in saturation extract ug/ml
Unfertilized	4.3	60	2.7
Fertilized and incubated 6 weeks at field capacity	3.9	46	17.1

Table 39. Changes in soil properties in the surface layer (0-15 cm) 5 years after lime application (IITA Onne substation, 1980).

Initial lime rate (1976) t/ha.	pH (H_2O)		Exch. Ca, meq/100g		Exch. Al, meq/100g		ECEC, meq/100g	
	Initial #	5 Yrs.	Initial	5 Yrs.	Initial	5 Yrs.	Initial	5 Yrs.
0	4.7	4.2	0.57	0.27	1.26	1.51	2.77	2.47
0.5	5.0	4.3	1.37	0.31	0.82	1.43	3.08	2.40
1	5.2	4.4	1.58	0.42	0.45	1.27	2.77	2.36
2	5.6	4.5	2.36	0.61	0.06	1.01	3.10	2.28
4	6.3	4.8	5.71	1.03	0.04	0.40	6.53	2.12

#Initial soil samples taken one month after lime application.

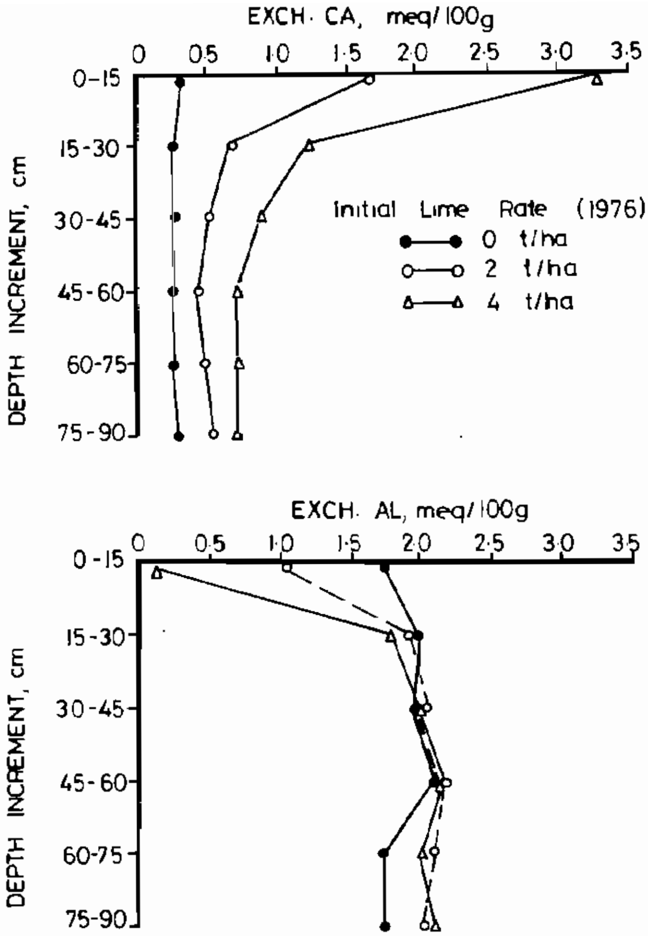


Fig. 30. Vertical distributions of exchangeable Ca and Al at 3 years after lime application.

grown. Thus, it is recommended that for Ultisols (Typic Paleudult) or for Ultisols with similar mineralogy and texture, annual rates of 200-400 kg/ha should suffice to maintain maize and cowpea yield. Under such circumstances, lime could be regarded as a form of fertilizer rather than a major soil amendment.

Leaching of nitrate under maize.

An experiment was established at Onne in 1980 to study the pattern of nitrate leaching under field conditions. Maize was planted in the first season and upland rice in the second season. Three methods of N application were used, 1 application at planting, 2 split applications: one-half at planting and one-half at 4 weeks after planting and 3 split applications. one-third at planting, one-third at 4 weeks after planting and one-third at 8 weeks after planting. A N rate of 150 kg/ha as calcium amonium nitrate was used. A bare fallow treatment was included. The experiment was a split-plot design with 4 replications. Lime and unlimed treatments were the main plot.

Downward movement of inorganic N (NH_4-N and NO_3-N) in the soil was monitored periodically up to a 120 cm depth (Fig. 31). At the end of 4 weeks (129 mm rainfall), the pattern of nitrate movement when all N was applied at planting in the unlimed plots was similar to the bare fallow and the crop plots. The peak concentration occurred between 30-60 cm. At the end of 8 weeks (477 mm rainfall), the nitrate peak in the cropped plots occurred at a depth of 60-90 cm, but the nitrate peak in the bare fallow plots was considerably deeper and broader, indicating greater leaching. At the end of the first season (940 mm rainfall), the nitrate peak moved to a depth of 105-120 cm. Liming increased the rate of nitrate leaching in both bare fallow and cropped plots. When N was split into 2 applications, nitrate peaks occurred in the upper layer between 0-30 cm both at 4 and 8 weeks after planting, indicating less leaching.

Splitting N into 2 applications significantly increased grain yield and N-uptake by the plant (Table 40), but fur-

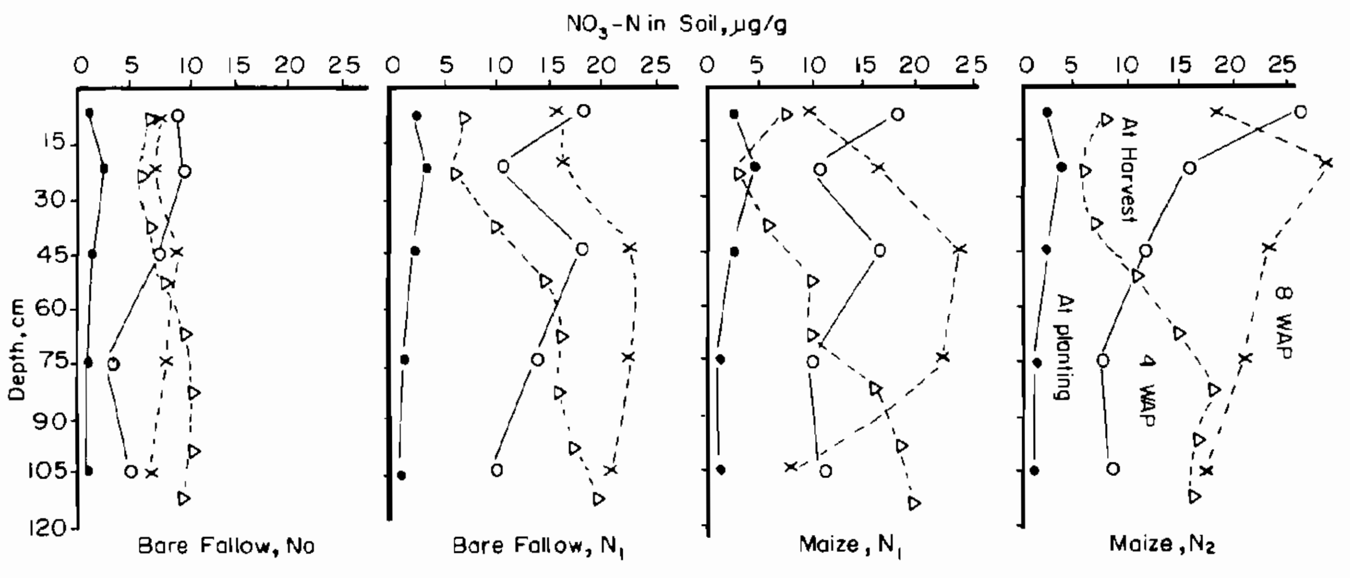


Fig. 31. Leaching of nitrate in unlimed plots under cropping and bare fallow. (No- no N applied, N_1-150 kg N/ha applied at planting, N_2-150 kg N/ha split application, one-half at planting, one-half at 4 weeks after planting.)

Table 40. Maize grain yield and N recovery as affected by methods of application (IITA Onne substation, 1980).

Treatment#	Grain yield kg/ha	N removed by crop (grain + stover) kg/ha	Estimated fertilizer N in soil (0-120 cm) at harvest++ kg/ha	Estimated recovery of applied N** %
LoN_1 (Bare)	-	-	70.6	47.1
LoN_1	2,492 c	54.5 d	58.9	75.5
LoN_2	3,208 ab	73.7 bc	43.0	78.5
LoN_3	3,376 ab	82.7 ab	55.3	92.0
$L N_1$	2,853 bc	61.4 cd	32.9	62.5
$L N_2$	3,499 a	81.6 ab	32.6	76.3
$L N_3$	3,717 a	92.4 a	59.1	100.8

#Lo = unlimed; L = limed, 2t/ha; N rate = 150 kg/ha; N_1 = one application at planting; N_2 = 2 splits; N_3 - 3 splits.
++Corrected for mineral N (NH_4-N and NO_3-N) in soil (0-120 cm) from unfertilized bare fallow plot (190.2 kg/ha).
***Crop removal plus estimated fertilizer N in soil (0-120 cm) at harvest.*

ther splitting into 3 applications had no significant effect on yield though it reduced leaching loss.

Estimated percentage recovery of applied N is also given in Table 40. Loss of applied N in the form of calcium ammonium nitrate under cropping was not as high as expected although more reliable measurements on N recovery can only be obtained with N-15 tagged fertilizers.

When N was applied in 3 split applications, nearly all the applied N could be accounted for by plant uptake and the amount present in the soil (0-120 cm) at the end of season. At 2 split applications, about 80 percent of the applied N was recovered in plant and soil.

It is important to point out that the unfertilized bare fallow plot contained 60-80 kg/ha of mineralized N (NH_4-N plus NO_3-N) in the surface 30 cm layer for both the unlimed and limed treatments, suggesting relatively high rates of mineralization during the early part of the cropping season. It appears that application of N fertilizer may not be necessary at the time of planting during the first season if sufficient mineralized N is already present in the surface layer.

Lysimeter studies

The installation at IITA of 6 monolith lysimeters (80 cm in diameter and 130 cm deep) with undisturbed profiles of the Ultisol (Typic Paleudult) from Onne was completed in early 1980. The primary objectives are to study leaching of nutrients under high-rainfall conditions and determine crop water use. The high-rainfall condition, which prevails at Onne, was simulated during the experimental period by supplementing natural rainfall with irrigation using the 1979 rainfall regime at Onne as a basis. Nutrient losses over the 2 cropping seasons were determined by measurements of fertilizer ions in the leachate collected as samples of the drainage through the profile, and evaporation/evapotranspiration was assessed by the water balance method.

Monolith lysimeter cutting and installation at IITA Onne substation.

Maize was planted as a test crop on 3 of the lysimeters and in the surrounding area to maintain adequate fetch while the remaining 3 were left bare. All except 1 of the lysimeters was tension drained by applying a suction of 0.2 atmosphere at the base of the column. Fertilizers were applied in each of the 2 seasons to all 6 lysimeters as follows:

N (Calcium nitrate): 150 kg/ha, 3 split applications
P (Monocalcium phosphate): 60 kg/ha, basal
K (Potassium chloride): 150 kg/ha, basal
MG (Magnesium sulfate): 30 kg/ha, basal

No lime was applied during this preliminary run. As a result, there was poor growth of maize inside the lysimeters due to strong soil acidity. On the basis of the preliminary results, total drainage through the seasons averaged 1,153 mm or 58 percent of the total equivalent rainfall (2,012 mm) received by the bare (uncropped) lysimeters and 977 mm or 49 percent of the total equivalent rainfall received by the cropped lysimeters. The corresponding values of evaporation and evapotranspiration were 832 mm and 1,035 mm, respectively, averaging 3.70 mm/day and 4.60 mm/day, respectively, over the period. Preliminary leaching data of nutrient cations and anions calculated as percentage of total amount applied are given in Table 41.

These data indicated that nitrate and magnesium ions leached readily; whereas, potassium ions, were preferentially retained. Further studies are being conducted under maize and upland rice cropping where adequate amounts of lime have been applied to ensure normal crop growth.

K and Mg response of cassava

Investigations on the K and Mg response of cassava varieties TMS 30395 and 30211 were initiated on an Ultisol

Table 41. *Percentage of applied cations and anions in the leachate after 2,012 mm of water under bare fallow (uncropped, weed free) IITA, 1980).*

Ions	Free drained Lysimeter 1	Tension drained (0.2 Atm) lysimeter 6
	%	
NO_3^-	78	70
C_a^{++}	35	30
Mg^{++}	64	60
K^+	9	9

at Onne in 1978. Results of the second year cropping during the 1979-1980 season are shown in Table 42. In the second year of cropping, the soil K-status even with K application was very low. There was a distinct effect of Mg application in increasing the soil Mg status. The tuber yields of both varieties showed a more pronounced and significant response to K application. Despite the presence of Mg deficiency symptoms without Mg applications, similar to the first year results, there was no definite response of tuber yield to Mg application.

Cropping systems

In 1980, research in cropping systems or crop management focused on the following areas: mixed cropping, alley cropping, live mulch system and the role of agroforestry in food crop systems. The ultimate goals are to achieve high and stable crop yields while maintaining long-range soil productivity. Several projects were initiated to investigate the inclusion of leguminous cover crops and managed tree and shrubs into food crop production systems in an attempt to find more efficient, low-energy input and stable alternative systems to traditional bush fallow cultivation. Special emphasis was given to the production system of plantain in the humid and perhumid regions.

Intercropping agronomy and meso/micro-climatic studies

Light regime and productivity in mixed crops. Competition for light and moisture are clearly 2 key factors in mixed cropping systems. As a follow up on previous studies showing or establishing a range of modifications that may be brought about in the light regime in maize canopies through modifications of planting geometry and density (IITA Annual Reports 1978 and 1979), studies were carried out in 1980 with the aim of quantifying and standardizing some of these relationships partly to provide a basis for optimal design in mixed cropping systems. Attempts were also made to relate the effects of the modified light climates within the established crop (maize) on the lower or slower growing intercrop (cassava).

Results show that at full development of the maize canopy in a maize/cassava mixture, the percentage of incident radiation depleted at cob height is a power function of the combined plant population. The relevant equation is as follows:

$$Y_{el} = 1.735X^{0.851} \qquad r = .917^{**}$$

where Y_{el} is the amount of light intercepted (to cob level), and X is the combined plant population (Fig. 32A). A similar relationship was obtained at ground level (Fig. 32B).

As previously reported (IITA Annual Report 1979), plant populations in this experiment were varied from 10,000 plants/ha in the pure cassava to 80,000 plants/ha in the maize/cassava mixtures. The maize (TZPB) population varied from 10,000 to 70,000 plants/ha by increasing the number of maize plants per stand from 1 to 7. Spacing was maintained at 1 m × 1 m with the plants along the same row.

For the lower or slower growing cassava, which was shaded through much of the growth of the maize, the crop yields were very significantly affected by the amount of light reaching it through the maize canopy (Fig. 33). Again, a similarly linear relationship was obtained between the cassava yield and the total light transmitted through the combined maize/cassava canopy at full maize development (Fig. 34). These amounts of transmitted light can also be systematically related to the combined plant population as shown in Fig. 35. The relationship between the 2 factors is expressed:

$$Y_g = 82.198e^{-0.0165X} \qquad r = -0.903^{**}$$

where Y_g is the amount of light transmitted through the canopy, and X is the combined plant population.

Table 42. *Effect of K and Mg application on tuber yield of cassava cultivars TMS 30395 and TMS 30211 and K and Mg status of an Ultisol (Typic Paleudult), Onne, 1980.*

Fertilizer Treatment kg/ha		Soil K and Mg status Me/100g		TMS 30395 Tuber yield t/ha		TMS30211 Tuber yield t/ha	
K	Mg	K	Mg	Fresh	Dry	Fresh	Dry
0	40	0.09	0.33	15.84	6.47	14.99	5.66
30	40	0.09	0.27	19.41	8.08	18.67	6.11
60	40	0.11	0.33	19.97	8.84	18.20	6.36
120	40	0.10	0.30	20.13	8.52	19.08	6.73
120	0	0.11	0.22	21.47	9.39	17.33	6.69
120	20	0.11	0.22	19.47	8.06	17.50	5.97
Mean				19.38	8.23	17.63	6.25

LSD (5%) Variety means fresh tuber 0.63; Dry tuber 0.78.
Between fertilizer treatments within variety: fresh tuber 3.48; dry tuber 1.83.
Between fertilizer treatments among variety: fresh tuber 5.29; dry tuber 2.88.

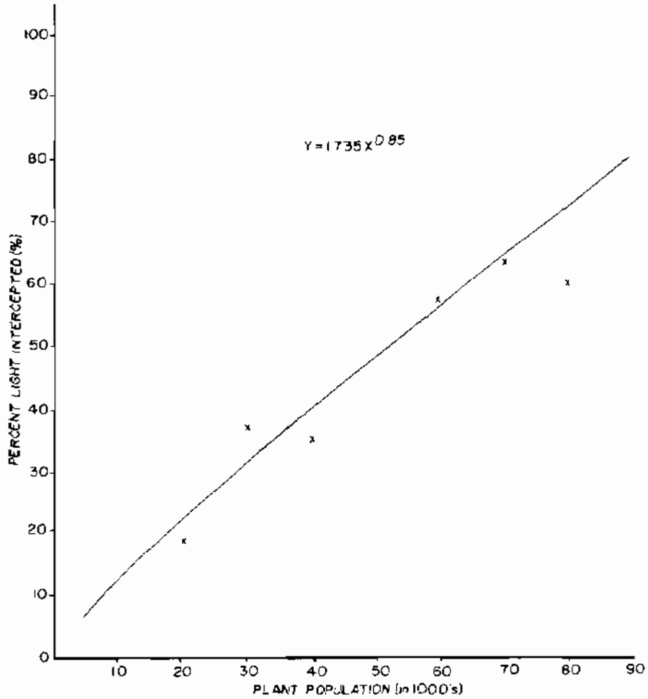


Fig. 32A. Light intercepted by mixed maize/cassava crop canopy (to cob level) at full maize development (10 wap) as a function of plant population.

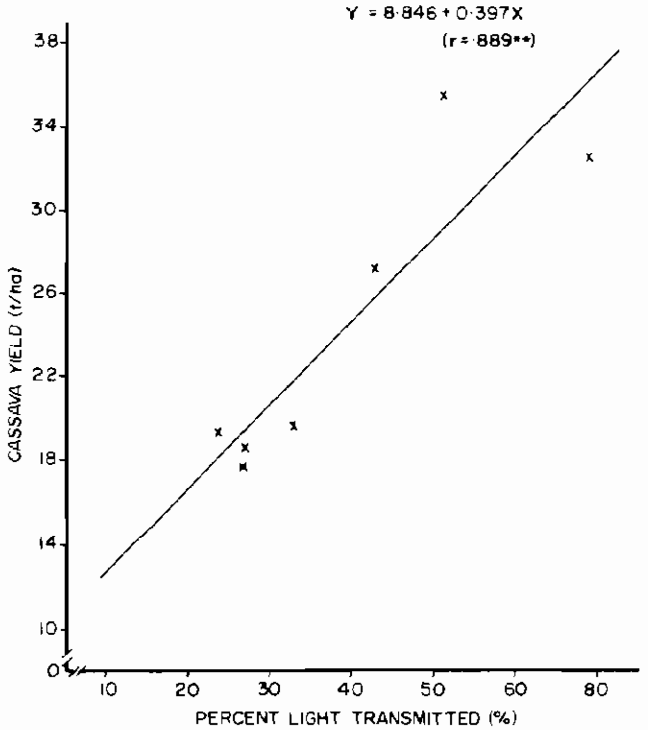


Fig. 33. Cassava yield in a maize/cassava mixed crop as affected by light transmission through the mixed crop canopy at maximum maize height.

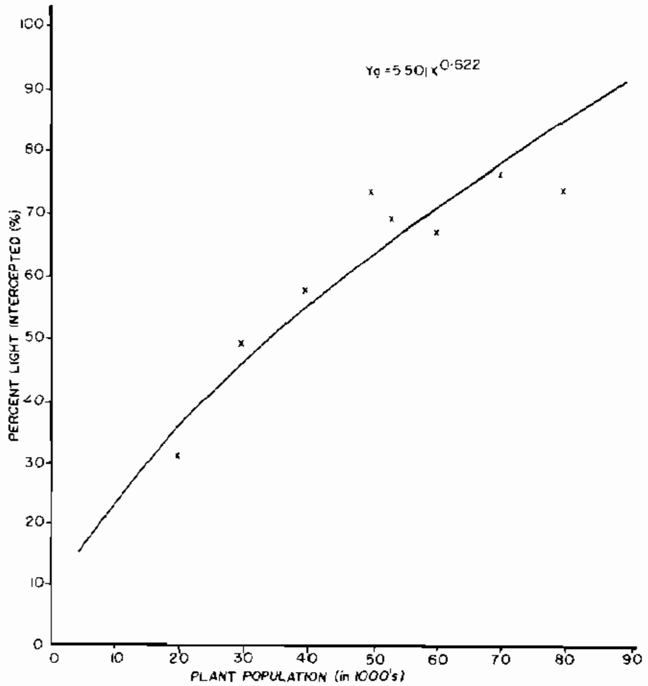


Fig. 32B. Light intercepted by mixed maize/cassava crop canopy (to ground level) a full maize development (10 wap) as a function of plant population.

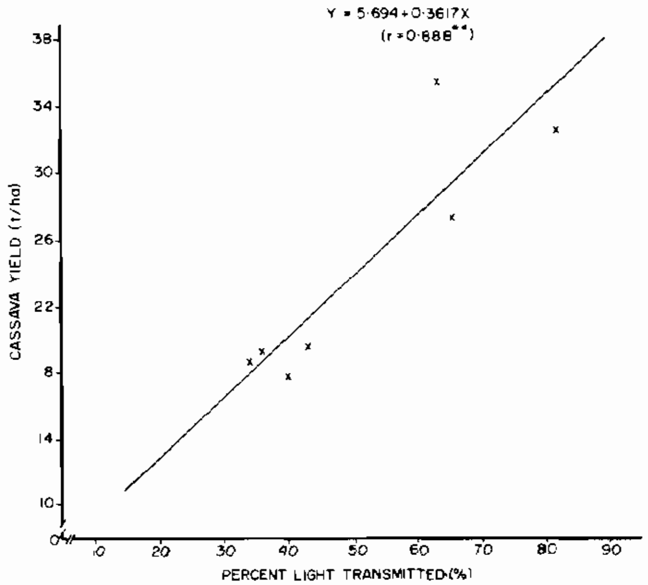


Fig. 34. Cassava yield in a maize/cassava mixed crop as affected by light transmission through the upper maize canopy at maximum maize height.

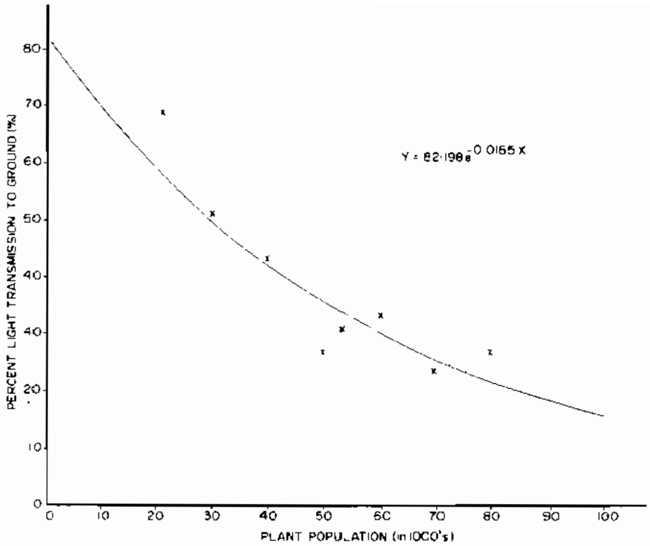


Fig. 35. Light transmission through mixed cassava/maize crop canopy at full maize development as a function of plant populations.

Induced micro-climate and crop response. In a related experiment in 1980, using cassava of relatively prolific growth, plant populations were maintained constant in 3 treatments at 12.500 plants/ha (cassava: 3001) and 25,000 plants/ha (maize: TZPB). In a fourth treatment, the maize population was increased to 40,000 plants/ha, and the cassava population was reduced to 10,000 plants/ha.

Pure cassava with 12,500 plants/ha constituted a sixth treatment, and pure maize at 25,000 and 50,000 plants/ha were treatments 5 and 7, respectively.

Analyses of the partial results show that the amount of light intercepted by the upper canopy of the maize (to cob level) is significantly related to yield.

Observations on soil moisture and temperature in the experiment also show marked differences in both variables under the different crops and crop combinations. Fig. 36 compares the 6 weekly average mean relative soil moisture contents under the pure maize, pure cassava and maize/cassava combinations, respectively. Evidently, the presence of cassava in the mixture has a beneficial effect on the moisture available to the maize while maize helps reduce the soil temperature as a result of rapid canopy development (Fig. 37).

Within the mixed crops, appreciable differences were observed with changes in planting geometry (Table 43). Similarly, air temperature and humidity as reflected by the wet bulb thermometer were also affected by the planting pattern (IITA Annual Report, 1979).

Table 43. Comparative mean relative mixture content*.

Treatment	1			2			4		
Period**	1	2	3	1	2	3	1	-2	3
Moisture content	72	67	102	94	85	123	83	70	112

**The moisture content is in % of value at FMC.*
***Period 1 = 2-6 WAP; Period 2 = 7-12 WAP; Period 3 = 13-18 WAP.*

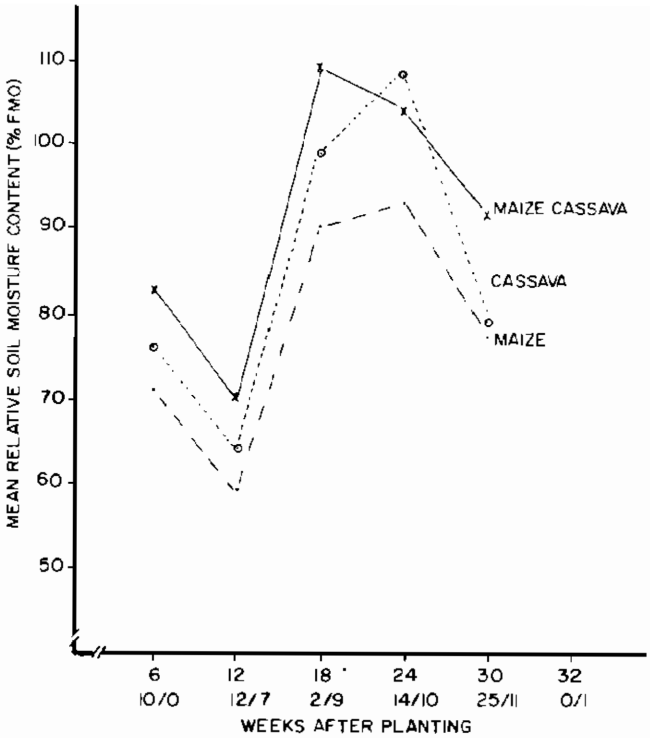


Fig. 36. Relative soil moisture content in different crop/crop mixtures as a function of time during the period of growth.

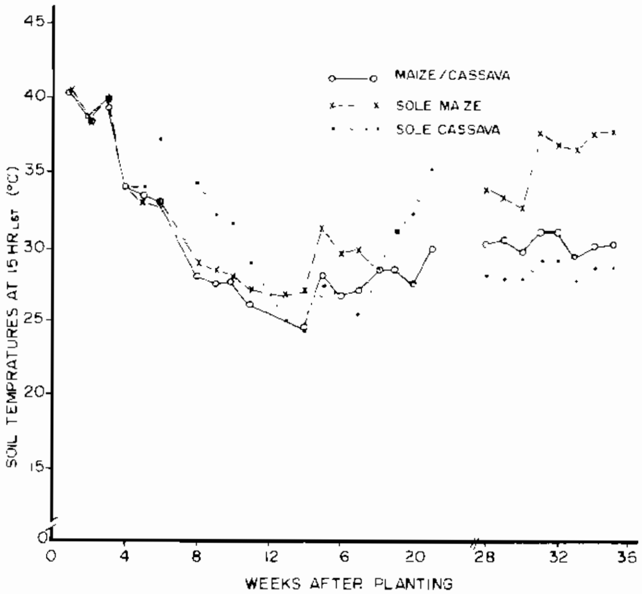


Fig. 37. Soil temperature in different crop/crop mixtures as a crop function of time during the period of growth.

Partial mechanization of maize/cassava intercropping. Yields of maize planted mechanically on ridges were not affected by cassava planted on the same ridges at 0, 7, 14 and 21 days after maize (IITA Annual Report, 1979). Herbicide, however, depressed maize yield significantly at the 5 percent probability level. The effects on cassava show that delay of up to 21 days in planting cassava was not critical to cassava yield (Table 44). However, signifi-

Table 44. Effect of relay times and herbicides on cassava yield in maize/cassava intercropping.

Cassava relay in days	Herbicide M/C[1]	Herbicide C[2]	No Herbicide M/C	No Herbicide C	Mean M/C	Mean C
0	16.8	7.6	22.6	25.7	19.7	16.6
7	22.4	12.2	22.9	27.0	22.7	19.6
14	16.7	13.9	23.5	22.3	20.1	18.1
21	13.0	9.1	23.1	20.6	18.0	14.8
Mean	13.9		23.5			

LSD	between herbicide	2.7
	Relay time	5.2
	Relay time same herbicide	7.3
	Relay time different herbicide	7.3

[1] *Maize/cassava*
[2] *Sole cassava*

cant cassava yield reduction was observed where herbicide was used. This yield reduction was ascribed not only to the sensitivity to the herbicide but also to weed competition resulting from failure of the herbicide. This observation is substantiated by a tendency toward lower yields by herbicide treated pure cassava. Shading by maize appeared to have retarded weed growth, thus, reducing the competitive effect on cassava. The results confirm the compatibility of maize/cassava in intercropping and highlight the potential hazard of herbicide failure.

N response in maize/cassava intercropping. The N response of intercropped maize/cassava on an Alagba soil (Oxic paleustalf) at Ikenne that was initiated during the 1978/1979 season was repeated during the 1979/1980 season. During the second year, the maize crop was affected by drought resulting in low yield (Table 45). Despite the low grain yields, the sole and intercropped maize showed significant responses to N application. As observed during the first year of cropping, intercropping with cassava had no effect on maize grain yield. In cassava, high tuber yields were observed with later harvesting (13 months after planting), but no significant response to N application was observed. This indicates that the N requirement is lower for the cassava than the associated maize. High N rates (120 kg N/ha) also tend to decrease the tuber yield of cassava.

Effect of maize population on cassava yield. An experiment was conducted to determine effects of maize population on cassava development and yield in intercropping where maize is planted in hills or clusters. It simulated farm situations where many seeds are placed in 1 position, and the number of surviving plants depends on chance or are deliberately selected by the farmers. The maize was spaced at 100m × 100 m with

Table 45. Effect of N application on yield of intercropped maize (variety TMS 30395) grown on Alagba soil (Oxic paleustalf) (1979-80).

N-Rate kg N/ha	Cropping mixture	Cassava fresh tuber yield t/ha	Maize grain yield	LER*
0	Maize (1 × .33 m, 1 plant/hill)	-	1.80	-
	Maize (1 × 1 m, 3 plants/hill)	-	1.74	-
	Cassava (1 × 1 m)	30.12	-	-
	Maize (1 × .33 m) + cassava (1 × 1 m)	29.11	1.93	1.90
	Maize (1 × 1 m) + cassava (1 × 1 m)	28.89	1.87	2.00
60	Maize (1 × .33 m, 1 plant/hill)	-	2.30	-
	Maize (1 × 1 m, 3 plants/hill)	-	2.40	-
	Cassava (1 × 1 m)	30.90	-	-
	Maize (1 × .33 m) + cassava (1 × 1 m)	27.10	2.45	1.95
	Maize (1 × 1 m) + cassava (1 × 1 m)	29.50	2.39	1.95
120	Maize (1 × .33 m, 1 plant/hill)	-	2.28	-
	Maize (1 × 1 m, c plants/hill)	-	2.12	-
	Cassava (1 × 1 m)	28.65	-	-
	Maize (1 × .33 m) + cassava (1 × 1 m)	24.85	2.52	2.05
	Maize (1 × 1 m) + cassava (1 × 1 m)	29.68	2.10	2.03
LSD (5%)		3.40	0.40	

Maize crop slightly affected by drought.
Cassava harvested at 13 months.
**Land equivalent ratio.*

1-7 plants/hill to give 10,000-70,000 plants/ha. Cassava was planted at 100 m × 100 m in the same rows as maize but spaced 50 m from the maize along the same row to give a population of 10,000 plants/ha. The land was plowed and harrowed but not ridged. The fertilizer recommendation used was for maize and consisted of a basal application of N.P.K. 15:15:15 at 400 kg/ha and a side dressing of 30 kg N/ha as urea 4 weeks after planting of maize.

The cassava growth was significantly affected by maize population with tuber yields being significantly lower at the higher maize populations. The marked differences between maize populations suggested that maize populations should not exceed 30,000 plants/ha if good cassava yields are expected. The maize yield indicates no serious yield reduction of maize population if kept at 30,000 plants/ha. The results also support the practice of thinning maize to 3 plants/hill in maize/cassava intercropping in West Africa.

Weed control in maize/cowpea intercropping. The effect of early weed interference in maize/cowpea intercrops is modulated by the growing season. During the 1980 first season, a maize/cowpea intercrop was more sensitive to weed interference than each of the crops grown in pure culture (Fig. 38.) However, during the 1980 second season, crop sensitivity to early weed interference peaked in both the sole and intercrop at 2 weeks after planting. This may be related to moisture conditions. Weed biomass at the 2-week stage was higher in the second season than the first season, thus, accounting for the more severe weed interference during the second season.

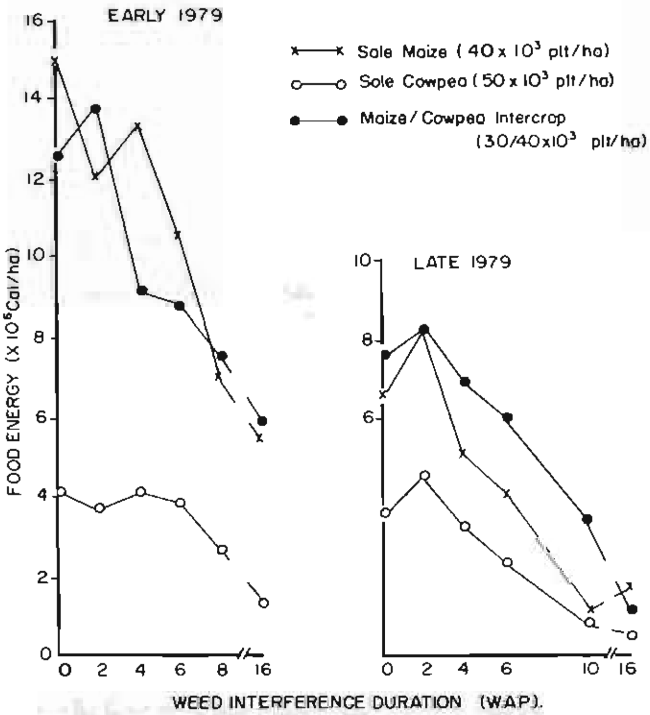


Fig. 38. The effect of weed interference on food energy values of maize/cowpea intercrop.

Alley cropping

Alley cropping systems in forest zone

Effect of N application on maize/*Leucaena* alley cropping. Results of a field experiment conducted at IITA on the effect of N application in the maize/*Leucaena leucocephala* alley cropping system are shown in Fig. 39. Substantial *Leucaena* dry matter and N yields are produced with a total of 6 prunings. The total annual N yield of over 180 kg N/ha was quite remarkable.

During this cropping year, there was a significant effect of the low N rates applied to the maize on the *Leucaena* dry matter and N yields. There was, however, only a slight effect from the high N rate applied.

The effect of N rates and removal of *Leucaena* prunings on maize grain yield is shown in Figure 40. The results clearly show that despite the high amount of N yield, there was still a need for application of low N rates for obtaining high yields. Removal of the *Leucaena* prunings reduced the yield to about 54 percent. Without N application but with *Leucaena* prunings only, the total maize

Pod of* Leucaena leucocephala, *a tree type legume being used for soil fertility restoration.

Collecting leaves from* Leucaena leucocephala. *The dried leaves will be used as a source of plant nutrient and organic matter, the stems as stakes and firewood.

grain yield was maintained at about 3.5 t/ha for the 2 seasons (total yield in 1979 was 3.6 t/ha.) The addition of the *Leucaena* prunings has a distinct effect on soil organic matter and N levels (Table 46.)

Effect of legume species and alley width. Legumes established between maize did not reach sizes at which the quantity of leaves was regarded as sufficient to contribute significantly to soil nutrient levels. Alley width had no significant effect on legume development during early stages. The leaf yield and potential N contributions are shown in Table 47. The leaf and N yield is related to alley width.

Because of the low potential N contribution, the plot was fertilized with 60 kg N/ha, 20 kg P/ha and 30 kg K/ha after a soil test. The plot was Rome plowed and maize planted with a single-row rolling injection planter in the 225 cm alley and with a 4-row rolling injection planter in the wider alleys. The spacing was 75 cm × 25 cm. The legumes were 75 cm from the nearest maize. Maize yields calculated with a correction for land devoted to legumes are shown in Fig. 41. Neither alley width nor legume species had a significant effect. It would appear that it is too early to observe the effects of the different treatments.

Selection and evaluation of woody species for alley cropping systems. The usefulness of fast growing woody and herbaceous legumes in alley cropping systems is being evaluated on the Alfisols at IITA and on the

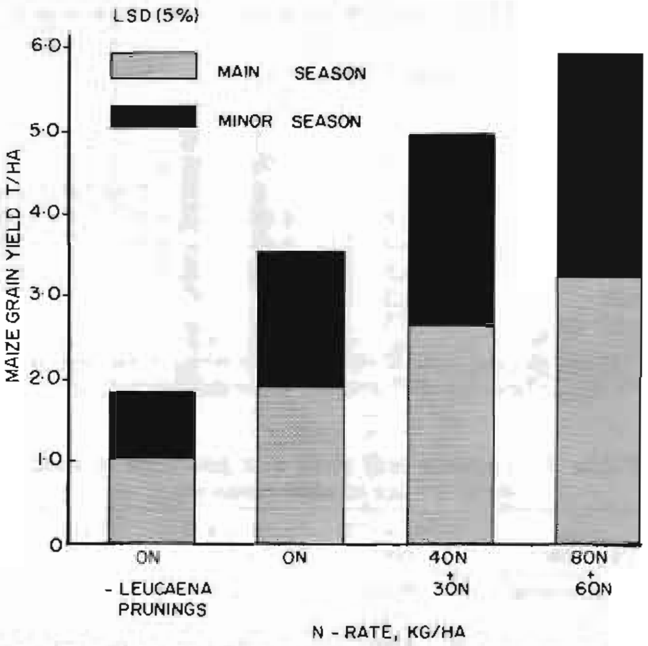


Fig. 40. Effect of N rates on maize grain yield from maize/Leucaena alley cropping system on Apomu soil series (Psammentic Usthorthent). (Main season N rates: 0, 40 and 80 kg N/ha; Minor season N rates: 0, 30 and 60 kg N/ha).

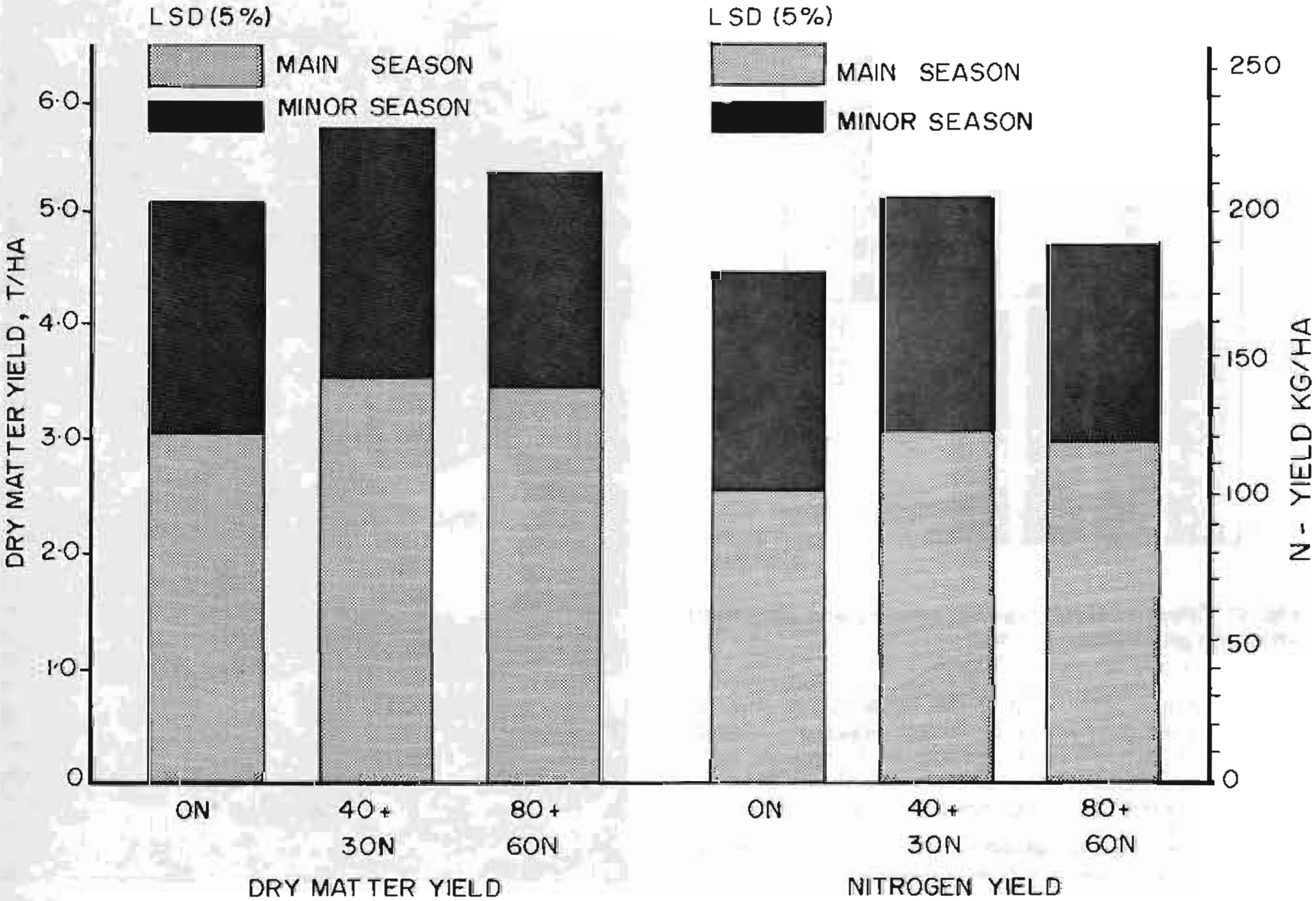


Fig. 39. Leucaena dry matter yield and N yield from maize/cassava alley cropping on Apomu soil series (Psammentic Usthorthent). (Main season N rates: 0, 40 and 80 kg N/ha; minor season N rates: 0, 30 and 60 kg N/ha).

Table 46. Some characteristics of Apomu surface (0-15 cm) soil before and after alley cropping.

Treatment* kg N/ha	$pH\text{-}H_2O$	Org. C (%)	Total N (%)	Extr. P (ppm)	*IN* Am. Acetate Extr. K	Ca.	Mg. me/100g	Na	ECEC
			1976 (Before alley cropping)						
	6.2	0.98	0.12	24.7	0.25	2.63	1.02	0.06	4.40
			End 1980 (with alley cropping)						
ON**	5.7	0.96	0.11	19.4	0.16	5.07	0.35		
ON	5.7	1.47	0.12	21.5	0.16	5.33	0.43		
30N	5.5	1.24	0.13	18.7	0.14	5.72	0.34		
60N	5.3	1.41	0.13	22.8	0.18	4.43	0.28		
LSD (5%)	0.1	0.67	0.01	3.3	0.07	1.18	0.08		

**Major season 1980 N rates 40 and 80 kg N/ha; Minor season 1980 N rates 30 and 60 kg N/ha.*
**Leucaena *prunings removed from this treatment.*

Table 47. Legume leaf yield and potential N yield in early stages of alley cropping.

Legume	Alley width cm	Leaf yield kg/ha dry wt.	N yield kg/ha
Pigeon pea	225	1321	47.6
	375	793	28.6
	675	440	15.9
Leucaena	225	1084	45.5
	375	651	27.3
	675	361	15.2
Tephrosia	225	600	22.8
	375	360	13.0
	675	200	7.6

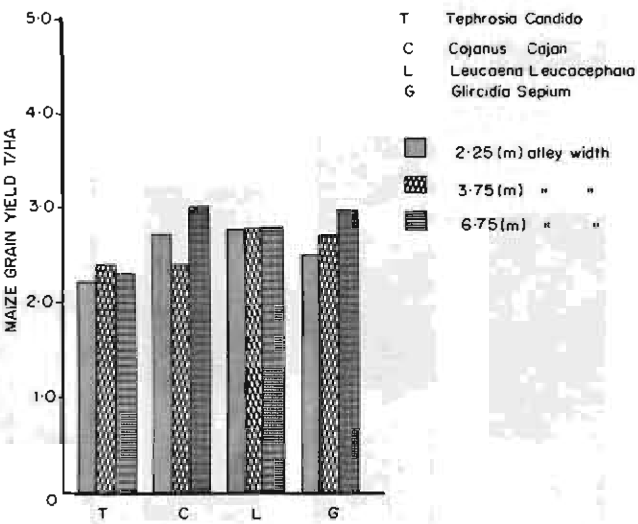


Fig. 41. Effect of shrub legume species and alley widths on maize grain yield.

strongly acidic Ultisols at Onne. Emphasis is given to those species that are established easily and can be maintained through basal sprouts and coppices when cut back periodically. The screening and evaluation includes more than 30 woody specimens as listed below:

(1) Planted and/or retained woody fallow species, such as *Acioa barteri*, *Anthonatha macrophylla*, *Alchornea cordifolia*, *Dalium guineense*, *Gliricidia sepium*, *Leucaena leucocephala* and *Tephrosia candida.*

(2) Fast growing pulp, fuelwood and/or soil ameliorating species, such as *Cordia alliodora*, *Albizia falcataria*, *Cassia siamea*, *Sesbenia grandiflora*, *Flemingia congesta*, *Samanea saman* and *Gmelina arborea*.

(3) Important multipurpose trees and shrubs, such as *Treculia africana*, *Irvingia gabonensis*, *Dacryodes edulis*, *Pterocarpus* spp., *Chrysophyllum albidum*, *Afzelia* spp. *Blighia sapida* and *Parkia clappertoniana*.

Acioa baterii, *one of the shrubs being tested for improved bush fallow.*

Alchornea cordifola *is an important native bush of West Africa, associated in natural bush fallow for soil fertility restoration.*

The results of the first 2 years of screening and evaluation indicate that, in general, the establishment and growth performance of the shrub species were better at IITA while the tree species were better at Onne (Figs. 42 a & b). Some of the shrub species that performed well are being included in the alley cropping trials.

Light regimes in potential tree-shrub species for alley cropping. Competition for light remains a key factor in the suitability of different species in mixed stands. Tests were made to determine the light characteristics within alleys of different tree-shrub species established over the past 2 years. The tree rows are oriented roughly east-west.

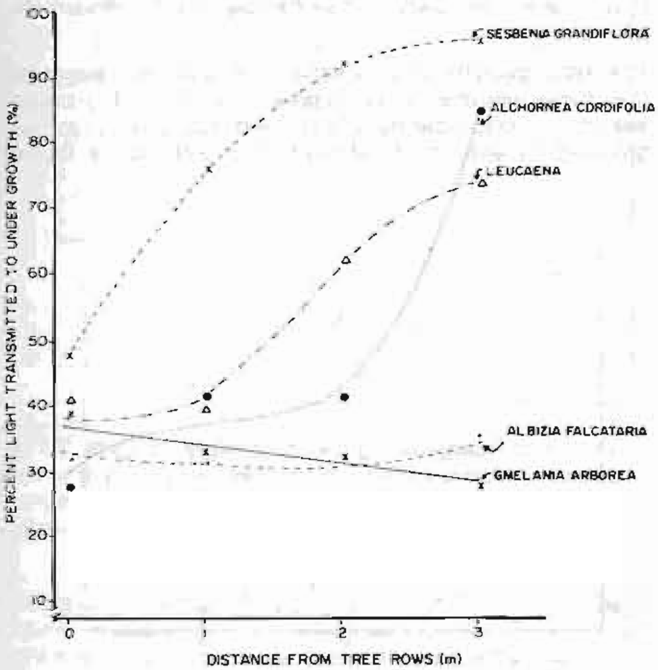


Fig. 43. Light transmission through the canopies of established fallow/alley cropping species in relation to distance from tree rows (trees in 4 m-rows, E-W; OBS in November).

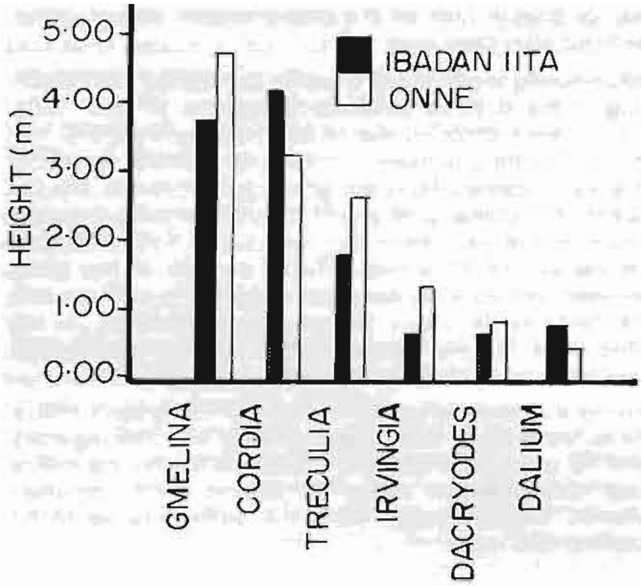


Fig. 42a. Relative growth performance of selected tree species at IITA and Onne after 18 months of establishment.

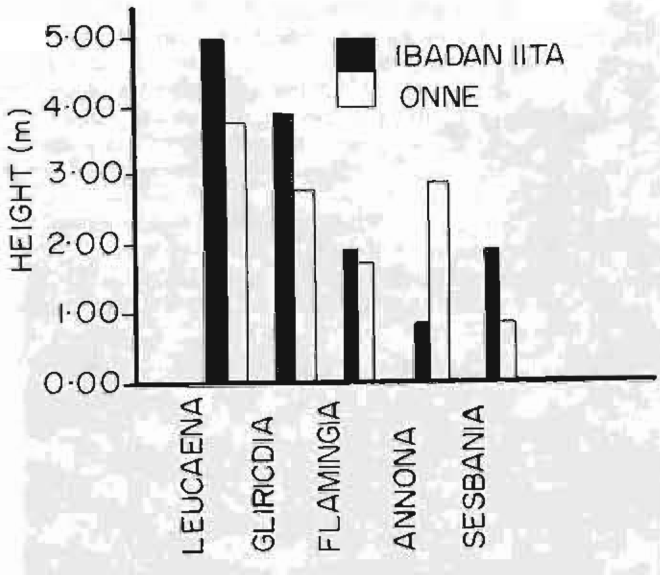


Fig. 42b. Relative growth performance of selected tree-shrub species at IITA and Onne after 18 months of establishment.

Figure 43 shows that *Albizia falcataria* and *Gmelanai arborea* planted in 4 m rows are clearly incompatible with alley cropping once they are fully established because of their strong depletion of incident light. They could be maintained possibly only as planted fallow.

Crops planted at less than 2 m from established *Alchornea cordifolia* will also suffer severely from shading. Reasonable performance can only be expected at distances of at least 3 m from the tree rows. This is also true of *Leucaenea leucocephala.* The distance from *Sesbania grandiflora* can be reduced to 2 m and even 1 m for crops with a fair degree of shade tolerance. In general, for all the species, except the latter, cutting back after the first year of growth may be the only practical way of using them for alley cropping.

Establishing leguminous trees or shrubs for alley cropping in the derived savanna.. Establishment and early maintenance costs appear to be major deterrents in the use of leguminous trees or shrubs for nutrient recycling in alley cropping. To overcome these problems, the legumes are being established by interplanting through maize. A trial evaluating the potential of this method in the derived savanna was initiated in 1980. In the interplanting, the legumes are spaced at 400 cm × 50 cm and the maize at 100 cm × 100 cm with 3 plants/hill. Seeds were used for *Tephrosia candida*, *Cajanus cajan* and *Leucaena leucocephala* and cuttings for *Gliricidia*.

Because of adverse rainfall during the first season, maize yields were lower than expected (Fig. 44). The legumes had no significant effect on maize yield, and the maize had no significant effect on legume yield; legumes planted without maize were the same size as those planted with maize.

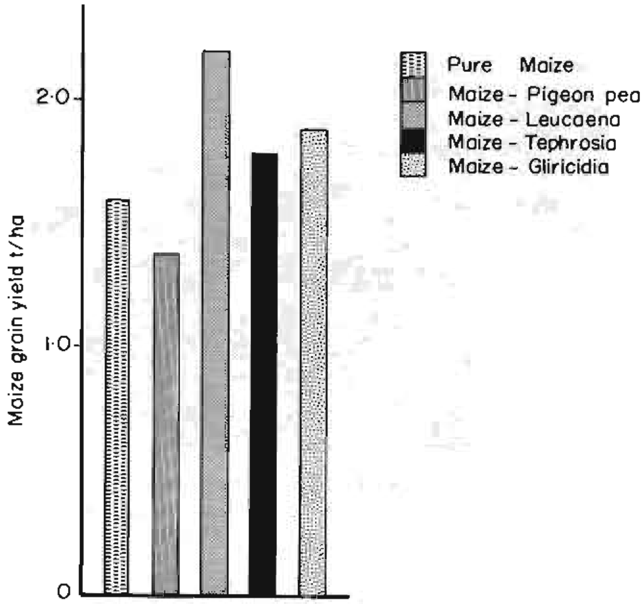


Fig. 44. Effect of shrub legumes on single maize crop.

Twenty-month-old* Albizia falcataria. *Among the fastest growing trees in the world, they are suitable agro-forestry species in the humid lowland tropics for control of* Imperata cylinderica *grass as well as for site fertility improvement and in the derived savanna as a planted fallow species.

Establishment of *Tephrosia* was very poor while that of the other legumes was good. Growth of both *Leucaena* and *Gliricidia* was poor even though adequate weed control was practised during the intercropping phase. By November (6 months after sowing), these 2 legumes were growing slowly with no marked effect on the adjacent vegetation. On the other hand, *Cajanus cajan* grew vigorously and by November dominated the field. A well developed canopy shaded out weeds preventing many from flowering (Fig. 45). A closer between row spacing (about 300 cm) could produce better weed control although a closer spacing may hamper tractor drawn implements.

The slow growth of *Leucaena* and *Gliricidia* suggests that these legumes may require more than 1 growing season to significantly affect field ecology. Vigorous growing *Cajanus cajan* interplanted with maize in the

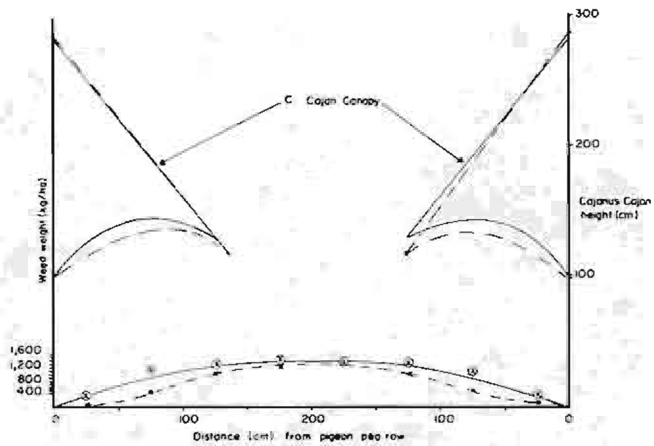


Fig. 45. Pigeon pea canopy structure and weed distribution in 4 m alley, 3 months after maize harvest, (maize/pigeon pea ——, ⊗, pure pigeon pea – – – –, — * –).

early rain could provide an effective green ground cover, less prone to fire hazard, in the savanna regions. The plants can be eradicated mechanically with the residue providing mulch suitable for no-tillage cropping. The potential contribution of N to the soil and protein for human and animal consumption are other factors that warrant further investigation of *Cajanus cajan* in savanna cropping systems.

On-farm trials—*Leucaena*-maize systems

The main objectives of the long-term, alley cropping farm trials that began in 1980 are as follows: (1) to identify and enlist the cooperation of a set of participating farmers, representing a range of farming systems and farmer types involved in the production of yam and maize in Nigeria; (2) to instruct the farmers on the agronomy of the prototypical *Leucaena*-maize-yam alley cropping system; and (3) to see to the establishment of the *Leucaena* hedgerows as an understory intercrop with first season maize in preparation for use as live *in situ* yam vine staking next year.

Trials were established on 9 plots at 6 different locations across the yam belt of Nigeria (Fig. 46). Periodic visits were made to each site to provide basic guidance and monitor progress. In all cases, the farmers were encouraged to feel free to modify the system to fit their needs. Information on such modifications provides for a better understanding of the working principles of appropriate alley cropping systems for smallholder conditions.

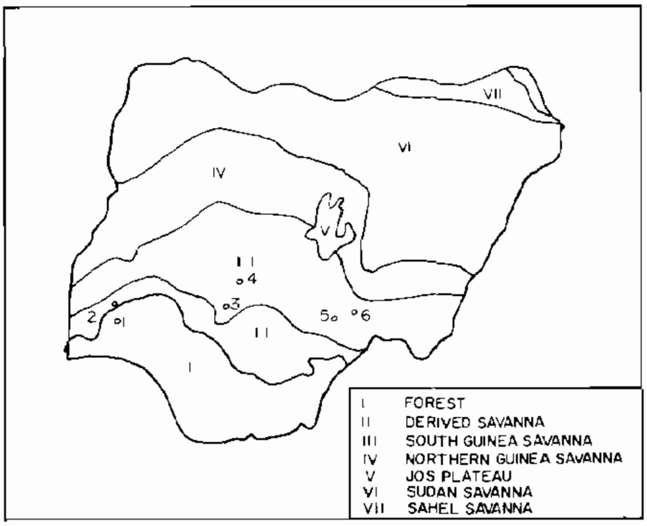


Fig. 46. Map of Nigeria showing ecological zones and sites of the Leucaena-maize-yam alley cropping system. Farm trials in 1980. 1. Lagbe 2. Ijaye 3. Osara 4. Tawari 5. Yandev 6. Zaki Biam.

First year trials have yielded a number of preliminary findings. *Leucaena* has been found to be a very hardy plant that established well even under extremely adverse conditions. A severe first season drought caused failure of the maize intercrop in most sites, but *Leucaena* growth continued at moderate levels. In order to cope with the economic effects of the drought, farmers attempted to substitute other intercrops such as cowpea and sorghum. Heavy shading under cowpea retarded *Leucaena* growth somewhat but from the standpoint of risk-aversive small farmers, suboptimal establishment growth of *Leucaena* appears to be a small price to pay for steps taken to obtain an economic yield from their fields in a bad year.

Where mechanized yam culture is likely to be an attractive way to reduce the labor costs of yam production, the trials indicate that a 4 m between-row spacing for *Leucaena* may be more suitable than the experimental 2 m spacing. Wider spacing may also be preferred where farming traditions favor multiple vine support by fewer stakes such as in the "tent staking" system of Tawari, Nigeria. While allowing for such modifications, it seems advisable to maintain a sufficient population of *Leucaena* to provide adequate mulch material, firewood and other by-products to maximize overall returns. Where firewood scarcity is a problem, the wood yield may be a significant component of the net economic return from the alley cropping system. The possibility of a double *Leucaena* row in the 4 m spacings should be investigated.

One potential variant, which aroused considerable interest among farmers for whom the labor costs of weeding are a major farm management constraint, is the use of *Leucaena* shade to control *Imperata cylindrica* and other heliophytic weeds. Although this use of alley cropping has yet to receive systematic attention, a possibility might be to rotate a 1 or 2 year closed-canopy fallow through a large field set up for alley cropping. If, for example, the field were divided into 4 sections, three-fourths could be in alley crop production in any given year with the remaining one-fourth in rotating fallow. Research is needed to evaluate the actual weed control potential of this alley cropping modification, but farmers indicate any innovation that minimized the herbicide need would be a major step toward making no tillage and mulch farming techniques more widely acceptable.

Linear programming model of *Leucaena*/rice alley cropping system

A linear programming model was developed to evaluate the economic attractiveness of an experimental *Leucaena*/-rice alley cropping system under West African smallholder conditions. Using production data representative of upland family rice farms in Sierra Leone and N response data from the Rokupr Rice Research Station in Sierra Leone, the model was used to explore the relative profitability of various rice growing activities at 0. 20, 40, 60, 80 and 100 kg N/ha from 3 different sources: urea; ammonium sulphate and *in situ Leucaena* hedgerows.

The main results indicate that under the conditions of smallholder production in the model, it is consistently more profitable to grow rice with N from *Leucaena* hedgerows than from either of the 2 mineral N sources. Furthermore, with labor as the limiting production factor, the 2 components of the *Leucaena*/rice alley cropping system always combine in the same economically optimal proportions of 0.37 ha (3,700 linear meters) of *Leucaena* hedgerow to 1.28 ha for rice. grown in the alleys between the hedgerows, for an optimum field size of 1.65 ha.

In order for rice production with urea or ammonium sulphate to become competitive with *Leucaena*-based rice production, subsidy levels of 97 and 99 percent, respectively, would be required.

The results of this modeling exercise must be regarded as provisional until validated by field trials, but the apparent economic attractiveness of the hypothetical *Leucaena*/rice alley cropping system would seem to justify the research attention of agronomists.

Live mulch systems

Live mulch crop production involves planting a food crop directly into a living cover of an established cover crop without tillage or destruction of the fallow vegetation. This incorporates the soil conservation features of organic mulch and no tillage and has the advantage of smothering weeds and contributing N in the case of a legum live mulch.

Weed competition, tillage and ground cover. Observations in 1980 showed marked differences in weed biomass due to the weed control method and ground cover type in maize. Although the field dry weight of maize stover used as ground cover averaged 10 t/ha, this was not enough to completely eliminate weed growth. Weed biomass was identical in the unweeded check of the conventional and no-tillage plots, and these were significantly higher than in the unweeded check of the live mulch plots (Table 48).

Table 48. Effect of weeding frequency and ground cover on weed competition and maize (TZE 4) yield (IITA, 1980 First season).

Ground cover	Weed control	Weed D. wt. (t/ha)	Grain yield[1] (t/ha)
Conventional tillage	Weed free	0 c	1.54 cde
	Weed × 2	0.8 b	1.65 cde
	Unweeded check	1.49 a	1.05 e
No tillage	Weed free	0 c	2.57 a
	Weed × 2	0.83 b	2.43 ab
	Unweeded check	1.4 a	1.84 bcd
Maize stover	Weed free	0 c	2.27 ab
	Weed × 2	0.91 b	2.39 ab
	Unweeded check	1.31 a	1.56 cde
Arachis repens	Weed free	0 c	1.36 de
	Weed × 2	0.27 c	1.52 cde
	Unweeded check	0.31 c	1.32 de
Psophocarpus palustris	Weed free	0 c	2.63 a
	Weed × 2	0.05 c	2.50 a
	Unweeded check	0.11 c	2.14 abc

Average stand concent of 50.27 × 10³ pl/ha.
[1]Means followed by the same letter in the same column are not significantly different at the 5% level of the New Duncan's Multiple Range Test.

The unweeded check, live mulch plots had fewer weeds at harvest than in each of the conventional and no-tillage and maize stover plots that were weeded twice. Uncontrolled weed growth significantly reduced the maize grain yield in the conventional and no-tillage and maize stover plots but not in the live mulch plots. These results confirm the finding of last year that live mulch crop production has potential for minimizing the need to control weeds in maize. The highest maize yield was observed in a live mulch plot in which *Psophocarpus palustris* was maintained.

High maize yields in this live mulch cover were not related to weeding treatment. On the other hand, comparable yields were obtained in no-tillage and maize stover plots that were weeded at least twice. Yield in the conventional-tillage plots was significantly reduced even when the plot was kept weed free.

Ground cover and N fertilization. The effect of ground cover on the N fertilizer requirement of maize was investigated. All plots received a blanket application of 30 kg P_2O_5 and K_2O/ha. Maize responded to varying levels of N fertilizer applied in the conventional and no-tillage and maize stover plots but not in the live mulch plot in which *Psophocarpus palustris* was the ground cover (Table 49).

Table 49. Effect of N fertilizer level and ground cover on maize (TZE 4) yield (IITA, 1980 First season).

Ground cover	N-fertilizer (kg/ha)	Grain yield (t/ha)
Conventional	0	1.24 d[1]
	60	1.49 cd
	120	1.51 cd
No-tillage	0	1.63 cd
	60	2.70 a
	120	2.51 ab
Maize stover	0	1.74 cd
	60	1.98 bc
	120	2.49 ab
Arachis repens	0	1.09 d
	60	1.72 cd
	120	1.45 cd
Psophocarpus palustris	0	2.47 ab
	60	2.39 ab
	120	2.41 ab

Average stand count of 50.6 × 10³/pl/ha
[1]Means followed by the same letter in the same column are not significantly different at the 5% level of the New Duncan's Multiple Range Test.

Typical live mulch stand in one of the field experiments in 1980.

Without N fertilizer, the maize yield was twice as high in the live mulch plot in which *Psophocarpus palustris* was the ground cover as in the conventional-tillage plot. Maize yield in the no-tillage and maize stover plots without N fertilizer was as low as in the conventional-tillage plot. The advantage of no-tillage over conventional tillage under continuous cultivation is demonstrated only when N fertilizer was applied. Without N fertilizer, the maize yield was as poor in the no-tillage plot as in either the conventional-tillage or maize stover plots. Results of this study show that the best live mulch treatment eliminated the need for a fertilizer application, and the N contributed by the legume cover in the live mulch maize was comparable to the 60 kg N/ha in the no-tillage maize.

The study of the live mulch production of maize shows that (a) continuous maize production is possible under the live mulch system without a bush fallow, (b) weed pressure can be minimized, and (c) the requirement for N fertilizer can be minimized or eliminated. These findings have far reaching implications among small-holder farmers who can neither afford the labor for weeding nor the chemicals for fertilizing. Live mulch is an attractive crop production practice that provides complete, year-round ground cover, thus minimizing soil erosion and soil structure loss.

Weed biology and herbicide research

Biology of tropical weeds

Little is known about the biology of weeds in relation to their control in tropical agriculture. Some aspects of weed research focus on reasons for crop yield reductions caused by weeds. Allelopathy and other factors of weed interference have been investigated in selected tropical crops to develop effective weed control strategies.

Allelopathy weeds vs. yams. Since previous observations have shown that yam (*D. rotundata*) is sensitive to weed interference, studies were carried out from 1978 to 1980 to assess the nature and extent of this sensitivity. A new method was designed and tested for assessing allelopathy in root and tuber crops closely simulating field conditions. Results of these studies show that full weed interference caused a 75 percent reduction in yam tuber yield (Table 50). When weed interference was limited to the above ground vegetative parts of both weeds and crops, only a slight yield reduction was observed; but when the leachete from the roots of weeds was allowed to come in contact with the soil in which the yam grew, yam tuber yield was significantly reduced. This yield reduction caused by allelopathy was consistent for the 3 years in which this study was carried out.

When moisture was not limiting and plants received a basal fertilizer treatment (30 kg N. P_2O_5 and K_2O/ha), the major reasons for the yield reduction caused by weeds were allelopathy and other soil related factors. Each of these 2 weed interference factors accounted for over 30 percent of the total loss caused by weeds (Fig. 47). Keeping crops weed-free appears to be the only way to minimize the yield reduction caused by weeds.

Weed interference studies. A study showed that a significant decline in leaf area index (LAI) and tuber yield of white yam occurred due to weed inference from 8 to about 16 or more weeks after planting in tubers planted at the onset of rains (Table 51).

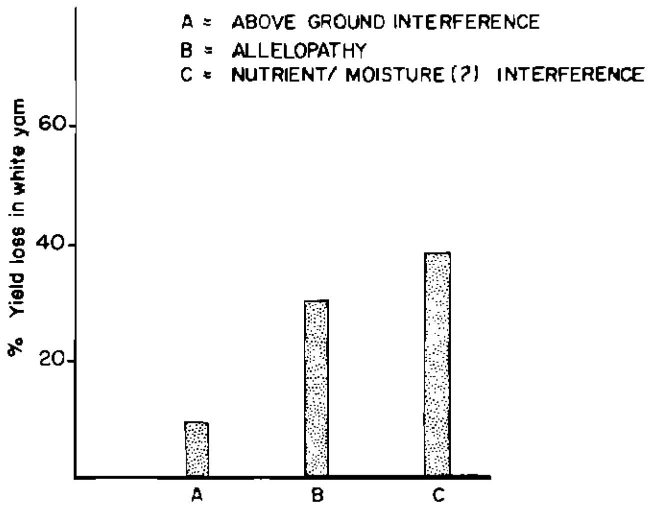


Fig. 47. Weed interference in yam.

Table 50. Mean fresh tuber yield and yield losses of white yam grown in wooden boxes as affected by mode of weed interference (1978-80)

Mode of weed interference	Fresh tuber yield			Yield loss		
	1978	1979	1980	1978	1979	1980
		kg/std			%	
Interference by aerial factors	1.83 ab[1]	0.72 ab	2.48 a	16.44	20.88	11.70
Interference by allelopathy + aerial factors	1.26 bc	0.58 b	1.38 b	42.47	36.26	37.80
Full interference	0.53 c	0.22 c	0.47 c	75.80	75.82	78.80
Weed-free check + polythene	2.19 ab	0.91 a	2.22 a	0.00	0.00	0.00
Weed-free check − polythene sheet	2.52 a	-	-	15.07	-	

[1]*Means followed by the same letter in the same column are not significantly different at the 5% level of the Duncan's New Multiple Range Test.*

Table 51. Mean values of yield and yield components of white yam as affected by duration of weed interference in the field (1978-79).

Duration of weed interference	LAI (at 12 WAP)		Time (weeks) to 100% tuber initiation		Fresh tuber yield (t/ha)	
	1978	1979	1978	1979	1978	1979
W. F. M.	0.55 ab[1]	0.58 a	12 a	10 a	20.08 a	17.57 a
W. I. 4	0.87 a	0.21 cd	14 d	10 a	18.75 ab	17.40 a
W. I. 8	0.29 b	0.18 d	14 a	10 a	13.96 bc	13.91 a
W. I. 12	0.22 b	0.16 d	14 a	10 a	12.47 bc	7.40 bc
W. I. 16	0.29 b	0.04 d	14 a	10 a	6.47 d	6.06 bc
W. I. 20	0.21 b	0.06 d	14 a	10 a	6.58 d	3.24 c
W. I. 24	0.30 b	0.02 d	14 a	10 a	4.88 d	1.89 c
W. I. M.	0.24 b	0.06 d	14 a	10 a	6.03 d	2.12 c
Weeded 3 + 8 + 12	0.94 a	0.74 a	14 a	10 a	19.71 a	12.25 bc
Weeded 3 + 8 + 12 + 16	0.82 a	0.55 bcd	14 a	10 a	20.88 a	17.28 a

[1]*Means followed by the same letter in the same column are not significantly different at the 5% level of the Duncan's New Multiple Range Test.*

In the absence of weed interference, dry matter production in yam vines and leaves peaks in phase II (vegetative growth stage) and phase III (tuber bulking growth stage). Weed interference during these periods severely reduces growth in those organs, and this reduction during phases II and III (12-16 weeks after planting) interferes with assimilate production necessary for optimum tuber bulking in the later part of phase III.

Dry matter production in weeds peaked at 8-12 weeks and declined thereafter, indicating that the maximum competition occurred during this period. Decline in tuber yield was also most pronounced at this period (Fig. 48).

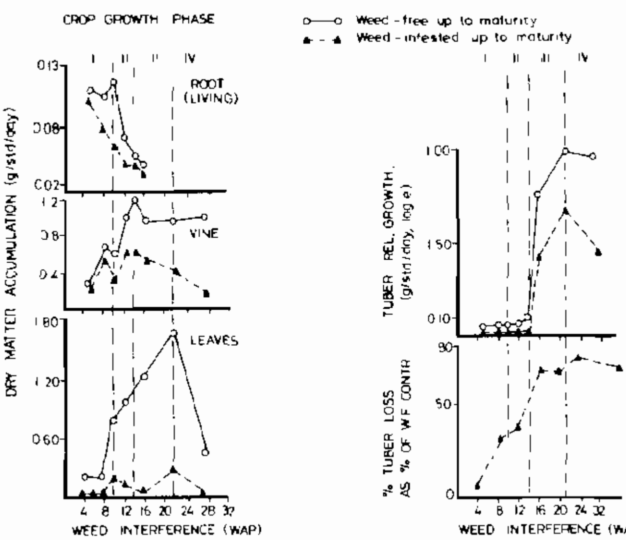


Fig. 48. Effect of weed interference on yield and yield components in yam.

Herbicide persistence in tropical soils

Field experiments were carried out at IITA and Onne to determine the persistence of some selected commonly used preemergence herbicides in the 2 ecologies. Atrazine, metolachlor and fluometuron were each applied at 3.0 and 6.0 kg/ha while pendimethalin was sprayed at 2.5 and 5.0 kg/ha on a conventional-tillage plot using a knapsack sprayer calibrated to deliver 200 1/ha spray volume. Herbicide persistence was monitored by a bioassay method involving tomato seedlings for atrazine and fluometuron and rice seedlings for metolachlor and pendimethalin.

Atrazine and metolachlor each at 3.0 kg/ha were less persistent than fluometuron and pendimethalin (Fig. 49). Generally, all herbicides were more persistent at IITA (rainfall 1,400 mm) than Onne (rainfall 2,400 mm). Atrazine at 3.0 and 6.0 kg/ha was present in soils at IITA at nonphytoxic levels at 8 and 12 weeks after treatment, respectively (Fig. 50). The persistence of metolachlor closely followed that of atrazine while fluometuron and pendimethalin showed pronounced persistence at IITA at both low and high rates. Fluometuron, especially at a high rate, persisted beyond the test period in the IITA soil. Pendimethalin at 2.5 kg/ha persisted at high levels for more than 8 weeks after treatment, but existed at very low levels at 12 weeks after treatment.

Persistence of atrazine in soils at Onne was very short and had declined to non-phytoxic levels by 8 weeks after treatment (Fig. 49). Doubling the rate of atrazine did not increase its persistence. Metolachlor applied at a high rate persisted in Onne for more than 8 weeks after treatment. Fluometuron could not be detected in the top soil at Onne by 12 weeks after treatment. Persistence of pendimethalin was identical at both IITA and Onne, irrespective of rates used.

While an atrazine sensitive crop could be planted at IITA and Onne locations at 12 weeks after treatment, a fluometuron sensitive crop could not be safely grown under soil and rainfall conditions at IITA within 12 weeks after treatment. All herbicides tested in soils at Onne were either nontoxic or had very low herbicidal activity at 12 weeks after treatment.

Plantain improvement

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

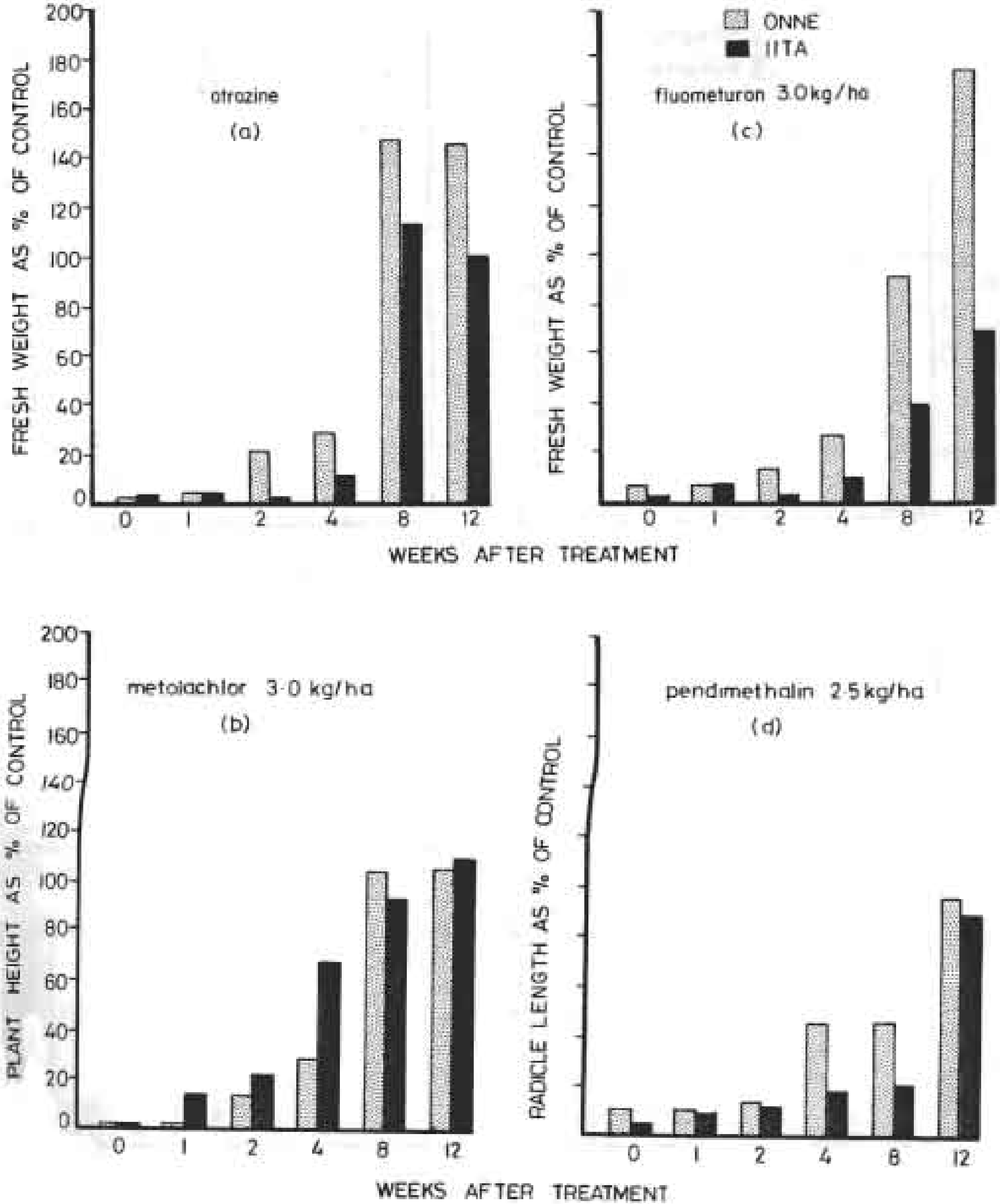


Fig. 49. Persistence of herbicides in surface soils.

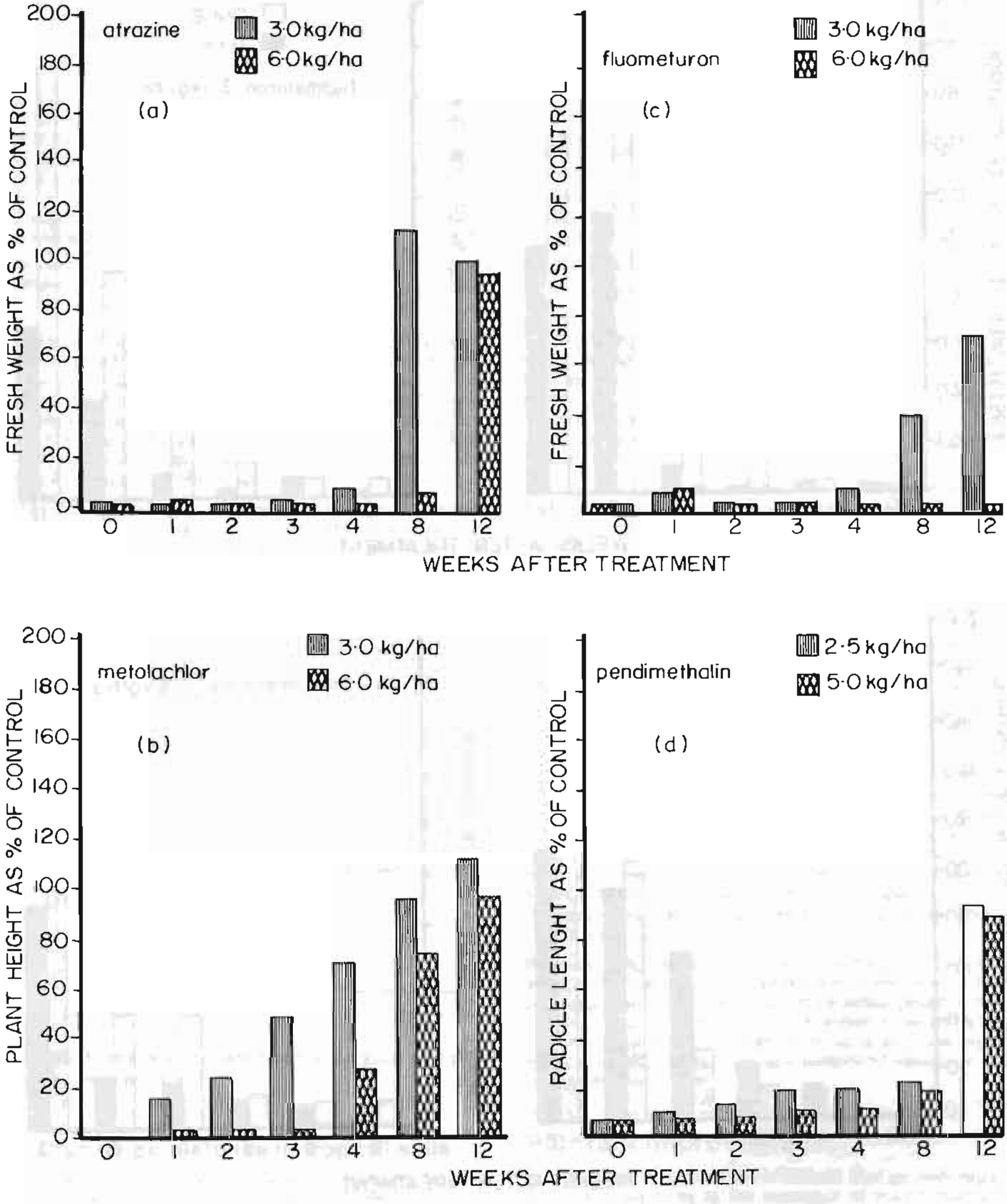


Fig. 50. Effect or rate (kg/ha) on herbicide persistence in soil.

use 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 2 field trials were conducted.

Physiological study of the suckering behavior

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 (Gibberillic acid, GA + NAA (Napthylene acetic acid), GA + cytokinin and ABA (abscisic acid); were applied on alternative days in 1ml 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.

Treatments with GA/NAA were not considered because the structure of the peepers seems to be changed. There were no significant differences in height and girth after 4 weeks among the peepers of the 16 treatments (2 durations × 2 concentrations × 4 hormones), except for the height of the GA 10^{-2} M treated peepers. Peepers injected with ABA were not significantly different in their growth from the control.

In the second trial, the mother plant was retained. Treatment began at 6 months after planting. Only 1 peeper per plant was treated. Treatments with GA/NAA and GA/NAA CYT were not considered because of abnormal changes in the peepers. Suckers injected with GA, GA + flurenol and GA + CYT showed, compared with the control, significant differences in height and girth after 6 weeks. Suckers injected with GA + CYT became significantly thicker.

Also, there were no significant differences between durations, but there were between the 2 concentrations. As in trial 1, peepers injected with ABA did not differ significantly from the control.

The effects of GA on suckers in Trial 2 proved that the significant growth of injected suckers is not linked to the duration of the injection but to the hormone concentration. In the next experiment, 1 ml of Ga 10^{-2} M was injected into the second peeper (P_2) at 10 days after emergence on 10 different plants. The injection was repeated once on the same peeper at 5 days after the first. The controls were no treatment (neutral control), and injection of 1 ml of H_2O also repeated once after 5 days. Observations were on the mother plant, P_1, P_2 and P_3 at the time of first injection and 6 weeks after the second injection (Table 52).

The GA treated peepers developed faster than the first peepers on the same stool and the GA injection did not significantly stimulate the growth of the first and third peepers. No effects could be observed on the main pseudostem. This points to a very localized action of GA on the treated suckers only, and an immediate change in the balance is enough to stimulate the growth. The H_2O-treated peepers did not show any difference in growth compared with the peepers of the neutral control, proving that tissue changes by the injection was not interferring with the development of a sucker.

Effect of Flurenol on apical dominance

Flurenol is known to counteract the apical dominance. This effect on plantain was compared with the neutral control (no treatment) and decapitation (Table 53). Flurenol was injected into the 4.5 month-old main pseudo-

Table 53. Mean height (Ho, H_6) and girth (Go, G_6) of the second peeper and the main pseudostem at 0 and 6 weeks (in cm). Number of peepers at 0 and 6 weeks (N_o, N_6).

		Control	Flurenol		Decapitation	
P_2	H_o	3.7	1.64		1.4	
	H_6	22.7	16.82		57.7	(1)
	G_o*	3.8	1.73		1.8	
	G_6	13.2	9.27		16.8	(5)
*Girth at soil level						
Mother-plant	H_o	182.6	146.3	(5)	157.9	
	H_6	264.5	211		-	
	$G_{o_{50}}$*	44.2	36.78	(5)	39.8	
	$G_{o_{100}}$*	37.9	31.4	(5)	32.9	
	$G_{6_{50}}$*	64.5	52	(1)	-	
	$G_{6_{100}}$*	52	42.4	(1)	-	
	N_o**	2.3	0.9	(5)	1.4	
	N_6	8.4	6.2		4.6	(1)

**Girth at 50 cm and 100 cm height*
***Number of peepers*
Means in the same row followed by (1) or (5) respectively, are significantly different for 1% and 5%.

Table 52. Height and girth of second peeper, mother plant pseudostem and number of peeper at 0 and 6 weeks after treatment.

		Control		Water		GA	
Type of Plant	Parameter	Start	6 weeks	Start	6 weeks	Start	6 weeks
$Peeper_2$	Height (cm)	8.1	24.6	8.2	28.6	7.6	87.6*
	Girth (cm)	6.7	13.4	8.3	16.4	6.6	20.1*
$Peeper_1$	Height	24.8	65.7	-	-	16.7	47.7
	Girth	13.1	24.9	-	-	10.2	19.5
$Peeper_3$	Height	5.2	15.5	-	-	4.6	20.8
	Girth	5.5	12.9	-	-	4.0	13.5
Mother plant	Height	200.1	285.9	200.0	277.5	196.6	285.8
	Girth (50 cm)	48.8	68.9	47.9	65.1	49.3	66.3
	Girth (100 cm)	41.1	54.7	40.1	53.2	41.9	54.1
	No. of peepers	4	10	3.8	9.6	3.8	8.6

**Significant differences between treatments at 5% probability.*

stems of 10 different plants and repeated a second time. Each time 2 ml was injected. Observations were made on the mother plant and the second peeper at the time of the first injection and 6 weeks after the second injection.

Flurenol treated plants did not show faster sucker development nor higher peeper production. Differences in the main pseudostem after 6 weeks are probably due to the selected plants in the beginning of the experiment. Thus, to counteract the apical dominance, repeated injections seem to be necessary to maintain the change in hormone balance. Decapitated plants gave bigger suckers (maiden suckers) as the control of Flurenol treated plants (peepers). Release from apical dominance was not stimulating higher peeper-number which suggests that the maiden suckers are dominating.

Effect of fertilizer and mulch

Plantain in backyards are growing under optimal conditions because of high level of nutrients, as well as organic matter (Table 54.) In this experiment, the nutritional requirements of 2 varieties of plantain (medium and giant False Horn) were compared with that of a banana (Kparanta). It is clear that in all cases fertilizer had strong positive effects on growth, whereas the effects of mulch appeared less pronounced. The combination of mulch and fertilizer showed positive interaction.

Table 54. Height and girth of a medium and a giant False Horn plantain and a banana after 5.5 months.

Treatments	Height (cm)	Girth (cm) at 50 cm height
False Horn giant plantain		
No mulch, no fertilizer	85.61 ab*	21.31 abc
No mulch, fertilizer	133.45 ab	31.14 abcd
Mulch, no fertilizer	119.14 ab	27.69 abc
Mulch and fertilizer	181.18 bc	42.92 cd
False Horn medium plantain		
No mulch, no fertilizer	56.92 a	15.91 a
No mulch, fertilizer	116.04 ab	27.30 abc
Mulch, no fertilizer	123.09 ab	29.39 abcd
Mulch and fertilizer	181.15 bc	40.96 bcd
Banana		
No mulch, no fertilizer	94.20 ab	22.94 abc
No mulch, but fertilizer	188.11 bc	38.78 abcd
Mulch, no fertilizer	153.17 abc	31.64 abcd
Mulch and fertilizer	266.95 c	53.14 d

**Means in the same column opposite the same letter(s) are not significantly different from each other at 5% levels. Mulch consisted mainly of Eupatorium.*

Eastern Cameroon Farming Systems Project

As part of the effect to develop the Eastern province of Cameroon in cooperation with Zapi-Est (Zone d'Actions Prioritaires Integrees de l'Est), the World Bank asked IITA to assist the then Cameroon National Office of Scientific and Technical Research in establishing a food crop research station in that province. One of the responsibilities of IITA is to conduct an agronomic survey of existing farming systems to determine research priorities for the regional food crop research.

Agroeconomic surveys. The agroeconomic survey was conducted with the following objectives: (1) to investigate and analyze existing farming systems, (2) to gather information on existing patterns of agricultural production and resource use, (3) to identify major constraints, and (4) to collect relevant information on marketing and output supplies. A report titled, "Survey of food crop farming systems in the Zapi-Est, East Cameroon," was published.

Field trials. The field trials on varietal improvement, cultural practices and fertilization were initiated in 1980 at Bertoua in the savanna zone and at Doume in the forest zone. The varietal improvement was carried out with maize, groundnut, soybean, cowpea and upland and lowland rice. Grain yield of selected maize varieties was 3 to 4 times that of the local variety; TZB was the top yielder with 6.1 t/ha. Streak is a major problem for maize production in the area.

Among the groundnut varieties tested, Bertoua Blanche gave the highest yield of 2.1 t/ha. Soybeans performed well in the area and yields ranged from 0.6 to 1.9 t/ha. The top yielder was variety 20-67 TB. Though cowpeas showed good growth, leaf diseases and insect damage were commonly observed after flowering. Grain yields varied from 0.2 to 1.4 t/ha with TVx 1948-OIE giving the highest yield. High yields of lowland rice were obtained with variety IM 16 giving the highest yield of 7.0 t/ha.

On newly cleared land at Bertoua, grain yield of maize variety Ekona Mixed Color responded significantly to N and P applications at rates of 60 kg N/ha and 40 kg P_2O_5/ha. Positive N × P interactions were also observed. Regardless of level of fertilizer application, maize yield increased significantly as the plant density increased from 33,000 to 66,000 plants/ha.

Field trials with groundnuts showed significant responses to application of lime, N and P (Fig. 51). N appli-

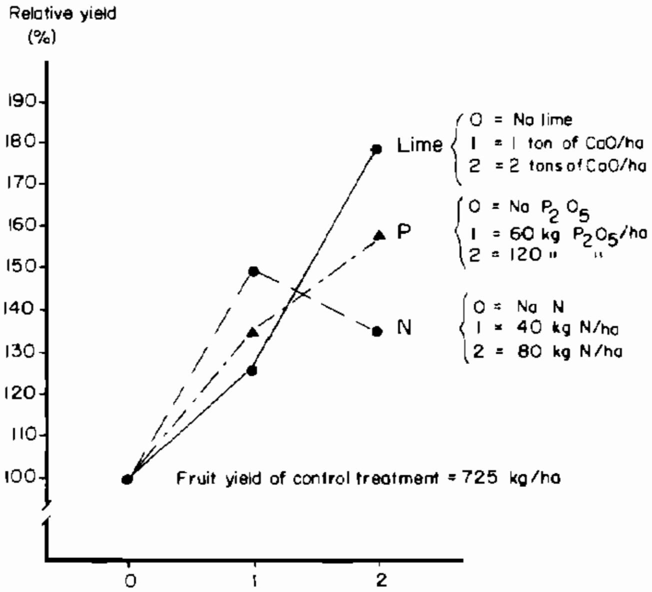


Fig. 51. Response of groundnut (CV Bertoua Blanche) to N, P and lime applications.

cation on long growth-duration rice variety IM 16 showed that time of N application greatly influenced yield (Table 55). While basal application of 50 kg N/ha at 1 day before transplanting did not increase yield, application of 50 kg N/ha at panicle initiation did. It appears that the best recommendation may be 50 kg N/ha basal applied and sidedressed with 50 kg N/ha at panicle initiation.

Table 55. Grain yield of irrigated rice variety IM 16 under different treatments of rate and time of N fertilizer application (Doume, 1980).

Fertilizer rate (kg N/ha)	Time of application[a]	Grain yield (t/ha)
0	-	4.6
50	50 (B)	4.6
100	100 (B)	5.3
50	50 (PI)	5.9
100	50 (B) + 50 (PI)	6.6
100	40 (B) + 30 (30 DT) + 30 (PI)	5.5

[a]B = Basal, 1 day before transplanting.
PI = Panicle initiation.
DT = Days after transplanting.

Maize/groundnut intercropping has been extensively utilized by local farmers. A field trial was conducted during the second season to evaluate the potential of this system and investigate the factors affecting yields of crops when they are planted in association. Among the intercropping treatments, the treatment of maize at 40,000 hills/ha seeded at 20 days after the seeding of groundnut at 133,000 hills/ha gave the highest monetary return (Table 56).

In general, however, the yield of both crops is reduced when the crops are planted in association. The amount of yield reduction varies with the seeding time of the affected crop in relation to the seeding time of the associated crop. The yield of maize planted in association with groundnut, for example, was reduced in the following order: maize seeded at 20 days before the seeding of groundnut > maize seeded at the seeding of groundnut > maize seeded at 20 days after the seeding of groundnut. A similar trend was also observed with groundnut yield, and obviously both crops reacted negatively to late planting and intercrop competition.

Small farms systems research (Atebubu District, Ghana)

The small farms systems research is a component of the USAID sponsored project of Managed Inputs and Delivery of Agricultural Services (MIDAS). The MIDAS project is designed to organize and distribute all the inputs necessary for food crop production by small farmers of Ghana.

The small farms system research is designed to assist the government in establishing an applied multidisciplinary small farms research capacity with the following objectives in mind:

(1) To obtain a sound knowledge of the existing farming systems, the socioeconomic environment and the positive and negative factors in services.
(2) To conduct applied research that is relevant to these circumstances and responds to the needs of the small farmers.
(3) To identify soil and farm management and production practices that eliminate constraints.
(4) To increase small farmer production and income.

The project was initiated in 1980 with an appraisal of the present food crop farming system practices in the region. For the survey, a group discussion approach was used that was supplemented by the visit to individual farmers and spot harvest checks. The survey covers 7 subdistricts—Atebubu, Amantiri, Abease, Prang, Kwame Danso, Kajaji and Yeyi.

The survey was completed in 1980 and a report titled, "An appraisal of the present farming systems of the Atebubu District of Ghana," was published. During 1980, preparations were also made in selection of a site for establishing the experiment station. Actual field experimentation, however, will be initiated in 1981.

Table 56. Yield of sole and intercropped maize and groundnut and their monetary values. (Bertoua, 1980 second season).

Treatment	Crop and date of seeding (M = Maize; G = Groundnut)	Plant density (× 10³ hills/ha)	Treatment	Crop Yield Kg/ha		Monetary value (CFAF)[1]		
				Maize	Groundnut	Maize	Groundnut	TOTAL
C_1	M on 1 August	50	C_1	3066	-	183,960	-	183,960
C_2	G on 1 August	200	C_2	-	2277	-	284,625	284,625
C_3	M on 1 August, and G on 1 August	40 / 133	C_3	2263	1206	135,780	150,750	286.530
C_4	M on 1 August, and G on 20 August	40 / 133	C_4	2959	539	177,540	67,375	244,915
C_5	M on 20 August, and G on 1 August	40 / 133	C_5	831	2122	49,860	265,250	314,790
C_6	M on 10 Sept., and G on 1 August	40 / 133	C_6	-	2245	-	280,625	280,625

[1]At 60 CFAF/Kg of maize grain and 125 CFAF/Kg of unshelled groundnut (Retain price of PROVIV-ZAPI, 1980).
[2]Maize seeded on this date did not germinate.
[3]Fertilizer rates maize 8°N − 8° P_2O_5; groundnut 2°N − 6° P_2O_5 in Kg/ha.

Root and Tuber Improvement Program

Introduction

During the past decade, the Root and Tuber Improvement Program has made significant progress in producing improved varieties of cassava and sweet potato. The improved cassava varieties are resistant to the 2 major diseases in Africa—cassava mosaic disease (CMD) and cassava bacterial blight (CBB). They are high yielding, good in consumer acceptance quality, low in cyanide and relatively well adapted in a wide range of environments in Nigeria.

The improved sweet potato varieties are resistant to the sweet potato virus disease complex (SPVD) and the African sweet potato weevil (*Cylas puncticollis*) and also high yielding and good in consumer acceptance quality and well adapted in a wide range of environments in many parts of Africa.

The seed from the improved varieties and populations of cassava and sweet potato were distributed to agricultural centers in many countries in the tropics for evaluation and selection. Many promising clones were selected from the seedling populations after evaluation under the local conditions. Some of the clones were found to be of excellent quality and performance and were multiplied and released in various countries in Africa, including Cameroon, Gabon, Liberia, Nigeria, Rwanda, Sierra Leone, Seychelles, Tanzania and Zaire.

New pests have recently become major problems on cassava in Africa. They are the cassava mealybug (*Phenacoccus manihoti*) and the cassava green spider mite (*Mononychellus tanajoa*). They are believed to have been introduced into Africa from Latin America. They have become widely spread and are limiting cassava production in some areas and are a threat to all of Africa. To mitigate the new pest problems, 2 research approaches have been adopted, host plant resistance and biological control. Sources of resistance to cassava green spider mite have been identified.

In yams (*Dioscorea* spp.), particularly white yam (*D. rotundata*), the essential techniques for hybridization, seed germination and seedling establishment and multiplication of material have been developed and routinely applied for yam improvement. The clones, resulting from the breeding program, are now under evaluation for yield, resistance to diseases and nematodes, quality and storability. The results indicate that further improvement of yams will be possible. However, the progress in yam improvement is slower than expected because of yams' natural low multiplication rate of planting propagules.

In cocoyam (both *Xanthosoma* spp. and *Colocasia* spp.), a large number of seedlings were screened based on flower promotion and hand pollination as breeding tools.

Cooperative programs have been established with the Programme National du Manioc (PRONAM) in Zaire and the Cameroon National Root Crops Improvement Program (CNRCIP) in Cameroon. Reports of these projects are included under the sections on crops, and individual annual reports are available from the respective organizations.

Cassava

Newly improved cassava variety, TMS 50395, consistently outyielded the IITA improved standard variety, TMS 30572. Improved low cyanide clones were produced that are relatively high yielding and resistant to CMD and CBB.

Resistance of cassava to cassava green spider mite (CGM) has been confirmed, and it appears to be associated with pubescence of the top young leaves. A predator (*Hyperaspis* sp.) of cassava mealybug (CM) has been multiplied and released in an attempt to control the mealybug. The population of the predator tended to increase. The CM in Latin America, which was previously regarded to be *Pheancoccus manihoti*, has been identified as *P. herreni*.

Genetic improvement

Performance of the best varieties

The fresh yields of 2 new IITA improved varieties, TMS 50395 and TMS 50207, significantly outyield the IITA improved standard variety, TMS 30572, which is being popularized by the National Accelerated Food Production Project (NAFPP) in Nigeria. TMS 50395 and TMS 50207 were most promising among the 10 best varieties tested. The fresh root yields of a 12-month crop grown at IITA without fertilizer were 33 and 30 t/ha, respectively (Table 1).

The quality of their gari (a form of processed cassava) was judged good by a taste panel as well. They are as resistant as TMS 30572 against CBB and CGM but less resistant to CMD and lower in dry matter percent and garification rate (the rate of the processed gari over the total fresh tuberous roots in terms of weight).

Performance of promising clones

The most promising clones of the 1976 series are TMS 61469 and TMS 61242 (Table 2). They outyielded TMS 30572 and are resistant to CBB and CMD. Their gari quality is also good; however, their dry matter percent and garification rate were lower than TMS 30572.

Low cyanide clones

The cyanide content of breeding clones has been evaluated using an enzymatic assay. Low cyanide clones have

Table 1. Performance of 10 cassava varieties tested (IITA, 1979-80).

Clone	Fresh yield t/ha	Dry matter %	Dry yield t/ha	CMD score	CBB score	CGM score	Gari quality	Garification rate %
TMS 50395	32.7	26.2	8.6	2.4	1.5	1.6	VG	13
TMS 50207	30.0	25.9	7.8	2.5	1.6	1.6	G	14
TMS 4(2)1443	23.4	29.6	6.9	2.4	1.8	3.0	M	18
TMS 30572	23.1	31.3	7.2	2.0	1.5	1.6	VG	19
TMS 30001	21.8	27.9	6.1	1.3	1.3	3.1	VG	15
TMS 30337	19.9	26.9	5.4	2.5	1.9	2.0	G	13
TMS 50193	17.8	28.3	5.0	2.5	1.9	1.5	G	12
U/1421*	16.8	29.6	5.0	2.0	1.6	2.3	M	15
TMS 4(2)0763	15.7	27.5	4.3	2.5	2.0	2.4	M	15
TMS 50548	12.9	21.2	2.7	2.6	2.0	3.0	M	12
60444**	4.7	23.1	1.1	2.5	2.5	2.1	VG	11
60506**	4.4	26.4	1.2	2.9	2.5	3.0	M	13
LSD (5%)	4.7							
SE	1.6							

**Variety from Nigerian National Root Crop Research Institute.*
***Standard varieties.*
Lower scores indicate resistance.

Table 2. Performance of clones of 1976 series tested (IITA 1979-80).

Clone	Fresh yield t/ha	Dry matter %	Dry yield t/ha	CMD score	CBB score	CGM score	Gari quality	G.R.* %
TMS 61469	24.6	29.7	7.3	1.9	1.5	2.1	VG	14
TMS 61242	24.2	25.6	6.2	1.9	1.5	1.9	G	13
TMS 61938	23.5	27.8	6.5	2.5	1.8	2.3	G	14
TMS 61513	22.8	24.5	5.6	2.4	1.5	1.5	G	11
TMS 62208	22.2	25.5	5.7	2.0	1.4	2.0	P	14
TMS 63397	21.7	28.2	6.1	2.0	1.7	2.4	G	18
TMS 62408	21.5	32.6	7.0	2.4	1.6	2.1	G	19
TMS 30572	20.9	27.7	5.8	2.5	1.5	1.9	VG	16
TMS 63385	18.5	24.7	4.6	2.5	1.6	1.8	G	13
TMS 62350	17.5	30.0	5.3	2.4	1.7	2.3	VG	19
TMS 60506	13.6	21.7	3.0	2.6	2.4	2.5	M	13

**G.R. = Garification Rate.*

Table 3. Performance of low cyanide cassava clones (IITA, 1979-80).

Clone	Fresh yield t/ha	Dry matter %	Dry yield t/ha	CMD score	CBB score	CGM score	Total HCN mg/100 g*
LCN 6068	31.8	30.2	9.6	2.5	1.5	2.0	3.3
LCN 518	22.7	34.4	7.8	2.3	1.5	2.3	8.9
LCN 6086	20.1	31.2	6.3		2.5	1.5	5.0
LCN 30474	17.1	33.6	5.8	3.5	1.8	2.0	7.2
LCN 3109-N-7	16.4	38.8	6.4	3.8	1.8	2.5	6.3
LCN A/41369	11.3	33.9	3.8	2.3	1.5	2.0	4.1
LCN 6051	8.9	25.7	2.3	4.0	1.5	2.0	9.2
LCN 3109-N-17	8.8	32.5	2.9	4.5	1.5	2.3	4.4
LCN 50067B	6.7	31.9	2.1	3.8	1.5	2.0	5.3

**HCN content of fresh tubers was tested using an enzymatic assay.*

been selected for their performance and evaluated for other agronomic characteristics. Low cyanide clones, LCN 6068, LCN 518, LCN 6065, LCN 30474 and LCN 3109-N-7, give relatively high fresh yields, dry matter percent and dry matter yields (Table 3).

LCN 6068 and LCN 518 are relatively resistant to CBB and CMD. LCN 6068 showed very low total cyanide content with 3.3 mg per 100 g fresh tuberous root. TMS 30001 also has shown to be low in cyanide content, high yielding and resistant to CBB and CMD.

CGM resistant clones

Sixty promising clones in terms of yield were tested for CGM resistance in a replicated trial. CGM damage ratings of top, young leaves of each clone were made based on a scale of increasing severity from 1 to 5 (IITA Annual Report 1979). The average CGM ratings of the clones were significantly different and ranged from 2.0 to 5.0. The clones with low CGM ratings (scale 2.0-2.5) were TMS 40764, TMS 4(2)1425, LCN A/50078, TMS 61324, TMS 30017, TMS 60142, 5326X, 5032, TMS 63397 and TMS 61677.

Heritability of CGM resistance

A broad sense heritability estimate of 71 percent was obtained for CGM resistance using damage ratings data of the 60 clones mentioned above. This high heritability indicates that selection of cassava breeding clones for CGM resistance can be effectively carried out at an early breeding stage.

Factors affecting garification rate

The fresh tuberous roots from the 26 clones tested in a uniform yield trial in the 1980 first season at IITA were processed into gari by the following steps: (1) peeling off the skin, (2) grating the peeled tuberous roots, (3) dehydrating and fermenting the grated tuberous roots, (4) sieving out the chaff, and (5) frying the pulp. The garification procedure adopted was fairly uniform in order to obtain reliable data of processed material. The results of processing fresh cassava tuberous roots are summarized in Table 4.

The highest loss in the processing procedure was as much as 41 percent after peeling, followed by a water loss of 20 percent after dehydrating and 11 percent after grating.

The correlation coefficients of percent remaining material at each processing stage with final gari yields are shown in Table 4. The best relationship of garification rate was observed with pulp weight after the fermentating and sieving procedures ($r = 0.96$), followed by its relationship with dehydrated tuberous roots ($r = 0.94$) and its relationship with dry matter percent ($r = 0.78$). Dry matter percent will be the best and simplest characteristic to predict the garification rate prior to processing fresh tuberous roots into gari.

The relationship between dry matter percent (X) and garification rate (Y) was further studied, and the results are summarized in Table 5. It would be possible to predict roughly the garification rate (Y) with dry matter percent (X) using the regression equation: $Y = 0.82 + 0.09 X$.

Table 4. Some characteristics of tuberous roots that affect and are related with garification rate.

Tuberous root characteristics	Mean %*	Loss %**	Relationship with G.R. (r)***
Total fresh tuberous roots (10 kg)	100.0	0.0	0.19
% Peeled tuberous roots	59.0	41.0	0.40
% Grated tuberous roots	48.2	10.8	0.77
% Dehydrated tuberous roots	28.0	20.2	0.94
% Pulp after fermentation and sieving out chaff	25.2	2.8	0.96
% Chaff	3.2		−0.36
% Dry matter	25.5		0.78
Garification rate	13.5		1.00

Average of 26 clones.
***Loss stands for percent loss from one step to the next in gari processing.*
****G.R. = Garification rate.*

Heritability of garification rate. A broad sense heritability of 87 percent was obtained for garification rate using the garification rate data of 26 clones mentioned above. This high heritability indicates that selection of cassava breeding clones for garification rate may be effectively carried out at an early breeding stage. Since garification rate is highly associated with dry matter percent of fresh tuberous roots, it would be possible to select cassava breeding clones for higher garification rate indirectly by selecting them based on higher dry matter percent. However, other gari quality characteristics need to be checked at an advanced stage of breeding.

Heritability of dry matter percent. A broad sense heritability of 80 percent was obtained for dry matter percent using the dry matter percent data from the uniform yield trial. This high heritability indicates that selection of breeding clones for dry matter percent may be effectively carried out at an early breeding stage.

Genetic correlation between dry matter percent and garification rate. Significant genetic correlation coefficient ($r_g = 1.35$) was obtained between dry matter percent and garification rate. This high genetic correlation

Table 5. The relationship between dry matter percent (X) and garification rate (Y).

Source	No. varieties tested	Correlation coefficient (r)	Regression
Uniform yield trial (II)	26	0.78	$Y = 0.80 + 0.08 X$
Uniform yield trial (I)	10	0.83	$Y = 1.24 + 0.11 X$
National coop. trial	10	0.79	$Y = 0.41 + 0.07 X$
Average		0.80	$Y = -0.82 + 0.09 X$

indicates that selection of cassava breeding clones based on dry matter percent may lead to a higher garification rate.

However, the relationship between fresh tuberous root yield and dry matter percent needs to be studied with special reference to garificaton rate and final gari yield.

Distribution of improved varieties in Nigeria

IITA has phased down the multiplication of cassava for distribution in Nigeria, having successfully involved the Federal Department of Agriculture in an aggressive multiplication program involving the National Seed Service.

During the year, 6,815 bundles or the equivalent of 1,363,000 planting pieces were supplied by this program to the Nigerian National Seed Service at Moor Plantation, Ibadan, and through them some of the Nigerian State Ministries of Agriculture.

Additionally, IITA's cassava multiplication program supplied approximately 600,000 cuttings to the Nigerian private sector, and helped 4 'contract farmers' multiply cassava on their farms for distribution.

Entomology

Screening for CGM and CM resistance

In 1980, CGM (*Mononychellus tanajoa*) was the dominant pest on cassava at IITA; CM, (*Phenacoccus manihoti*) appeared at the station but did not reach epidemic levels until the end of the year.

Cassava green spider mite (CGM). Entomology work concentrated on finding resistance against CGM in cassava germplasm and breeding clones and seedlings. Twenty-seven germplasm clones and 228 seedlings were selected in April and May showing only mild CGM symptoms, scores 1 and 2 in a scoring system that ranges from 1 to 5 (IITA Annual Report 1979).

The 27 germplasm clones were planted in April and September (5 plants per row with 2 replications) to confirm the resistance and monitor the mite population on older and younger cassava. This also provided information on the best age and time of planting for optimum screening conditions. The mite population was monitored on 1 finger of the first expanded leaf. Four leaf samples were taken per week per clone. On the sample, the total number of adults, first instar, older nymphs, eggs and males

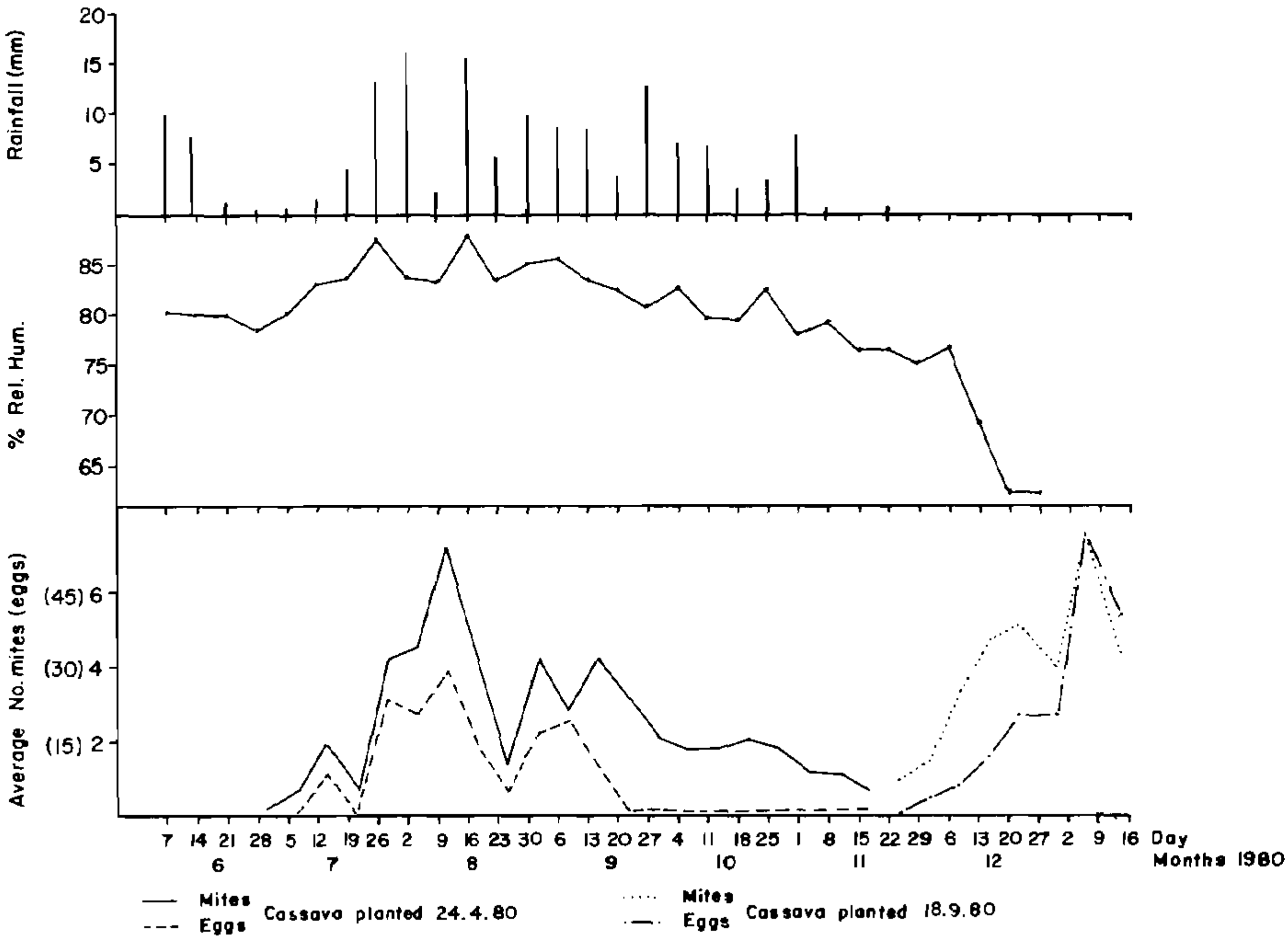
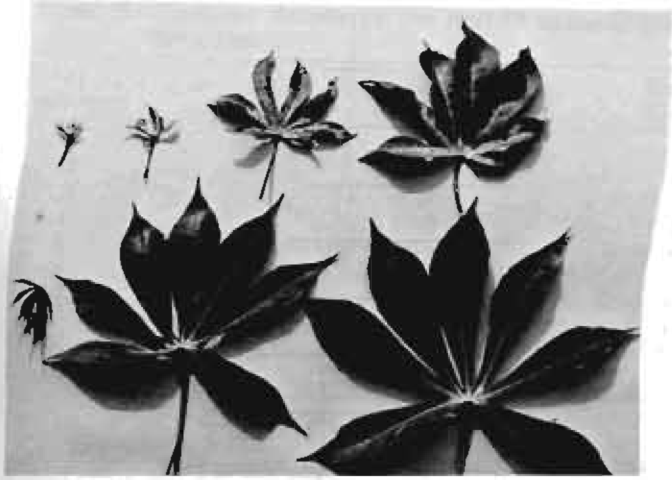


Fig. 1. Development of green mite population on early and late planted cassava in relation to rainfall and relative humidity.



A leaf area reduction caused by the green spider mite on a susceptible cassava clone compared to normally developed leaves on a resistant clone.

were counted. These detailed counts provided information on the population structure of each clone at any given time during the infestation period.

In Fig. 1, the mean number of adults and eggs per leaflet is demonstrated for the early and late plantings. Rainfall and relative humidity are also included because it is believed that these influence the mite population development.

In the early planting, natural mite infestation did not occur because of rain. Therefore, artificial infestation was carried out in June by putting infested shoots of infested plants on top of this planting. The mite population increased in spite of rain; however, the symptom expression never exceeded 2-3. This shows that the rainy season is not suitable for screening.

For optimal screening conditions, cassava should be planted in August or September (rainy season: April-October). Also, young cassava is generally attacked more than old cassava (older than 7 months). Mites need young, succulent leaves for a population buildup.

In the late planting, natural mite infestation did occur, and the peak of the population correlated with severe symptom expression. In January, 1981, the mite population decreased. At the same time, the late planting started to produce shoots again. It was during this time the relative humidity was too low, 46 percent compared to 60-70 percent as optimum. From observations in March-April, 1980, the mite population will probably increase again with the increase in humidity and the onset of rain. Out of the screening of the late planting, only 2 clones could be identified with a score of 2.

The 278 seedlings were planted (3 plants per row), but only 148 established. In Table 6, the frequency distribution according to the score classes is demonstrated. Only 18 seedlings were holding the resistance by showing score 2 or 3. Only 1 month later with the mite population decreasing and the new growth increasing did score values lower. This observation shows that scoring has to be done at a critical time to differentiate clonal differences.

From preliminary observations obtained during 1979 and 1980, it was speculated that symptom expression and actual mite population density do not necessarily correspond. Therefore, 4 clones, 3 with score 2 showing resistance in the field and 1 control showing no resistance in the field, were selected to study the vertical distribution of the mites among the first 15 leaves.

Table 6. Frequency distribution of CGM score values obtained from 148 cloned seedlings (IITA, 1980).

Score	Scoring date: 29/12/80
1.0	-
1.5	-
2.0	4
2.5	3
3.0	11
3.5	14
4.0	25
4.5	16
5.0	72

Planting date: 23/9/80.

Figures 2 a, b, c and d show that there are different distribution patterns. The control clone was called a susceptible type because it showed a heavy upper-shoot infestation, which resulted in severe leaf area reduction.

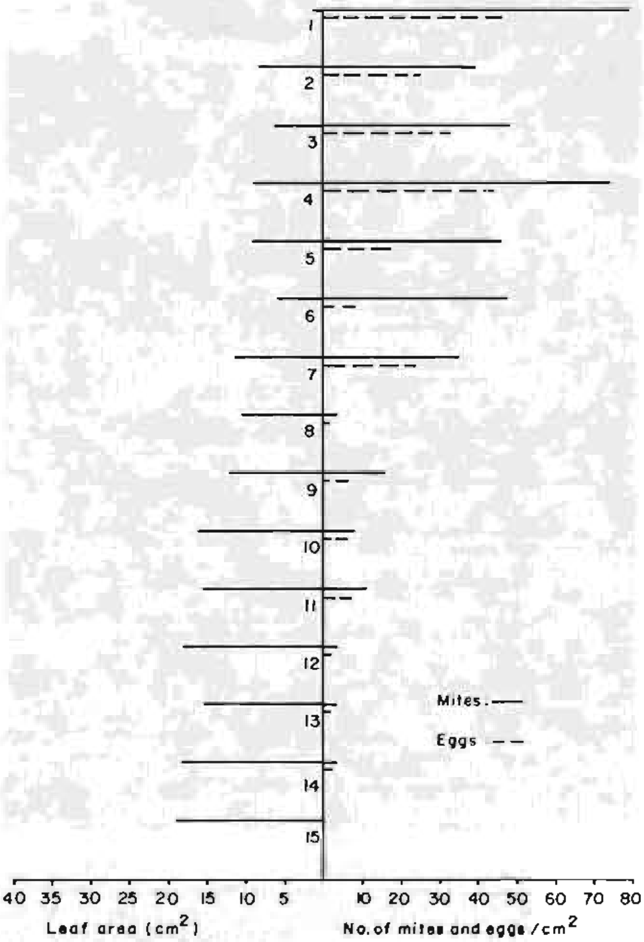


Fig. 2a. Susceptible type.

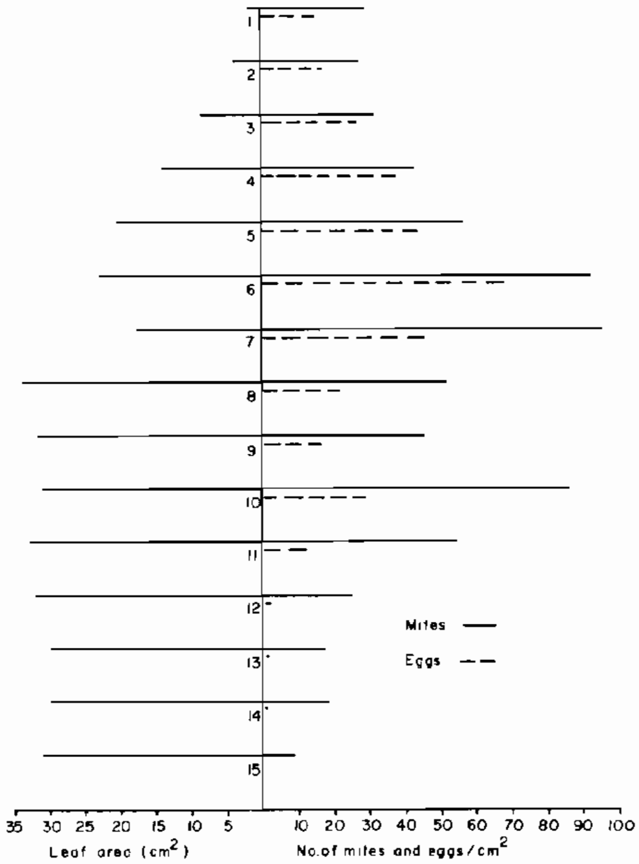


Fig. 2b. Tolerant type.

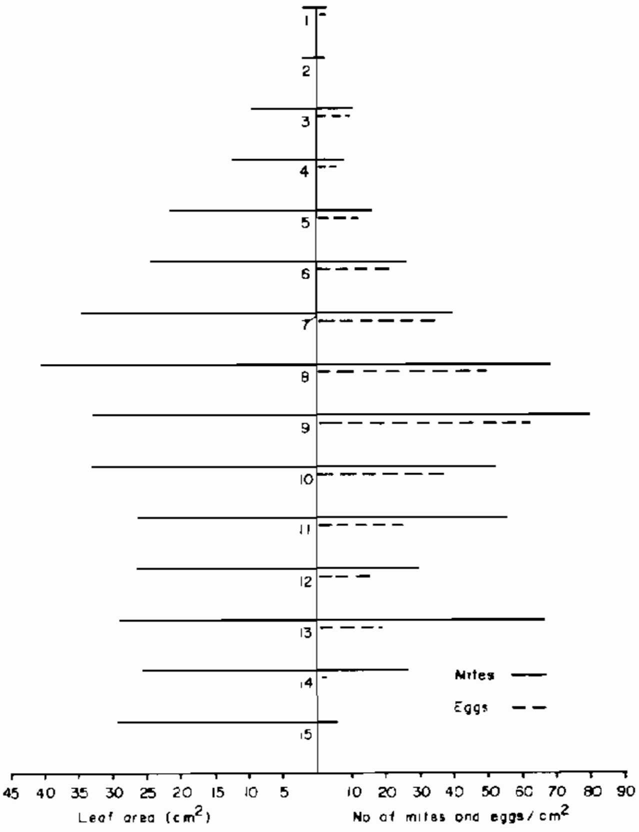


Fig. 2c. Shoot resistant type.

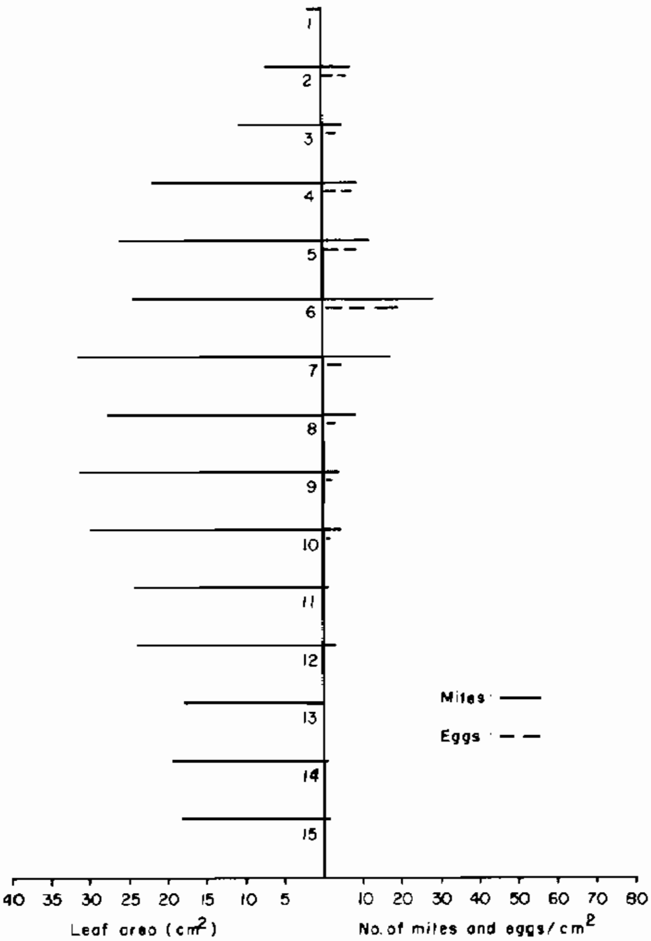


Fig. 2d. Resistant type.

A second clone was called a tolerant type because it showed less infestation on the top leaves; but still, infestation was high enough to be able to cause leaf reduction. A third clone was called a shoot-resistant type because it showed less infestation on the shoots. No leaf reduction occurred since the leaves could expand. A fourth clone was called a "resistant type" because the mite population showed an overall low infestation.

Overall, the results showed that symptom scoring alone might result in selecting accidentally a plant type that harbors a high mite population. Since the mite sucks plant sap and causes wounds that lead to high transpiration, this situation should be avoided. To test this hypothesis, careful yield loss studies should be carried out on these 4 plant types.

The results on the vertical mite distribution raised the question of the cause of this uneven distribution. In Tanzania and later in IITA, it was observed that nearly all cassava clones showing degrees of mite resistance had trichomes on the young top leaves. To see whether there was any relation between trichome density and resistance, the trichomes of the above mentioned 4 plant types were counted on each leaf (Table 7).

The trichome numbers per mm² show that there is at least a clear difference between the susceptible type and the resistant type. Also, between the shoot resistant type and the tolerant type, trichome densities differ signifi-

Table 7. Trichome density on the first 15 cassava leaves of 4 cassava clones in relation to CGM resistance (IITA, 1980).

Leaf position	Susc. type hairs/mm²	Toler. type hairs/mm²	Shoot resist. type hairs/mm²	Resist. type hairs/mm²
1	6.95	10.45	14.50	15.00
2	1.95	7.40	11.80	7.90
3	1.80	4.90	10.85	4.85
4	1.05	5.55	7.20	5.00
5	0.3	4.60	7.10	6.75
7	0.15	5.60	7.35	4.60
9	0.85	4.55	5.20	2.50
11	0.10	4.15	5.72	2.45
13	0.10	3.70	5.75	1.70
15	0.04	3.05	5.25	3.15

cantly. Only in the case of the resistant plant did the number of trichomes decrease quickly on the lower expanded leaves. In this case, another factor contributing to low mite damage might be involved.

To find out what the role of trichomes might be in relation to mite behavior, studies are presently going on. First observations indicate that trichome distances less than 0.3 mm make it difficult for the mite to rest along the leaf midrib. Trichome distances less than 0.2 mm make it difficult for the mite to feed and rest because the average length and width of the female mite is 0.3 mm and 0.2 mm, respectively. Detailed behavior studies are necessary to confirm this.

Cassava mealybug (CM). Screening for CM resistance was carried out at Abeokuta, Nigeria, where CM was present. Because of the long rainy season and cool harmattan weather in December, 1980, the spread of the CM in the test field was low. Therefore, artificial infestation was carried out with eggs. The CM population increased slowly.

Based on observations at Abeokuta, it was found that some IITA improved varieties, TMS 30572 for example, were able to recover quickly from CM attack while local varieties were only able to recover slowly—they showed bunchtop symptoms until June although the CM population had already vanished 2 months earlier.

Biological control for CM

IITA has begun a biological control program to solve the CM problem. During the year, a major task was to explore the potential areas of origin of *P. Manihoti* in Central and South America for it and its natural enemies. The importation of natural enemies against the pest followed by bionomic studies, mass cultures, large-scale releases and monitoring operations are the procedures underlying this program.

Exploration. An intensive search was carried out covering parts of Mexico, Guatemala, Honduras, Costa Rica, Venezuela and Colombia.

Potential host plants for *P. manihoti*, both cultivated and wild cassava, were investigated. Areas with the potential to bear *P. manihoti* extend between 30 degrees latitude N and S.

IITA's surveys of cultivated cassava and 13 species of related *manihoti* species yielded more than 20 species of CM, many of which had not been described before, 8 species of parasitoids and 3 species of predators. Furthermore, the CM in Latin America, which was previously regarded as *P. manihoti*, has been identified as *P. herreni*.

Mass culture of parasitoids. Failures in rearing parasitoids collected on the South American CM is explained

Cassava plant with heavy mealybug infestation. When the terminal shoot (the preferred part) is completely destroyed, the cassava mealybug moves to the leaves. Note the development of a fungus on the mealybug honeydew on the stem.

Predator mass culture. Daily check of predator development.

by the specificity of the parasitiods for *P. herreni* (new name for the CM in South America). The parasitiod that will control the African mealybug have yet to be found.

Mass culture of predators. Predators collected by the Commonwealth Biological Control Institute in South America were mass cultured in 80 cm × 50 cm × 50 cm wooded cages. Potted cassava plants infested with CM were placed in the cages.

Some cages were "breeding cages" in which only adult predators were confined to reproduce. When the young predator larvae hatched, the plants in these cages were removed and placed in "growth cages" for larval development and pupation.

More than 2,000 *Hyperaspis* sp. coccinellids were produced for releases. The culture will be extended for a production of up to 100,000 coccinellids per month in a first phase for research on biology and ecology and for releases around the year.

Release of natural enemies. The first mass release of 2,000 coccinellids of *Hyperaspis* sp. was done in an experimental field in Abeokuta. Further releases will be made year around at a rate of up to 50,000 coccinellids per month. Two techniques of release were carried out: (a) release of 1,000 adult coccinellids on 12 sites in a ½ ha cassava field; (b) release of 1.000 adult coccinellids on 12 plants in small cages fixed on the terminal shoot in ½ ha cassava field at 2-week intervals. Results of life table studies that are being carried out in the field to assess the population dynamics of CM and measure the impact of these releases will be available next year.

Bionomics. To carry out the program successfully, the details of life cycles, development thresholds, life spans, fecundity and behavior of both the CM and its natural enemies are important. Early findings on the CM are shown in Tables 8 and 9. The knowledge of the biological characteristics of each natural enemy will make early selection on species to be used under given ecological conditions possible.

Table 8. Effect of temperature on the development of CM (IITA, 1980).

Development stage	Duration in days 20°C	27°C
Egg	12.5 ± 5h*	6.7 ± 5h*
1st	9.14	6.4
2nd	6.8	4.3
3rd	6.7	4.2
4th	**	4.8

**Period of time between the moment females were placed on leaves and the removal of the eggs.*
***Not available when the report was written.*

Table 9. Effect of temperature and age on the fecundity of CM (IITA, 1980).

Age interval (days)	Avg. No. eggs/day 20°C	27°C
1-3	15.0	32.9
4-6	12.5	23.1
7-9	10.8	17.3
10-12	9.0	11.9
13-15	8.2	12.4
16-18	7.4	
*		

**To be continued.*

The population of CM was very high during the 1979-80 season in southern Nigeria, as shown by the number of dead and injured plants in 5 randomly selected fields on a farm in Abeokuta (Table 10).

Table 10. Number and percent of dead and injured plants after the 1979-80 dry season CM attack (Abeokuta, 1979-80).

Field #	Total # plants	Dead plants %	Severely injured plants %	Slightly injured plants %
1	1540	9.29	10.19	0.84
2	3460	19.36	10.29	2.72
3	3870	8.01	5.71	5.14
4	2160	13.75	10.05	6.71
5	1594	6.65	7.03	8.41
Total	12624	12.09 ± 0.29	8.42 ± 0.25	4.63 ± 0.18

From July to September, 3 cassava fields were sampled weekly in Abeokuta. In each field, 10 rows were randomly chosen, and the total number of plants as well as the number of plants showing curled leave, i.e., presence of *P. manihoti*, were counted.

Table 11 shows the total number of plants counted in each field and the number of plants with CM. The number of adult CM per infested plant ranged between 5-30.

Over the period investigated, 5-15 percent of the plants exhibited CM-infestation symptoms. These observations show that the CM is able to maintain a relatively high population throughout the rainy seasons, an average of 9.76 ± 0.52 percent of the plants being infested. The CM present were well-protected from the rain under the curled leaves.

Bunch-top symptoms persisted from the dry season through the rainy season. CM survives the rainy season in its normal life cycle; there are no quiescent or diapause stages.

Pathology

Cassava mosaic disease (CMD)—vector transmission frequencies

Effect of cultivar characteristics. A trial was conducted to determine the frequency of CMD transmission by whiteflies (*Bemisia tabaci*). Test plants free of CMD symptoms (henceforth, referred to as CMD free) were generated by rooting single node cuttings from seedlings of cultivars TMS 30395 and 60444. Each test plant was subjected to inoculation feeding by 25 CMD agent carrying whiteflies. For the whiteflies, the CMD agent came from the same source. The test plants were held under the same post-inoculation growing conditions of 25/18°C (day/night temperatures). The infection rate was determined 60 days after inoculation feeding by expression of the characteristic CMD symptoms. The trial was conducted twice.

In TMS 30395, CMD symptoms were seen on 25 percent of the plants in trial 1 and on 19.4 percent in trial 2. In 60444, CMD symptoms were seen on 58.3 and 48.5 percent of the plants, respectively, for the 2 trials (Table 12). These results indicate that the transmission frequency to field-resistant TMS 30395 was significantly less (based on arc sin transformation of the data) than field-susceptible 60444. These vector transmission data compare favorably with a 2-year average field CMD incidence of 16.1 percent in TMS 30395 established from CMD-free cuttings.

Table 12. Effect of cassava cultivar characteristics on the vector transmission frequency of CMD (IITA, 1980).

Test	Parent	No. of seedlings inoculated	No. of seedlings infected	Percent infection
1	TMS 30395	36	9	25.0
	60444	36	21	58.3
2	TMS 30395	36	7	19.4
	60444	35	17	48.6

Distribution of CMD agent in cassava plants. The distribution pattern of the CMD agent with plant tissue was determined by cutting and reestablishing stem pieces of seedling plants resulting from cultivars TMS 30395 and 60444 infected by artificial inoculation through *B. tabaci* transmission of the agent. The stems were cut into basal, middle and apical pieces at 90 days after they first expressed CMD symptoms and replanted separately in individual pots for symptoms redevelopment in whitefly-proof isolation units maintained at 25/18°C (day/night temperatures).

The results indicate that the CMD agent is localized in the basal part of the plant in seedlings resulting from cultivar TMS 30395 while it is continuous throughout seedlings from cultivar 60444 (Table 13).

Table 13. Distribution pattern of CMD agent in basal, middle and apical cassava stem pieces (IITA, 1980).

Cultivar	Seedlings tested	Percent CMD symptom expression in plants established from infected stem pieces		
		basal	middle	apical
TMS 30395	16	62	7	4
60444	38	97	76	71

Rate of field CMD-infection of CMD-free plants. The CMD-infection rate through transmission by *B. tabaci* feeding in plants of 6 varieties established from CMD-free cuttings and a highly resistant variety, TMS 30395,

Table 11. Number examined and percent of cassava plants infested with CM during the rainy season (Abeokuta, 1980).

Week #	Field #1 Sampled	Field #1 Found infested	Field #2 Sampled	Field #2 Found infested	Field #3 Sampled	Field #3 Found infested	X %	S.E. (±)
1	692	81*	1595	210	908	65	11.14	0.56
2	608	35	1475	102	944	50	6.18	0.44
3	627	91	1472	278	979	123	15.98	0.66
4	626	79	1566	276	961	144	15.83	0.65
5	560	75	1560	114	856	83	9.14	0.53
6	586	50	1367	33	834	39	4.38	0.39
7	605	82	1645	57	805	35	5.70	0.42
					Overall average		9.76	0.52

**Number of plants examined/number of CM infested plants.*

was investigated over a period of 180 days after planting (Fig. 3). The data, based on a sample of between 130-200 CMD-free plants at the onset of the trial, indicate that field CMD-infection rates at 30 days after planting range from 79.3 percent for TMS 30835 to 35.8 percent for TMS 30572. Field CMD-infection rates increase to between 90-100 percent after 180 days for all 5 varieties tested, except TMS 30395.

Yield reduction from cassava mosaic disease. A comparison was made of sample means of fresh root weight and green foliage weight, respectively, per plant from 20 randomly selected pairs of test plants from 7 improved cassava cultivars where each pair consisted of a plant established from a CMD-symptomless cutting and established from a CMD-infected cutting. The yield comparisons were made at 7 months after planting (Tables 14 and 15).

The differences in average green foliage weight between the paired plants was highly significant for 5 of the improved varieties tested. There were no significant differences in average foliage weight of CMD-free and CMD-infected TMS 30555 and TMS 30395 plants. The percentage reduction due to CMD ranged from 6.45 percent for TMS 30395 to 41.3 percent for TMS 30835.

The differences in average fresh root weight between the paired plants was highly significant for 6 of the improved varieties tested. There was no significant difference in root weight of CMD-free and CMD-infected TMS 30157 plants. The percentage reduction due to CMD ranged from 24.4 percent for TMS 30157 to 60.1 percent for TMS 30835.

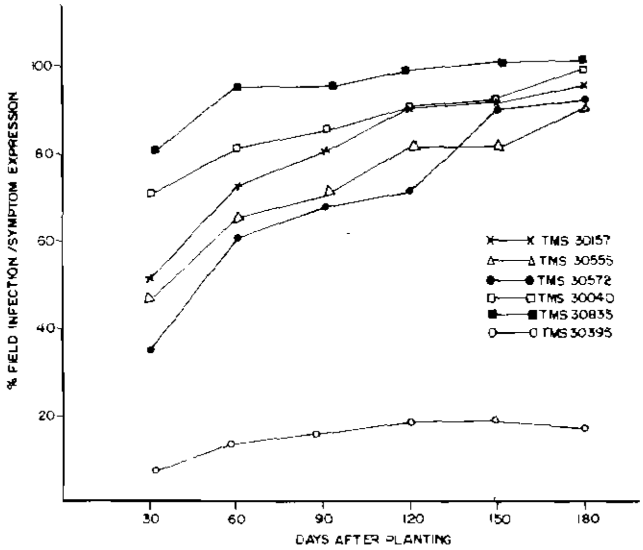


Fig. 3. Rate of CMD infection of CMD-free plants.

TMS 30395 has consistently shown the least reduction in fresh root yield among the improved varieties tested over 3 seasons, ranging from 27.0 percent to 32.0 percent. TMS 30157, based on the differences in average fresh root yield between plants established from CMD-free and CMD-infected cuttings, appears to have a high level of tolerance to CMD (Table 15).

Table 14. Effect of CMD on green foliage weight of 7 cassava varieties at 7 months after planting (IITA, 1980).

	Green foliage Wt./plant (kg) of plants established from:			
Cultivar	CMD-free cuttings	CMD-symptomed cuttings	Difference	% Reduction
TMS 30211	0.377	0.244	0.133** ± 0.006	35.2
TMS 30572	0.700	0.450	0.250** ± 0.011	35.7
TMS 30555	0.330	0.370	−0.040 ± 0.009	−10.8
TMS 30040	0.440	0.290	0.150** ± 0.008	34.0
TMS 30835	0.460	0.270	0.190** ± 0.009	41.3
TMS 30395	0.310	0.290	0.020 ± 0.007	6.45
TMS 30157	0.630	0.380	0.250** ± 0.003	39.5

***Significant at P = 0.01.*

Table 15. Effect of CMD on fresh root weight of 7 cassava varieties at 7 months after planting (IITA, 1980).

	Root Wt./plant (kg) of plants established from:			
Cultivar	CMD-free cuttings	CMD-symptomed cuttings	Difference	% Reduction
TMS 30211	1.600	0.855	0.745** ± 0.042	46.5
TMS 30572	3.050	2.090	0.960** ± 0.064	31.4
TMS 30555	1.560	1.000	0.560** ± 0.033e	35.8
TMS 30040	2.040	1.410	0.630** ± 0.050	30.8
TMS 30835	1.830	0.730	1.100** ± 0.040	60.1
TMS 30395	2.330	1.700	0.630** ± 0.041	27.0
TMS 30157	1.270	0.960	0.310 ± 0.043	24.4

***Significant at P = 0.01.*

There were significant correlations between fresh root and fresh foliage yield differences for TMS 30835 and TMS 30572 (Table 16).

Table 16. Simple correlations (r) between fresh root and fresh foliage yield differences due to CMD in 7 cassava varieties (IITA, 1980).

Variety	Mean root yield difference (kg/plant)	Mean foliage yield difference (kg/plant)	r
TMS 30835	1.10	0.19	0.748**
TMS 30572	0.96	0.25	0.703**
TMS 30211+	0.74	0.13	0.346
TMS 30555	0.56	−0.04	0.398
TMS 30040	0.63	0.15	0.214
TMS 30395	0.63	0.02	0.082
TMS 30157	0.31	0.25	0.485*

***Significant at P = 0.01.*
**Significant at P = 0.05.*

Cassava anthracnose disease (CAD)—epiphytic populations of *Collectotrichum manihotis* on cassava. Green symptomless cassava stem pieces collected from field grown plants were washed thoroughly in sterile water, air-dried and cut into 3 mm thick sections. The sections were surface sterilized in 95 percent ethanol and placed either on potato dextrose agar (PDA), bean pod agar (BPA), malt agar (MA), cassava leaf extract agar (LEA) or water agar (WA). Each test medium was put on 20 agar plates, each of which contained a stem section. The plates were incubated at 27°C for 6 days. The resultant mycelial growths on the incubated plates were transferred as small agar blocks from the margins of the plates to fresh PDA at 4-day intervals. Slide preparations made from the PDA cultures were examined under the compound microscope.

Collectotrichum manihotis conidia were consistently observed in slide preparations from a range of 20-60 percent of the stem pieces planted on the different media indicating the existence of epiphytic populations of the fungus in the field. The role of these epiphytic populations in the etiology and epidemiology of CAD disease is under investigation.

Nematology

Screening for root-knot nematode resistance

The available germplasm is being systematically screened for resistance to root-knot nematodes. Root-knot nematodes are ubiquitous in cassava growing areas and readily attack the plant feeder roots and occasionally the storage roots.

Stakes of 56 cassava lines were planted in the greenhouse in 23 cm diameter plastic pots in washed river sand. Six weeks later when new root growth was well developed, a first series was inoculated with *Meliodogyne incognita*, race 2, and a second series was inoculated with *M. javanica*. The inocula consisted of 15,000 eggs per pot.

The plants were grown in the greenhouse in a controlled temperature table at 26 ± 1°C sand temperature. Plant tops grew at ambient temperature. After 5.5 months exposure to root-knot nematode attack, the sand was sampled to determine the numbers of root-knot nematode juveniles in each pot. The roots were removed, washed free of sand and subjectively rated for the degree of root gall development. The nematode reproductive rate was estimated by an egg count from the roots of each plant. Eggs were separated from the roots using the sodium hypochlorite-agitation method and their numbers estimated by the dilution method.

The IITA Block F groundbeds (10 m × 15 m) were each separately inoculated with 1 of the 2 species of root-knot nematodes and planted to tomato for nematode establishment and population increase. After 8 weeks, seeds of cassava were planted 45 cm apart in the row with 45 cm between rows. After 5 months growth, the plants were uprooted, the roots removed, washed free of soil and subjectively rated for root gall development.

In the greenhouse, all cultivars were highly susceptible to 1 or both root-knot nematodes with exception of a single susceptible rating (Tables 17 and 18).

As all the lines tested were susceptible (S) or highly susceptible (HS) to 1 or both of the root-knot nematodes, none of the germplasm is suitable as a source of resistance in a cassava improvement breeding program.

Table 17. Cassava representative resistance/susceptibility test ratings in greenhouse screening trials with the root-knot nematode,* Meloidogyne incognita, *race 2 (IITA, 1980).

Cassava designation	Resistance rating	Egg count per plant	Root-knot index	Juveniles per liter of soil
60741	HS	104,000	3.2	1,543
52026	HS	102,000	3.6	309
60121	HS	88,000	3.6	2,777
63385	HS	88,000	3.0	926
u/1421	HS	86,000	3.8	4,629
4(2)0378	HS	81,000	3.6	540
4488	HS	72,000	3.6	1,234
40160	HS	70,000	3.8	7,098
4(2)0763	HS	69,000	3.8	5,555
40081	HS	69,000	3.6	1,852

Table 18. Cassava representative resistance/susceptibility test ratings in greenhouse screening trials with the root-knot nematode,* Meloidogyne javanica *(IITA, 1980).

Cassava designation	Resistance rating	Egg count per plant	Root-knot index	Juveniles per liter of soil
60741	HS	110,000	3.6	10,801
4(2)0763	HS	91,000	3.6	15,430
60142	HS	87,000	3.0	694
52026	HS	58,000	3.4	225
30001	HS	50,000	3.4	5,863
61469	HS	47,000	3.4	8,024
61513	HS	42,000	3.2	4,629
61898	HS	39,000	3.6	1,466
63385	HS	35,000	3.4	154
60776	HS	32,000	3.6	25,922

Cassava as a suitable host for the root-knot nematode was best estimated by the number of eggs isolated from each plant (Tables 17 and 18). The root-knot index and the numbers of juveniles per plant showed extreme variations and should be used as susceptibility or resistance criteria in conjunction with the egg count (Tables 17 and 18).

Root-knot index means and eggs-per-plant means show that *M. incognita* is more aggressive than *M. javanica*. This is in line with observations on other food crops (Table 19).

Table 19. Cassava test means for resistance/susceptibility to the root-knot nematodes,* Meloidogyne incognita, *race 2 and* M. javanica. *Means of 41 plants for each species (IITA, 1980).

Nematode	Mean no. eggs/plant	Root-knot index mean	Mean no. juveniles per liter of soil
M. incognita	39,817	3.09	2,206
M. javanica	24,713	2.86	3,107

In the groundbeds, the feeder roots of seedling cassava proved difficult to collect, and the mean number of eggs per plant and the root-knot index means of 232 plants for each of the 2 nematode species were inadequate to determine plant resistance or susceptibility status (Table 20).

The experience with growing cassava seedlings in groundbeds for resistance testing shows that the plant can be screened easier and more reliably in the greenhouse.

Table 20. Seedling cassava groundbed score means for resistance/susceptibility to the root-knot nematodes,* Meloidogyne incognita, *race 2, and* M. javanica. *Means of 232 plants for each species (IITA, 1980).

Nematode	Mean number eggs/plant	Root-knot index mean
M. incognita	238	2.88
M. javanica	17	1.50

Tissue culture and virus indexing

Distribution of cassava for international testing

The etiology of CMD has not been fully resolved. It is, however, clear that: (a) symptom expression is good at 20-25°C, (b) virus can be isolated only from the tissue that expresses CMD symptom, (c) apical meristem does not usually contain the virus unlike the fully grown tissues, (d) heat treatment minimizes the location of the CMD agent in the apical meristem and (e) the putative CMD agent is sap-transmissible to *N. benthamiana*.

Using the above set of information, a CMD-indexing technique has been developed whereby it is possible to obtain "CMD-free" cassava in a tissue culture form. This procedure (outlined below) meets with the quarantine requirements of Nigeria and phytosanitary certificates have been issued to 4 clones so far determined to be CMD-free. It is planned to distribute these materials only within Africa in response to requests from national programs.

To obtain the virus free cassava plants through meristem tip culture, cassava cuttings were planted in a growth chamber at 35°C for 1 month. Apical buds were excised and surface sterilized for 2 minutes in 70 percent ethanol and for 20 minutes in a 5 percent filtered solution of calcium hypochlorite. Meristem tips of about 0.3 mm were then asceptically dissected and cultured in 16 mm × 125 mm glass culture tubes containing 5 ml of Kartha and Gamborg medium additioned with myoinositol, 100 mg; Adenine sulfate dihydrate, 80 mg; thiamine HCl, 0.1 mg; pyridoxine HCl, 0.5 mg; nicotinic acid, 0.5 mg; and glycine, 2 mg; the pH was adjusted to 5.7 ± 0.1 before sterilization. After 4 to 6 weeks of growth in a culture room with white fluorescent lamps giving 5,000 lux at plant level at 29°C by day and 24°C by night with a photoperiod of 12 hours, plantlets reached the height of 3-5 cm and were then transferred to a mixture of sand and vermiculite in a humidity chamber. They were kept there for about 10 days and then transferred to an insect-free isolation room.

The temperature in the isolation room was kept between 20-25°C, which is favorable for symptom expression of CMD. If no symptoms were observed over a period of 8 months, they were considered virus free. An additional test was done by mechanical inoculation of sap from the apex of the cassava plant on *Nicotiana benthamiana*.

The distribution is done in tissue culture to African national program for international testing. Single node cuttings of virus-free plants are cultured in plastic tubes containing 10 ml of the medium with the following composition per liter: Murashige and Skoog salts solution; sucrose, 30 g; mycinositol, 100 mg; thiamine HCl, 0.1 mg; pyridoxine HCl, 0.5 mg; nicotinic acid, 0.5 mg; glycine, 2 mg; and agar, 8 g. The pH was adjusted to 5.7 ± 0.1 before sterilization. The culture conditions were as described for the meristem tip culture.

These plants can be transferred to soil when they arrive in the recipient country. The tubes are accompanied by the import permit, the phytosanitary certificate and a handbook with recommendations on the handling of the material.

Zaire's National Manioc Program (PRONAM)

Genetic improvement

Seedling and clonal evaluations and yield trials were conducted at many locations in the Bas-Zaire, Bandundu and Kasai regions, and promising clones were identified. Clone A56 consistently produced the highest tuber yield with 20 t/ha over 8 environments (Table 21), and it was but one of 7 clones that outyielded the local variety in the Bas-Zaire region. Three varieties selected by PRONAM outyielded the local variety in the Bandundu region, and early yield trials of varieties selected show

Table 21. Tuber yield (t/ha) of 15 clones in the final yield trial over 8 environments.

	Environments								
Clones	1	2	3	4	5	6	7	8	Average
A 56	37.1	-	16.4	16.3	14.9	5.8	25.8	16.4	19.95
179/2	37.7	15.5	15.9	11.3	14.5	11.8	23.6	11.2	17.69
70/4	36.1	12.6	19.5	14.7	16.5	9.2	21.0	8.0	17.20
344/6	42.5	14.8	12.3	11.0	13.4	7.9	21.5	8.7	16.51
Coll. 45	23.1	-	20.0	11.8	14.1	7.0	21.6	11.5	15.58
174/2	33.1	18.1	11.2	9.8	12.4	10.5	18.0	6.8	14.99
122/2	26.4	12.0	14.3	11.0	14.1	10.9	21.3	8.7	14.84
Mpelolongi	25.5	7.7	16.9	12.6	11.1	6.0	24.0	-	14.83
429/7	24.6	12.2	18.2	11.0	11.9	8.1	16.8	14.0	14.6
280/7	27.4	8.9	15.6	10.6	9.6	5.1	25.4	12.7	14.41
30085/28	15.3	13.2	13.0	10.7	12.8	5.9	27.4	9.9	13.53
02864	20.8	10.5	13.5	10.7	13.6	7.2	18.5	13.1	13.49
B 136	24.8	-	8.1	7.2	11.1	6.6	21.1	8.3	12.40
30093/1	13.4	13.4	13.6	11.3	13.6	5.2	13.1	9.7	11.66
30261/11	13.2	12.9	12.3	9.4	9.0	7.4	19.2	6.2	11.21

Environments: 1 Mankewa 1977-78 2 Mpalukidi 1977-78 3 Mankewa 1979
4 Mpalukidi 1978-79 5 Mankewa 1979-80
6 Mpalukidi 1979-80 7 Mimpese 1978-79
8 Gimbi 1979-80

promising results in comparison to the best local variety in the Kasai region.

Not only are these varieties promising for their high yields but some for their resistance to CMD, CBB, CAD and 2 extremely important insects that cause severe yield reduction—CM and CGM—as well as now a suspected disease.

CM resistant clones. New sources of resistance to CM have been identified in cultivated cassava. On the basis of negative field screening of cassava seedlings, 123 plants with least CM damage were selected. Further screening of the clones established from the selected plants under artificial infestation with CM showed a clear difference between national program selections, 02864, and the CM-resistant seedlings. The scoring distribution of these selected seedlings against CM is presented in Table 22.

Table 22. Distribution of scores for 105 selected seedlings against CM in the field.

	Scores						
Pest	1	2	3	4	5	Total	p̂
CM	13	41	41	10	0	105	.64

Planted as a susceptible check, 02864 consistently showed a score of 4 and could be marked clearly in the field from a distance. About 13 percent of the selected plants maintained their resistance to CM. Furthermore, 21 out of 105 clones tested showed multiple resistance (scores 1-2) to CMD, CGM and CM.

Fifty-five seedlings showing a score of 1-2 in the field were cloned and further tested for CM resistance in the greenhouse. After artificial infestation with CM, these clones were scored from 2 to 12 weeks with the following results (Table 23).

The greenhouse screening results confirm that certain clones possess CM resistance. It is, however, important to mention that CM were present on the lower surface of the leaves of these resistant clones.

Table 23. Distribution of scores for 55 selected clones against CM in the greenhouse.

	Weeks after infestation					
Score	2	4	6	8	10	12
1	0	0	0	0	0	0
2	48	36	26	21	18	18
3	7	19	28	26	27	26
4	0	0	1	8	8	5
5	0	0	0	0	2	6
Total	55	55	55	55	55	55

CGM resistant clones. The seedling and clonal nurseries and the preliminary yield trial planted at different times in the Kasai region were screened against CGM. Early planted material (5-7 months old) had the least CGM damage, but late planted material (2-3 month old) showed variation in the degree of attack. Ten clones—PYT 60882/4, PYT60965, 60965/6, GPTMS 51460/1, GPTM × 20949/6, TMS 50860/3, GPHS 5033/14, S 097, KADO and KAZE—showed the best tolerance.

Disease resistant clones. Along with screening for resistance to CMD, CBB, CAD, CM and CGM, clonal evaluation and yield trials were conducted. Some levels of resistance were also detected for a disease that has as yet an unknown etiology. The disease symptoms begin with growing tissues on the tertiary branches from 5 to 6 leaves from the plant's tip. Later, the leaves above this site begin to drop off, and, finally, the stem begins to die. The last disease symptoms appear very much like tip die-back in severe CBB infestation. Unlike CBB, however, no gum exudation is observed on the stem.

The disease appeared in an epidemic form in the Bas-Zaire and Bandundu regions. Scoring of clones in a preliminary yield trial showed the following results (Table 24).

Table 24. Scoring of clones in preliminary yield trial against the disease.

	Scores						
	1	2	3	4	5	Total	$\hat{p}$
Frequency	2	9	22	24	15	71	.35

The results show that a majority of the clones are susceptible to the disease. However, several clones showed resistance.

Fifteen clones in the final yield trial were planted in the middle of December in 2 soil types. Scoring of these clones in the 2 areas showed that the disease is more serious under poor, sandy, soil conditions (Table 25).

Table 25. Comparative scores of 15 clones grown in 2 different soil types.

	Scores						
Soil	1	2	3	4	5	Total	$\hat{p}$
Mankewa (fertile silty loam)	4	7	4	0	0	15	.75
Mpalukidi (sandy)	1	6	6	1	1	15	.58

Cassava planted in the end of January and later did not show disease symptoms, thus suggesting that disease appearance has some relation to plant age.

The disease scores for the clones that outyielded the local variety in the Bas-Zaire region in comparison to 02864 are presented in Table 26. The improved varieties showed tolerance to susceptibility to the disease. Even with the existing tolerance level, high yields can be achieved provided the planting is done in October-November.

Table 26. Disease scores for 7 high-yielding varieties.

	Location	
Variety	Mankewa	Mpalukidi
A56	2.9	2.9
179/2	1.3	1.5
70/4	1.8	2.8
344/6	2.1	3.3
Coll. 45	1.4	2.4
174/2	1.4	2.3
122/2	1.6	2.0
02864	3.1	3.4

Quality evaluation

The best 7 varieties and the national program selection, 02864, in a final yield trial at Bas-Zaire were tested for the quality of their preparation of 'chikwangue' (Ndika and Nsesa), 'fufu' and leaf 'pondu.' The taste scores given by the individuals in the taste panel were quite variable. The average taste scores in respect of Chikwangue, fufu and pondu preparations are given in Table 27. The fufu prepared from the tubers of variety collection 45 was considered to be the best. The fufu prepared from tubers of varieties 174/2, 122/2 and A 56 were below the level of acceptability. The above varieties, however, gave very good preparation of Chikwangue (Ndika). Chikwangue (Nsesa) from 6 of 7 varieties was as good as from the variety 02864. The pondu prepared from the leaves of variety A 56 was liked the most while variety 179/2 was liked the least. Pondu from the leaves of variety collection 45 was also not liked by the taste panel.

Table 27. Tuber and leaf preparation quality for 7 high-yielding varieties.

			'Chikwangue'		
Variety	Root taste	'Pondu'	Ndika	Nsesa	'Fufu'
A 56	Sweet	Very good	1.8	1.7	0.6
179/2	Bitter	Bitter	1.9	2.0	1.8
70/4	Sweet	Good	1.9	0.9	1.0
344/6	Sweet	-	1.6	2.0	1.8
Coll. 45	Bitter	Not liked	1.9	1.6	2.0
174/2	Sweet	-	1.9	1.2	0.4
122/2	Sweet	Very good	2.1	1.5	0.2
02864	Sweet	Good	1.6	1.8	1.6

3 = best
2 = better
1 = good
0 = not liked

Cameroon National Root Crops Improvement Program (CNRCIP)

Genetic improvement

At its 2 regional centers in Cameroon—Nkolbinsson and Nyombe—over 60,000 seedlings were raised in the Nkolbinsson region and 16,000 in the Nyombe region. Seedling and clonal evaluations and yield trials were conducted at many locations within the areas of these regional centers, and promising clones were identified. In the Nkolbinsson region, local cultivar Otele 1 showed the highest average yield with 61.5 t/ha and a mean CMD infection of 1.49 (Table 28).

Table 28. Yield, mean tuber weight and mean CMD infection of the 7 best local clones evaluated (Nkolbinsson 1979-80).

Clone	Yield t/ha	Fresh root size in weight (g)	CMD score
Otele 1	62	654	1.5
Etoudi 2	53	854	1.8
White en Monyo	47	398	0.8
Alot Bikon	47	657	1.3
Ekali 6	46	303	0.9
Ekali 1	39	448	1.3
Mbong Avie 1	36	563	1.1

Yam

Improving the yield, quality and storability as well as the resistance to virus, scorch and nematodes in yams is among the major concerns of IITA's yam research program.

Genetic improvement

White yam (*Dioscorea rotundata*)

Hybridization, evaluation and selection of white yam continued at 2 sites; IITA and Mokwa, Nigeria, in 1980. Staked and unstaked yield trials were grown at IITA while only unstaked yield trials were grown at Mokwa.

A total of 600 seedlings out of 900 representing 66 families were selected from the nursery beds for the hill trials next year. Because of the limited population size, selection pressure was reduced.

In the unstaked yield trials at IITA, 6 (from 41), 14 (from 26) and 4 (from 10) clones were selected from the hill trials, preliminary yield trials and intermediate yield trials, respectively, for further testing next year. The clones in the intermediate yield trial had a mean fresh tuber yield of 7 t/ha (Table 29). Only clone R17-76-367 outyielded the standard local variety Nwapoko in the trial.

In the unstaked yield trials at Mokwa, 10 clones, including the local cultivars Angbara and Gbangu were tested in an intermediate yield trial. All of IITA's clones, except for 2, outyielded these local cultivars. One IITA improved clone yielded 32 t/ha, which was twice that of the local checks. Three clones were selected for further testing. In the staked yield trials at IITA, 21 (from 72), 29 (from 82) and 8 (from 18) clones were selected from the hill trials, preliminary yield trials and the intermediate yield trials, respectively, for further testing next year. The clones in the intermediate yield trial had a mean fresh tuber yield of 22 t/ha.

Table 29. Intermediate yield trial of unstaked white yam (IITA, 1980).

Clone	Fresh tuber yield t/ha	Scorch score*
R17-76-367	16.6	3
Nwapoko	12.0	3
W44-D220	9.6	3
R16-213-373	5.0	3
TDr 821	4.4	4
W44-D153	4.2	3

**Subjective score from 1-5; 1 = No damage by scorch; 5 = Severe damage.*

Table 30 shows the result of the staked advance yield trial where Nwapoko and TDr 821 were used as checks. The clones were planted at 1 m × 1 m spacing in a randomized complete block design with 3 replications and 10 plants per plot.

The results indicate that 3 clones outyielded the checks. The performance of clones selected at Mbiri, Nigeria, tested at IITA are shown in Table 31. TDr S-4002-9 showed a high resistance to scorch; they had high yields.

Water yam (*Dioscorea alata*)

The most promising 27 clones of water yam that flower and have high-scorch resistance were maintained in a crossing block. Many hand crosses were made at peak flowering. At the beginning of the dry season, they were watered in an attempt to prolong growth duration. Some seeds were obtained.

The multiplication of 3 of the leading water yam clones, TDa 291, TDa 310 and TDa 297, continued in 1980. Plans to distribute them to institutions were made.

The result of the staked advanced yield trial of *D. alata* at IITA is shown in Table 32. Although TDa 291 and TDa 297 showed high resistance to scorch, they were the lowest yielders. TDa 251 and TDa 204 had the highest fresh tuber yield of 44 and 39 t/ha, respectively. These clones will be multiplied next year.

Table 30. Advanced yield trial of staked white yams (IITA, 1980).

Clone	Fresh tuber yield t/ha	SCORES* Scorch	Virus	Nematode
W 512	30.3	2.3	2.7	4.0
TDr 779	29.3	1.9	2.3	2.7
TDr 819	25.1	2.3	1.7	2.7
Nwapoko	24.1	1.9	2.4	1.0
TDr 148	24.6	2.2	1.8	3.0
R16-215-16	22.0	2.9	2.9	2.3
W4-B58	20.1	2.9	3.3	3.3
R16-215-148	20.7	3.2	2.6	4.0
TDr 667	17.0	1.0	0.2	0.6
TDr 821	7.7	4.0	3.4	4.7

**Subjective scores from 1-5; 1 = No damage by scorch, virus or nematode; 5 = Severe damage.*

Table 31. Advanced yield trial of staked white yam clones selected at Mbiri (IITA, 1980).

Clone	Fresh tuber yield t/ha	SCORES* Scorch	Virus
TDr-819	31.6	4.3	2.6
TDr-4002-9	29.0	1.0	3.0
TDrS-4001-40	15.3	5.0	2.6
RB6-114-1052	37.8	5.0	3.0
TDrS-4001-C226	35.9	5.0	2.6

**Subjective score from 1-5; 1 = No damage by scorch, virus or nematode; 5 = Severe damage.*

Table 32. Advanced yield trial of staked water yam (IITA, 1980).

Clone	Fresh tuber yield (t/ha)	Scorch score*
TDa 251	44.4	2.5
TDa 204	38.7	3.0
TDa 5	31.1	2.6
TDa 310	27.3	2.5
TDa 291	22.9	1.5
TDa 297	11.1	1.5

**Subjective score from 1-5; 1 = No damage by scorch; 5 = Severe damage.*

The result of the unstaked intermediate yield trial is shown in Table 33. TDa 5 gave the highest yield under unstaked conditions at IITA although the incidence of scorch was high. The selection for high-yielding water yam under unstaked condition will continue next year. The clones TDa 291 and TDa 310 have excellent tuber shape (round and uniform), which is regarded to be important for mechanical harvesting and processing.

Table 33. Intermediate yield trial of unstaked water yam (IITA, 1980).

Clone	Fresh tuber yield (t/ha)	Scorch score*
TDa 5	24	4
TDa 251	13	4
TDa 297	22	2
TDa 291	23	−2

Subjective score from 1-5; 1 = No damage by scorch; 5 = Severe damage.

Cluster yam (*Dioscorea dumetorum*)

Cluster yam breeding is still on a small scale. Hill trials and preliminary yield trials consisted of 11 clones. Selections from these based on cluster size and shape, smoothness and nematode resistance were made for further testing. Thirteen clones were tested in the staked intermediate yield trial at IITA. Ten of these clones gave very high yield, fresh weight basis, and based on the above mentioned characteristics, they have been selected for the advance yield trial next year. A few of these clones produced a reasonable number of seeds, which will continue to be used in the breeding program.

Presprouted setts

An experiment was conducted in order to determine the effect of presprouting on water yam yield and number of tubers of TDa 291. The setts were divided into 2 batches, presprouted and control, and were planted in a randomized complete block design with 6 replications. The control yielded 36 t/ha of fresh tuber compared to 29 t/ha for the presprouted. However, the number of tubers for the presprouted was more than the control, each giving 22 and 16 tubers, respectively.

Pathology

Foliar necrosis disease

The etiology of the disease of *D. alata* generally described as "anthracnose," "scorch" or "lightening" never has been adequately and convincingly determined. Attempts to induce the characteristic symptoms by artificial inoculation with various fungi normally associated with these symptoms have been unsuccessful. The results of field and laboratory studies at IITA in 1980 on the etiology of *D. alata* foliar necrosis follow.

Association between early necrotic spotting and subsequent prevalence and severity of foliar necrosis. The degree of association between the magnitude of foliar necrotic spotting in *D. alata* foliage during early season growth and the subsequent prevalence of severity of foliar necrosis in 8 *D. alata* clones was determined from counting: (1) the average number of necrotic spots on randomly selected leaves (2 per plant) from 10 plants of each clone during May and June; (2) the total number of leaves with foliar necrosis symptoms from the 10 plants during July and August and (3) the foliar necrosis severity score (0-5 scale of increasing severity) from the 10 plants (Table 34). The linear multiple regression analysis of the data indicates that there were no significant associations between the magnitude of foliar necrotic spotting in *D. alata* foliage during early season growth and

***Foliar necrotic spotting in* D. alata.**

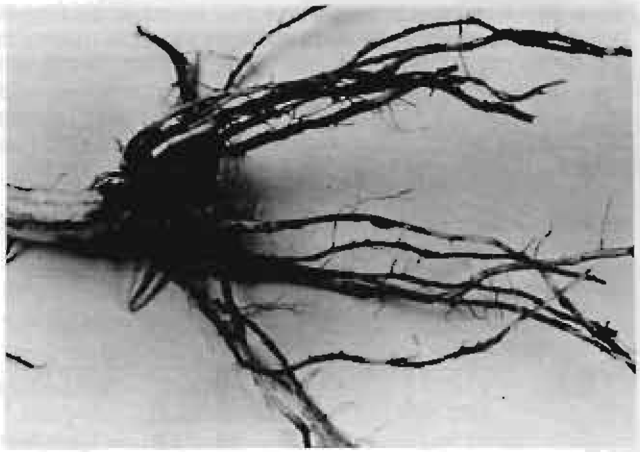
the subsequent prevalence or severity of foliar necrosis in the 8 *D. alata* clones evaluated. There was, however, a significant correlation (r = 0.8) between the prevalence of foliar necrosis and the severity. The data and analysis of results indicate that subsequent prevalence or sever-

Table 34. Prevalence of necrotic spotting and subsequent prevalence and severity of foliar necrosis in* D. alata *(IITA, 1980).

Clone	Mean of necrotic spots	Prevalence of foliar necrosis	Severity rating
TDa 200	114.0 ± 17.79	19.1 ± 1.59	3.4 ± 0.34
TDa 291	128.5 ± 15.44	7.5 ± 0.05	1.0 ± 0
TDa 297	46.8 ± 8.34	1.7 ± 0.97	0.3 ± 0.15
TDa 300	105.8 ± 8.08	18.5 ± 1.90	3.1 ± 0.38
TDa 310	9.4 ± 3.50	6.6 ± 0.83	1.5 ± 0.31
TDa 251	120.8 ± 16.72	13.0 ± 1.89	1.9 ± 0.28
TDs Sasa	21.5 ± 8.80	3.1 ± 0.92	0.7 ± 0.15
TDa 5	138.2 ± 13.30	10.6 ± 1.60	2.2 ± 0.29

***Foliar necrosis in* D. alata.**

Healthy D. alata *roots.*



D. alata *roots with extensive necrosis.*

ity of foliar necrosis in *D. alata* are independent of the magnitude of foliar necrotic spotting during early season growth.

Association between onset of tuberization and severity of foliar necrosis in *D. alata*. The degree of association between the onset of tuberization and the severity of foliar necrosis in *D. alata* was determined by the Cramer estimate of association analysis. The data used was for severity ratings in each of 20 plants for 3 unnamed clones and presence or absence of evidence of tuberization in each of the test plants at 4 months after planting (Table 35).

The Chi square analysis of the data indicate that there was no significant association between onset of tuberization and severity of foliar necrosis in *D. alata* for the 3 clones evaluated.

Association between root necrosis and prevalence of foliar necrosis in *D. alata*. The degree of association between root necrosis and the prevalence of foliar necrosis in 3 clones of *D. alata* was recorded in July, 4 months after planting. There was no significant association determined by Fisher's Exact Test for a 2 × 2 table (Table 36).

The data indicate that under the conditions in which the test was done, foliar necrosis was independent of root necrosis.

Table 35. Test of association between onset of tuberization and severity of foliar necrosis in* D. alata *(IITA, 1980).

Clone	Evidence of tuberization	Plants with severity scores 1	2	3	Total plants observed	Chi squared W 2df	V	SD
Clone 1	+	27	8	5	40	4.18	0.264	± 0.126
	−	8	7	5	20			
		35	15	10	60			
Clone 2	+	37	12	15	54	0.86	0.120	± 0.275
	−	3	2	1	6			
		40	14	16	60			
Clone 3	+	17	6	1	24	1.05	0.133	± 0.176
	−	24	7	5	36			
		41	13	6	60			

+ Evidence of tuberization; − no evidence of tuberization.
V = Cramer coefficient of association must lie between 0 and 1 inclusive, 0 indicates no association and 1 complete association.

Table 36. Association between foliar necrosis and root necrosis in D. alata (IITA, 1980).

Clone	Evidence of foliar necrosis	Evidence of root necrosis			Prob.
Clone 1	+a	4	2	2	0.068 NS
	−a	16	6	10	
		20	8	12	
Clone 2	+a	3	2	1	0.2 NS
	−a	17	8	19	
		20	10	20	
Clone 3	+a	6	6	0	0.077 NS
	−a	14	8	6	
		20	14	6	

(+a)—Evidence of foliar necrosis, (−a)—no evidence of foliar necrosis out of 20 plants evaluated for each clone.

Association between level of tuber maturity and severity of foliar necrosis in *D. alata*. The degree of association between the level of tuber maturity and the severity of foliar necrosis in 3 *D. alata* clones was determined by the proportional reduction in error test. The data used were for tuber maturity at 6 months after planting and foliar necrosis severity scores (0-5 scale of increasing severity). The proportional reduction in error $\lambda C/R$ for each clone was calculated (Table 37).

The data indicate no significant association between the 2 parameters for clones 1 and 3 and a possible slight association ($\lambda C/R = 0.4$) in clone 2.

Relationship of leaf age with prevalence and severity of foliar necrosis in *D. alata*. The prevalence and severity of foliar necrosis was recorded for 3 *D. alata* clones, TDa 300, TDa 251 and TDa 5, on leaves at 3, 10, 15, 20 and 25 days after they were fully expanded during June-August (Table 38). Leaves of all the ages monitored developed necrotic lesions during the observation period, and the results indicate that the characteristic "scorch" symptoms (necrotic lesioning and total lamina necrosis) were expressed as early as 3 days after the leaves became fully expanded.

Effect of shading on prevalence and severity of foliar necrosis in *D. alata*. The prevalence and severity of foliar necrosis in 3 *D. alata* clones under 3 shading treatments, (1) zero shading—(100 percent natural light), (2) 20 percent shading—(80 percent natural light) and (3) 30 percent shading—(70 percent natural light), was monitored over a period of 9 months (Table 39). Analysis of variance

Table 37. Proportional reduction in error test for association between degree of tuber maturity and severity of foliar necrosis in D. alata (IITA, 1980).

Clone	Evidence of tuber maturity	No. of plants with foliar necrosis severity score	0	1	2	3	λ C/R
1	+	39	1	6	22	10	0.257
	−	21	12	5	3	1	
		60	13	11	25	11	
2	+	38	0	2	21	15	0.400
	−	22	0	18	4	0	
		60	0	20	25	15	
3	+	21	0	13	5	3	0.032
	−	39	17	16	6	0	
		60	17	29	11	3	

$\lambda C/R$ is the relative improvement in predicting the foliar necrosis severity when degree of tuber maturity is known.
$\lambda C/R = 0$, no association.
$\lambda C/R = 1$, complete association.
+ evidence of tuber maturity, − evidence of tuber immaturity.

Table 39. Effect of shade on the prevalence and severity of foliar necrosis in D. alata (IITA, 1980).*

Treatment	Clone	Foliar necrosis: Mean prevalence No. of leaves/plant	Mean Severity 0-5 scale
1	1	14.6	1.33
	2	19.5	1.57
	3	6.0	1.11
2	1	15.8	1.27
	2	12.8	1.38
	3	12.8	1.21
3	1	20.6	1.21
	2	4.8	1.15
	3	13.3	1.34

**Shade was provided by screen mesh with varying mesh sizes.*
Mean prevalence and severity scores from 6 reps./clone/treatment with 1 plant/rep.

Table 38. Prevalence and severity of D. alata foliar necrosis at various stages of leaf development (IITA, 1980).

Variety	3 days A	3 days B	10 days A	10 days B	15 days A	15 days B	20 days A	20 days B	25 days A	25 days B
TDa 300	57%	1.0	71%	1.0	100%	1.0	100%	1.0	100%	1.0
TDa 251	75%	1.0	87%	1.4	100%	1.5	87%	1.5	100%	1.8
TDa 5	50%	1.0	90%	1.1	100%	1.3	100%	1.5	100%	1.8

Prevalence and severity of foliar necrosis on leaves.

Severity rating based on a scale of 0-5 increasing severity where 0 = no necrosis and 5 = total lamina necrosis.
A = Prevalence of foliar necrosis in percent of leaves of total number of leaves/plant.
B = Severity score.

indicates that there were no significant differences in the prevalence or severity of foliar necrosis due to shading in any of the 3 clones evaluated.

Prevalence and severity of foliar necrosis in *D. alata* clones. The percentage of prevalence (percent of total number of leaves/plant and the severity rating 0-5 scale of increasing severity) were monitored in 8 *D. alata* clones during their growth cycle up to 6 weeks prior to harvesting. The data indicate that under field conditions at IITA, foliar necrosis prevalence ranged from 2.3 percent of the total leaves/plant with necrosis (TDa 297) to 53.7 percent (TDa 300) (Table 40). Both TDa 300 and TDa 310 were rated 3.5 on the foliar necrosis severity scale compared to a rating of 1.0 for clones TDa Sasa, TDa 297 and TDa 291, respectively.

Table 40. Incidence and severity of foliar necrosis in 8 D. alata clones 6 weeks prior to harvesting (IITA, 1980).

	Foliar necrosis		
Clone	% Incidence necrotic leave/plant	Severity rating 0-5 scale	Mean tuber yield kg/plant
TDa 5	24.7 (806.5)	2.5	2.2
TDa Sasa	5.7 (649)	1.0	3.9
TDa 251	42.8 (603)	3.0	3.1
TDa 310	50.6 (167.5)	2.5	1.4
TDa 300	53.7 (555)	3.5	2.4
TDa 297	2.3 (912.5)	1.0	3.1
TDa 291	14.3 (680.5)	1.0	4.0
TDa 200	48.2 (449.5)	3.5	2.8

Represents average number of total leaves/plant for each clone.
Prevalence and severity ratings determined from 2 plants/clone and mean yield from 20 plants/clone.

Effect of Benomyl application on the prevalence and severity of foliar necrosis in *D. alata.* The prevalence and severity of mixed cultivars of foliar necrosis in *D. alata* was monitored and recorded following 5 foliar spray applications of 500 g Benomyl/ha a.i. at 14 day intervals. The spraying schedule was from June to August. The development of foliar necrosis during this period in treated plants compared to that in untreated plants is presented in Table 41.

The prevalence of foliar necrosis at the start of the observation period was 2-7.7 percent (33/119) for the untreated plants compared to 29.0 percent (34/117) for the treated plants. The severity ratings (0-5 scale of increasing severity) were 1.73 and 1.18, respectively. At the termination of the Benomyl treatment, 90 days after the first treatment, the incidence was 93.2 percent (111/119) and 97.4 percent (114/117) for the control and Benomyl treatments, respectively, and the severity ratings were 2.13 and 2.21, respectively.

Table 41. Effect of Benomyl on the prevalence and severity of D. alata foliar necrosis (IITA, 1980).

	Incidence	Severity Rating	Incidence	Severity Rating
Treatment	1/7/80		28/8/80	
Untreated	33/119 (27.7%)	1.73	111/119 (93.2%)	2.13
Benomyl	34/117 (29.0%)	1.18	114/117 (97.4%)	2.21

Severity rating based on a 0-5 scale of increasing severity.

These results indicate that under IITA conditions, Benomyl application at 14-day intervals over a period of 90 days between June and August did not reduce the prevalence and severity of foliar necrosis in *D. alata.*

Effect of soaking treatments on leaves of *D. alata.* *D. alata* leaves were detached from screenhouse and field-grown plants at various stages of growth and tested for their reaction to soaking treatments. All test leaves were surface sterilized in a filtered solution of 4 percent calcium hypochlorite for 5 minutes and rinsed twice in sterile distilled water and then subjected to the soaking tests. All soaking tests were conducted in 14 cm diameter polystyrene petri dishes in a laboratory maintained at 26°C ± 2°C with a light intensity that varied from 600-2,000 Lux. The results from the 6 soaking tests are as follows:

Test 1. Leaves from all 8 clones, TDa 291, TDa 251, TDa 300, TDa 5, TDa 200, TDa 310 and TDa Sasa, soaked in ordinary tap water developed necrotic lesions and diffuse foliar necrosis (Table 42) in some instances, in less than 24 hours after the start of the treatment.

The mean incidence of necrotic lesions for all clones tested was 31.2 percent, and that of diffuse foliar necrosis was 23.7 percent. Forty-five percent of all leaves tested did not develop any foliar reaction after 7 days. Clones TDa 200 and TDa 300 exhibited the highest (55 percent) and lowest (10 percent) incidence of necrotic lesions, respectively, while clones TDa 291 and TDa 251 exhibited the highest diffuse foliar necrosis (35 percent) and TDa 300 exhibited the lowest (10 percent). Eighty

Table 42. Foliar reaction of 8 D. alata clones to wetting: total submergence (IITA, 1980).

Foliar reaction after 7 days	TDa 291	TDa 297	TDa 251	TDa 300	TDa 5	TDa 310	TDa Sasa	TDa 200	Mean
Necrotic lesions	3	7	4	2	9	7	7	11	
%	15%	35%	20%	10%	45%	35%	35%	55%	31.25%
Foliar necrosis	7	6	7	2	5	3	4	4	
%	35%	30%	35%	10%	25%	15%	20%	20%	23.75%
No reaction	10	7	9	16	6	10	9	5	
%	50%	35%	45%	80%	30%	50%	45%	25%	45%

Total number of leaves tested per clone = 20.

percent of the leaves of clone TDa 300 did not develop foliar symptoms.

Test 2. Leaves from all 8 clones soaked in either 100 ppm Benomyl, 0.15 percent Streptomycin sulphate or ordinary tap water for 7 days developed necrotic lesions and diffuse foliar necrosis. The highest foliar necrosis was recorded from the streptomycin sulphate treatment (71.8 percent), and the foliar necrosis incidence was almost as high in the Benomyl treatment (34.3 percent) as in the ordinary tap water treatment (37.5 percent). The results indicate that neither the streptomycin sulphate nor Benomyl provided any protection against the development of necrotic lesions and diffuse foliar necrosis.

Test 3. Leaves either soaked in ordinary tap water, spread on moist filter paper (10 ml ordinary tap water/day) or spread on dry filter paper developed necrotic lesions and foliar necrosis generally within 7 days but not before 48 hours of the start of the treatment. The necrotic lesions and foliar necrosis on leaves subjected to the dry filter paper treatment were of the same type observed for the other 2 treatments. However, the necrosis on leaves in the dry filter paper treatment was invariably preceeded by an intense yellow/bronzing similar to symptoms observed on attached leaves in field grown plants.

Test 4. Leaves soaked in distilled water or ordinary tap water developed necrotic lesions and diffuse foliar necrosis with no marked differences in incidence in either of the 2 treatments. The results indicate that there are no elements in tap water absent in distilled water, which may be responsible for inducing necrotic lesions.

Test 5. Necrotic lesions and diffuse foliar necrosis developed on leaves with and without virus-like symptoms when soaked in ordinary tap water. While 10 percent of the leaves with symptoms did not develop any foliar reaction, all of the leaves without developed necrosis.

All the 8 *D. alata* clones tested were susceptible to the development of necrotic lesions and diffuse foliar necrosis, which are similar or identical to anthracnose and "scorch" symptoms developed on attached leaves in the field. The rapidness with which necrosis developed on leaves after this detachment and soaking in water and the appearance of a dark discoloration within the areas of the leaves that become necrotic suggests the involvement of a plant metabolite in the etiology of foliar necrosis.

Virus disease incidence

A virus disease of *D. alata* characterized by severe chlorosis, veinal necrosis and occasionally green vein-banding and distortion was observed in field plot tests at IITA within 7 days after sprouting in certain *D. alata* clones. The incidence of this disease in 8 *D. alata* clones at 30 days after sprouting is summarized in Table 43. At 3 months after planting, TDa Sasa had a 90 percent virus disease incidence and manifested the most severe disease expression of all 8 clones.

Determination of the source of *D. alata* virus. To determine whether a virus was present and can be carried over in *D. alata* planting material, cubes of fresh tuber tissue were macerated in 0.01 M phosphate buffer and the juice expressed was used to inoculate *Nicotiana benthamiana* seedlings. In 2 inoculation tests, 3 of the 10 seedlings developed a characteristic vein yellowing followed by a more generalized mosaic of yellow and green patches on the leaves and stunting. The untreated *N. benthamiana* seedlings did not develop any symptoms.

Leaf dip preparations from the infected *N. benthamiana* plants, which were examined by the electron microscope, revealed virus particles identical to particles observed from *D. alata* leaf dip preparations.

This preliminary observation together with the field incidence and severity of the suspected virus disease of *D. alata* suggests that a high percentage of setts may be virus carriers and account for the high percentage of the severe disease expression detected soon after *D. alata* sprouts in the field.

Table 43. Incidence of* D. alata *virus disease clones (IITA, 1980).

D. alata clones	Virus disease incidence
TDa Sasa	13/20 (45%)
TDa 291	15/20 (75%)
TDa 297	18/20 (90%)
TDa 310	18/20 (90%)
TDa 300	19/20 (95%)
TDa 200	20/20 (100%)
TDa 5	20/20 (100%)
TDa 251	20/20 (100%)

Nematology

Hot water therapeusis for the control of plant-parasitic nematodes is a long established practice on several root, tuber, bulb, rhizome and runner propagation-type crops. For white yam tubers, time and temperature combination recommendations range from 46°C to 52°C with up to 60 minutes steeping. This investigation reports on the upper and lower time and temperature combinations and on tuber barn storage, sprouting and emergence after planting.

Newly harvested white yam, cv Nwapoko, was exposed to hot water therapeusis (Table 44).

Table 44. Hot water therapeusis time and temperature treatments of white yam,* Dioscorea rotundata, *cv Nwapoko[a] (IITA, 1980).

Treatments °C		Time of exposure in minutes						
		10	20	30	40	60	80	100
35		x	x	x	x	x	x	x
40		x	x	x	x	x	x	x
45		x	x	x	x	x	x	x
50		x	x	x	x	x	x	x
55		x	x	x	x	x	x	x
60		x	x	x	x	x		
65		x	x	x	x	x		
70		x	x	x				
Water control[b]		x	x	x	x	x	x	x
Dry control[b]	x							
8 hr. steep[b]	x							

[a]*Five yam tubers in each treatment.*
[b]*At room temperature.*

The water bath consisted of a 20-liter kettle with water temperature maintained by an electric hotplate. The water bath was over heated 3-5°C to allow for cooling by immersion of the room temperature tubers. Temperature was further adjusted and maintained by adding cool water or by heat from the hotplate. After treatment, the tubers were air dried and allowed to cool at room temperature. Control treatments were as follows: (1) a water steep at room temperature for similar times as hot water therapeusis, (2) an 8 hour water steep at room temperature and (3) a nontreated dry control.

Sprouts occurring in barn storage were cut off to conserve tuber moisture and energy. Tuber weight ranged from about 750 g to 1,250 g. Each treatment consisted of 5 tubers.

Water steeping at room temperature from 10 minutes to 8 hours had no effect on the storability, sprouting or emergence of the tubers after planting. Hot water therapeusis at time and temperature combinations at or less than 55°C for 40 minutes had no effect on the storability, sprouting in storage or emergence after planting.

An exception might be 45°C for 60-100 minutes, which had a higher number of tubers with sprouts in barn storage than other treatments. Hot water therapeusis at time and temperature combinations at or greater than 55°C for 60 minutes induced or aided tuber rot. Treatment at 60°C for 20 minutes had tubers with a 20 percent wet rot and an 80 percent dry rot. Below that time and temperature combination, tubers were lost to dry rot; above that, tubers were lost to wet rot. Dry rots were generally slow in acting (weeks or months) while wet rots destroyed all tubers involved in 2 weeks or less. The wet rot was most frequently initiated at the distal end of the tuber.

The safe hot water therapeusis time-temperature combination for the white yam, cv Nwapoko, for control of the yam nematode is from 45°C for 40 minutes to 55°C for 40 minutes. The higher temperatures and shorter times would allow for more efficient use of equipment and labor.

Other white yam cultivars should fall within these limits for safe hot water therapeusis, but small scale trial runs should be made first.

Culture development of the yam nematode, *Scullonema Bradys*

The screening of germplasm for resistance to nematode parasitism in a food crop improvement program requires a diverse bank of germplasm and a source of nematodes with which to challenge the plants. Some groups of nematodes are rather easy to culture such as the root-knot nematodes that can supply 1 million or more eggs from a single tomato plant atter 6-weeks growth. The yam nematode has a slower rate of reproduction, and the eggs are laid singly in a dispersed manner in soil or plant roots. Hence, the gathering ot sufficient numbers ot yam nematodes for a screening program becomes a first problem.

The Foot technique consists of growing roots from tuber pieces or storage roots in sand in glass jars held in a dark place. White yam (cv Ekpe) tuber pieces about 4 cm^3 were surface sterilized in 1 percent sodium hypochlorite for 30 minutes. The tuber pieces were sealed in 250-ml glass jars on sterlized washed river sand. The jars were held at room temperature in a dark place and examined periodically for root development. After 4 weeks, 9 tuber pieces out of 12 had produced some roots and each jar was inoculated with 15 yam nematodes. The tuber pieces were incubated a further 8 weeks and then examined for yam nematode population development.

In the greenhouse, 6 pots each of sweet potato (Tlb-4) and cowpea (Prima) in washed river sand were inoculated with 25 yam nematodes. After 12 weeks, sand samples were examined for nematode population development.

In the Foot technique, all tuber pieces and developed roots had decomposed. No yam nematodes were recovered from the sand.

From the sweet potato cultures in the greenhouse, a mean of 238 ± 62 yam nematodes per liter of sand were recovered. From the cowpea cultures, a mean of 178 ± 88 yam nematodes per liter of sand were recovered.

The yam tuber does not appear to be a suitable energy source for root development for use with the Foot technique under the conditions of this trial. The culturing of yam nematode populations in pots in the greenhouse under sweet potato or cowpea would be feasible.

Chemical and hot water therapeusis for yam nematode control

Control of the yam nematode in white yam tubers is essential for the production of clean planting material in research and farming programs. Several chemical and hot water treatments were attempted for the control of this nematode.

Newly harvested white yam, cv Nwapoko, were exposed to chemical and hot water therapeusis for the times, temperatures and combinations given in Table 45. Water bath conditions were those as given above. The tubers were planted in the microplots a few days after treatment in November. Each wounded tuber was shown to be infected with yam nematodes.

Table 45. Chemical and hot water therapeusis treatments for control of the yam nematode, **Scutellonema bradys,** *on the white yam,* **Dioscorea rotundata,** *cv Nwapoki (IITA, 1980).*

Treatment	Concentration %	Tubers treated
Tecto & cool water	1,500	10
Tecto & hot water[a]	1,500	10
Hot water only[a]		10
Cool water only		10
Aldicarb	1,000	5
Aldicarb + granules[b]	1,000 + 0.15 g ai/microplot	4
Miral	1,000	5
Miral + granules[b]	1,000 + 0.15 g ai/microplot	4
Wounded tubers		10
Control		10

[a]*50°C for 30 minutes.*
[b]*Applied to soil 5 months after planting.*

Overall emergence for all treatments was 80 percent with nonemergent tubers randomly distributed throughout all treatments. Waterlogging during September and October evidently contributed to excessive tuber rot in the field (Table 46). None of the treatments gave 100 percent control of the yam nematode.

The nonemergence of 20 percent of the yam tubers is well within the control loss and should not be attributed to treatment effect here. It is significant that the standard hot water therapeusis did not give 100 percent control of the yam nematode and combination treatments did not contribute to nematode kill (Table 46).

Table 46. Total yam nematode count and white yam harvest data (IITA, 1980).

Treatment	Yam nematode[a]	Field rot %	Tuber number	Tuber mean wt. kg
Tecto & cool water	104	40	9	1.4
Tecto & hot water	6	60	4	1.7
Aldicarb	0	80	1	1.6
Aldicarb + granules	122	40	2	2.5
Miral	65	20	4	1.4
Miral + granules	53	75	1	0.8
Hot water only	36	20	12	1.3
Cool water only	19	30	7	2.5
Wounded tubers	235	80	2	0.7
Control	57	40	6	1.2

[a]*Growing season total count for the yam nematode per liter of soil.*

Nematode and white yam ethepon-induced interaction

The application of chemical compounds to plant foliage and roots has been shown to influence plant-parasitic nematode population development and later plant metabolism. The objective of this trial was to determine the influence of a plant growth regulator on nematode population development when applied to white yam.

Stored white yams were exposed to treatment by the plant growth regulator, Ethephon (2-chloroethyl) phosphonic acid, in the preplant tuber form and as a foliar spray during the growing period. Ethephon concentrations ranged from 5 ppm to 320 ppm. Suitable control treatments were included. Tubers were steeped in a 20-liter kettle for 4 hours and air dried before planting. Foliar spray with Tween 80 sticker-spreader was applied to the runoff point. Soil samples were taken with a soil tube to a 20 cm depth.

Plant-parasitic nematodes were recovered from all microplot soils. The yam nematode was recovered from all soils. No trends were set, and between plot variations precluded any significant differences between populations.

Quality evaluation

Screening for tuber total N levels

Water yam (*Dioscorea alata*). Total N was determined in tubers of 6 high-yielding varieties of water yam. Much higher values had been reported for these varieties last year. Although the relative amount of N present in each variety still follows largely the same pattern ($r = 0.84$), the values obtained this year for total N (percent dry weight) are consistently lower by about 40 percent (Table 47). This might indicate a tremendous influence of the environment on N content of water yam.

Table 47. Total N (percent dry weight) in water yam (D. alata) (IITA, 1980).

Clone No.	Total N. (% dry wt.) Pep. 1 1979	Pep. 2 1980	Mean
TDa 5	1.44	0.88	1.16
TDa 251	1.33	0.83	1.08
TDa 204	1.20	0.78	0.99
TDa 297	1.13	0.86	1.00
TDa 310	1.08	0.72	0.90
TDa 291	0.94	0.60	0.77
Mean	1.19	0.78	0.98

White yam (*Dioscorea rotundata*). Total N was determined in tubers of 10 promising varieties of white yam. Mean of total N is 0.67 percent, but due to lack of availability of material, good replication was not possible.

Tissue culture and virus indexing

Maintenance of yam *in vitro*

Fifteen clones of the water yam *Dioscorea alata* are kept in germplasm collections *in vitro*. Single node cuttings 1 cm long were taken from greenhouse-grown plants, surface sterlized and cultured in a medium with the following composition per liter: Murashige and Skoog salts solution; sucrose, 20 g; myoinositol, 200 mg; thiamine HCl, 0.2 mg; pyridoxine HCl, 1 mg; nicotinic acid, 1 mg; glycine, 4 mg; L-cysteine, 50 mg; benlate, 20 mg and agar, 8 g. The pH was adjusted to 5.7 ± 0.1 before sterilization.

Cameroon National Root Crops Improvement Program (CNRCIP)

Agronomy

An agronomy trial was carried out in the Nyombe region to study the effect of staking and nonstaking on the yield of 3 cultivars of yam, Jakiri, Nuyuka and the local variety (Table 48).

Sweet potato

The problems of sweet potato production include low yield and poor storability as well as the sweet potato weevil, *Cylas puncticollis*, and the sweet potato virus (SPVD). Some high yielding lines have been identified and encouraging progress is being made in improving resistance to the weevil and SPVD.

Table 48. Effect of staking and nonstaking on yield of 3 cultivars of yam (D. dumetorum) *(Ekona, 1980).*

Cultivar	Treatment	Yield (t/ha)
Jakiri	Staked	33.9
	Nonstaked	25.6
	Staked	15.4
Muyuka	Nonstaked	12.4
	Staked	24.0
Local	Nonstaked	21.4

Genetic improvement

Performance of promising clones

Advanced sweet potato clones were tested at IITA and at other sites in Nigeria (Tables 49 and 50). In all the trials, the clones were evaluated for both fresh and dry matter percentage, storability and weevil and virus resistance (Table 49).

The yield performance of these clones was lower at other sites than IITA. Two clones, TIS 8441 and TIS 8244, outyielded the leading variety, TIS 2498, at IITA. The mean performance of the clones over all locations indicated that only TIS 8441 yielded higher than TIS 2498. The highest dry matter content of 39 percent was contained by TIS 71244, but the highest mean dry yield for all locations was obtained by TIS 2498.

Other IITA clones tested are shown in Tables 50 and 51. Among the 8 series, the clones that yielded more fresh weight than TIS 2498 were TIS 8227, TIS 8337, TIS 8504

Table 49. Uniform yield trials of 25 IITA improved sweet potato clones in 4 locations (IITA, Onne, Jos and Zaria, 1980).

Clone	Fresh yield t/ha	DM yield t/ha	DM %	Weevil score*	Virus score*
Tlb 4	3.5	1.1	32.8	.62	1.75
TIS 2498	14.5	4.9	34.7	.62	.25
TIS 6046	9.1	2.6	31.1	.75	.63
TIS 6089	5.4	1.3	25.9	.25	2.38
TIS 6093	7.4	2.1	29.8	.75	0
TIS 6179	7.5	2.3	33.7	.38	.50
TIS 70150	10.5	3.4	34.4	.75	.38
TIS 70314	9.7	3.5	36.9	.62	.88
TIS 70357	14.1	5.2	37.2	.37	.25
TIS 70399	8.5	2.8	34.6	.75	0
TIS 70683	10.8	3.7	36.5	.63	1.0
TIS 71102	11.3	3.9	36.3	.25	0
TIS 71244	9.9	3.7	38.0	.63	1.0
TIS 71354	9.2	2.9	34.1	.38	.63
TIS 8064	10.6	3.5	33.8	.25	.25
TIS 8140	7.4	2.1	29.9	.75	.50
TIS 8141	8.8	3.1	35.4	.50	0
TIS 8143	11.6	3.9	32.8	.63	.75
TIS 8163	8.0	2.8	34.5	.50	.13
TIS 8164	11.5	3.7	32.8	.75	1.25
TIS 8244	14.5	4.2	30.5	.50	.50
TIS 8250	14.6	3.3	22.9	1.13	.75
TIS 8266	11.5	3.7	32.7	.50	.38
TIS 8437	11.6	3.7	32.9	.25	.63
TIS 8441	15.7	4.7	33.8	.38	.38
Mean (cl)	10.3	3.3	33.1	.58	.61
SE ($\bar{X}$)	.65	.31	.06	.07	.19

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

Table 50. Advanced yield trials of 26 sweet potato clones (80 series) in 4 replications (IITA, 1980).

Variety	Fresh yield t/ha	DM %	DM yield t/ha	Mean weevil score	Mean virus score
Tlb 4	9.5 j	30.90 cdef	2.9 g	1.5	2.7
TIS 2498	34.7 bcd	32.67 bcd	11.2 abc	0	0
TIS 2534	32.2 bcd	29.50 defgh	9.5 abc	0	.5
TIS 8068	27.6 defg	35.02 ab	9.6 abc	1.0	1.7
TIS 8069	29.0 de	34.82 ab	10.0 abc	.2	.2
TIS 8133	19.9 ghi	26.60 hi	5.3 ef	.2	4
TIS 8209	18.5 hi	25.97 i	4.7 efg	1	2.2
TIS 8227	37.8 abc	30.07 cdefg	11.3 abc	1	0
TIS 8249	13.7 ij	25.40 i	3.5 gf	0	3.7
TIS 8265	29.0 de	29.52 defgh	8.5 bcd	0	1.3
TIS 8282	32.4 bcd	25.70 i	8.3 cd	1.2	0
TIS 8291	29.6 cde	33.05 bc	9.7 abc	.2	0
TIS 8314	22.8 efgh	29.20 efgh	6.6 ed	.5	0
TIS 8337	43.2 a	27.15 ghi	11.5 a	1.5	.5
TIS 8343	32.7 bcd	30.17 cdefg	9.8 abc	.7	.75
TIS 8401	33.8 bcd	30.30 cdefg	10.0 abc	0	.5
TIS 8407	34.5 bcd	30.02 cdefg	10.4 abc	.7	1.7
TIS 8409	34.8 bcd	30.15 cdefg	10.4 abc	.5	1
TIS 8415	20.4 fghi	31.97 bcde	6.5 ed	.5	1.2
TIS 8420	31.3 bcd	30.60 cdef	9.5 abc	1.2	1.2
TIS 8446	34.0 bcd	28.37 fghi	9.6 abc	1.5	.7
TIS 8451	28.5 def	37.72 a	10.6 abc	0	0
TIS 8501	21.9 fghi	32.12 bcde	6.8 ef	1	2
TIS 8504	35.7 abcd	28.50 fghi	10.1 abc	.5	.5
TIS 8524	38.6 ab	27.07 ghi	10.4 abc	1	0
TIS 8559	17.5 hi	37.17 a	6.5 ed	.7	3

Table 51. Advanced yield of 25 sweet potato clones (90 series) in 2 replications (IITA, 1980).

Variety	Fresh yield t/ha	DM %	DM yield t/ha	Mean weevil score	Mean virus score
TIb 4	13.2 cdef	33.0	4.3 cdef	1	2.5
TIS 2498	32.7 ab	34.0	11.1 a	0	0
TIS 9068	18.8 bcde	31.2	5.8 bcdef	0	0
TIS 9093	22.6 abcde	33.9	7.6 abcd	0	1.5
TIS 9101	25.5 abc	29.9	7.6 abcd	0	0
TIS 9102	14.5 cdef	28.3	5.5 cdef	0	0
TIS 9111	4.7 f	33.1	1.5 f	2	0
TIS 9123	23.3 abcd	32.9	7.7 abcd	1	1
TIS 9127	19.5 abcde	31.3	6.1 bcde	5	1
TIS 9163	23.5 abcd	29.0	6.4 bcde	5	0
TIS 9172	15.5 cdef	35.6	5.9 bcdef	1	0
TIS 9191	14.0 cdef	23.0	3.0 ef	0	1
TIS 9198	19.9 abcde	31.3	6.2 bcde	1.7	0
TIS 9217	20.4 abcde	40.6	8.3 abcd	1	2
TIS 9227	8.5 ef	29.3	2.6 ef	3	1.5
TIS 9232	26.4 abc	30.1	8.1 abc	1.5	0
TIS 9251	23.5 abcd	28.7	6.8 abcde	2	3
TIS 9265	33.1 a	30.4	10.0 ab	5	0
TIS 9291	20.8 abcde	34.1	7.1 abcde	1	1
TIS 9416	15.0 cdef	28.4	4.2 cdef	1	0
TIS 9434	14.7 cdef	13.0	1.6 f	0	0
TIS 9444	15.1 cdef	24.6	3.7 def	1	3.5
TIS 9465	19.9 abcde	29.9	6.1 bcde	.5	0
TIS 9479	14.3 cdef	31.8	4.6 cdef	0	2
TIS 9497	10.9 def	26.2	2.8 ef	1.7	3

and TIS 8524. However, this was not always paralleled with the total dry yield. Among the 9 series, only 1 clone, TIS 9265, yielded more than TIS 2498, but again, the highest total dry matter yield was obtained by TIS 2498. The best clones will be advanced for further evaluation next year.

From a preliminary yield trial, 269 clones were selected, based on yield and other root characteristics. These will be further evaluated for their response to viruses before being advanced to replicated yield trials.

Over 1,000 selections were made from seedlings; the sources were Argentina, Cameroon, Rwanda, Solomon Islands, Tanzania and both hand and out crosses at IITA. These selections now will be advanced to the preliminary yield trial.

Four crossing blocks with parents selected for desirable traits such as resistance to weevil and virus, high dry matter and good source or sink potentials were planted in isolation for hand crosses and open pollinations.

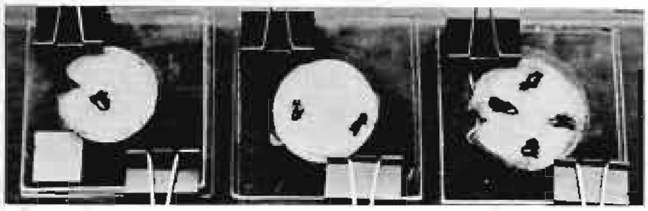
Entomology

Screening for sweet potato weevil resistance

In 1980, it became evident that further progress in raising the level of weevil resistance could only be made by getting more information about the mechanisms of resistance and improving screening methods.

Preference test. To prove that larvae prefer certain sweet potato clones, a larvae preference test was developed. This test involved 3 clones, TIS 2532 and TIS 3017

In a sweet potato larvae preference test, the combination TIS 2532-TIb 4-TIS 2532 demonstrated that in the less susceptible TIS 2532, fewer feeding holes appeared.



Demonstration of weevil larvae development in 3 Tlb 4 slices. Slices were infested with 1, 2 and 4 eggs.

with less weevil damage and Tlb 4 with high weevil susceptibility. Slices of uniform thickness (3 mm) were prepared of each clone and sandwiched together. The middle slices, artificially infested with 4 eggs, were from Tlb 4 between 2 slices of TIS 2532 or TIS 3017 in a first set of experiments and from TIS 2532 or TIS 3017 between 2 slices of Tlb 4 in a second set of experiments. The sandwiched slices were covered with 2 glass plates to reduce water loss. In this way, it was ensured that the larvae had a complete choice situation.

A disc method was developed to measure the amount of food intake by the larvae quantitatively. With a corkborer, discs from the feeding area and beside the feeding area were cut and dried to dry weight.

The results shown in Table 52 and 53 clearly indicate that in all possible combinations Tlb 4 was preferred over TIS 2532 and TIS 3017.

Improved mass screening technique. A mass screening technique with bags, based on an experimental design of 1979, was modified this year.

Two tubers were placed in a cloth bag. Seven females and 2 males were put into the bag and allowed to lay eggs for 4 days. Then, they were removed and the bags with the infested tubers stored for 19 days. After 19 days, emerging adults were counted every 2 days for 12 days. The temperature was never lower than 25°C. Each clone was replicated 4 times.

With this method, 387 sweet potato clones selected as less weevil infested from the preliminary yield trial were tested. In addition, 2 advanced second season yield trials were screened with the same method. Fig. 4 shows the frequency distribution of the mean values of weevils and check of the preliminary yield trial clones. These clones have been preserved and will be retested to confirm the result. In addition, a theoretical exercise has been attempted to predict the population increase based on the theoretical numbers of eggs laid by 7 females in 4 days. Taking into account 2 percent egg mortality, 29 viable eggs should have been layed by 7 females/day. Based on this calculation, 17 clones had a negative increase in the population. This means that in theory the weevil population would die out. The base for this was taken from an egg laying test with 10 females.

In Tables 54 and 55, the 10 best clones in terms of weevil resistance obtained from 2 advanced yield trials are shown. Each trial included 23 clones. Weevil recovery values as low as 25 percent of the control were found, which is encouraging.

Table 52. Test of weevil larvae preference of TIS 2532 and Tlb 4 based on larvae food uptake (mg dry wt.), IITA, 1980.

	Arrangement			
	A. TIS 2532—Tlb 4—TIS 2532		B. Tlb 4—TIS 2532—Tlb 4	
	Tlb 4*	TIS 2532	Tlb 4	TIS 2532*
	2.56	0	3.43	0.33
	3.05	0	2.58	0.50
	1.54	0	0.30	0.20
	2.00	0.20	2.76	0.66
	2.52	0	2.58	0.50
	1.00	0.93	1.69	0.67
	2.94	0	1.88	0.79
	1.28	0.68	1.47	0.80
	3.60	0	0.32	1.00
	2.39	0.39	1.30	0.77
Average	2.18	0.22	2.03	0.59

**Egg infested clone*

Table 53. Test of weevil larvae preferences of TIS 3017 and Tlb 4 based on larvae food uptake (mg dry wt.), IITA, 1980.

	Arrangement			
	A. TIS 3017—Tlb 4—TIS 3017		B. TIS 4—TIS 3017—Tlb 4	
	Tlb 4*		Tlb 4	TIS 3017*
	0.90	2.28	2.02	0.36
	1.85	0	1.67	0.93
	3.20	0	1.94	0.16
	2.20	0	2.89	0.17
	0.20	3.50	0.94	3.28
	2.70	0	2.10	0.21
	1.68	0	2.66	0.76
	2.53	0	1.18	0.83
	1.06	0	1.94	0.44
	2.11	0	2.66	0.85
Average	1.84	0.58	2.00	0.8

**Egg infested clone*

Table 54. Sweet potato clones selected to be less weevil susceptible from advanced yield trial (laboratory bag test IITA, 1980).

	Total No. of weevils	Av. No. of weevils**
TIS 8068	106	4.41
TIS 8249	118	4.61
TIS 8446	143	5.63
TIS 3069	148	6.23
TIS 8314	166	6.63
TIS 2498	169	6.76
TIS 8133	173	7.22
TIS 8501	191	7.65
TIS 8343	185	7.70
TIS 8337	188	7.83
Tlb 4	402	16.77

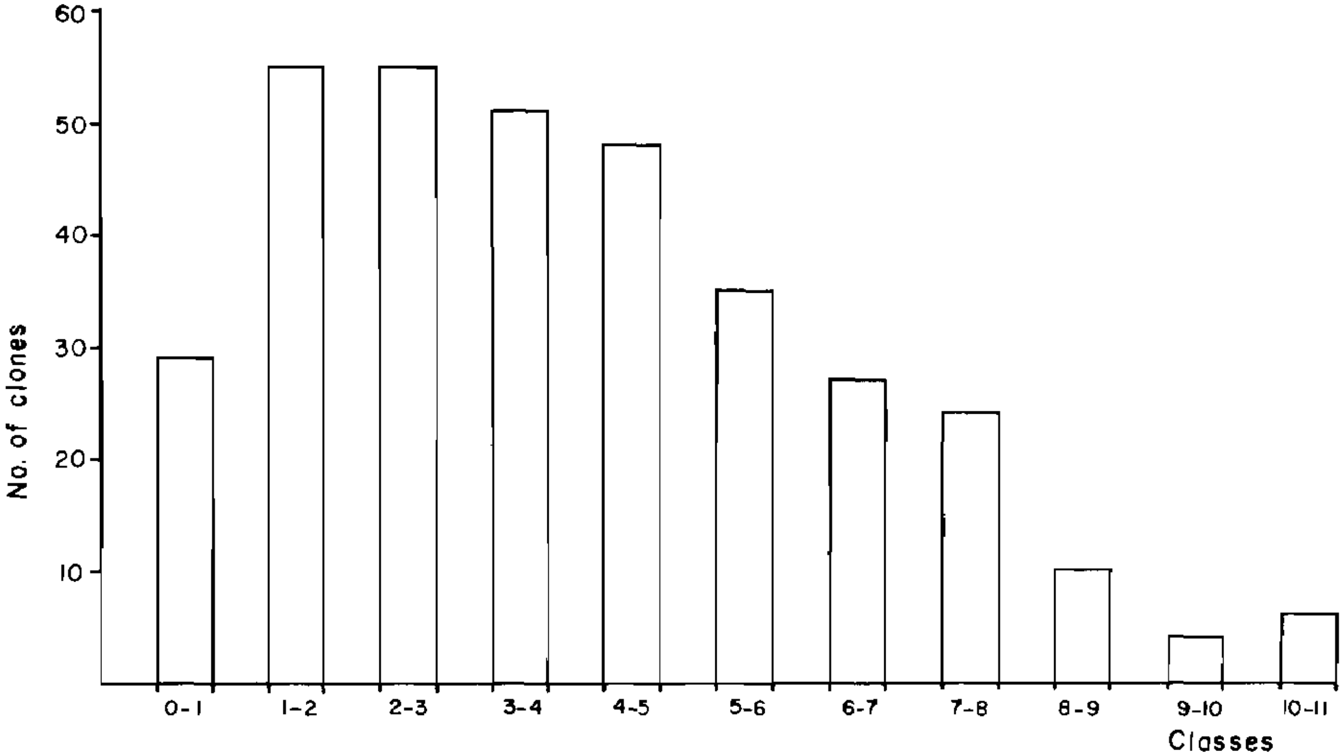


Fig. 4. Frequency distribution of weevil samples resulting from bag test on 374 preliminary sweet potato yield trial clones.

Table 55. Sweet potato clones selected to be less weevil susceptible from advanced yield trial (laboratory bag test IITA, 1980).

TIS 9163	111	4.62
TIS 9093	115	4.79
TIS 9217	117	4.87
TIS 9232	117	4.87
TIS 9416	128	5.33
TIS 9134	149	6.20
TIS 9068	149	6.20
TIS 9191	159	6.62
TIS 9102	166	6.61 *4 replications
Tlb 4	345	14.37 6 observations

*Mean of 4 replications.
**Mean of 24 observations.

Nematology

Screening for root-knot nematode resistance

The available germplasm at IITA is being systematically screened for root-knot nematode resistance as part of the sweet potato improvement program. Root-knot nematodes are of common occurrence in sweet potato growing areas and readily attack the feeder roots and frequently disfigure storage roots and in addition, open infection courts for invasion by secondary rot organisms.

Cuttings of sweet potato vines were planted in 12-cm plastic pots in washed river sand. Four weeks later, when new root growth became well developed, a first series was inoculated with *M. incognita*, race 2, and a second series was inoculated with *M. javanica*. The inoculum rate for each series was 18,000 eggs per pot. The plants were grown in the greenhouse in a controlled temperature table at 26 ± 1°C sand temperature. Plant tops grew at ambient temperature. After 8 weeks exposure to root-knot nematode attack, the roots were removed, washed free of sand and subjectively rated for the degree of root gall development. The nematode reproductive rate was estimated by an egg count from the roots of each plant.

The 192 sweet potato clones determined to be susceptible or highly susceptible to 1 or both root-knot nematode species are listed in Table 56. The 194 sweet potato clones not showing the development of a high degree of a host-parasite relationship with the root-knot nematodes will be retested to confirm resistance.

Table 56 illustrates the need to consider egg count in conjunction with the degree of root galling in establishing plant susceptibility. Extremes in egg count and the root-knot index are sometimes independent of the other and could lead to a faulty conclusion if relied upon singly. The *M. incognita* egg count mean was significantly greater than that of *M. javanica*. This is in line with observations on the cassava germplasm and other food crops. There was no significant difference in root gall development expression between the 2 species on sweet potato.

Nematode control on sweet potato

Block CS-4 at IITA had been previously shown to contain a plant-parasitic nematode population density of about

Table 56. Sweet potato, **Ipomoea batatas,** *IITA germplasm collection representative resistance/susceptibility test ratings in greenhouse screening trials with the root-knot nematodes,* **Meloidogyne incognita,** *race 2, and* **M. javanica** *(IITA, 1980).*

	M. incognita			M. javanica		
Sweet potato designation	Resistance rating	Egg count plant	Root-knot-index	Resistance[a] rating	Egg count per plant	Root-knot[b] index
BIS-36	HS	1,978,000	4.0	HS	46,000	3.6
TIS-2001	HS	903.000	3.9	HS	27,000	3.6
TIS-2119	HS	17,000	4.0[d]	HS	881,500	3.8
SI-301-3	HS	645,000	3.9	HS	4,000	3.0
TIS-3268	HS	25,000	3.9	HS	348,000	3.8
TIS-2120	C	0	0.0	HS	166,000	3.6
LM-246-6	HS	164.000	3.2	C	0	0.0
TIS-2196	HS	150.000	3.0	C	0	0.0
BIS-6	HS	138.000	1.5	HS	3,000	1.0
TIS-2536	HS	134.000	3.8	HS	8,000	3.0

[a]*Resistance ratings: HR = highly resistant, R = resistant, MR = moderately resistant, S = susceptible, HS = highly susceptible.*
[b]*Root-knot index: 0 = no galling, 4 = maximum galling.*
[c]*No satisfactory parasite-plant interaction observed or it needs confirmation.*

20,000 nematodes per liter of soil. The root-knot, root lesion and spiral nematodes were more or less in equal numbers. The site was obtained for this trial after a further crop of rice followed by maize had been grown.

Tlb 4 sweet potato vine cuttings were used as propagation material. D-D Mixture (1, 3-dichloropropene + 1, 2-dichloropropane) was applied 1 week before planting at the rate of 300 1/ha using hand equipment. Application depth was about 20 cm in the ridge. Aldicarb (2-methyl-carbamoyl oxime) at the rate of 2.5 hg/ha, Oxamyl (methyl N; N'-dimethyl-N- [methyl carbamoyl oxy] -1-thiooxamimidate) at the rate of 2.5 kg/ha and Carbofuran (2, 3-dihydro-2, 2-dimethyl-7-benzofuranyl methylcarbamate) at the rates of 2.5 and 10 kg/ha were applied as a band of granular material beneath the planting site and about 5 cm below the vine cutting and about 15 cm below the ridge surface.

Ethephon [(2-chloroethyl) phosphonic acid] was applied to vine cuttings as a spray and a combined steep and spray. Vine cuttings were steeped for 3 horus at 50, 100 or 300 ppm. Foliar sprays of 50, 100 or 300 ppm were applied 2 and 5 weeks after planting the steeped vine cuttings. In other treatments, foliar sprays were applied 2, 5 and 8 weeks after planting at the rates of 200, 400 and 600 ppm at each spraying. The sprays were applied to the runoff point, using Tween 80 spreader-sticker. Each treatment was replicated 6 times. Plants were 1 m apart in the ridge, and there was 1 m between ridges with 2 m separating the plots. There were 20 vine cuttings in each plot.

None of the treatment yields were different at the 5 percent level of significance (Table 57). A phytotoxic reaction occurred with the D-D Mixture and the Ethephon steeps at 100 and 200 ppm as indicated by the survival percentage and the June plant vigor rating (Table 57). D-D Mixture controlled the root-lesion, spiral and ring nematodes. Carbofuran at 10 kg/ha reduced spiral nematode populations but not root-lesion nematode populations. All other treatments did not have a significant affect on nematode populations.

Quality evaluation

Screening for leaf Total N levels

Since the top, young sweet potato leaves may be used as a preferred leafy vegetable in many countries in Africa, the leaves of 613 sweet potato clones were screened for Total N (percent dry weight) to estimate crude protein levels and make selections for superior lines with high protein content.

Only the young but fully formed leaves (fourth-seventh leaf from the top of the vine) were picked for analysis. N levels in the leaves ranged from 2.08 to 4.42 percent. The bulk of the population (Fig. 5) fell in 1 category where N ranged between 2.5-3.5 percent. Only 4 percent of the population showed very high levels of N (>4.0 percent),

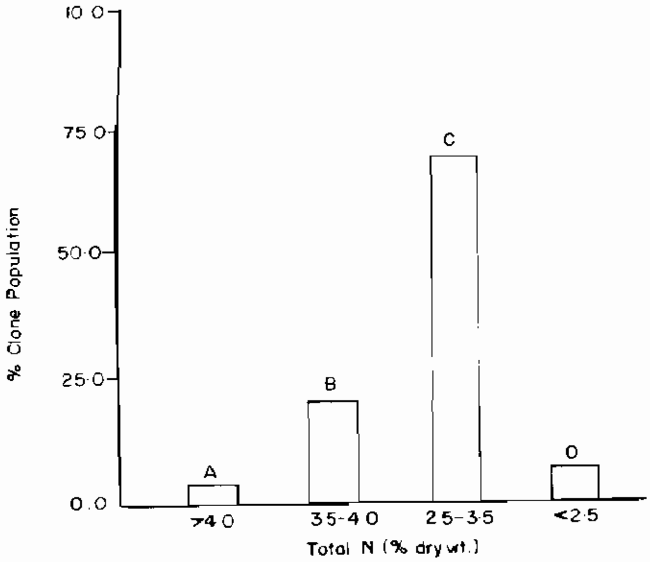


Fig. 5. Screening of sweet potato germplasm (613 clones) for total N (percent dry weight) in leaves (IITA, 1980).

Table 57. Sweet potato and plant-parasitic nematode observations on the nematode chemical control trial[a].

Treatment	Yield T/ha[b]	Nematode populations Final[c]	Preplant[d]	Surviving plants[e] %	Vigor Juen	rating[f] October
Aldicarb	15.6	380	3,908	97	101	100
Ethephon steep 50 ppm	14.3	246	3,961	75	91	91
Ethephon spray 200 ppm	14.0	283	3,220	100	112	114
Oxamyl 2.5 kg/ha	13.9	222	3,805	97	96	96
Control	13.8	197	2,752	98	100	100
Ethephon steep 100 ppm	12.1	413	3,724	24	41	96
Carbofuran 2.5 kg/ha	11.8	386	3,961	98	108	104
Ethephon spray 600 ppm	11.7	347	5,100	99	99	110
Carbofuran 10 kg/ha	11.1	475	4,961	93	95	98
Ethephon spray 400 ppm	10.2	319	2,997	98	98	106
Ethephon steep 300 ppm	9.7	374	4,127	8	46	87
D-D 300 1/ha	9.3	107	4,561	92	48	81
Mean	12.3	312	3,923	81.5	86.3	98.6
P = 0.05	NS					

[a]*Means of 6 replications.*
[b]*Yield calculated on a basis of per plant means.*
[c]*Final (October) plant-parasitic nematode population means per liter of soil.*
[d]*Preplant (April) plant-parasitic nematode population means per liter of soil.*
[e]*Six weeks after planting.*
[f]*A blind, subjective rating with the control treatment = 100.*

and similarly only 6 percent showed very low levels of N (<2.5 percent).

Out of these 613 clones, about 25 clones containing high N will be selected and reevaluated in replicated trials as the germplasm tested provided to replicates (there were only 4 plants/clone). Reproducibility of the above data, however, was checked by resampling every twentieth sample in the field after 1 week intervals.

Older leaves had less total N (percent dry weight) than the younger leaves on the same vine. However in some clones, older leaves had as much N as very young leaves. The implicity of this behavior of the N content of leaves on the N content of storage roots is yet to be determined.

For a set of 25 selected, high-yielding varieties of sweet potato, N was determined on both leaves and storage roots. N content in leaves varied from 3.26 to 4.0 percent but the N content in storage roots varied from 0.37 to 1.08 percent (Table 58).

These 25 selected, high-yielding varieties were also subjected to a panel test for their food tasting quality. Sweet potatoes were individually wrapped in aluminum foil and were baked at 100°C for 3 hours. The score for different aspects of cooked tuber quality are listed in Table 59. Tubers from 10 clones tasted more like yam and were not sweet tasting and, hence, were more acceptable than the others.

Table 58. Total N (percent dry weight) in leaves and tubers of selected high-yielding sweet potato varieties (IITA, 1980).

Clone	T.N. (% dry wt.) Leaf	Tuber
Tlb-4	3.98	1.08 a
TIS-2498	3.61	0.53 efgh
TIS-6046	3.77	0.57 defgh
TIS-6089	3.98	0.77 abc
TIS-6093	3.74	0.56 defgh
TIS-6179	3.62	0.44 hi
TIS-70150	3.94	0.65 bcde
TIS-70314	3.59	0.71 abcd
TIS-70357	3.48	0.80 a
TIS-70399	3.90	0.77 ab
TIS-70683	3.54	0.50 efghi
TIS-71102	3.47	0.48 fghi
TIS-71244	3.26	0.51 efghi
TIS-71354	3.73	0.59 defgh
TIS-8064	3.82	0.51 efghi
TIS-8140	3.63	0.53 efgh
TIS-8141	3.90	0.61 defg
TIS-8143	3.46	0.46 ghi
TIS-8163	4.01	0.64 bcde
TIS-8164	3.60	0.54 efgh
TIS-8244	3.44	0.61 defg
TIS-8250	3.78	0.64 bcde
TIS-8266	3.88	0.62 cdef
TIS-8437	3.63	0.37 i
TIS-8441	3.71	0.52 efghi

Tissue culture and virus indexing

Distribution of sweet potato for international testing

Many requests for improved varieties of sweet potato were addressed to IITA during 1980. To satisfy these requests, plants from 54 clones of sweet potato were obtained through meristem tip culture.

Twenty of the sweet potato plants in meristem tip culture are from improved varieties of sweet potato, and, after having gone through virus indexing, they were found virus free.

Table 59. Sweet potato quality evaluation (IITA, 1980).

Variety	Morphology Smooth/ Ridged	Skin-Color White/Red-Magenta	Eating Quality of a Cooked tuber: Flesh Color	Texture Hard/ soft	Sweet-ness −, +, + +	Yamlike taste +/−	Rating for taste	Chemical Analysis: Flour color	Crude protein (% d.w.)	% TDM
Consumer Preference	S	W	White	H	−	+	Excellent	White		
TIb-4	S	Light R-M	Orange Yellow	S	+ +	−	V. poor	Deep Orange	6.75	33.55
TIS-2498	R	Deep R-M	White	S	+	−	Fair	Yellow-Grey	3.31	31.08
TIS-6046	R	V. light R/M	Yellow	S	−	−	Good	Yellow-Brown	3.56	27.75
TIS-6089	S	W	Orange	S	+	−	Fair	Deep Orange	4.81	22.77
TIS-6093	S	W	White	S	−	−	Poor	Pale Yellow	3.50	24.63
TIS-6179	R	V. light	White	S	−	−	Good	Pale Yellow	2.75	30.02
TIS-70150	R	V. light	Yellow	H	+	−	Fair	Yellow-Brown	4.06	32.10
TIS-70314	S	V. light	White	H	−	+	Excellent	White	4.44	32.44
TIS-70357	R	Light	Light Yellow	H	−	+	V. Good	Greyish Yellow	5.00	32.36
TIS-70399	S	V. light	White	H	−	+	V. Good	White with little Grey	4.81	32.68
TIS-70683	S	Deep R-M	White	S	+	−	Poor	Brown	3.13	26.66
TIS-71102	R	W	Light Yellow	H	+	+	Good	Yellow	3.00	32.07
TIS-71244	S	W	White	H	+	−	V. Good	Brown	3.19	36.12
TIS-71354	R	R-M	White	S	+	−	Fair	Light Yellow Brown	3.69	29.96
TIS-8064	S	R-M	Light Yellow	H	+	+	Good	Light Yellow	3.19	32.36
TIS-8140	S	Deep R-M	White	S	+	−	Poor	Light Brown	3.31	24.64
TIS-8141	R	Deep R-M	White	H	−	+	V. Good	Greyish White	3.81	30.57
TIS-8143	S	Deep R-M	White	S	+	+	Good	Brownish White	2.88	30.21
TIS-8163	R	R-M	White	S	+	−	Fair	Yellow-ish White	4.00	27.93
TIS-8164	S	W	White	H	−	+	Excellent	White	3.38	26.55
TIS-8244	S	Deep R-M	Purple streaks	S	−	−	V. Poor	Purple Brown	3.81	23.61
TIS-8250	R	Light R-M	Light Orange	S	+	−	Poor	Dark Orange Brown	4.00	17.56
TIS-8266	S	Deep R-M	White	S	+	−	Poor	Pale Yellow	3.88	29.85
TIS-8437	S	Deep R-M	White	S	−	−	Fair	White	2.31	27.30
TIS-8441	S	W	White	H	−	+	Excellent	V. light Brown	3.25	34.07

Plantlets of yam, sweet potato and cassava (left to right) attained from single node cuttings.

Checking growth of sweet potato plantlets in the culture room at IITA.

The methods of obtaining the virus-free sweet potato clones through meristem tip culture were as described (IITA Annual Report 1979). When the plants reach a height of 3-5 cm, they are ready for distribution.

The distribution is done in tissue culture to African and Asian national programs for international testing. Single node cuttings of virus-free plants are cultured in plastic tubes containing 10 ml of multiplication medium and the culture conditions were as described for the meristem tip culture (IITA Annual Report 1979).

These plantlets can be transferred to soil when they arrive in the recipient country. The tubers are accompanied by the import permit, the phytosanitary certificate and a handbook with recommendations on the handling of the material.

The tissue culture material is as much as possible hand-carried to shorten the time of transport and increase the efficiency of the distribution. Virus indexing has been improved by using, in addition to the grafting to the test plant, *Ipomea setosa*, serologically specific electron microscopy (SSEM).

The sweet potato germplasm in tissue culture now counts more than 300 clones. Some clones are kept for up to 19 months without transfer to fresh culture medium. To induce slow growth, the culture are kept at 20°C by day and 17°C by night, and mannitol (3 percent) was added to the culture medium.

Cameroon National Root Crops Improvement Program (CNRCIP)

Genetic improvement

Over 20,000 seedlings were raised at Nkolbisson and 12,000 at Nyombe. Seedling and clonal evaluation trials and yield trials were conducted at many locations in these regions, and promising clones were identified, some of which yield up to 35 t/ha.

Tables 60 and 61 show the best clones selected from 2 IITA seed introductions at Nkolbisson, and Table 63 shows the results obtained from multilocation trials at Nyombe. Tlb 1 gave the highest dry matter yield although clone 002 gave the highest fresh yield.

Entomology

Sweet potato weevil. The sweet potato weevil (*Cylas punticollis*) is the most important pest of this crop in south central Cameroon. It causes injuries to the vines as well as the tubers and strongly limits the sweet potato's production and commercialization.

Tables 61 and 62 show that the damage caused to the vine is similar over the 2 cropping seasons. On the other hand, the damage caused to the tuber is more important during the second season, when dry weather and expanding tubers crack the soil. Weevil attacks are very rare and mostly limited to the tuber neck during the first season.

No resistance could be identified, but relatively important differences in the behavior of the clones, grouped by family, could be observed (Table 62).

The clones resulting from TIS 3290, 3247, 5003, 5270, Tlb 11, Tlb 8 and TIS 2532 were very heavily or heavily attacked; clones from Tlb 2, TIS 3030 and TIS 3017 were moderately attacked, and family TIS 2330 was lightly attacked.

Pathology

Sweet potato virus (SPVD). During the 1979 first and second seasons very few virus symptoms could be observed in the selection plots, except on the family 5270 *in which 57 percent of the clones did show symptoms* (Table 63).

However, during the 1979-80 dry season, the multiplication of the selected material was done by tuber plantation (for line purification reasons), and 36 percent of the clones showed virus infection even though they had never shown symptoms before.

From this, 95 percent reexpressed symptoms during the 1980 first season in at least 4 localities of the multilocational trial even though the trials were set up from apparently clean vines.

Quality evaluation

A preliminary acceptability test on the quality of selected clones was carried out with 20 persons at Nkolbisson in

Table 60. Characteristics of the 10 best clones of the first IITA introduction.

	Yield 1979 (t/ha)		Yield 1980 (t/ha)				Virus		Weevil (Vine/Tuber)		Dry matter	
N°	Nkolbisson 1st season	Mbankomo 2nd season	Niga 1st season	Nkometou 1st season	Essasok 1st season	Mean (t/ha)	1979	1980	1979 (2S)	1980 (1S)	2/79	1/80
Tlb 8-4	10.0	11.2	19.0	22.0	19.0	16.2	0	0.35	1.2/1.5	2/0	30.8%	29.1%
Tlb 8-1	22.2	8.6	15.5	-	19.0	16.3	0.5	0.75	0.5/1.5	1/0	38.3%	27.0%
TIS 2328-38	15.4	7.9	21.3	15.0	20.0	15.9	0.5	0.9	1.5/3	2/0	35.8%	33.0%
TIS 3017-1	16.4	8.0	-	-	21.5	15.3	0.25	0.75	1.5/2.5	1.2/0	33.1%	31.7%
TIS 3290-4	11.2	7.6	-	14.0	26.0	14.7	0.5	0	1/2	1.5/0	39.2%	-
TIS 2328-10	16.6	8.3	19.9	-	13.0	14.4	0.5	2.0	1.0/1	1.7/0	36.5%	32.4%
Tlb 8-20	17.2	6.0	10.4	-	23.5	14.2	0	1.8	1.2/1.5	2.2/0	36.9%	31 %
TIS 2330-2	16.9	8.6	12.4	11.0	18.0	13.3	0	0.7	1.5/1	1.5/0	32.9%	23 %
Tlb 8-24	16.2	14.3	10.8	11.0	12.7	13.0	0	0.1	1.7/2	1/0	39.8%	39 %
TIS 3017-7	8.6	9.4	-	-	21.0	13.0	0.5	0.75	1/1	2.5/0.7	34.3%	30 %

Table 61. Characteristics of the 15 best clones of the second IITA introduction.

	Yield (t/ha)			Virus		Weevil (Vine/Tuber)		Dry matter	Color	
N°	Nkolbisson 2nd season 1979	Essasok 1st season 1980	Nkometou 1st season 1980	Nkolbisson 2nd season 1979	Essasok 1st season 1980	Nkolbisson 2nd season 1979	Essasok 1st season 1980	1st season 1980	Interior	Exterior
Tlb 2-26	21.8	16.5	-	0	0.5	1/1	1/0	32.1	Y	Ro
Tlb 2-21	15.8	21.0	-	0	1.5	1.5/0.5	1.5/0	34.6	Y	R
Tlb 11-12	6.0	27.0	-	0	0	1.5/1	1/1	29.0	C-O	Co
Tlb 2-24	21.4	8.7	-	0	1.0	2/2	2.7/0	34.3	Y	Ro
TIS 2330-3	5.6	24.25	30.6	0	0	1/2	1/0	-	B	R
Tlb 11-10	5.2	23.0	15.0	0	0	1/1	2/0	28.0	Y	Co
TIS 5270-34	3.8	22.0	23.0	0.1	0	1.5/2	1.5/2	33.2	C	P
Tlb 11-45	5.4	20.0	-	0	1.0	2/2	1.5/0	29.2	C-Vi	R
Tlb 11-62	2.4	21.5	-	0.5	1.5	1.5/2	1.5/0.5	-	Do	R
Tlb 11-19	5.6	17.5	-	0	0.5	1.5/2	1.5/0	-	C	Co

Virus affection: estimated by the mean frequency of the symptoms (0 = 0%, 0.5 = 10%, 1 = 25% of the plants)

Weevil attack: on vines and tubers (V/T)
—on vines: 0: no attack/1: low attack 2: moderate attack/3: high attack
—on tubers: 0-2: light 5-6: heavy, 3-4: moderate 7-8: very heavy

Color Code:
Y = Yellow
C = Cream
O = Orange
B = White
Ro = Rose-Red
R = Red
Ro = Rose
Vi = Violet
Co = Copper
P = Purple
Do = Deep orange

Table 62. Weevil attack on roots of the second IITA introduction (Nkolbisson, 1979 Second season). Rem: LOCAL: 1 clone: Moderate attack = 2.83

Parent	Number of clones	Frequency (2) inside the intensity classes on all clones: Light 0-2	Moderate 3-4	Heavy 5-6	Very Heavy 7 and +	Number of clones	Class: Low	Class: Mean
TIS 3030	58	21%	26%	19%	34%	0	-	-
TIS 5272	61	10%	20%	22%	48%	3	3	0
TIS 3017	41	41%	5%	17%	37%	2	2	0
TIS 324	43	2%	12%	30%	56%	1	1	1
TIS 2532	46	13%	20%	15%	52%	1	1	0
TIS 2330	30	37%	27%	23%	13%	2	2	0
TIS 5003	22	9%	14%	36%	41%	1	1	0
TIS 3290	17	0%	12%	6%	82%	0	-	-
TIS 5125	56	9%	36%	16%	39%	5	5	0
Tlb 11	82	12%	13%	25%	50%	8	7	1
Tlb 2	59	20%	24%	39%	17%	5	3	2
Tlb 8	79	8%	18%	22%	52%	3	2	1
TOTAL:	594	15%	19%	23%	43%	31	27	4

Table 63. Yield, dry matter percent and SPVD score (0-5) of sweet potato in an advanced yield trial (Nyombe, 1980).

Cultivar	Fresh Yield	DM%	Dry Yield (t/ha)	% of Tlb 1	Virus Score
Loc 2961	5.6	33.5	1.9	25	1.0
Tlb 1	16.1	46.0	7.4	100	0.5
001	12.9	24.0	3.1	42	1.0
002	20.3	36.0	7.3	99	2.0
003	15.0	-	-	-	1.5
004	18.5	34.5	6.4	86	0.5
005	3.8	30.0	1.1	15	3.8
006	11.2	-	-	-	3.8
007	8.4	-	-	-	4.0
008	14.3	34.0	4.9	66	1.5
009	12.7	-	-	-	3.8
010	9.0	-	-	-	3.8

1980 on the harvest of the 1979 second season (Table 64). Everybody agreed on the very good or good quality of the local clones, Nkolbisson 1, CIB 23 and CIB 46.

Flesh color was important: deep orange (52393) and violet (or purple) were rejected while white or yellow were accepted. Dry matter content was a determinant: high values correspond with good or very good taste while low values (34-35 percent dry matter content), corresponded with bad to very bad taste.

Agronomy

Results obtained at Nkolbisson, Mbankono and Nkometou show that identical or even higher yields may be produced from growing the local clone Nkolbisson 1 during 1 cycle of 6 months than 2 seasons of 4 months, and the required cultivation practices may be reduced (Table 65).

Table 64. Acceptability test: Sweet potato taste classification by number of persons.

	VG	G	F	B	VB	% DM	Internal color
TIB 1	8	9	0	3	0	36.5	Yellow
TIB 2	8	5	2	4	1	39.7	Cream
29	0	6	5	8	1	32	Yellow-violet
221	7	8	2	3	0	33.9	Yellow
224	5	9	6	0	0	29.0	Yellow
226	6	8	4	2	0	34.2	Yellow
228	1	4	2	12	1	29.3	Yellow-violet
81	1	10	6	3	0	38.3	Cream
84	3	6	2	6	3	30.8	Orange
824	5	10	5	0	0	39.8	Yellow
835	2	10	6	2	0	31.4	Cream
1117	0	4	2	14	0	33.5	Yellow-orange
1145	7	2	0	8	3	39.0	Yellow-violet
1147	0	1	6	12	1	35.6	Orange
232810	9	4	3	4	0	36.5	Yellow
232834	0	2	3	8	7	29.1	Cream-yellow
232838	6	6	2	5	1	35.8	Yellow
232839	0	2	1	14	3	32.2	Grey
23302	0	9	5	5	1	32.0	Cream
25325	0	4	3	11	2	30.2	Cream-yellow
30171	2	6	6	5	1	33.1	Cream
30172	3	9	4	3	1	40.8	Grey
30174	0	2	3	9	6	33.3	Yellow
30302	0	9	5	5	1	32.9	Cream
32903	0	1	5	11	3	33.3	Cream-violet
52393	0	1	0	13	6	31.8	Deep-orange
CIB 23	6	5	5	4	0	37.6	White
CIB 46	8	6	3	3	0	37.5	White
Nkolbisson N° 1	9	11	0	0	0	39.6	White

VG = Very Good
G = Good
F = Fair
B = Bad
VB = Very bad
% DM = Dry matter

Table 65. Mean yield of the local clone Nkolbisson 1 over different growing periods in 3 localities.

Localities	4 months (1st season)	4 months (2nd season)	6 months
Mbankomo	8.9 t/ha	3.6 t/ha	12.9 t/ha
Nkolbisson	5.8 t/ha	1.95 t/ha	9.8 t/ha
Nkometou	6.5 t/ha	-	10.3 t/ha

Cocoyam

The cocoyam disease complex is one of the main problems to be overcome in cocoyam breeding. In collaboration with research teams from other institutions, IITA is intensifying its efforts to identify means of overcoming this constraint.

Genetic improvement

Performance of promising clones

Several clones of *Xanthosoma sagittifolium* and *Colocasia esculenta* maintained in the germplasm were chemically induced to flower and hand pollinated. Eight of the leading *Xanthosoma* clones are being maintained in a special crossing block for hand pollinations.

Thirty clones of *Xanthosoma* planted in 3 replications in the preliminary yield trial were chemically treated with gibberillic acid (GA_3) to promote flowering. Many hand pollinations were made on flowering plants. These plants also were evaluated for disease resistance and growth habit.

The performance of 45 clones of *Xanthosoma* in a replicated preliminary yield trial was very good with fresh tuber yields ranging from 4-35 t/ha. Twenty-six clones have been selected for further testing. The performance of the *Colocasia* clones was not as good as that of the *Xanthosoma* spp. Of the 47 clones tested, 12 have been selected for further testing.

The hybridization program will be intensified in order to increase the population size from which further selections can be made.

Agricultural economics

Cocoyam survey

Cocoyam is a poorly documented but important food crop. The purpose of a survey was to collect information about the manner in which cocoyam is at present planted, cultivated, harvested and utilized in Nigeria. Specific questions were as follows: What are the planting practices? How do the farmers use the different varieties? With what other crops is cocoyam associated? What is the labor utilization for cocoyam? What are the harvest and storage practices? Which marketing and processing practices are important?

The 2 highest cocoyam producing states in Nigeria—Anambra and Imo—were selected as well as Ondo State, the highest cocoyam producing state west of the Niger, for the survey. In each state, 3 or 4 villages where cocoyam was considered to be an important food staple were selected upon recommendation of local agricultural officers. In each of the villages, individuals in 6 or 7 households were interviewed. It turned out that in most of these, it was the women who grew cocoyam.

The sampling method was aimed at providing general information about the systems in which cocoyams are grown rather than at testing specific hypotheses. The selection method of villages and households might be biased because of accessibility of villages, willingness of farmers to cooperate or personnel preferences of local agricultural officers. However, the results provide a sufficiently general picture of cocoyam production in each of the 3 states so that relevance of the results can be claimed.

The main results of this study were as follows:

(1) The planting dates for cocoyam in Nigeria vary from March-April to April-May and seem to be dependent on the planting and the harvest dates for yam. As such, the cocoyam farming system is a component of a larger yam-based farming system. This is further confirmed by the intercropping and rotation patterns that were reported.

(2) The different cultivation methods for different varieties of cocoyam are not distinguished. All varieties are cultivated on well-drained, fertile, upland soils. The choice of variety seems largely dependent on the method of food preparation. Qualities as 'hard' vs. 'soft' and 'scratchy' vs. 'sweet' are important.

(3) Sole crop farming of cocoyam is rare. Mixed cropping with maize is the general mixture although the yam-cocoyam-maize association is very common. Intercropping with tree crops is also often practiced.

(4) Cocoyam is a less labor intensive crop than cassava for field work. The labor utilization is estimated to be about 142 mandays/ha.

(5) The most important storage methods are a shady place in the field, in huts or barns, in the houses and in pits. Successively, these methods protect the cocoyam better against pests, diseases and sun.

(6) Forty percent of the farmers surveyed grow cocoyam as a cash crop, selling at least half of the yearly production. The taste of cocoyam is considered to be less than that of yam (white or yellow) but better than the taste of maize and cassava. Pounding is the most common form of food preparation.

(7) Ninety-two percent of the farmers surveyed have recently increased their cocoyam production indicating a growing popularity of this crop.

It seems, therefore, that cocoyam is no longer a "poor man's crop" but rather a "crop with promising economic value."

In Nigeria, farmers are increasing their cocoyam production, for the crop is perceived to be less labor intensive than cassava. It can be easily cultivated in association with food or tree crops. Its nutritional value, taste, labor requirements in food preparation and market value give the crop an economic edge over cassava.

The implications of this study for cocoyam breeding are as follows: (1) cocoyam deserves further attention because of its economic value and potential; (2) characteristics such as 'hard' vs. 'soft' and 'scratchy' vs. 'sweet' are important; (3) the breeding of new varieties should be done without restricting its usefulness as an intercrop; and (4) the period of cocoyam consumption can be prolonged if planting is done earlier in the season (as in Ondo). This requires cocoyam varieties with better drought resistance.

Cameroon National Root Crops Improvement Program (CNRCIP)

Genetic improvement

Approximately 1,000 seedlings were raised at both Nkolbisson and Nyombe, and seedling and clonal evaluations were carried out, but no promising clones were identified. Most plants were affected heavily by a severe yellowing disease and root rot.

This disease is the most important problem of cocoyam production in Cameroon. It seems to be associated with soil-borne fungi of the family *Pythiaceae*. Nematodes and root-mealybugs may also play a role in a disease complex as well as viruses.

Epidemiological studies led to the conclusion that root rot can appear in 2 different forms. The first produces dwarf plants in 2 months after planting; they do not produce cormels. The second leads to a sudden wilting of well-developed, vigorous plants from July-August on.

A disease transmission study gave no direct evidence of an air-borne disease. To broaden the germplasm base, local cultivars of cocoyam from Cameroon were collected as well as clones originating from IITA, U.S.A., Puerto Rico and Trinidad.

Agronomy

In the Nkolbisson region an intercropping trial, including cocoyam with cassava, maize or plantain at different densities, was planted in 1979-80 to slow down the disease. However, the sole cropping performed the best (Table 66). Shading and crop competition reduced early crop development before the onset of the yellowing disease.

During 1980-81, cocoyam and taro (*Colocasia* spp.) were intercropped at different densities and designs, as taro is not affected by the yellowing disease this crop could be used as a barrier. Ridomil was the only effective fungicide against the disease in 1979-80 (Table 67).

In the Nyombe region, similar results were obtained. The outbreak and spread of the disease could not be stopped nor slowed down by: (1) intercropping cocoyam with cassava, maize, plantain or (2) planting cocoyam in different spacing. None of the following chemical treatments used were effective to control the root rot disease: Orthodifolatan (Catafol), Aliette, Bidomil or Furadan.

Table 66. Cocoyam yield obtained by different intercropping patterns (Nkolbisson, 1979-80.)

	Crop densities		Yields (t/ha)		
Crops	Cocoyam stands/ha	Other crops stands/ha	Cocoyam Cormel	Cocoyam Cormel	Other crops
Cocoyam	10,000	-	5.9	10.2	-
Cocoyam and maize 1	10,000	50,000	1.6	1.2	2.2
Cocoyam and maize 2	4,400	53,333	1.9	1.8	1.9
Cocoyam and cassava	10,000	10,000	1.1	1.7	
Cocoyam and plantain	10,000	1,333	1.5	1.3	

Table 67. Treatments and corresponding cocoyam yield with "clean" and "diseased" planting material.

			Cocoyam Cormel Yield (t/ha)	
Treatment	Applic dose	Applic. rhythm	"Diseased" planting material	"Clean" planting material
1. Control	-	-	3.8	6.5
2. Insecticide				
a) GAMMACTIF 25 pm	2 kg/ha	1 month	4.0	6.0
b) FURADAN	2 gr/st	1 month	2.9	6.9
c) FURADAN	4 gr/st	1 month	1.6	4.2
d) FURADAN	6 gr/st	1 month	4.2	7.5
e) METHYL PARATHION	2 kg/ha	15 days	2.0	5.1
f) METHYL PO + GAMACT	2 + 2 kg/ha	1 month	3.3	2.9
3. Fungicide				
RIDOMIL	1 gr/stand	15 days	8.1	8.4

Cereal Improvement Program

Introduction

Research on genetic improvement of rice and maize is emphasized. Both crops are of fundamental importance in the African economy, and both have an immense potential in terms of yield improvement as well as expansion of the area cultivated.

The area under rice in Africa is still relatively limited. Nevertheless, demand for rice has been growing strongly. In large part, this reflects a dietary shift connected with urbanization. Maize is one of the major staple foods in many countries in Africa. It is also in increasing demand as animal feed. IITA scientists are seeking solutions to African-specific problems such as the maize streak virus (MSV) and stemborers and the African forms of rice blast and rice yellow mottle virus (RYMV). The research is being conducted in collaboration with the International Rice Research Institute (IRRI) and the Centro International de Mejoramiento de Maiz Y Trigo (CIMMYT). Both IRRI and CIMMYT have out-posted scientists to IITA.

For organized multilocational testing, some of the work is being done directly by IITA in collaboration with African national programs. However, maximum benefit is derived from 2 regional organizations. The Semi-Arid Food Grains Research and Development Project (SAFGRAD) is the main vehicle for multilocational maize testing in the semi-arid areas. In the case of rice, IITA participates in the organized international testing program of the West African Rice Development Association (WARDA). An IITA scientist is posted with WARDA in Liberia. Reports on these projects are included under the sections on crops, and individual annual reports are available from the respective organizations.

Maize

The major objective of the maize improvement program is to develop stable, high-yielding varieties adapted for the different ecologies in Africa. The main emphasis is on varietal stability through resistance breeding for the major diseases and insect pests in Africa. Population improvement combined with multilocational testing (Table 1) and, when possible, artificial infesting and screening techniques are used as major breeding strategies. Resistance breeding for MSV was emphasized during 1980 as in previous years.

Hybrid maize varieties are used commercially in a number of countries in East Africa, Kenya, Malawi, Tanzania, Zambia and Zimbabwe. Hybrids were developed by the

Super susceptible symptom of maize to maize streak virus (infested by virus at early stage).

Resistant breeding nursery of maize against maize streak virus, showing resistant plants right and susceptible plants left.

Table 1. ***Location and number of entries of maize tested in different locations in Nigeria during 1980.***

Location	No. of entries	Remarks
IITA	9,500	Breeding nurseries, Yield trials
Onne	1,500	High-rainfall yield trials
Ikenne	1,860	Yield trials
Mokwa	950	Derived savanna yield trials
Funtua	3,107	Savanna yield trials
Gusau	792	Savanna yield trials
Jos	665	Mid-altitude—*turcicum* resistant trials
Umudike	328	Stemborer resistant trials
Owo and Kabba	1,800	Downy mildew resistant trials

Each entry tested in 2-4 replications.

Institut de Recherches Agronomiques Tropicales et des Cultures Vivrieres (IRAT) in West Africa, Ivory Coast, Senegal and Upper Volta, but they are not used extensively because of inadequate seed production. A program to explore the potential use of variety × line (top-cross) hybrids for high-management, commerical farming was initiated during 1979 and continued in 1980. The major advantage of top-cross hybrids is the relative simplicity of seed production. The program concentrates on the development of inbred lines (S_3-S_4) with good combining ability, adaptability and resistance to disease and insect pests.

Genetic improvement

MSV resistance breeding

Multilocational testing of TZSR-W-1 and TZSR-Y-1. TZSR-W-1 and TZSR-Y-1 are newly developed, streak-resistant populations (IITA Annual Report 1979) combining a number of streak-resistant varieties into 2 streak-resistant populations—white and yellow. A wider genetic base was achieved with better potential adaptability and agronomic characters. Bulk seeds of TZSR-W-1 and TZSR-Y-1 were compared to TZPB and TZB, 2 improved, high-yielding varieties widely grown in Nigeria, in 4 locations (Table 2). No significant yield differences were observed between the 2 streak-resistant varieties and TZPB or TZB. The high yield advantage of the streak-resistant populations under streak epidemic was previously described (IITA Annual Report 1979).

Table 2. Grain yield (t/ha) of TZSR-W-1 and TZSR-Y-1 at 4 locations in Nigeria (1980).

Variety	Ibadan[1]	Ikenne[2] 1st	Ikenne[2] 2nd	Mokwa	Funtua[1]	Mean
TZSR-W-1	4.4	6.2	3.3	5.2	5.4	5.0
TZSR-Y-1	4.7	7.6	4.2	5.7	5.6	5.6
TZPB (Check)	4.5	6.4	3.3	5.5	5.8	5.2
TZB (Check)	4.5	5.7	3.6	6.3	6.5	5.5
LSD (5%)	1.2	1.6	1.0	1.8	1.8	1.5

[1]*Average yield of 2 trials: Nigerian national zone maize variety trial and IITA advanced yield trial.*
[2]*Ikenne: 1st: first season (April-August); 2nd: second season (September-December).*

Seed drying of newly developed TZSR-W-1, streak resistant, white maize variety for Nigerian Green Revolution Project.

For further improvement of TZSR-W-1 and TZSR-Y-1, half-sib family trials were conducted in 5 different locations in Nigeria, IITA, Onne, Ikenne, Mokwa and Funtua; representing a wide range of environments from the high-rainfall area of Onne in southern Nigeria to the savanna area of Funtua in northern Nigeria (Tables 3 and 4). Based on yield, days to flowering, disease reaction and other agronomic characteristics, 50 half-sib families were finally selected from each population for the new cycle of selection. The data obtained for the selected families are encouraging, indicating that further improvement for yield potential and agronomic characteristics can be achieved.

Remnant seeds of the selected 50 half-sib families were planted in the 1980-81 dry season for recombination (full-sib). Emphasis has been given to select plants with desirable plant height and low ear placement. The best 250 full-sibs will be selected from each population for international testing in cooperation with the national

*Table 3. **Grain yield (15 percent moisture) and agronomic characteristics of selected half-sib families of TZSR-W-1 (Average over IITA, Onne, Ikenne, Mokwa and Funtua, 1980).***

Original pedigrees	Number of half-sibs tested	Number of half-sibs selected	Yield (t/ha)	Days to flowering	Height (cm) Plant	Height (cm) Ear	*H.* maydis*
TZPB	100	15	6.9	61	235	129	1.4
TZB	122	12	6.0	60	237	127	1.2
Tlaltizapan 7322	40	7	5.5	60	222	123	2.0
Gemiza 7421	33	6	6.6	63	226	125	1.1
Poza Rica 7422	19	1	8.9	60	240	135	1.7
ZCA × TZSR-W	12	2	4.6	63	225	119	1.5
SC × TZSR-W	9	1	5.8	62	240	132	1.5
TZSR-W	39	6	5.4	62	215	128	1.2
Check: TZSR-W	-	-	3.4	65	249	137	1.5
Mean	387	50	6.2	61	230	127	1.4
S.D.	-	-	1.6	1.4	9.7	7.2	0.3

**1-5 score; 1 = resistant, 5 = susceptible.*

*Table 4. **Grain yield (15 percent moisture) and agronomic characteristics of selected half-sib families of TZSR-Y-1 (Average over IITA, Onne, Ikenne, Mokwa and Funtua, 1980.)***

Original pedigrees	Number of half-sibs tested	number of half-sibs selected	Yield (t/ha)	Days to flowering	Height (cm) Plant	Height (cm) Ear	*H. maydis** (1-5)
Poza Rica 7428	40	14	6.8	61	232	125	1.2
096EP6	6	1	5.7	62	232	120	1.5
Suwa 1 (S) C6	1	1	7.5	59	185	110	1.5
TC, Early DMR (S) CS3	1	1	3.2	58	190	115	1.5
N28 × TZSR-Y	23	2	6.7	60	221	119	1.0
IB32 × La. Rev. Crosses	101	10	7.9	64	239	126	1.6
TZSR-Y	171	21	6.3	61	240	132	1.5
Check: TZSR-W	-	-	3.5	64	245	135	2.0
Mean	343	50	6.8	61	235	128	1.5
S.D.			1.65	2.2	14.8	7.5	0.5

**1-5 score, 1 = resistant, 5 = susceptible*

programs of 6 countries in West Africa; Benin, Cameroon, Ghana, Ivory Coast, Nigeria and Upper Volta.

Early-maturing, streak-resistant populations. MSV incidence is usually higher in planting in the second season in a bimodal, rain-distribution area and in late planting in the first season in a unimodal, rain-distribution area. Therefore, streak-resistant, early-maturing varieties may be even more important than medium-maturing varieties. The program was initiated in the 1977 dry season by crossing early-maturing varieties, TZE 3, TZE 4, TZE 14 and TZE 15, with TZSR-W and TZSR-Y (Fig. 1).

During 1980, 42 white and 94 yellow S_3, streak-resistant lines were developed. These lines were recombined (half-sib) during the 1980 second season. The level of streak resistance of bulk seeds of the recombined families was confirmed in the screenhouse with viruliferous leafhopper infestation.

Mid-altitude, streak-resistant populations. MSV is a major constraint for maize production in the mid-altitude ecology (700-1,400 m above sea level). Streak epidemic with more than 85 percent infection was observed during 1980 in Angola. Streak incidence is also high in Tanzania, Zaire, Uganda and Zambia. The streak-resistant populations developed by IITA are lacking resistance to *P.*

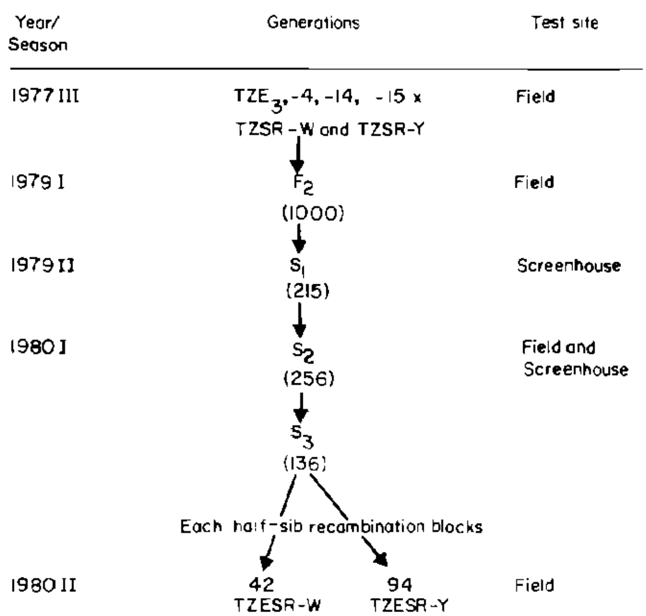


Fig. 1. Breeding procedures of TZESR white and yellow populations.

sorghi (rust) and *H. turcicum* (blight), which are major diseases in the mid-altitude ecology. Therefore, IITA's maize program initiated specific projects to create mid-altitude, streak-resistant populations. Varieties from Cameroon, Kenya, Tanzania, Zambia and CIMMYT were collected and crossed with streak-resistance sources (Table 5). Segregating progenies in different breeding stages were tested during 1980 at Jos, Nigeria (1,200 m above sea level). Selected breeding lines were sent to Tanzania and Zambia for adaptation tests.

Table 5. Base populations for mid-altitude, streak-resistant populations (1980).

Origin	Name of varieties	Generation
Zambia, Zimbabwe	ZCA, ECEM-573, SR 52 ('80 Jos sel. 48 S_1)	BC_3, S_2, S_1 + $\underline{Ht_2}$
Kenya	Ka-umani, H614, 7801	F_1
Tanzania	Ilonga, 7480, 7621, 7696, etc.	F_1
Cameroon	BacoA, BacoB	F_1
CIMMYT	Tlalt 7844, etc.	F_2
Others	US corn belt × mid-altitude	S_1

Streak-resistant, back-up populations. Selected varieties from CIMMYT, EVT 12, EVT 13, ELVT 18A and ELVT 18B; IITA/SAFGRAD, RUVT 1 and RUVT 2; African national programs and the Asian Regional Maize Program (ARMP) were crossed with streak-resistant donors (Table 6). Resistant segregants will be grouped into the early and medium maturity and mid-altitude populations. These sources of germplasm will be added in the future for further widening of the genetic diversity of the streak-resistant populations.

Table 6. Base populations for streak-resistant, back-up populations (1980).

Source	No. of varieties	Generation	Name of varieties
EVT 12	8	F_2, BC_1	Ferke 7622, Kisanga 7729 Kaniama 7725, etc.
EVT 13	6	F_2, BC_1	Across 7728, -7735, Siete Lagoas 7728, etc.
EVT 18A	14	F_1, F_2	Ominita 7643, Across 7643, La Maquina 7827 etc.
EVT 18B	7	F_1, F_2	Ferke 7635, Suwan 7726, Pool 16, Poza Rica 7726, etc.
RUVT-1	6	F_1	BDS III, Niwara
National	24	F_1, S_2	SR 52, Katumani, H614, 7480, etc.
ARMP	5	F_2	Suwan 1 × G.K. Early DMR comp. etc.

Segregating susceptible and resistant plants to maize streak virus in back-up maize populations.

Downy-mildew, streak-resistant populations. Downy mildew *(Sclerospora sorghi)* is causing severe losses of maize yield in parts of Ondo, Kwara and Bendel States of Nigeria. It is even more widespread in Zaire. Good levels of resistance to downy mildew were developed in Indonesia, Philippines and Thailand. These varieties are being used as a source of germplasm to develop downy-mildew resistant and downy-mildew, streak-resistant varieties adapted to Africa. This project is being done in cooperation with the National Cereal Research Institute (NCRI), Nigeria. It is also planned to develop closer cooperation with the national program of Zaire.

Screening of segregating germplasm for downy mildew was done at Owo and Kabba in Ondo and Kwara States of Nigeria, respectively, with artificial inoculation. In general, weather conditions were not favorable for disease development. A total of 1,809 entries for downy-mildew resistance and downy-mildew, streak-resistance including populations, S_1, S_2, S_3 and S_4 line were tested. Based on downy-mildew and other disease resistance and agronomic characteristics, 82 downy-mildew resistant white, 26 downy-mildew resistant yellow, 37 downy-mildew streak-resistant yellow and 10 downy-mildew, streak-resistant white advanced breeding lines were selected for recombination (half-sib). The downy-mildew resistant and downy-mildew, streak-resistant lines are being recombined at NCRI and IITA.

Effect of streak resistance in heterozygous conditions. Under streak epidemic, streak-resistant varieties show a very significant yield advantage over streak-sensitive varieties (IITA Annual Report 1978, 1979).

It was also observed that the F_1 between streak-sensitive varieties and streak-resistant donors shows intermediate disease symptom. The effect of streak-resistant genes in heterozygous condition was studied by crossing 20 streak-susceptible varieties (1 IITA, 14 CIMMYT, 5 Asian) with TZSR or IB32. The F_1 progenies and the susceptible varieties were grown in 2 different fields with and without artificial viruliferous leafhopper infestation (Table 7).

Under natural infestation, the susceptible varieties had 25 percent more average yield reduction than the same varieties crossed with streak-resistant donors. This may be attributed to natural infestation and heterotic effects. On the other hand, under artificial infestation, the susceptible varieties had 95 percent more yield reduction than the same varieties crossed with streak-resistant crosses. Even if the 25 percent yield reduction was due to the heterotic effect of the crosses between 2 different materials, 70 percent yield reduction can be attributed to MSV under artificial infestation. Variety × streak-resis-

Table 7. Effect of MSV on grain yield (IITA, 1980).

No. of varieties	Streak-resistant source	Grain yield (t/ha) Natural Sus.	Grain yield (t/ha) Natural Res.	Grain yield (t/ha) Infested Sus.	Grain yield (t/ha) Infested Res.	% yield reduction of sus. over res. var. Natural	% yield reduction of sus. over res. var. Infested
14	TZSR	3.5	4.5	0.1	2.7	22	95
6	IB32	2.5	3.9	0.1	2.4	36	96
20	Average	3.2	4.3	0.1	2.6	25	95

tant line (top-cross) or variety × variety (varietal-cross) may be a rapid temporary solution to MSV as a major constraint to maize production.

Genetic studies of MSV resistance. Three homozygous susceptible inbred lines were crossed with streak-resistant donor IB32 S_5 lines in 1979. Advanced generations, including F_1, F_2 and both backcrosses, were developed. Two sets, IB32 × B73 and IB32 × Mo17, of 6 generations, including 2 parents; Pr (resistant) and Ps (susceptible), F_1, F_2, Br (backcross to resistant parent) and Bs (backcross to susceptible parent) were tested in both the screenhouse and field, except for the IB32 × B14 cross and its advanced generations, which were only tested in the field. Relatively uniform virus infestations were achieved in all experiments by viruliferous leafhopper infestation. MSV ratings were taken at 2 weeks after mid-silking, based on a 1 to 5 rating scale (1 being highly resistant and 5 being highly susceptible). Mean and genetic variance components for the 3 sets of all crosses are summarized in Table 8. Average phenotypic variance comprized 55 percent additive genetic (V_A = 0.756), 26 percent nonadditive genetic (V_D = 0.352) and 19 percent environmental (V_E = 0.254). Both narrow- and broad-sense heritabilities were estimated, accounting for 55 percent (nH) and 78 percent (bH), respectively. Assuming the top 5 percent of segregating resistant plants were selected for resistance, genetic gains through selection for the 3 F_2 populations would be on average 1.3 units per generation. Fig. 2 shows frequency distributions in percentages of MSV ratings for 7,112 maize plants of parents, F_1, segregating progenies from 3 sets of crosses of resistant inbred IB32 (Pr) with 3 susceptible inbred lines.

Table 8. Average MSV ratings (scale 1 to 5) of parents, F_1, F_2 and backcross progenies (1980).

Cross (P_r × P_s)	Parent P_r	Parent P_s	Parent F_1	Advanced generation F_2	Advanced generation B_r	Advanced generation B_s
IB 32 × B73	1.2	5.0	2.6	2.5	2.2	3.4
IB 32 × Mo17	1.2	5.0	2.7	2.9	2.2	3.6
IB 32 × B14	1.7	5.0	1.9	1.4	1.8	3.7
Mean	1.2	5.0	2.4	2.3	2.1	3.6
No. plants	289	306	404	2,734	2,121	1,258

The minimum number of controlling gene loci were estimated by the formula of Castle-Wright. These estimates argue strongly for about 2-3 gene pairs or an average of 2.6. However, this minimum gene number estimate can be biased downward by epistasis and other nonadditive phenomena. This data suggest that both the backcross and the recurrent selection could be effective methods for streak-resistance breeding. F_3 progenies will be tested next year in order to confirm the conclusion drawn in this study.

National maize varieties for streak-resistant conversion. New, improved varieties are being developed by

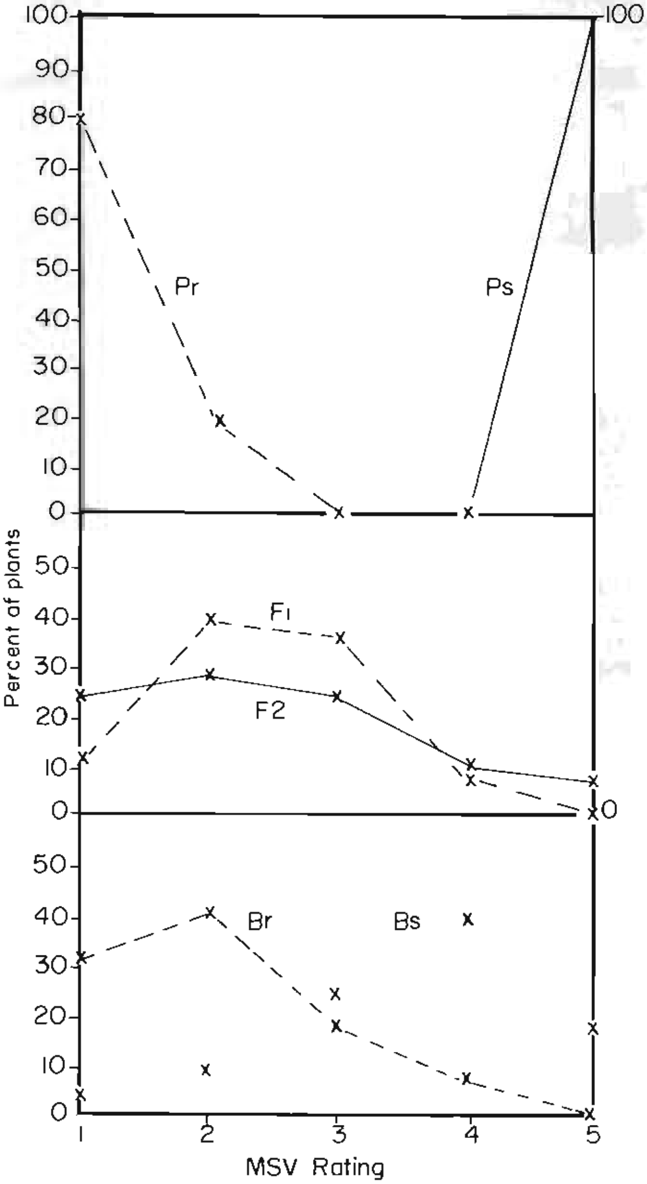


Fig. 2. Frequency distributions in percentages of MSV ratings for 7,112 plants of parents, F1 and segregating progenies from 3 crosses of resistant inbred IB 32 (Pr), with 3 susceptible inbred lines (Ps).

different national programs. These varieties have high-yield potential and good adaptation to local conditions. However, they lack streak resistance. Attempts to develop streak-resistant varieties under natural streak infestation usually failed due to a high escape rate in the field. The following breeding procedure is being used to convert national maize varieties to streak resistance:

National varieties are crossed with streak-resistant sources, and S_1 lines are developed under artificial streak infestation. Seeds of the S_1 lines are sent to the national programs for adaptation tests, and remnant seeds are kept at IITA. Selected lines, based on the data from the national programs, are recombined at IITA and backcrossed to the original recurrent parental variety. A new S_1 line will be developed under artificial streak infestation for the new improvement cycle. When sufficient levels of streak resistance and adaptation are achieved (2-3 cycles), the continuation of the improvement program will be done by the national programs (Table 9).

Table 9. National maize varieties for streak-resistant conversion (1980).

Country	Varieties	Conversion for:	Generation
Zambia	ZCA, ECEM, SC. N3 (testing in Zambia '81)	SR, Ht	S_2, BC_3
Tanzania	Ilonga, 7480, 7621, 7996, 7792	SR	F_1
Kenya	Coast comp. Katumani B.	SR	F.
Cameroon	Ekona-W, Ekona-Y	SR	F_1
Nigeria	MSC-Y	SR	F_1

SR = Streak resistance.
Ht = Helmimthosporium turcicum.

IITA/CIMMYT cooperative program for streak-resistant conversion. Through the international breeding program, CIMMYT has identified population 43 (La Posta) and a number of experimental varieties with high-yield potential and adaptation for different countries in Africa. The purpose of the IITA/CIMMYT cooperative project is to introduce streak resistance into these varieties. Initially, full-sib families of population 43 and 1,200 plants of each of the experimental varieties were tested in the screenhouse with artificial streak infestation. Only a few plants were identified as having some degree of resistance. The same materials were planted in the field, and crosses were made with TZSR-W-1 and TZSR-Y-1. It was decided to convert the experimental varieties to streak resistance by the backcross method and transfer the center for international improvement of population 43 from CIMMYT to IITA with the major emphasis on streak resistance.

Maize stemborers resistance breeding

Resistance breeding against stemborers, especially *Sesamia calamistis*, has been carried out at IITA for the last several years. Major screening procedures have been conducted under severe natural epibiotic conditions at Umudike, Nigeria. In 1980, selected stemborer-resistant lines were tested in a screenhouse under *Sesamia* larva infested conditions. Selected 195 recombined half-sib ears were tested at Umudike (planted on July 20).

Dead heart percentage of the field was 87.5 percent indicating severe infestation of *Sesamia*. One hundred and four ears from 60 half-sib families were selected based on the *Sesamia* ratings, clean ears against ear rot and ear insects and agronomic characteristics (Table 10). The selected ears are recombined in a half-sib isolated field. Average borer resistance ratings of the selected 60 families were 3.6 based on the 1 to 5 average score, which is significantly lower than the rating scale of the 5 control varieties (4.8).

In addition, 127 borer- and streak-resistant families were also tested at Umudike. Fifty-three ears were selected from 29 families (Table 10). These borers-streak resistant selected families are also included as female rows in the TZBR half-sib recombination field. Further accumulation of apparently minor genes will be carried out continuously under natural and artificial stemborer conditions.

Table 10. Summary of selected families for borer resistant and borer and streak resistant populations (Umudike, 1980).

	No. of families		Harvested Ears	Borer resistant ratings*	
	Tested	Selected		Tested	Selected
Borer resistant	95	60	104	4.2	3.6
Borer and streak resistant	129	29	53	4.6	3.8
Checks	5	-	-	4.8	-

* *1-5 score; 1 = resistant, 5 = susceptible.*

Population improvement

IITA released varieties, TZB and TZPB, are widely grown in about 100,000 ha in Nigeria. These varieties also have shown good performance and adaptation in Cameroon, Gabon, Republic of Benin, Sierra-Leone and other West African countries. Population improvement of these varieties is done continuously by a mass selection method to supply seeds for multiplication to the National Seed Service in Nigeria. The U.S. × tropical populations, TZUT and TZUTSR, are also included in this program. In addition, progeny testing for specific adaptation was initiated in 1980 for TZPB in the high-rainfall areas and TZB in the savanna areas.

TZB. Two hundred and eighty-eight S_1 lines were tested at 2 northern locations in Nigeria, Mokwa and Funtua. Thirty-six lines were selected based on yield and agronomic traits. Selected lines were recombined during the 1980-81 dry season. Further testing of half-sib families will be made at selected areas in northern Nigeria in 1981.

TZPB. Two hundred and fifty TZPB half-sib families were tested with 3 replications for yield and agronomic traits at Onne. Thirty-six lines (14.4 percent) were selected, considering yield, ear-rot tolerance, tip cover, disease resistance, etc. The average yield of the selected lines was 5.5 t/ha compared to 4.2 t/ha for TZPB, which was used as a control. Selected families are being recombined during the 1980-81 dry season and will be tested

Improved U.S. × Tropical (TZUT) maize plants with good agronomic characteristics in the full-sib recombination block.

again at Onne in 1981. The major objective of this population is to develop a high-rainfall adapted variety with high yield and good disease resistance, especially to ear rot and *H. maydis*. Next year, each recombined family also will be tested for tolerance to acid soil.

TZUT. The major objective of U.S. × tropical crosses is to transfer the efficient plant architecture of the U.S.A. corn belt genotypes into tropically well adapted and disease-tolerant populations.

Three hundred and twelve half-sib lines were tested with 2 replications at 6 locations in Nigeria; IITA, Onne, Ikenne, Mokwa, Funtua and Gusau. Seventy lines were selected for high yields and good agronomic characteristics. Based on the results, the selected lines were separated into 2 populations, northern and southern. Each population has been recombined by the full-sib method. The selection cycles will continue separately in the humid and savanna ecologies, respectively.

Bulk seeds of TZUT were tested for their yield and adaptation at 5 locations in Nigeria (Table 11). This population flowers in 53 days, 1 week later than TZE 4, and matures in 100 days, 10 days later than TZE 4. The average yield was significantly higher than TZE 4 and other TZE varieties tested. Seed color is still segregating for both yellow and white.

TZUTSR. One hundred and thirty-three derived U.S. × tropical lines from crosses between Hawaiian germplasm and TZSR varieties were recombined for good agronomic characteristics and disease resistance during 1980. Bulk seeds were tested for their yield during 1980 in 5 locations in Nigeria (Table 11). Results seem quite promising for further improvement of this population. The S_1 line will be developed among the selected individual plants to test for resistance to streak and other diseases as well as agronomic characteristics next year.

Table 11. Grain yield (t/ha) of U.S. × tropical maize composites at 5 locations in Nigeria (1980).

Variety	IITA	Ikenne	Mokwa	Funtua	Gusau	Average	Yield index
TZUT-SR	4.9	7.4	5.8	7.3	1.8	5.4	150
TZUT	5.1	5.6	6.0	5.4	3.4	5.1	142
Check TZE_4	2.7	4.4	3.1	5.0	2.7	3.6	100
TZE_{17}	2.8	4.2	3.3	4.5	1.8	3.3	92
TZE_3	2.3	3.7	2.0	4.0	2.4	2.9	81
TZE_{15}	2.7	3.5	2.0	3.6	1.4	2.6	72

S.E. = 0.3; LSD (5%) = 1.0; LSD (1%) = 1.3.

Table 12. Results of the early-maturing Nigerian zonal variety trials (IITA and Funtua, 1980).

	Grain yield (t/ha)			% Grain moisture			Plant No. harvested
Variety	Funtua	IITA	Mean	Funtua	IITA	Mean	(mean)
TZUT	4.0	2.8	3.4	27	36	32	62
DMR-YE	3.4	3.0	3.2	23	34	29	70
NE-Y	3.4	2.7	3.1	23	33	28	64
Kewasoke	3.8	2.1	3.0	26	34	30	55
TZE 17	3.0	2.2	2.8	24	32	28	65
TZE 15	3.1	1.6	2.4	24	31	28	62
TZE 4	2.1	2.2	2.2	24	30	27	66
LSD (5%)	1.3	0.8					

National and international trials

National zonal maize variety trials, Nigeria. IITA cooperated with the national maize program in Nigeria by evaluating the most promising breeder releases in different environmental conditions.

In the early-maturing variety trials, TZUT was the highest yielding variety, which performed particularly well in Funtua (Table 12). DMR-YE, developed at NCRI also performed well and had, on the average, 3.3 percent lower moisture content than TZUT. In the medium-maturing variety trials, TZSR-Y-1 and TZSR-W-1 were the best performing entries (Table 13).

CIMMYT international trials. Two varietal trials, ELVT 18A and ELVT 18B (Table 14), were conducted at IITA in the 1980 first season, and 3 varietal trials, EVT 14A, EVT 14B and ELVT 20 (Table 15), were conducted at Ikenne in the 1980 second season. In ELVT 18A, 5 experimental varieties had higher yields than TZPB (2-12 percent). These experimental varieties were derived from Population 22 (Mezcla tropical blanca), Population 28 (Amarillo Dentado) and Population 43 (La Posta). It was reported that experimental varieties from these populations have shown good performance in Nigeria and elsewhere in lowland tropical regions of Africa. The data from ELVT 18B revealed that 3 experimental varieties were (3-13 percent) higher yielding than the best check, TZB, and were 4-6 days earlier in days to 50 percent silking. These are yellow varieties derived from Population 26 (Mezcla Amarilla) and Population 35 (Antigua × Republica Dominicana). EVT 14A and EVT 14B contain varieties that are early to intermediate in maturity (90-105 days), and ELVT 20 contains varieties that are more suitable for subtropical conditions. In EVT 14A (Table 15), the 5 highest yielding varieties outyielded the best check, TZUT, by 22-24 percent and were earlier maturing. In EVT 14B, the 5 highest yielding varieties outyielded the best check, TZUT, by 8-17 percent and were earlier maturing. These early varieties are promising. In ELVT 20, none of the experimental varieties yielded as well as the best check, TZUT. These varieties are of temperate × tropical background and did not seem adapted well enough to these environmental conditions.

Line development

The major objective of IITA's hybrid program is to develop a collection of elite inbred lines, mainly S_3-S_4, with adaptation to the different ecologies of Africa, disease and insect resistance, vigor and good combining ability. The best available tropical maize varieties, many of which are from CIMMYT, are being used for extraction of the lines with special emphasis of genetic diversity. These lines will be available to any country for a hybrid program. However, the lines can also be used for the development of better disease and insect resistant synthetic varieties or for population improvement breeding (Fig. 3).

Table 13. Results of the medium-maturing Nigerian zonal variety trials (IITA and Funtua, 1980).

	Grain yield (t/ha)			% Grain moisture			Plant No. harvested
Variety	Funtua	IITA	Mean	Funtua	IITA	Mean	(mean)
TZSR-Y-1	4.8	4.1	4.4	31	31	31	70
TZSR-W-1	5.1	3.7	4.4	36	29	33	73
TZB	4.6	3.6	4.1	33	32	33	69
TZPB	4.1	3.8	4.0	36	29	32	67
MSRB-W	4.5	3.4	3.9	29	29	29	70
Western Yellow	3.2	3.3	3.2	35	31	32	64
LD	2.1	3.1	2.6	38	40	39	42
LSD (5%)	1.3	1.0					

Table 14. Summary of ELVT 18A and ELVT 18B (IITA, 1980 First season).

Trials	Variety	Grain (t/ha)	Yield-index	Days to 50% silking	Grain moisture (%)	Plant No. harvested
ELVT 18A	Ferke (1) 7622	3.9	112	58	22	34
	Omonita 7643	3.9	111	59	23	40
	Poza Rica 7822	3.8	108	56	22	38
	Across 7643	3.8	108	58	22	37
	Poza Rica 7728	3.6	102	56	23	31
	TZPB (check)	3.5	100	60	23	29
LSD (5%)		0.9				
ELVT 18B	Across 7635	3.9	113	50	28	28
	Tocumen (1) 7835	3.7	108	49	28	28
	Suwan 7726	3.6	103	51	30	30
	Ferke (2) 7635	3.4	99	50	29	29
	Pichilingue 7726	3.3	97	52	29	29
	TZB (check)	3.4	100	55	34	34
LSD (5%)		0.6				

Table 15. Summary of EVT 14A, EVT 14B and ELVT 20 (Ikenne, 1980 Second season).

Trials	Variety	Grain (t/ha)	Yield-index	Days to 50% silking	Grain moisture (%)	Plants No. harvested
EVT 14A	Poza Rica 7931	4.5	124	47	30	41
	Bahia 7835	4.5	124	51	29	43
	Pichilingue (1) 7835	4.4	123	50	32	44
	Tocumen (1) 7931	4.4	123	48	26	40
	Tocumen (1) 7626	4.4	121	53	32	42
	TZUT (check)	3.6	100	55	35	36
	TZE4 (check)	2.5	70	49	26	34
LSD (5%)		1.0				
EVT 14B	Pirsabak (1) 7930	4.2	117	48	26	44
	Jutiapa (1) 7930	4.2	115	47	23	41
	Poza Rica 7930	4.1	113	50	24	39
	Blanco Christ.-2	4.1	113	49	26	44
	Pirsabak (2) 7930	3.9	108	48	25	41
	TZUT (check)	3.6	100	55	34	39
	TZE 15 (check)	2.8	74	49	24	37
LSD (5%)						
ELVT 20	Tlaltizapan 7844	3.7	91	54	37	43
	Tlaltizapan 7845	3.7	91	49	31	41
	Tlaltizapan 7734	3.3	81	54	34	41
	Tlaltizapan 7833	3.2	80	54	33	39
	Across 7734	3.0	72	52	29	40
	TZUT (check)	4.1	100	55	36	43
	TZE 17 (check)	3.4	58	49	28	34
LSD (5%)		0.8				

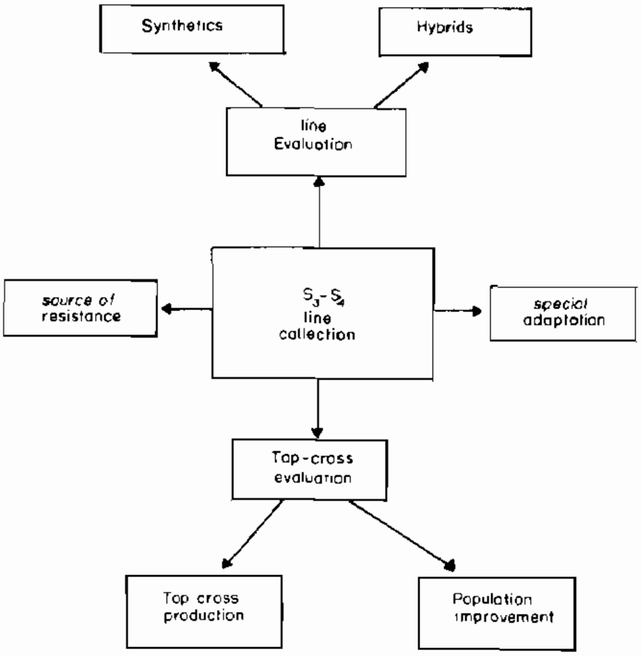


Fig. 3. Possible uses of line collection of tropical maize.

During 1980, the program for line development was continued. Table 16 summarizes the different breeding stages of the genetic materials under this program at the end of the year.

So far, 17 advanced high-combining lines were identified (Table 17). Seeds of these lines are being increased and will be available for any interested national or international program. Some of the lines can be used as sources of resistance to the major tropical leaf diseases such as *P. polysora* and *H. maydis*. Emphasis is given to convert the 2 most widely used inbred lines in the U.S.A., B73 and Mo17, for *P. polysora* and streak resistance. In addition, improved S_4 early-maturing, streak-resistant lines also are available (Table 18).

Table 16. Brief summary of maize inbreeding program (IITA, 1980).

Generations	No. of lines	Specific traits
S_1	2,500	Resistant to streak, rusts and/or blights.
S_2	1,895	Resistant to streak, downy mildew, rust and/or ear rot.
S_3	352	Resistant to streak and/or lodging.
S_4	50	Resistant to rust and/or blight.
S_5	37	Resistant to streak, but susceptible to lodging (IB32 related lines).
Inbred	32	Introduced tropical and temperature lines

Top-crosses testing

Top-crosses (variety × line) are being used usually as a means to test the combining ability of inbred lines. To simplify seed production, an intermediate stage, the commercial use of top-crosses, is being proposed by IITA's scientists. A number of top-crosses were tested in comparison to the varieties used as parents in the top-cross with encouraging results (IITA Annual Report,

Table 17. High-combining tropical maize lines (IITA, 1980).

Line	Origin	Silking days	Plant height (cm)	Ear height (cm)	Resistance*		
					Polysora	*Maydis*	*Eldana*
TZPB 1808	TZPB	59	172	96	2.5	1.5	2
TZPB 1838	TZPB	57	140	75	1.5	1.5	1.5
TZPB 1986	TZPB	56	163	66	1.5	1.5	1.5
95	Cambodia PR7A	61	90	31	1	1.5	2
174	Veratiqua	60	183	93	1.5	2	2.5
177	Veratiqua	58	190	100	1	2	3
189	Veratique	60	201	111	1.5	1.5	3
226	Veratiqua	61	182	83	1	1.5	2
239	Veratiqua	60	147	96	1	1.5	2
276	Veratiqua	58	152	81	2	1.5	3
279	Veratiqua	59	152	62	2	1.5	2
Ant 2C	Cuban flint	61	157	56	1	1	2
HI 29	Hawaii	56	161	81	2	2	2
CM 201 (Hi)	India/Hawaii	53	172	62	3	2	2.5
IB32	IITA	61	192	96	1	1	2
B73	Iowa	55	131	37	4	3	3
Mo17	Missouri	54	130	40	4	1.5	2

1-5 socre: 1 = resistant, 5 = susceptible.

1979). The testing program was extended to 5 different locations throughout Nigeria

Early-maturing top-crosses. Twenty-three early-maturing top crosses and 5 early-maturing composites were tested at 5 locations in Nigeria (Table 19). Four top-crosses had significantly higher yields than the best check, TZE_4, with an average increase of 35 percent in yield throughout the 5 locations. However, variety × location interaction was highly significant. An increase of 57, 52, 91, 58 and 24 percent in yield was obtained comparing the best top-cross with the best composite check at IITA, Ikenne, Mokwa, Funtua and Gusau, respectively

Namely, an average of 56 percent increase in yield of the best top-cross was obtained in each location.

Medium-maturing top-crosses. Four hundred and twenty-one medium-maturing top-crosses, including some single cross hybrids between different S_1-S_4 lines or inbred lines, were tested at various locations in Nigeria in preliminary yield trials. Results of the highest-yielding 4 top-crosses or single-cross hybrids at IITA,

Table 18. Promising tropical streak-resistant maize lines (IITA, 1980).

Line	Plant height (cm)	Ear height (cm)	Resistance*		
			Polysora	*Maydis*	*Eldana*
ESR-Y-9	175	90	1.5	1	1.5
ESR-Y-18	170	70	1.5	3	2.5
ESR-Y-24	170	80	1.5	2	1.5
ESR-Y-30	168	70	1.5	1	3
ESR-Y-51	155	60	2.5	2.5	2
ESR-W-18	122	51	1	1	3.5
ESR-W-34	115	55	1.5	1.5	2
ESR-W-43	125	55	1.5	1.5	1.5
ESR-W-75	130	55	1.5	2	2
ESR-W-79	150	55	1	3.5	1.5

1-5 score; 1 = resistant, 5 = susceptible.

Table 19. Grain yield (t/ha) of selected promising early-maturing maize varieties at 5 locations in Nigeria (1980).

Variety	IITA	Ikenne	Mokwa	Funtua	Gusau	Avg.	% Yield index
$TZE_{[illegible]}$ × 95	3.4	5.9	5.1	7.3	3.6	5.0	140
$TZE_{[illegible]}$ × 95	4.3	5.4	6.3	5.6	2.9	4.9	136
TZE_4 × 174	4.4	6.7	3.1	7.9	1.9	4.8	133
$TZE_{[illegible]}$ × 174	3.7	6.3	4.3	6.1	3.4	4.7	132
TZE_4 × 276	3.5	5.1	4.3	7.8	1.6	4.6	128
TZE_4 × 279	4.1	5.4	4.6	6.9	1.6	4.5	126
TZE_4	2.7	4.4	3.1	5.0	2.7	3.6	100
$TZE_{[illegible]}$	2.8	4.2	3.3	4.6	1.8	3.3	92
$TZE_{[illegible]}$	2.5	4.1	3.0	3.6	2.9	3.2	90
$TZE_{[illegible]}$	2.3	3.7	2.0	4.0	2.4	2.9	80
$TZE_{[illegible]}$	2.7	3.5	2.0	3.6	1.4	2.6	74
Overall Mean (28 varieties)	3.8	5.1	4.0	5.8	2.5	4.2	117

S.E. = 0.3; LSD (5%) = 1.0; LSD (1%) = 1.3.

Ikenne, Mokwa, Funtua and Gusau are summarized in Table 20 in comparison to the most widely used composite varieties in Nigeria, TZPB or the average of the 2 composite varieties. These results show, again, the significant advantage in yield of selected top crosses over composite with good management. The average advantage in yield of the best top-cross in each one of the locations was 57 percent.

Table 20. Grain yield (t/ha) of selected promising top-cross maize varieties at 5 locations in Nigeria (1980).

Top cross	Yield (t/ha)	% Yield index
IITA		
Tlal 7644 × IB32	6.5	178
TZPB 1746 (S_1) × F44 (HI)	6.4	174
Gemeiza 7644 × IB32	6.4	174
TZPB × IB32	6.3	170
Check (TZB)	3.7	100
SE ($\bar{x}$)	1.2	
Ikenne		
ETO 76 × 158	9.8	163
MMB × 400	9.5	158
226 × 95	9.2	153
Tlal. 7322 × 86	8.9	148
Check (TZB, TZPB)	6.0	100
SE ($\bar{x}$)	1.5	
Mokwa		
MMB × 276	8.4	142
TZPB × 180	8.1	137
LM 7422 × 95	7.8	132
PR 7422 × 228	7.8	132
Check (TZB, TZPB)	5.9	100
SE ($\bar{x}$)	1.0	
Funtua		
ICA. L. 25 × TZPB 1838	9.2	153
TZPB × 228	9.0	150
ICA. L. 27 × TZPB 1838	8.9	148
Tlal. 7322 × 279	8.9	148
Check (TZPB, TZB)	6.0	100
SE ($\bar{x}$)	1.4	
Gusau		
Tx 29A × Tuxp C 110	7.2	149
TZSR-Y × 228	6.9	144
PR 7428 × 189	6.5	136
TZSR-Y × 372	6.0	126
Check (TZPB)	4.8	100
SE ($\bar{x}$)	0.9	

PR—Poza Rica; LM—La Maquina; MMB—Milo Maya Brazil; Tlal.—Tlaltizapan.

Entomology

Artificial rearing of maize stemborers

For insect-host plant resistance work, it is important to ensure that uniform pest infestations are obtained at the desired stage, time and intensity. This would eliminate or minimize the mistaking of escapes for resistant lines. This is of particular importance when working with lepidopterous insects, for they seldom occur in uniform levels; therefore, insects should be produced in large numbers so as to infest plants artificially. At IITA, a new insect rearing facility has been set up to generate the supply of insects to be used for resistance screening by artificial infestation.

Several diets were evaluated in 1980 for rearing *Eldana saccharina* and *Sesamia calamistis*. Of these diets, 4 were selected for further testing. These included soyflour wheatgerm, cowpea flour casein, cowpea flour torula yeast and corn soy milk (CSM). The results obtained from soyflour wheatgerm diet compare most favorably with the growth and development reported in the literature for the natural diet of the stemborers (Table 21). This diet is now being used as the rearing medium.

Of the 2 borers, the *Eldana* culture is presently in its seventh generation while *Sesamia* is in its sixth on the artificial diet. A suitable diet must have the following characteristics: high larval survival, normal larval development, high adult reproductive capacity, etc., therefore, these parameters are monitored every 2 months. The life cycle for *Eldana* and *Sesamia* (egg to egg) takes about

Table 21. Growth and development of E. saccharina and S. calamistis on 4 artificial diets.

Developmental Parameter	Diet[a] 1 ♂	1 ♀	2 ♂	2 ♀	3 ♂	3 ♀	4 ♂	4 ♀
Av. pupal weight (mg)								
Eldana	104.9	158.2	99.4	153.1	101.7	152.5	95.2	156.7
Sesamia	160.3	241.2	145.5	201.0	144.2	203.6	157.5	218.7
Av. pupation time (days)								
Eldana	17.6	18.3	20.4	21.8	21.5	22.6	27.1	29.7
Sesamia	25.3	26.4	26.6	30.9	26.7	28.7	32.0	35.0
Av. emergence time (days								
Eldana	8.7	8.8	8.1	8.8	8.2	8.1	9.1	8.9
Sesamia	11.2	11.5	11.0	11.7	11.8	11.6	12.1	11.7
Total development time (days)								
Eldana	26.3	27.1	28.5	30.6	29.8	30.7	36.2	38.6
Sesamia	36.5	37.9	37.8	42.6	38.5	40.3	44.1	46.7

[a]*Major ingredients of the diets are as follows: (1) Soyflour wheat germ; (2) Cowpea flour casein; (3) Cowpea flour torula yeast; (4) Corn soy milk (CSM) human food supplement.*

32 and 42 days, respectively. Table 22 shows the oviposition status for the last 2 generations of each of the borers. These data are comparable to what is reported in the literature.

Because a main ingredient of the diet—the soyflour—is at present obtained from the U.S.A., local substitutes are being evaluated, such as cowpea flour, which can be more readily obtained at a much lower cost. Preliminary results so far obtained are encouraging.

Table 22. Oviposition trends in successive generations.

Species	No. of eggs/♀ October 1980	December 1980
Eldana	419.5	462.0
Sesamia	345.8	353.5

Evaluation of leafhopper distribution methods

The efficiency of 2 distribution methods of viruliferous leafhoppers under field conditions was compared: leafhoppers released in the field by cage and leafhoppers released by the newly improved method (IITA Annual Report, 1979) in which 3-4 leafhoppers are applied to each plant individually.

Two maize varieties, TZPB (streak sensitive) and TZSR-Y-1 (streak resistant), were tested with and without the 2 infestation techniques. A split-plot design (varieties as main plots) with replications was used; each treatment was in 5 m × 5 m plots. Two border rows of TZSR-Y-1 were planted a month before planting the experiment to minimize movement from plot to plot.

The results clearly demonstrate the efficiency of the newly-improved method compared to a random release of the same number of leafhoppers (Table 23). Unfortunately, the 2 border rows did not prevent the movement of leafhoppers; therefore, high infection percentages with streak were observed without infestation in the streak-sensitive TZPB. This experiment also showed the high level of resistance achieved in TZSR-Y-1 and the yield advantage of this variety under streak epidemic.

Table 23. Evaluation of MSV infestation methods and effect on grain yield of maize under field screening (IITA, 1980 third season).

Variety/Treatment	Streak infection %	Grain yield (t/ha)
TZPB (No-resistant)		
Improved	99.0 a	.4 c
Release	61.0 b	.8 c
No-Infestation	55.0 b	1.1 c
TZSR-Y-1 (Resistant)		
Improved	5.0 c	1.9 b
Released	3.0 c	2.1 ab
No-Infestation	3.7 c	2.2 a

Semi-Arid Food Grains Research and Development Project (SAFGRAD)

Genetic improvement

Regional uniform variety trial-1 (RUVT-1). Early-maturing varieties originating from different national programs, IITA, SAFGRAD and CIMMYT, were tested in 14 countries. Table 24 shows the origin of the different varieties and the mean of grain yield and days to flower across 9 of their locations. Pool 16, TZE 3 and TZE 4 were the earliest maturing varieties taking 50-51 days to flower. IRAT 102, ZM10, BDS III and Early Yellow took 53-55 days to flower; other varieties were later. Pool 16 was the highest yielding entry (3.4 t/ha); the varieties in the same maturity group, TZE 3 and TZE 4, yielded 2.5 and 2.4 t/ha, respectively. Among the other early varieties, BDS III. a complex hybrid, performed well.

Table 24. Regional uniform variety trial-1. Mean of grain yield and days to flower across 9 locations (1980).

Variety	Origin	Grain yield	Days to flower
Pool 16	CIMMYT SAFGRAD	3.4	50
IRAT 100	Upper Volta	3.2	57
TZPB	IITA/ SAFGRAD	3.0	63
BDS III	Senegal	2.9	54
IRAT 102	Upper Volta	2.9	55
Mexican 17	Ghana	2.8	57
Early Yellow	Ghana	2.8	53
Niwara Comp.	Benin	2.6	60
ZM 10	Senegal	2.6	55
TZE3	IITA/ SAFGRAD	2.5	50
TZE4	IITA/ SAFGRAD	2.4	51

Table 25 shows the trial sites and the 3 highest-yielding entries at each location. Pool 16 was among the 3 highest-yielding varieties in 7 of the 9 locations. This is an indication of yield stability across different environments. One cycle of mass selection in Pool 16 in a seed-increase field has been completed at Kamboinse, Upper

Table 25. Regional uniform variety trial-1. Three highest yielding varieties at each location (1980).

Location	Three highest yielding varieties
Saria, Upper Volta	BDS III, Pool 16, Early Yellow
Sebba, Upper Volta	ZM 10, TZE3, TZE4
Bouake, Ivory Coast	TZPB, Pool 16. NIWARA Comp.
Conakry, Guinea	IRAT 100, BDS III, Pool 16
Yundum, Gambia	IRAT 100, Pool 16, BDS III
Guiring, Cameroon	Pool 16, BDS III. Mexican 17
Masantola, Mali	TZE3, Pool 16, ZM 10
Katibougou, Mali	IRAT 100, BDS III, Pool 16
Nyankpala, Ghana	IRAT 100, IRAT 102, TZPB

Volta, and seed will be available to national programs for on-farm testing and further multiplication next year.

Regional uniform variety trial-2 (RUVT-2). Medium-maturing varieties from 4 national programs, SAFGRAD/IITA and CIMMYT were screened for the mean of grain yield and days to flower across 7 locations (Table 26). The earliest maturing varieties were Ferke (1) 7635, HN2 and BDS III, taking 56 days to flower. The highest yielding entry was IRAT 81, a complex hybrid, which flowered in 63 days, followed by Comp. 4, TZPB and TZSR-W. In Table 27, the test locations and the 3 highest-yielding varieties at each location are presented. IRAT 81 was among the highest yielders at 5 of the locations.

At all locations, some varieties could be identified that outyielded the local check in both RUVT-1 and RUVT-2.

Table 26. Regional uniform variety trial-2. Mean of grain yield and days to flower across 7 locations (1980).

Variety	Origin	Grain yield (t/ha)	Days to flower
IRAT 81	Upper Volta	3.6	63
Comp. C4	Ghana	3.2	62
TZPB	IITA/ SAFGRAD	3.0	63
TZSR-W	IITA/ SAFGRAD	3.0	63
Ferke(1) 7635	CIMMYT	2.9	56
NH2	Benin	2.9	56
Massayomba	Upper Volta	2.8	62
TZB	IITA/ SAFGRAD	2.8	63
BDS III	Senegal	2.7	56
CJ1	Benin	2.6	61
Golden Crystal	Ghana	2.1	59

Table 27. Regional uniform variety trial-2. Three highest yielding varieties at each location (1980).

Location	Three highest yielding varieties
Bobo Dioulasso, Upper Volta	IRAT 81, Composite 4, Golden Crystal
Kamboinse, Upper Volta	BDS III, Composite 4, Ferke(1) 7635
Bouake, Ivory Coast	IRAT 81, TZPB, Composite 4
N'Dock, Cameroon	TZB, IRAT 71, TZSR-W
Ira San, Cameroon	IRAT 81, Golden Crystal, Ferke(1) 7635
Nyankpala, Ghana	IRAT 81, Massayomba, BDS III
Yundum, Gambia	NH2, CJ1, Golden Crystal

Family testing trials. Four trials, each with 140 full-sib families and 4 checks were designed and distributed to 4 different countries. The following populations were included in these regional full-sib family trials (RFTT): TZE 4, TZE 3, TZPB and TZSR. Based on the results obtained, 67 families of TZE 4, 49 of TZE 3, 90 of TZPB and 86 of TZSR were selected for recombination to initiate a new cycle of selection next year.

New introductions. As a back-up activity for the SAFGRAD regional trials, new promising materials obtained from different sources were evaluated for yield and other agronomic characters in replicated trials at 3 locations in Upper Volta: Farako-Ba, Kamboinse and Saria. Considering both earliness and yield. Hungarian Composite, Population 31 (Amarillo Cristalino-2), Pool 18 and Pool 30, all of which originated from CIMMYT, were found to be promising. Seed of these materials is being multiplied during the 1980-81 dry season for further evaluation in the semi-arid region.

High-quality protein maize. Two variety trials: EVT 15A and Special O_2 trial, consisting of hard endosperm O_2 materials received from CIMMYT; were conducted at Kamboinse. Unfortunately, both trials suffered severe drought immediately after flowering, and, therefore, the real potential of these varieties was not realized. In the special O_2 trial, Temperate White H.E.O_2 gave the highest yield of the new varieties tested (4.2 t/ha) and flowered in 45 days. In EVT 15A, yields were very low due to drought and no conclusions can be drawn.

Breeding for earliness and high yield. Full-sib families were generated in 7 populations in 1980: TZE 7, TZE 8, TZE 9, TZE 12, TZE 14, TZE 15 and TZE 16. These families will be evaluated for yield next year, and the best ones will be combined into 2 composites, white and yellow.

Early-maturing populations from other national and international institutions have also been introduced. Mass selection was practiced in promising populations received from CIMMYT, which will be tested in the regional trials next year.

Breeding for disease resistance. With increasing maize cultivation, MSV may become important in the semi-arid zone. Therefore, 390 half-sib families of TZSR (W) were received from IITA and planted for evaluation and selection. Due to severe drought, only 133 pairs of full-sib ears could be selected. Their progenies will be evaluated during the next cropping season.

Temperate x tropical crosses. Six promising temperate subtropical pools from CIMMYT were further evaluated, and the seed was multiplied in 1980. Also, promising lines of U.S. x tropical origin received from IITA were identified and increased for further evaluation next year.

Entomology

Research on insect pests of maize was started in 1979. Millipedes, termites and armyworms (*Mythimna unipuncta*) were found to be the main problems. Infestation by millipedes and termites varied greatly among different locations and experimental plots. Infestation by borers was only noticed in early planted maize. In 1980, experiments were designed to study the effect of planting dates on insect infestation and grain yield and to find out an effective chemical control of termites and millipedes.

Effect of planting date on insect infestation. Four planting dates, 5 June, 10 June, 10 July and 25 July, and 3 maize varieties, Jaine Flint de Saria (JES) and TZE 3, both early maturing, and TZPB, medium maturing, were studied under protected and unprotected conditions. Protection was done by application of 2.5 kg carbofuran/

ha a.i. before planting and 30 days after planting and 0.7 kg endosulfon/ha a.i. at silking.

The infestation of all insects was very low. In general, protected plots had comparatively less infestation than unprotected plots, and higher damage for termites and armyworm was observed in the first planting date (Table 28). JFS was damaged slightly more than the other varieties by armyworms. Because of early drought, the crop was badly damaged, and, therefore, no reliable yield data were obtained.

Table 28. Percent termites and armyworm infestation at 4 planting dates (Kamboinse, 1980).*

		Planting Dates**				
Insect	Treatment	D_1	D_2	D_3	D_4	Mean
Termites	Protected	7.3	1.2	1.0	1.8	2.8
	Unprotected	22.7	.5	6.3	4.6	8.5
	Mean	14.9	0.9	3.7	3.2	5.7
Armyworm	Protected	2.5	1.3	1.1	1.1	1.5
	Unprotected	16.7	7.5	9.6	1.1	8.7
	Mean	9.6	4.4	5.4	1.1	5.1

*Average of 3 varieties.
**D_1 = 5 June; D_2 = 10 June; D_3 = 10 July; D_4 = 25 July.

Observations on other insects. In July, a severe infestation of *spodoptera exempta* was noticed in maize and sorghum. The infestation seems to be associated with weeds either within the field or close by. One application of 40 g decamethrin (Decis)/ha a.i. gave excellent control of this pest.

Agronomy

The major emphasis of the IITA/SAFGRAD maize agronomy program during 1980 was to identify simple management practices to improve the water balance in the 700-90 Omm belt. Twenty-three (20 Kamboinse and 3 at Saria) agronomy trials were planted in 1980 between 6 June and 16 August, and practices to minimize the risk of drought stress were identified.

Tied ridge trials. During 1979, tied ridges gave consistently higher yields than flat seedbed or single ridges even though there were no dry periods during the growing season. Therefore, in 1980, the research included looking into more specific tied ridge systems. Four tied-ridge systems (Table 29 and 30) in a factorial combination with 2 N levels on both an upper-slope soil and a lower-slope soil (hydromorphic soil) were carried out.

Table 29. Effect of tied ridges on grain yield of maize on upper slope (Kamboinse, 1980).

Ridging system	Mean
1. Control (flat soil)	1,170
2. All ridges tied	2,520
3. Ridges tied every 2 furrows	1,970
4. All ridges tied, but only ½ in August	2,400
LSD (5%)	905

Table 30. Effect of tied ridges on grain yield of maize on lower slope (Kamboinse, 1980).

Ridging system	Mean
1. Control (flat soil)	1,250
2. All ridges tied	1,290
3. Ridges tied every 2 furrows	1,480
4. All ridges tied, but only ½ in August	1,640
LSD (5%)	530

The trial was planted on 14-15 July with an early-maturing variety, TZE_3 (90 days to maturing). The rains ended 9 September.

On the upper-slope soil (Table 29), there was a significant increase in yield by using tied ridges. An average yield of 1,170, 1,970 and 2,520 kg/ha was obtained on flat soil, half of the ridges tied and all of the ridges tied, respectively. Both the number and weight of grains increased.

On the lower-slope soil, there were no statistically significant differences in yield among the ridging systems. Plain ridges and all of the ridges tied gave similar yields, 1,250 and 1,290, respectively. However, the yields were achieved through different combinations of the yield components. There was higher grain number with lower grain weight in the plain ridges compared to the tied ridges. This indicates that the tied ridges may be exposed to water logging while the plain ridges to drought stress during the grain filling period in the lower slope. This is supported by the higher yields obtained when only half of the ridges were tied. The economics of the systems will be studied next year.

Toposequence and planting date trials. Two maize varieties, TZE 4 and TZPB (90 and 110 days to maturity, respectively), were planted on 2 planting dates on land strips more or less perpendicular to the slope, from the upper slope to the lower slope.

Grain yields increased markedly as maize was planted closer to the hydromorphic soils in the lower slope (Table 31). Mean yield was 585 kg/ha in the highest strip and 3,260 in the lowest strip. The crop received a high level of fertilizer and, therefore, the effect of crop position on the toposequence appears to be mostly a direct effect of better moisture conditions toward the lower slope. The planting date also had a very significant effect on mean grain yields: 2,780, 1,200 and 640 kg/ha for 14 June, 5 July and 17 July, respectively. But the effect of planting date was more marked for TZPB, medium maturing, than for TZE4 early maturing.

The risk of drought stress may, therefore, be reduced by planting early, by planting early maturing varieties and/or by planting on the hydromorphic soils in the lower slopes. It is important to point out, however, that on the lower-slope soils, yields have been reduced, in some cases, by water logging or even flooding.

Soil preparation trials. The experiment was carried out in Kamboinse with 6 soil preparation methods, 2 levels and early- and medium-maturing varieties, TZE_4 and TZPB, respectively. The planting date was 25 June on wet soil without effective rain until 9 July on a newly cleared land. The results, even though not significant largely because of large experimental error, were similar to those obtained before IITA/SAFGRAD and IRAT. Trac-

Table 31. Effect of toposequence and planting dates on grain yield (kg/ha) of maize (Kamboinse, 1980).

Variety	Planting Date	Position from upper to lower areas 1	2	3	4	5	Mean
	June 14	1590	2180	2650	3990	4200	2920
TZE4	July 5	620	845	1030	2120	4040	1730
	July 17	110	520	390	955	1900	775
	Mean	775	1180	1360	2350	3380	1810
	June 14	1120	1760	1580	3760	5020	2650
TZPB	July 5	80	150	270	690	2120	660
	July 17	0	35	0	200	2270	500
	Mean	400	650	620	1550	3130	1270
	June 14	1350	1970	2120	3870	4610	2780
Mean	July 5	350	495	650	1400	3080	1200
	July 17	55	275	195	575	2080	640
	Mean	585	915	985	1950	3260	1540

LSD (5%)	
Positions	592
Dates	524
Dates at same position	1174
Varieties	178
Varieties at same position	398
Varieties at same date	308
Varieties at same date and position	689

tor plowing gave the highest yeilds mainly because of deeper soil preparation and better water infiltration into the soil. Zero tillage was no better than the traditional farmer's method.

Weeding trials. An experiment involving a factorial combination of low- and high-fertility levels and 5 hand-hoe weeding systems crust was planted on 11 July using an early-maturing variety, TZE 4 (Table 32). They were controlled by either application of pre-emergent herbicide or periodic hand weeding or both. There was a consistent increase in grain yield when the number of weedings was increased from 0 to 1 and from 1 to 2. The increase in yield was greater at the high-fertility level. Treatment 4 involved late weedings, 4 and 7 weeks after planting, to evaluate the effect of early weed competition on maize

Table 32. Effect of weeding on grain yield (kg/ha) of maize (Kamboinse, 1980).

Weeding treatment	Fertility levels Low	High	Mean
1. No weeding	1,960	2,200	2,080
2. 1 weeding (4 WAP*)	2,070	2,900	2,490
3. 2 weeding (2 and 5 WAP)	2,250	3,320	2,790
4. 2 weeding (4 and 7 WAP)	2,780	3,270	3,030
5. 4 weeding (2 WAP; 10 days)	2,610	2,860	2,730
Mean	2,340	2,910	2,620

LSD (5%)	
Fertility level	219
Weeding	331
Fertility level × weeding (same fertility level)	468
(different fertility levels)	472

WAP = weeks after planting.

yield. Although this treatment received no preemergent herbicide, weed growth was not excessive (about 20-30 percent ground cover by weeds, less than 25 cm high) at the time of the first weeding. It seems that the negative effect of early weed competition, if any, was more than compensated by the positive effect of cultivation, 3,030 kg/ha vs. 2,080 kg/ha for treatment of vs. 2,080 kg/ha for the weeding treatment, and the timing of the weeding in relation to the rainfall pattern.

Residue management trials. An experiment involving 3 crop residue managements, low- and high-fertility levels and 2 varieties was initiated in Kamboinse in 1979 (Table 33).

Table 33. Effect of residue management on grain yield of maise (Kamboinse, 1980).

Fertility* level	Variety	Residue management No residue	Residue	Residue × 2	Mean
	TZE3	1,000	1,050	1,600	1,210
Low	Local	900	890	1,350	1,080
	Mean	1,000	970	1,470	1,140
	TZE3	850	1,850	1,980	1,560
High	Local	980	1,980	2,150	1,710
	Mean	910	1,920	2,060	1,630
Mean	TZE3	920	1,450	1,790	1,390
	Local	990	1,430	1,750	1,390
	Mean	950	1,440	1,770	1,390

LSD (5%)	
Fertility levels	129
Residue managements	374
Residue managements at same fertility	529
Varieties	207
Varieties at same fertility	293
Varieties at same residue management	359
Varieties at same residue management and fertility	507

**Low: 40-23-14 (1979) and 37-23-14 (1980)*
High: 120-69-42 (1979) and 83-23-14 (1980).

Crop residues were produced in 1979. and the residue management started in 1980. The land had been tractor plowed and disked early in 1979. Mean grain yields in 1979 were 2,230 kg/ha and 2,810 kg/ha for the low- and high-fertility levels, respectively.

There was a highly significant effect of crop-residue management and fertility, and the interaction between crop residue management and fertility was also statistically significant (Table 33). At the low-fertility level, there was no difference in mean grain yield between removing the residue and leaving it on the ground (1,000 kg/ha and 970 kg/ha, respectively). At the high-fertility level, the grain was higher with than without residue (910 kg/ha and 1,920 kg/ha, respectively). These results show the highly beneficial effect of crop residues on protecting the soil from the rainfall impact and increasing water infiltration and storage in the soil. The effect of crop residues is a combination of various reasons, including mulching, nutrition and biological activity. The termite activity was higher in the plots with more residue; and by decomposing and incorporating part of the residues and digging tunnels and galleries in the soil, they seem to greatly enhance water infiltration and penetration into the soil. It should be noted also that when the crop residues were removed. there was no response to the increase in fertility level (1,000 kg/ha and 910 kg/ha for low and high fertility, respectively); water was the limited factor.

Maize-cowpea rotation trials. A rotation trial involving maize and cowpeas that was started in 1979 at Saria was continued in 1980 (Table 34).

Table 34. Effect of cowpea-maize rotation and fertility levels on grain yield (kg/ha) of maize (Saria, 1980).

Rotation	Fertility level		Mean
	Low	High	
1. Maize/Maize	690	1,490	1,090
3. Cowpea/Maize	1,400	2,130	1,760
4. Maize/Maize	1,000	1,330	1,160
6. Cowpea/Maize	1,320	2,120	1,720
Mean	1,100	1,770	1,430
LSD (5%)			
Fertility level			416
Rotation			413
Fertility level × Rotation (same fertility level)			585
(different fertility levels)			643

There was a highly significant effect of crop rotation and a significant effect of fertility level. The grain yields of maize were significantly higher under maize following cowpeas than under maize following maize both under low- and high-fertility levels. The positive effect of preceding maize with cowpeas may not be due to nitrogen fixation by the legume because no apparent nitrogen deficiency symptoms were observed.

Rice

In 1980, rice researchers at IITA continued to focus their attention on the varietal improvement for free draining upland (dryland), near-saturated valley bottoms (hydromorphic) and irrigated/shallow flooded (swamp) conditions.

Research on the development of plant type for dryland rice was stepped up by evaluating several varieties with contrasting plant characteristics under the 3 ecologies. Evaluating different methodologies for identifying drought resistant cultivars was continued. Blast resistance was a major target during 1980 as in the past. Diseases such as sheath blight and leaf scald that appeared to increase in their incidence require more attention in the future. Superior dryland cultivars with resistance to major dryland stresses, such as drought, blast and panicle discoloration, were developed.

Development of, hitherto, neglected hydromorphics was considered as a priority to raise the rice production in Africa. Varietal improvement needs for hydromorphics seem to be near to those for swamps. Because of these interlinks, the approach taken for this ecology is by testing of the superior cultivars identified for lowlands and shallow flooded swamps. Emphasis on hydromorphic rice research will be increased in the future.

For irrigated/swamp rice, 3 improved semi-dwarf varieties were developed that have serious attributes required for their adaptability and acceptability in the region.

Varietal nominations from IITA to the international testing programs of WARDA and IRRI and various national programs, particularly that of Nigeria, Republique Populaire du Benin and Brazil, were increased.

To facilitate the cooperation and simplify record-keeping of elite lines ITA accession numbers were assigned to advanced selections that are ready for testing by collaborators. Pedigrees for the list of cultivars mentioned in this report with ITA numbers are listed in Table 35.

Table 35. Pedigree for the list of ITA numbers mentioned in this report.

ITA No.	Pedigree	ITA No.	Pedigree
116	TOx 86-1-3-1	165	TOx 504-6-5-3-1
117	TOx 356-1-1-1	169	TOx 504-14-7-1
118	TOx 475-1-1-1	170	TOx 504-14-14-1
119	TOx 490-3-108-1-1	173	TOx 504-21-120-1
120	TOx 502-25-118-1-1	174	TOx 504-25-3-2-1
121	TOx 514-16-101-1	175	TOx 504-26-109-1
122	TOx 515-22-107-1	178	TOx 515-22-112-3-1
123	TOM 1-3	182	TOx 516-20-102-5-1
125	TOx 502-25-116-2-1	183	TOx 516-28-103-2-1
129	TOx 95-3-3-3-1	184	TOx 516-28-103-3-1
130	TOx 95-5-1-1	185	TOx 516-28-103-5-1
131	TOx 95-8-1-1-3	186	TOx 516-28-103-8-1
132	TOx 340-1-5-1	187	TOx 516-28-103-9-1
135	TOx 378-1-6-1	189	TOx 516-33-103-1
137	TOx 475-1-105-1	207	TOx 490-3-103-3-1
138	TOx 475-1-106-1	208	TOx 500-2-104-1
139	TOx 490-6-103-1-1	212	6850*
141	TOx 490-6-125-4-1	216	TOx 475-1-2-1-1-1
144	TOx 502-8-112-1	222	TOx 728-2
145	TOx 502-10-104-6-1	225	TOx 502-47-130-1
146	TOx 502-10-107-3-1		
150	TOx 502-41-1-1	230	6902*
153	TOx 502-46-3-1	231	6906*
157	TOx 503-5-103-4-1	232	6911*
158	TOx 503-5-112-1	234	6832*
162	TOx 503-7-116-1	235	TOx 1785-19-18
164	TOx 504-4-106-1-1	256	TOx 503-1-52-1

**Selections from the material originating from CIAT.*

Genetic improvement

Dryland rice

Organized multilocational testing was carried out for dryland rice in Nigeria at IITA, Onne, Ikenne and Funtua in dryland conditions but also at IITA in hydromorphic condition to estimate the potential yielding ability. The tiers of varietal testing were observational, preliminary, advanced and elite yield trials, and the entries were decided based on the previous years' performance.

The incidences of drought and blast, which have been the frequent and predominant dryland stresses in the previous years, were rather low in 1980. However, the incidence of panicle discoloration prevailed while that of sheath blight and leaf scald increased, particularly at Onne. Observations indicated that entries having wide and droopy leaves were generally more susceptible to sheath blight and leaf scald.

Significant progress was made in the genetic improvement for the major dryland stresses such as drought, blast and panicle discoloration. The resistance to lodging is higher in these improved cultivars than the local cultivar, OS 6. Many are intermediate statured while few are short statured. The range of growth duration is 100-120 days, and their grain yield under dryland ranges from 2 to 4 t/ha. Table 36 shows the characteristics of the superior cultivars that are being tested widely by various national and international programs. Emphasis in the near future will be to increase yield potential and incorporate resistance to sheath blight and leaf scald. Efforts will also be to obtain short stature and narrow leaf types. Cultivars with a longer growth duration of 120-140 days will also be selected.

Table 36. Superior upland cultivars being tested by national and international programs (1980).

Cultivar	Height (cm)	Duration (days)	Resistance to stresses*			
			Blast	Scald	PD**	Drought
ITA 116	140	120	R	MR	R	MR
ITA 117	110	110	R	MR	MR	R
ITA 118	120	110	R	MR	MR	MR
ITA 120	120	100	R	MR	R	MR
ITA 135	140	115	R	MR	R	MR
ITA 162	130	120	R	MR	MR	MR
ITA 173	150	120	R	MR	R	R
ITA 186	130	110	R	R	R	MR
ITA 225	115	120	R	MR	R	MR
ITA 235	115	115	R	MR	MR	MR

**R = Resistant, MR = Moderately Resistant.*
***Panicle discoloration.*

Hydridization and early generation material for dryland rice. Several new crosses were made. Approximately 200 F2, 1,000 F3 and 1,600 F4-F6 lines were evaluated, and further selections were made (Table 37).

A short mutant derived from irradiation of OS 6 was used as a source of short stature. It has been crossed to OS 6 and Moroberekan. Other short mutants from Ngovie, TD 58, Khao Maleuh and TOx 95 were also widely used in hybridization. In addition, IITA is participating in IRRI's Rapid Generation Advance (RGA) program. For this purpose, several F3 lines derived from 43 crosses were sent for generation advance at IRRI.

Dryland rice yield trials. Observational, preliminary, advanced and elite yield trials were conducted with 144, 49, 24 and 11 varieties, respectively, in hydromorphic conditions at IITA and in dryland conditions at IITA, Onne and Ikenne. The performance of the top 10 yielders in each trial and the performance of OS 6 is presented in Tables 38-41. Several IITA varieties and introductions outyielded OS 6. Among them, ITA 119, Pattambi 1787,

Table 37. Pedigree, growth duration and blast reaction of different upland breeding lines (1980).

Cultivar	Combination	Blast reaction[1]	Growth duration (days)	Culm[2] length (cm)	Recommended[3] ecology
ITA 235	OS 6 mutant/OS 6	3-4	115-120	71	WF, T
TOx 1785-19-20	OS 6 mutant/OS 6	3-4	115-120	73	WF, T
TOx 1369-7-1	TOx 516-7-14/ TOx 475-1-1-2	1-2	120-125	74	WF, T
TOx 1369-13-1	TOx 516-7-14/ TOx 475-1-1-2	1-2	120-125	76	WF, T
TOx 1369-17-1	TOx 516-7-14/ TOx 475-1-1-2	1-2	120-125	75	WF, T
TOx 1011-4-2	IRAT 13/DP689// TOx 490-3-2-3	1-2	95-100	65	WF, T
TOx 1011-4-1	IRAT 13/DP689// TOx 490-3-2-3	1-2	95-100	66	WF, T
TOx 503-52-1	Moroberekan/TOx 7	1-2	123-125	6	WF, T
TOx 718-1-23	IRAT 13/OS 6	3-4	110-115	80	T, S
TOx 718-1-24	IRAT 13/OS 6	3-4	110-115	75	T, S
TOx 1006-18-20	TOx 502/TOx 737-6	1-2	100-115	NT	T, S
TOx 1006-13-15	TOx 502/TOx 737-6	1-2	100-115	NT	T, S
TOx 1008-15-20	Norin 12//IRAT 13/ DP 689	1-2	90-105	NT	T, S
TOx 1012-12-3	IRAT 13/DP 689// TOx 490-3-1-1	1-2	118-125	60	WF, T
OS 6 (Check)	-	3-4	120-125	89	
IAC 25 (Check)	-	1-2	95-100	82	

[1]0-9 score; 0 = No lesion; 1-2 = Resistant; 9 = Very susceptible.
[2]Nt: Not tested.
[3]WT = Wet forest; T = Transitional; S = Savanna.

ITA 207 and Sona are semi-dwarfs while the others are intermediate. However, ITA 119 and ITA 207 were selected in dryland. They are derivatives of a LAC 23/IET 1444 cross and differ in plant morphology from that of Pattambi 1787 and Sona by having lower tillering ability and thicker and deeper roots. One other major difference is that unlike the lowland semi-dwarfs, which have short and erect leaves, ITA 119 and ITA 207 have droopy lower leaves, which enables them to compete with weeds, and erect upper leaves for more efficient utilization of solar radiation. Both of them, however, have red kernel and, hence, are not usually preferred by most consumers.

Table 38. Performance of selected cultivars in upland observational variety trial (1980).

Cultivar	Height (cm)	Duration (days)	Grain yield (t/ha) Hydromorphic IITA	Dryland Ikenne	Mean
ITA 207	85	108	3.6	3.3	3.4
ITA 186	140	110	4.0	2.8	3.4
IRAT 13	116	112	4.1	2.0	3.0
ITA 185	138	110	3.4	2.5	3.0
ITA 170	128	98	2.7	3.2	3.0
ITA 208	124	104	3.2	2.7	2.9
SONA	79	144	3.0	2.5	2.8
M 133-6-1-2	119	110	2.7	2.8	2.7
ITA 187	134	110	2.6	2.8	2.7
ITA 216	117	102	3.4	1.8	2.6
OS 6	174	118	2.2	2.6	2.4

ITA 119 was superior in the physiology trials and drought screening studies at IITA. The National Cereals Research Institute (NCRI), Nigeria, reported that ITA 119 being short and lodging resistant was superior to OS 6 and produced a mean grain yield of 3.0 t/ha in the zonal trials in Nigeria.

ITA 116 and ITA 118 continued to maintain their superior performance in 1980. The Institute of Agricultural Research and Training (IAR&T), Nigeria, reported that ITA 118 had a grain yield of 4.2 t/ha at Akure, Nigeria. All of these cultivars and ITA 120, ITA 135, ITA 162 and ITA 186 have been included in the Nigerian Green Revolution Program. Although not tested in yield trials, ITA 235 derived from OS 6 short mutant × OS 6 was found to be very promising. It is about 25-40 cm shorter and 5-7 days earlier in maturity than OS 6. It maintains the desirable characters of OS 6 such as seedling vigor, moderate resistance to blast and drought stress, long and well exerted panicles and acceptable grain quality. It is superior to OS 6 in lodging resistance under high levels of N. A sister line, TOx 1785-19-20, also possesses superior characters of OS 6 and is about 20-25 cm shorter.

Table 39. Performance of selected cultivars in upland preliminary variety trial (1980).

Cultivar	Height (cm)	Duration (days)	Grain yield (t/ha) Hydromorphic IITA	Dryland Ikenne	Dryland Onne	Mean
PATTAMBI 1787	87	121	3.8	2.8	2.7	3.1
ITA 158	130	114	4.4	3.4	1.4	3.0
ITA 182	130	110	2.4	3.5	2.4	2.8
ITA 189	137	111	2.9	2.7	2.2	2.6
ITA 125	116	94	2.7	2.6	1.7	2.5
ITA 144	139	113	3.1	2.6	1.7	2.5
ITA 138	135	113	3.1	2.6	1.6	2.4
ITA 137	127	113	2.4	3.1	1.5	2.4
ITA 174	127	105	2.9	2.7	1.4	2.3
ITA 129	158	127	2.5	2.7	1.6	2.3
OS 6	162	115	2.3	2.6	1.9	2.3

LSD (5%) = 1.22 t/ha for grain yield.

Table 40. Performance of selected cultivars in upland rice variety trial (1980).

Cultivar	Height (cm)	Duration (days)	Grain yield t/ha Hydromorphic IITA	Dryland Ikenne	Dryland IITA	Dryland Onne	Mean
ITA 139	136	112	3.0	2.9	3.2	2.7	3.2
ITA 157	138	124	4.3	2.6	2.3	2.6	3.0
ITA 184	130	108	3.6	2.7	2.4	2.9	2.9
ITA 175	117	117	3.6	2.4	2.4	2.2	2.9
ITA 183	135	119	4.0	1.9	2.8	2.4	2.8
ITA 165	134	109	2.6	2.4	2.8	3.2	2.7
ITA 141	135	121	3.0	2.6	2.3	2.8	2.7
ITA 178	130	118	2.8	3.6	2.4	2.6	2.5
ITA 182	135	117	2.1	3.0	2.4	2.6	2.5
ITA 120	121	96	1.4	3.7	2.3	2.2	2.4
OS 6	161	118	3.0	2.6	2.3	2.8	2.1

LSD (5%) = 0.84 t/ha for grain yield

Table 41. Performance of selected cultivars in upland rice variety trial (1980).

Cultivar	Height (cm)	Duration (days)	Grain yield (t/ha) Hydromorphic IITA	Dryland Ikenne	Dryland IITA	Dryland Onne	Mean
ITA 119	99	115	3.5	2.5	2.8	2.4	2.8
ITA 162	129	118	3.0	2.9	2.3	2.5	2.7
ITA 118	120	111	3.0	2.9	2.3	2.5	2.7
ITA 117	113	109	3.0	3.0	2.5	2.0	2.6
ITA 164	155	116	2.8	2.5	2.6	1.9	2.5
ITA 135	137	114	2.9	2.8	2.3	1.9	2.5
ITA 116	143	116	3.5	1.6	2.4	1.7	2.3
ITA 132	138	113	2.9	2.6	1.8	1.8	2.3
ITA 130	140	116	2.7	1.9	2.0	2.0	2.1
ITA 173	150	120	2.9	2.5	1.2	1.9	2.1
OS 6	164	117	2.9	2.1	1.9	1.2	2.0

LSD (5%) = 0.73 t/ha for grain yield.

Additionally, several promising F4 lines that were uniform in height, maturity and had high levels of blast resistance were identified. TOx 1369-7-1, TOx 1369-13-1 and TOx 1369-17-1 yielded much higher than OS 6. They have intermediate stature, upright leaves and sturdy culms. Observations indicate that these lines can withstand severe stresses in Nigeria, such as blast and highly leached acid soils at Onne and hydromorphic sandy soils at Agenebode.

TOx 1012-12-3 is highly resistant to blast and also exhibits clean panicles with good grain filling. Results from the observational yield trials in the 1980 dry season indicate that it is a high yielding cultivar to be suitable for the wet forest and transitional zones.

Breeding lines of TOx 1006, TOx 1008 and TOx 718 performed well under savanna ecology at Funtua while TOx 503-1-52-1 and TOx 1011-4-2 and TOx 1011-4-1 per-

TOx 86-1-3-1 (ITA 116), an intermediate statured variety, was superior to OS6—the most widely grown tall, upland variety in Nigeria.

formed well under wet forest and transitional zones at Agenebode and IITA, respectively.

International Upland Rice Observational Nursery (IURON, 1980). Observations were carried out at IITA and Ikenne with a view to identifying sources of material for use as potential cultivars or parents in IITA's hybridization program. In general, sources from Asia, especially dwarf and semi-dwarfs, performed poorly on the highly leached and low nutrient status soils at IITA; whereas, the same cultivars performed better at Ikenne (Table 42). Blast—both leaf and panicle—was not severe at either location, but leaf scald and dirty panicle incidences were severe at both. Incidence of leaf scald was observed to be progressively severe from panicle initiation to harvest. The dirty panicle syndrome was more severe at IITA than Ikenne. Compared to entries from other sources, materials evolved from IITA and IRAT were found to be much more resistant to blast and dirty panicles. ITA 116 (local check) and ITA 117 were outstanding. Among semi-dwarfs, IR 5931-110-1 and IR 9690-1-1-1-7 were found to be the best entries with growth durations of about 130-135 days. Both are also resistant to blast, leaf scald, panicle discoloration, RYMV and have long grains with acceptable endosperm character.

International Upland Rice Yield Nursery (IURYN, 1980). Twenty-eight varieties with ITA 116 as a local check were planted at Ikenne (Table 43). Tested entries matured in 108-140 days while ITA 116 matured in 116 days. ITA 116 was the tallest, 148 cm, and lodged while entries tested were dwarf or semi-dwarfs. There was no long drought stress, and the moisture regime was quite favorable during the reproductive stage. Incidence of blast, both leaf and neck, was not severe so that blast scorings were low. Leaf scald and panicle discoloration were quite severe, in general; yet, there were many entries with low scores (tolerant) for leaf scald as well as panicle discoloration.

There were 6 entries that yielded higher than ITA 116 (3.0 t/ha). Among these, IR 5931-110-1 and BG 35-2 yielded 3.9 and 3.8 t/ha, respectively. Also, IR 5853-118-5 and C171-136 had yields of 3.1 and 3.0 t/ha, respectively.

All are shorter than ITA 116 and resistant to lodging and leaf blast. IR 5931-110-1 and IR 5853-118-5 (IR 52) are long grain types with acceptable endosperm character. In the 1979 International Rice Blast Nursery (IRBN), these 2 entries had shown high levels of resistance to leaf blast in 90 percent of the testing locations, including locations in Liberia and Nigeria. They mature in about 120 days, which is quite suitable for the transition zone. IR 9560-2-6-3-1, IR 9995-96-2 and Gama 318 mature in about 140 days, which may prove to be suitable to the high-rainfall zone of coastal West Africa with total annual precipitation of about 2,400 mm spread over 6 months. All are dwarfs with good blast resistance. Promising entries will be further evaluated in 1981.

Fixed lines from IRRI. Twenty-five fixed lines (F5-F6) derived from crosses involving African land races, such as Lac 23, 63-83, Moroberekan and OS 6, were evaluated under dryland conditions at IITA. The nutrient status of the plot was low, and drought stress was experienced at the early vegetative and tillering phases followed by very wet weather during the reproductive phase. Leaf scald, panicle discoloration and sheath rot were quite severe. A moderate incidence of neck blast was also observed during the ripening stage. In general, entries performed poorly, except 2 lines—IR 6234-33-3 (MRC 172-9/63-83) and IR 7790-18-1-2 (IR 790-28-1-6/63-83//IR 2035-290-1-1). They were resistant to blast and leaf scald having intermediate plant stature (105-110 cm), medium growth duration (120-125 days) good tillering ability and drought tolerance. They will be further evaluated in 1981.

Observational nursery at Goiania, Brazil. Upon the request from the Centro Nacional de Pesquisa—Arroz, Feijao, Goiania, Brazil, seed for 20 IITA advanced dryland varieties were sent, which were evaluated in an observational nursery. The results show that while several selections were as good as the check variety, IAC 47, ITA 120 and ITA 116 were superior for blast resistance and grain yield (Table 44).

WARDA-coordinated variety trials (upland) at IITA. Sixteen varieties in each of 2 yield trials of short and medium maturity groups were evaluated under dryland conditions at IITA. Check varieties for short, ITA 116 and ITA 117, and for medium, ITA 119 and ITA 130, were in-

Table 42. Characteristics of rice materials selected in IURON-1980.

Serial No.	1980 IURON Entry No.	Designation	Height		5% flowing days		Blast[2] Score		Leaf Scald[2] Score		RYMV	Grain Character	Endosperm Character
			IB	IK	IB	IK	IB	IK	IB	IK	IITA		
1.	6	IR 1529-12-2	96	109	102	90	3	3	3	3	0	Thin Slender	Translucent
2.	32	IR 5931-110-1	92	95	101	95	3	1	1	1	0	Slender	Abdominal speck
3.	59	C 924-9	116	125	107	102	5	3	3	0	0	Slender	Translucent
4.	62	IR 3646-8-1-2	120	130	107	103	5	1	3	3	0	Thin Slender	Abdominal speck
5.	74	IR 5440-1-1-1	112	119	107	105	1	0	1	1	0	Slender	Prominent White belly
6.	75	IR 5540-1-1-3	130	135	105	98	1	0	3	3	0	Slender	Prominent White belly
7.	78	IR 5931-81-1-1	102	111	101	106	3	0	0	1	0	Slender	Abdominal speck
8.	166	IRAT 138	101	134	100	98	0	0	0	0	0	Bold	Abdominal speck
9.	169	IR 5987-20-1	129	147	103	98	0	0	0	0	0	Long	Translucent
10.	179	TOx 494-5-1-2	107	139	100	104	1	1	0	1	0	Bold Long	Translucent
11.	181	TOx 504-14-11-1	117	130	105	105	3	1	0	3	0	Bold Long	Trace White belly
12.	199	IR 2371-760-1482	87	98	100	101	1	1	3	3	1	Bold Long	Abdominal speck
13.	212	IR 9690-1-1-1-7	93	95	105	105	0	0	0	0	0	Slender	Trace White speck
14.	-	IR 43 Check	71	81	103	106	1	1	0	0	1	Slender	Translucent
15.	-	ITA 116 (Check)	148	150	90	92	1	1	1	1	0	Bold Long	Translucent

(1) IB = IITA; IK = Ikenne
(2) 0-9 score; 0 = No lesion; 1-2 = Resistant; 9 — Very susceptible.

*Table 43. Characteristics of rice materials selected in IURYN-1980**

Serial No.	Entry No.	Designation	Yield kg/ha**	Height (cm)	Days to maturity	Leaf Blast	Neck Blast	Panicle Discolouration	Rynscosporium	Helminthos-porium	Milling Out-turn %	Head grain %	Grain type
1.	13	IR 5931-110-1	3918 a	114	118	1	0	3	3	1	57.0	44.5	L. Slender
2.	2	BG 35-2	3810 ab	94	118	2	1	3	2	2	54.0	50.0	V. Bold
3.	17	IR 8072-31-2	3256 abc	83	111	1	3	7	3	2	57.0	41.5	S. Slender
4.	6	IET 4049	3164 abcd	83	123	2	1	5	2	2	54.5	49.0	S. Slender
5.	11	IR 5853-118-5	3160 abcd	86	125	2	0	5	2	2	55.0	50.5	L. Slender
6.	4	C171-136	3083 abcde	116	125	2	1	1	2	3	61.0	52.5	Bold
7.	28	ITA 116 (Local Check)	3070 abcde	148	116	1	0	1	3	2	58.5	51.6	L. Bold
8.	20	IR 9560-2-6-3-1	2991 abcde	83	138	0	0	3	2	3	58.5	53.0	S. Bold
9.	26	IR 1529-430-3 (IR 43 Check)	2929 bcdef	81	132	1	0	5	2	2	57 5	44.0	S. Bold
10.	21	IR 9669 SEL	2808 cdef	76	137	0	0	3	2	4	59.0	53.5	Bold
11.	16	IR 7790-18-1-2	2718 cdefg	127	123	1	3	5	3	3	64.5	55.5	L. Slender
12.	25	MW 10	2670 cdefg	85	108	1	5	5	3	1	-	-	-
13.	7	KMP 34	2645 cdefg	79	114	1	1	7	1	3	62.5	54.5	L. Slender
14.	10	IR 5716-18-1	2629 cdefg	98	120	3	1	7	2	2	51.0	37.5	L. Slender
15.	24	MALA/J 15	2591 cdefg	100	117	2	5	7	3	2	-	-	-
16.	12	IR 5929-12-3	2560 cdefg	104	113	5	5	3	5	5	-	-	-
17.	15	IR 6115-1-1-1	2520 cdefg	73	121	2	2	9	1	1	54.5	43.0	S. Slender
18.	14	IR 5982-7-6-1	2495 cdefg	87	128	1	1	3	2	2	52.0	44.5	L. Slender
19.	19	IR 9410-80	2416 cdefg	82	115	1	1	5	3	2	57.0	47.0	S. Slender
20.	27	IR 2035-242-1 (IR 45 Check)	2414 cdefg	78	134	1	1	9	2	2	54.5	44.5	S. Slender
21.	9	IR 5260-1	2362 cdefg	85	109	3	3	5	3	6	-	-	-
22.	3	BP1-R1-6 (MRCY 38)	2258 defg	112	129	2	2	1	2	4	-	-	-
23.	1	B733.C-167-3-2	2235 defg	110	125	1	1	7	2	4	-	-	-
24.	8	IR 3646-8-1-2	2131 efg	126	126	2	2	3	3	3	54.5	39.5	S Slender
25.	22	IR 9995-96-2	2110 efg	87	140	1	3	7	3	5	49.0	40 0	S. Slender
26.	5	GAMA 318	2006 fg	96	139	3	2	5	3	5	-	-	-
27.	18	IR 8085-48-2	1971 fg	94	120	2	2	7	3	4	-	-	-
28.	23	Kn 96	1691 g	100	135	2	1	5	4	3	-	-	-

**At Ikenne, Net plot size: 1 × 4.8 m.*
***LSD (1%) 983 kg/ha.*
Column with the same letter are not significantly different at 1% level.

cluded. Because of planting late in the season, the grain yields were generally low with a range from 776 to 1,380 kg/ha in the short duration group and from 956 to 1,586 kg/ha in the medium duration group. None of the entries outyield local checks.

In a WARDA initial evaluation trial (upland) at IITA, the top 10 yielders were IR 4535-8-2-1, TOx 515-22-107-1-1, TOx 504-6-5-3-1, IRAT 104, C168-134, TOx 516-28-3-105-1. TOx 503-7-116-1, TOx 515-22-112-3-1, R4482-3-3-3-3

Table 44. Top 6 rice yielders in observational nursery (Goiania, Brazil, 1979-80).

Cultivar	Height (cm)	Days to flower	Neck* blast score	Accept-** ability score	Grain yield (t/ha)
ITA 120	107	78	3	5	5.49
ITA 116	131	106	3	7	5.20
ITA 130	131	103	-	5	4.97
ITA 153	101	84	3	7	4.93
ITA 125	118	78	5	7	4.86
ITA 118	103	105	-	7	4.19
IAC 47 (Check)	148	97	7	5	4.91

**Score of 1-9; 1 = very resistant, 9 – very susceptible.*
***Score of 1-9; the lower the score the higher the acceptability.*

and local check, ITA 116. The grain yield of the check variety, ITA 116, ranged from 112 to 676 g/m^2.

Swamp and hydromorphic rice

Production potential for rice in Africa, particularly in hydromorphic and shallow swamp or irrigated lowland ecologies, is considered very high.

Semi-dwarf (IR8) plant type for improved swamps with good water control and intermediate (IR5) plant type for hydromorphics and swamps with fluctuating water depths (not exceeding about 30 cm standing water) have generally been found suitable.

Improved semi-dwarf cultivars with high yield and medium maturity (115-130 days) having tolerance to Fe toxicity and resistance to blast disease are now available. Research is underway to incorporate tolerance to RYMV.

Another objective, in addition to having the above desirable traits, is to develop cultivars with a wider range of maturity groups and good grain quality. In order to meet the demands of the highlands of Central and East Africa, cultivars tolerant to low temperatures will be initiated.

The screening for general performance and adaptation of fixed lines is being done through multilocational tests in Nigeria in cooperation with NCRI and the ANIMO

(World Bank) Rice Project, Nigeria. Screening and selection for blast resistance, RYMV tolerance and grain type is done from the early generations by IITA. The screening for Fe toxicity tolerance is being accomplished through cooperation with 2 institutes in Liberia, the Central Agricultural Research Institute (CARI) and WARDA. In addition, international testing is being accomplished through the testing programs of WARDA in West Africa and through IRRI worldwide.

Elite cultivars for swamps. In tests in various locations, ITA 121, ITA 123 and ITA 212 were 3 high-yielding, semi-dwarf rice cultivars for improved swamps (Tables 45 and 46).

ITA 121 (Moroberekan/SE 363G, Ikong Pao) was initially selected in dryland environments up to the F3 generation and then selected in low nutrient irrigated paddies where it was superior to all the 120 other lines tested. Further, it exhibited good performance in well-managed paddies yielding up to 7.5 t/ha.

ITA 123 is a semi-dwarf mutant of OS 6. Although ITA 123 has thick and deep roots similar to OS 6, it is moderately susceptible to panicle discoloration under dryland conditions. However, under irrigated paddies, it has performed well in comparison to other varieties in various tests conducted in Nigeria. In addition to having high yield potential, the grains of ITA 123, which are long, slender and translucent, are preferred grain types by urban consumers in the region. At Onne, under rainfed upland conditions, this line was moderately resistant to blast, where several other semi-dwarf mutants of OS 6 died because of severe leaf blast.

ITA 212 (BG 90-2[4]/Tetep) was selected from 250 F4 lines obtained from CIAT. BG 90-2 is a high yielding improved swamp rice variety in West Africa that needed improvement, especially in blast resistance and grain translucency. Tetep was used as a donor for these 2 traits, and ITA 212 was selected retaining the superior yield potential of BG 90-2. Selection for blast resistance was done with IITA's horizontal blast resistance screening methodology. In a large seed multiplication plot at IITA, ITA 212 yielded 5.8 t/ha.

Table 45. Superior irrigated rice cultivars.

Cultivar	Plant height (cm)	Growth duration (days)	Resistance to blast	Grain type	Percent grains translucent
ITA 121	92	130	MR	A	40
ITA 123	100	122	MS	A	90
ITA 212	98	128	R	B	60

MR = Moderately resistant; MS = Moderately susceptible; R = Resistant.

ITA 123 is a high-yield potential semi-dwarf rice suitable for improved swamps. It also has long, slender and translucent grains.

Table 47. Promising advanced rice lines for swamps (IITA, 1980).

Cultivar	Plant height (cm)	Grain yield (kg/ha)
TOx 498-101-4-1	124	5195
TOx 711-17-9-1	130	5152
TOx 711-17-11-1	134	4986
TOx 711-16-1-1	122	4936
ITA 123	108	4580
SONA	108	3711

Promising advanced lines for swamps. Among F5 lines and above that were evaluated, derivatives from TOx 498 and TOx 711 (IRS/Suakoko 8) of intermediate stature (120-135 cm) and from medium to long duration (130 days) were promising. Among the higher yielders, further selection was made for nonchalky grain character and their performance is presented in Table 47. All the advanced lines are also being screened for tolerance to Fe toxicity in Suakoko, Liberia.

*Table 46. Performance of ITA 121, ITA 123, ITA 212 and some recommended rice cultivars in Nigeria.**

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

National Cereals Research Institute Zonal Trials, 1980.

Hybridization and early generation material for swamps. About 300 breeding lines of crosses BG 90-2⁴/Tetep and IR 262/Bahagia from CIAT were screened and selected at IITA during 1979-80. Many high yielding lines were identified. The reactions of these cultivars to blast and RYMV are shown in Table 48.

During the 1980 rainy season, promising cultivars of 6833, 6838, ITA 212, ITA 230, ITA 231 and ITA 232 performed well under hydromorphic sandy soils at Agenebode. In spite of high plant density, no lodging was observed in these cultivars. Their grain yields ranged from 5.4 to 5.9 t/ha.

Cultivars ITA 231 and ITA 232 are taller than those lines from the BG 90-2 backcross. Their plant types are similar to IR5. However, they have much better disease resistance and better grain quality. Results from the second planting at Agenebode indicated that ITA 231 was outstanding under low management practices. It yielded 6.0 t/ha when Suakoko 8 produced only 3.3 t/ha under the same conditions.

Besides ITA 212, these cultivars have not been evaluated under multilocation testing. Therefore, in 1981, ITA 212, which has been nominated to the WARDA yield trials, and ITA 230 and ITA 231 will be tested in Nigeria under the National Accelerated Food Production Project (NAFPP) minikit trials and in a few selected locations.

Cooperative trials with Anambra/Imo (World Bank) Rice Project. A N x variety trial with 20 varieties, a preliminary variety trial with 12 varieties and an observational trial with 20 varieties were conducted at Adani, Bende and Ogboji locations in eastern Nigeria, where a large number of farmers grow swamp rice. The varieties tested were improved selections from IITA, IRRI, CIAT and All India Co-ordinated Rice Improvement Project (AICRIP).

The results support previous observations on the superiority of ITA 121, ITA 123 and ITA 212. In addition, ITA 222, 6857 from CIAT, IET 5734 from AICRIP and IR 9669 were promising in various trials. A more systematic evaluation of the varieties is planned with ANIMO (World Bank) project for 1981.

International Rice Yield Nursery—Early (IRYN-E, 1980). Twenty-eight cultivars from Bangladesh, India, Iran, Pakistan, Philippines, Taiwan, Thailand and IRRI with BG 90-2 as a local check were evaluated at IITA under irrigated paddy conditions. The mean grain yield of all the entries was 3.4 t/ha, which was attributable to low fertilizer management and wide spacing (25 cm × 25 cm—single seedling) (Table 49). BG 90-2 yielded 3.5 t/ha, Chianung-sen-yu 13 (Taiwan), *MTU 2419* (India), *PK 174-13-1-5* (Pakistan) and BR 169-1-1 (Bangladesh) yielded over 4 t/ha. All have intermediate plant stature (100-120 cm), medium growth duration (130 days) and long and translucent grains. Other entries with long and translucent grains are BKN 7033-13-1-1-3-2, BR 161-28-58, *IR 9828 91-2-3* and IR 13429-196-1 with yields comparable to BG 90-2.

Fixed lines from IRRI. Twenty-eight fixed lines (IR cross number 9,000 and above) were evaluated under irrigated paddy conditions. All have early to medium growth duration, high yield potential and high levels of resistance to diseases and pests under Asian conditions. Two local checks, BG 90-2 and ITA 123, yielded 3.9 and 4.6 t/ha, respectively; whereas, many lines tested gave comparable yields (Table 50).

IR 17494-32-3-1-1-3 (4.7 t/ha) and IR 9814-5-2-2 (4.6 t/ha) were the highest yielders with slender grains but chalky endosperm. Three entries—IR 9224-162-3-1-3-2 (4.3 t/ha), IR 15314-30-3-1-3 (4.2 t/ha) and IR 13429-109-2-2-1 (3.8 t/ha) were selected for their long, slender and translucent grains and for further tests.

WARDA coordinated variety trials (irrigated) at IITA. Two yield trials for short and medium duration each comprising 14 entries were evaluated. ITA 121 was an entry in the short duration trial while ITA 123 and ITA 212 were used as check varieties for both trials. ITA 212 with 4.1 t/ha was the highest yielder in both trials. ITA 121, ITA 123, BG 90-2 and 541 B-P-58-5-3-1 in short duration and *Nizersail*, *IR 3464-4-3-2*, *ITA 123* and *Jagannath* in medium duration yielded in the range of 3.6-4.0 t/ha.

Two hundred and fifty-four lines were evaluated in a WARDA initial evaluation trial. Based on general performance and grain yield, the top 10 cultivars were FAROX 188ᴬ, CR 210-1011, FAROX 188, FAROX 187, BR 51-46-5/HR 56, FAROX 188ᴮ, RP 79-2, IET 5854, TOS 124 and FAROX 120.

Screening for Fe toxicity. Sixty F3 lines and ITA 121, ITA 123 and ITA 122 were screened for Fe toxicity tolerance with the cooperation of CARI and WARDA. Scoring for tolerance was done at tillering, panicle initiation and dough stages of the crop. Observations on vigor, flowering dates, plant height and neck blast incidence were also recorded. Progenies from TOx 714 (ROK 5/IR 937-55-3), TOx 739 (IR 1529-677-2/ROK 3), TOx 900 (IR 42/BPI 76-9 × Dawn) and TOx 909 (4445/Suakoko 8) and among the fixed lines, ITA 222 (improved Mahsuri/IET 1444) were promising.

Table 48. Promising lowland rice cultivars identified (IITA and Agenebode (Tiffany Farm), 1980).

Cultivar	Combination	Blast*	RYMV*	Culm length (cm)	Growth duration (days)
ITA 212	BG 90-2⁴/Tetep	1-2	7-8	85	125-130
ITA 234	BG 90-2⁴/Tetep	0	7-8	86	125-130
ITA 230	BG 90-2⁴/Tetep	1-2	7-8	74	125-130
6833	BG 90-2⁴/Tetep	1-2	7-8	86	125-130
6838	BG 90-2⁴/Tetep	3-4	7-8	85	125-130
ITA 231	IR 262/Bahagia	1-2	3-4	112	130-135
ITA 232	IR 262/Bahagia	0	3-4	102	130-135
BG 90-2		9	7-8		
OS 6 (Check)		3-4	3-4		

*0-9 score; 0 = No lesion; 1-2 = Resistant; 9 = very susceptible.

Table 49. Performance of higher yielders in International Rice Yield Nursery—Early (IITA, 1980).

Serial No.	Entry No.	Designation	Grain yield (kg/ha)	Height (cm)	Days to 50% flowering	Leaf Blast	Neck Blast	Panicle discolouration
1.	8	Chianung-sen-yu	4227 a	101	101	1	3	2
2.	20	MTU 3419	4024 ab	98	99	1	1	2
3.	22	PK174-13-1-5	4005 ab	95	100	0	3	1
4.	7	BR 169-1-1	3973 ab	122	98	1	0	1
5.	19	MRC 603-303	3922 abc	99	105	1	0	1
6.	14	IR 9828-91-2-3	3888 abcd	91	100	2	3	2
7.	23	R7-2-3-1	3768 abcd	100	97	1	3	2
8.	21	PAU 41-8-31-1-PR407	3751 abcd	92	102	0	0	1
9.	16	IR 13429-196-1	3712 abcd	92	101	0	0	2
10.	5	BR 161-28-25	3693 abcd	93	97	2	3	1
11.	6	BR 161-28-58	3578 abcd	98	999	1	3	2
12.	28	BG 90-2 (Local Check)	3469 abcd	88	94	1	0	1
13.	3	BKN 7033 13-1-133-2	3467 abcd	96	97	2	0	1
14.	18	MR 355	3448 abcd	132	99	1	3	1
15.	13	IR 9761-13-1	3392 abcde	89	83	0	0	1
16.	4	BR 109-74-2-2-2	3325 abcde	95	95	2	3	1
17.	9	IR 36	3208 bcde	87	97	1	3	1
18.	15	IR 13427-40-2-3-3	3109 bcde	95	96	1	1	2
19.	27	UPR 251-101-2	3093 bcde	84	89	0	2	2
20.	25	TNAU 1756	2968 cde	85	89	1	0	1
21.	2	BAU 19-3	2965 cde	92	98	1	0	2
22.	17	KAOHSIUNG 139	2925 cde	92	92	0	0	2
23.	26	TNAU 8870	2869 de	102	81	1	5	3
24.	10	IR 9129-209-2-2-2-1	2843 de	86	89	0	3	1
25.	11	IR 209-48-3-2	2787 de	86	101	1	1	2
26.	12	IR 9224-117-2-3-3-2	2744 de	85	107	0	0	1
27.	24	RASHT 507	2718 de	97	89	0	1	2
28.	1	BAU 2-3-43	2424 e	87	92	1	3	1
		Mean	3361 -	-	-	-	-	-

Table 50. Yield of some early to medium duration materials from IRRI tested under irrigated paddy conditions (IITA, 1980).

Serial no.	Designation	Yield (kg/ha)	Height (cm)	Grain character*
1.	IR 9828-41-1-1	4260	103	Slender, with speck of AB. W.*
2.	IR 9224-162-3-1-3-2	4360	96	L. Slender Translucent
3.	IR 9224-2-3-3-2	4080	104	Slender—With speck of AB. W.
4.	IR 9761-19-1	4075	100	Slender, Translucent
5.	IR 13247	4065	97	Bold, Speck of AB. W.
6.	IR 9814-5-2-2	4636	114	Slender, Chalky
7.	IR 13423-17-1-2-1	4095	113	S. Slender with prominent AB. W.
8.	IR 13525-43-2-3-1	3945	109	Slender, traces AB. W.
9.	IR 13540-56-3-2-1	3810	132	Bold, Long, speck of AB. W.
10.	IR 15314-30-3-1-3	4245	102	Slender Translucent
11.	IR 15318-2-2-2-2	4425	124	Bold, AB. W.
12.	IR 17494-32-3-1-1-3	4730	110	L. Slender, Chalky
13.	BG 379-2	3985	113	Short Bold Chalky
14.	IR 50	1880	99	Med. Slender Translucent
15.	IR 13429-109-2-2-1	3770	106	Slender, Translucent
16.	IR 15689-49-2-2	3835	99	Slender, Translucent
17.	BG 90-2	3940	110	Bold, Translucent
18.	ITA 123	4580	108	L. Slender, Translucent

*AB.W = Abdominal White.

Pathology

RYMV

To support the screening work on RYMV, an inheritance study on resistance to the virus was conducted from the F_1 and F_2 populations of 6852 × Lac 23.

Plants were inoculated with RYMV at the maximum tillering stage (45 days after transplanting). Disease readings were taken at 3 weeks after inoculation and at maturity.

The F_1 population from 6852 (susceptible) × Lac 23 (resistant) were highly tolerant, indicating that resistance is controlled by complete dominant genes. Segregations in the F_2 population gave a 9:6:1 genetic ratio, suggesting that resistance in Lac 23 is conditioned by 2 dominant genes (Table 51). Further studies on the populations of the F3 families and the backcrosses will confirm the above genetic ratio.

Table 51. Observed and expected values of F2 populations of cross BG 6852 × Lac 23 on RYMV reactions (IITA, 1980).

Group	Observed	Expected	$(O-E)^2/E$
Tolerant	148.0	130.5	2.35
Moderate	71.0	87.6	3.15
Susceptible	13.0	14.5	0.16

S^2 = 5.66; (P = 0.05-0.10)

Incidence of fungi in dryland

To enable harvesting in the rainless periods in a high rainfall area, a possibility is to plant late (August) in the season. With this objective, several cultivars with a maturity range of 90-130 days were evaluated from August to December.

Dryland cultivars, ITA 118, ITA 186 and ITA 225, and a semi-dwarf lowland type, ITA 123, yielded about 4.0 t/ha. Most of the cultivars had severe leaf senescence, and some died. Leaf samples were collected from different cultivars, and the fungi present in them are presented in Table 52. *Curvularia* and *Nigrospora* species were predominant followed by *Helminthosporium* and *Rhyncosporium* species. However, *Piricularia* was not observed. Greater emphasis will be given in the future to these pathogenic fungi affecting both foliage and panicles.

Physiology

Plant type under different ecologies

Rice in West Africa is mostly grown under upland conditions, including hydromorphic and dryland.

Ideo-plant type for irrigated lowland rice has been extensively studied while that for upland rice has been limited mainly because of the difficulty in evaluating drought resistance. Little information is available on the growth habit of rice under upland conditions.

An experiment was carried out to determine the plant traits limiting the grain yield under different ecologies.

Sixteen cultivars were selected to cover a wide range of genetic background (Table 53). Cultivars are generally non-photoperiod sensitive and highly or moderately blast resistant, except IR 5.

They were grown under irrigated lowland, hydromorphic and dryland conditions during the rainy season (June to October). Spacing was 25 cm × 20 cm with 1 plant per hill (20 plants per m²). The average moisture content in the soil was 25.4 percent and 9.9 percent in hydromorphic and dryland conditions, respectively, representing 80 percent or more of the field capacity during most of the growth stages. There was a severe incidence of blast on IR 5 under dryland conditions while the rest of the varieties were almost free in all ecologies.

Growth duration and leaf number. Growth duration from sowing to full maturity of cultivars used ranged from 110 to 150 days, and leaf number on main culm ranged from 11 to 18. These characters hardly changed in different ecological conditions. Plants did not exhibit any severe drought stress symptoms such as leaf rolling or poor exertion throughout the growth stages.

Plant height. Plant height was taller in the traditional upland cultivars than in the improved irrigated lowland cultivars (Fig. 4, left). The difference was greater under irrigated lowland or hydromorphic conditions than under dryland conditions. Entry Nos. 1, 2, 3, 5, 7, 14 and 15

Table 52. Major fungi* on the leaf samples collected (Onne, December 1980).

	Common Fungal Spores					
Cultivar	Curvularia	Nigrospora	Helminthosporium	Rhyncosporium	Alternaria	Leaf damage
IR 45	✓	✓	✓			Very low
ITA 186		✓	✓			Low
ITA 145	✓	✓				Moderate
ITA 146	✓	✓			✓	Moderate
TOx 504-14-111-1	✓	✓	✓			Moderate
TOx 507-6-104-1	✓					Severe
ITA 121	✓	✓				Moderate
ITA 222	✓			✓		Severe
TOx 894-6	✓	✓	✓	✓		Severe
Blast spreader	✓					Severe

**Based on the blotter tests on spotted leaf samples. For samples from plots where the whole plants died, no definite suggestions were possible.*

Table 53. Rice cultivars used (IITA, 1980).

Entry No.	Cultivar	Cross (Origin)	GD** (days)	Leaf No.***
1.	Moroberekan	Trad. African	134	17.7
2.	LAC 23 (white)	Reselect. Trad. African	139	16.9
3.	63-83	Reselect. Trad. African	127	14.1
4.	Dourado Precoce	Brasil	110	11.6
5.	OS 6	Improved traditional	123	13.8
6.	IRAT 13	Short mutant of 63-83	120	13.3
7.	ITA 116	63-83/IR 773-A1-36-2-1	126	14.4
8.	ITA 117	13a-18-3-1-3//OS 6/IR 154-61-1-1	120	14.0
9.	ITA 119	LAC 23 (red/TOx 7-4-2-3-B2	122	13.5
10.	ITA 122	Moroberekan /IR 30	116	13.4
11.	ITA 150	63-83/Dourado Precoce	110	11.4
12.	Tough C24	Moroberekan/IR 30	114	13.9
13.	IR 5	Peta/Tangkai Rotan	150	16.9
14.	IR 1416-131-5	IR 400-28-4-5/Tetep	147	16.5
15.	Suakoko 8	Siam 25/Malinja^3	143	17.2
16.	6869	BG 90-2^4/Tetep	140	16.0

** 1- 3 = Traditional upland cultivars.*
4-12 = Improved upland cultivars.
13-16 = Improved irrigated lowland cultivars.
***Growth duration from sowing to full maturity.*
****On the main culm.*

lodged during the ripening stage in irrigated lowland and hydromorphic conditions.

Tiller/panicle number. Panicle number was larger in the improved irrigated lowland cultivars than in either the traditional or improved upland cultivars (Fig. 4, right). The difference was greater under dryland than irrigated lowland conditions. The tiller number was larger shortly after sowing under dryland conditions than irrigated lowland or hydromorphic conditions and attained a maximum before flowering when the difference between irrigated lowland and dryland is much greater in improved irrigated lowland cultivars (Fig. 5).

Grain yield. Grain yield was 2.5-7.6, 2.0-7.4 and 0.6-2.9 t/ha in irrigated lowland, hydromorphic and dryland conditions, respectively (Fig. 6). Improved irrigated lowland cultivars were higher yielders under irrigated lowland or hydromorphic conditions than under dryland conditions. Many of the recently released materials from IITA, such as ITA 116, ITA 117, ITA 119, ITA 122 and Tough C24, outyielded the widely grown traditional cultivar, OS 6, in

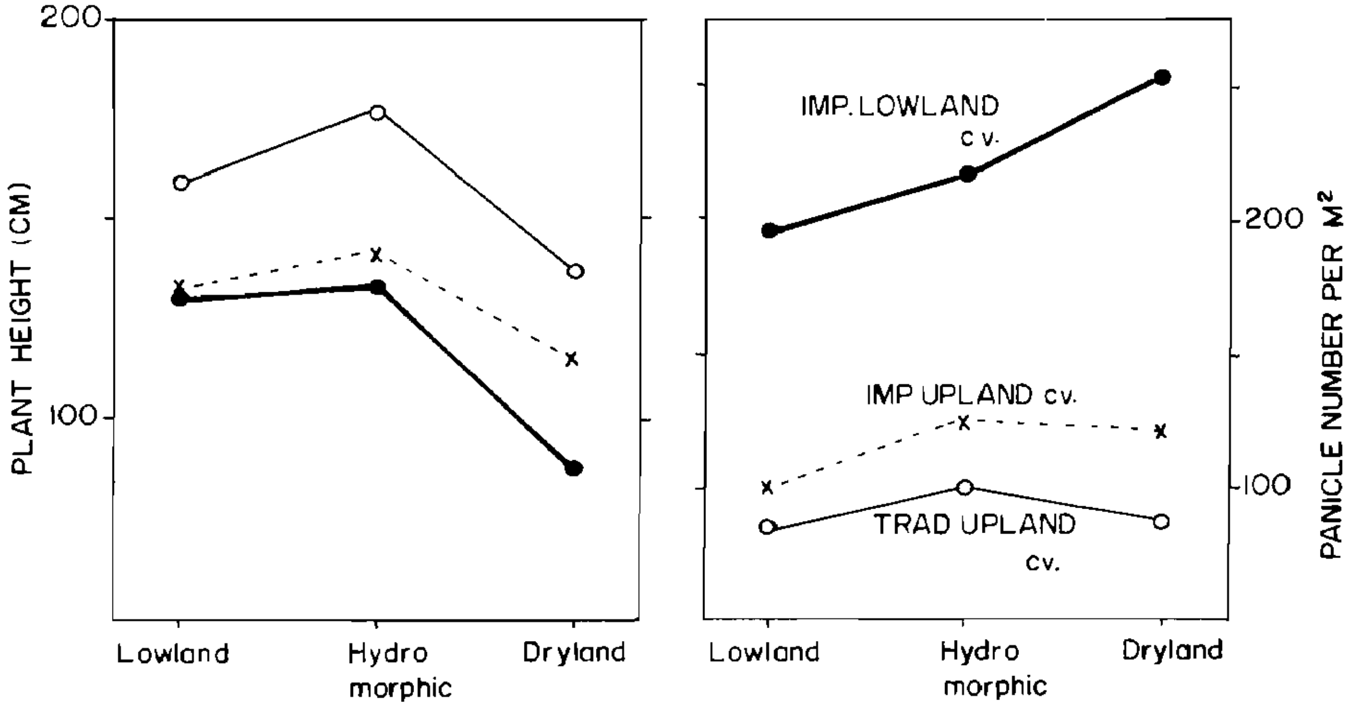


Fig. 4. Plant height and panicle number of rice cultivars under different ecologies.

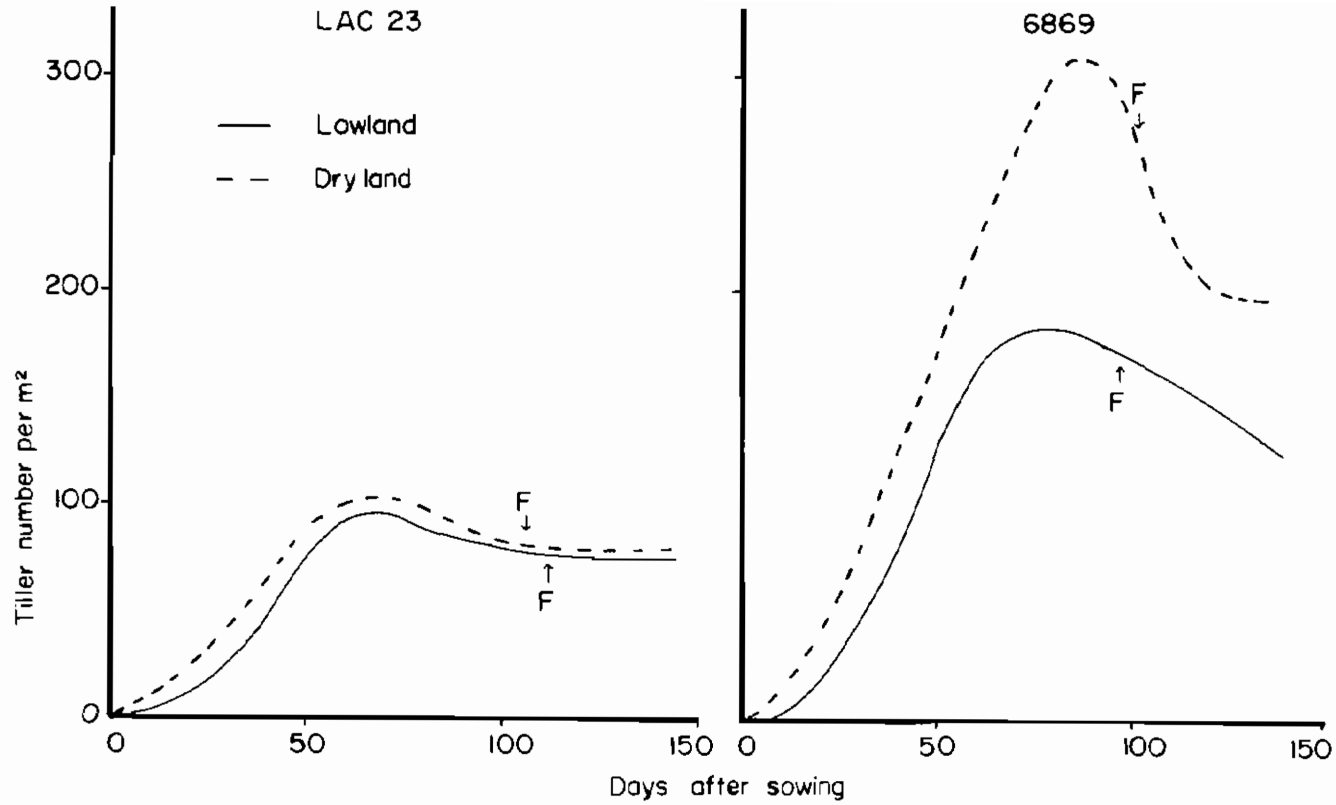


Fig. 5. Tiller number of LAC 23 and BG 6869 at successive growth stages. F = 50% flowering.

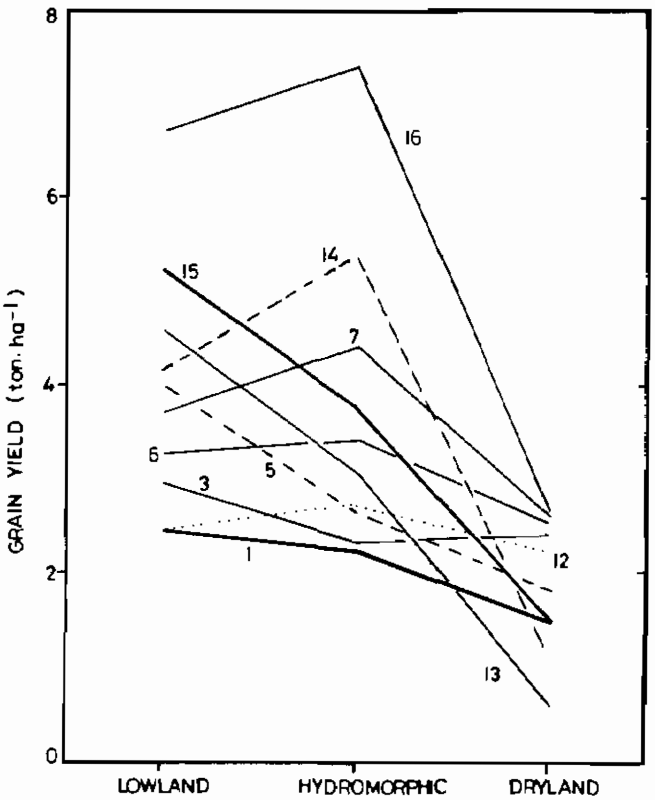


Fig. 6. Grain yield of various rice cultivars under different ecologies (grain yield based on 14% moisture content as rough rice).

dryland. However, they may not be able to outyield OS 6 under irrigated lowland conditions.

Grain yields of irrigated lowland cultivars are not necessarily lower than those of upland cultivars even if they are grown in dryland. However, percentages of milling out-turn are lower in irrigated lowland cultivars than in upland cultivars, especially when compared for head rice, perhaps due to drought stress (Table 54).

Table 54. Percentage milling out-turn of selected cultivars under different ecologies (IITA, 1980).

		Milling Out-turn (%)					
		White rice			Head rice		
Entry No.	Cultivar	L*	H	D	L	H	D
1.	Moroberekan	68	57	61	62	33	54
3.	63-83	65	66	62	57	61	55
5.	OS 6	67	60	64	63	46	56
7.	ITA 116	65	65	62	64	60	57
14.	IR 1416-131-5	60	55	26	54	43	10
16.	6869	63	60	40	56	48	23

**L = Irrigated lowland; H = Hydromorphic; D = Dryland.*

Yield potential of dryland rice is apparently limited in spite of large breeding efforts being done already. Hydromorphic rice holds greater yield potential, but this potential has not yet been fully exploited in Africa by way of land improvement or management. Ideo-plant type is essentially the same for hydromorphic and irrigated lowland rice.

Dry matter production. The plant total dry weight was larger under dryland than irrigated lowland conditions during early growth stages because of retarded plant growth (under irrigated lowland conditions) due to transplanting, especially with traditional upland cultivars (Fig. 7). Later, the plant dry weight was larger under irrigated lowland and hydromorphic conditions than dryland conditions. The difference in dry weight between irrigated lowland and hydromorphic conditions and dryland conditions was more pronounced after flowering to full maturity. Panicle dry weight was larger in irrigated lowland and hydromorphic conditions after flowering.

Dry matter and grain yield. The total weight at harvest was from 0.81 to 1.67 kg/m², from 0.86 to 1.96 kg/m² and from 0.49 to 1.23 kg/m² in irrigated lowland, hydromorphic and dryland conditions, respectively (Fig. 8).

The larger dry weight of the plants seems to be associated with higher grain yield. Harvest index of cultivars used was generally lower, especially that of irrigated lowland cultivars when grown under dryland conditions. 6869 was the only cultivar possessing a harvest index of nearly 0.5.

Panicle number and panicle weight. The panicle number of most cultivars used was lower than that of high-yielding type (Fig. 9). Only IR 5 and IR 1416-131-5 produced more than 200 panicles/m². This is perhaps a reflection of the high pressure to select larger single panicles, consciously or unconsciously, given by the breeders during various selection stages for upland rice in Africa.

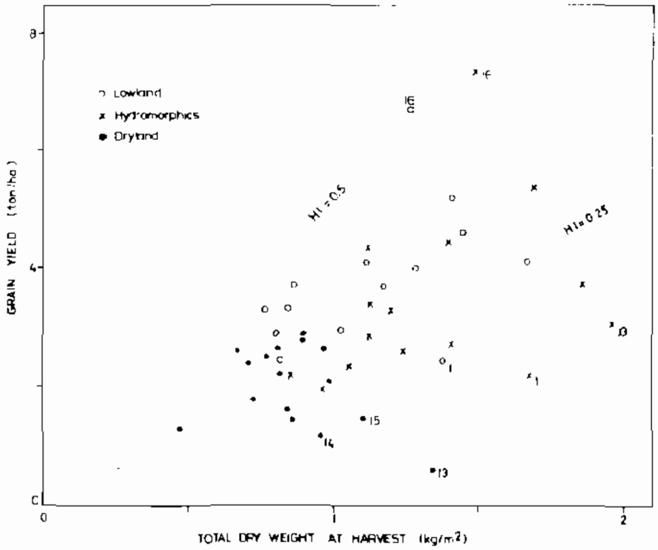


Fig. 8. Relationship between total dry weight at harvest and grain yield.

Improvement of upland rice should not only be pursued through an increase in panicle size but also in panicle

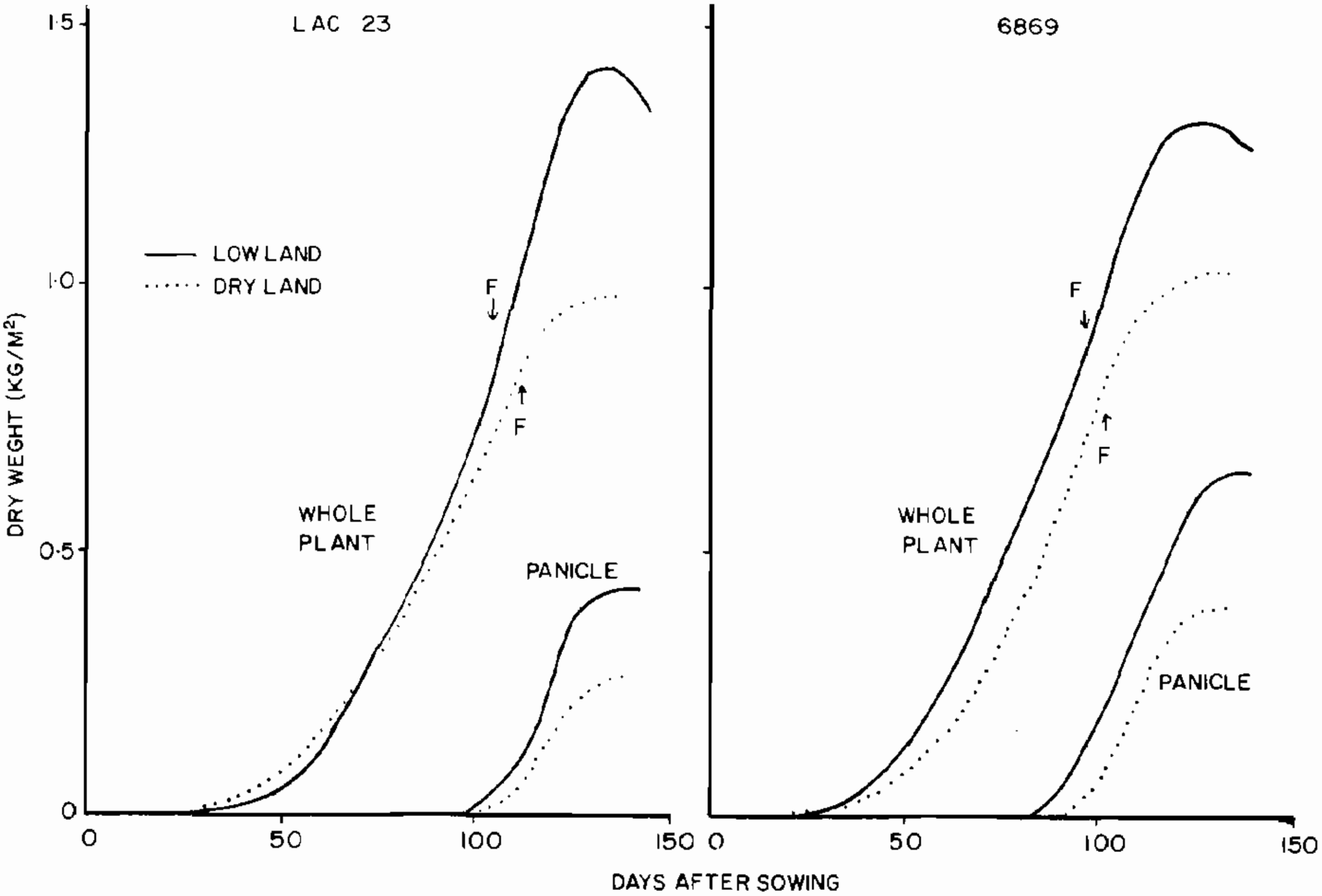


Fig. 7. Dry weight of whole plant and panicle of LAC 23 and BG 6869 at successive growth stages. F = 50% flowering.

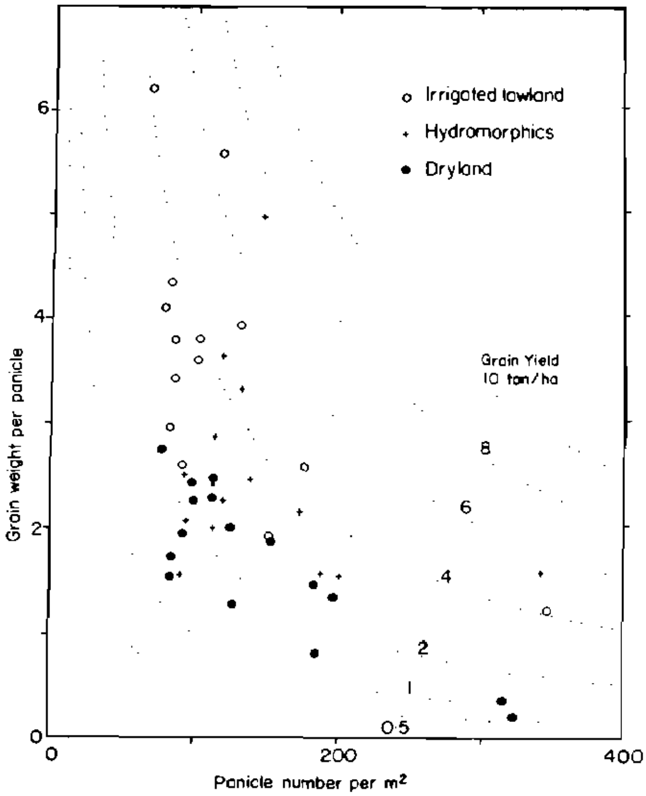


Fig. 9. Relationship between panicle number and grain weight per panicle.

number. Since panicle weight is contributed by the number of spikelets per panicle, percentage filled grain and grain weight, further analysis of these yield components are still being made.

The results obtained so far indicate that an optimum planting density for dryland rice is lower than that for irrigated lowland rice because of poor water holding capacity and low nutrient status of degraded soils under tropical upland conditions. Studies on optimum density on dryland rice is, therefore, essential for varieties with different tillering habits.

Root character and drought. Root dry weight as well as proportion of root weight to total dry weight of upland cultivars were similar under different ecologies (Fig. 10). Those of irrigated lowland cultivars were significantly larger under dryland than irrigated lowland or hydromorphic conditions.

Scoring for root thickness was done in terms of the proportion of thick and thin roots during ripening (Table 55).

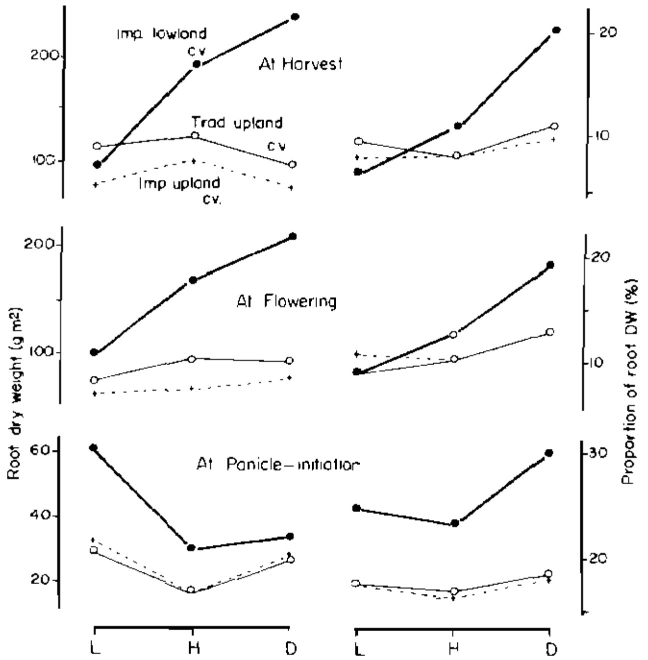


Fig. 10. Root dry weight and proportion of root dry weight to total dry weight of rice cultivars at 3 growth stages under different ecologies.

Table 55. Root thickness of rice cultivars under 3 water regimes (IITA, 1980).

Entry No.	Cultivar	Lowland	Root thickness score* Hydromorphic	Dryland	Mean
1.	Moroberekan	4	1	1	2.1
		4			
2.	LAC 23		1	3	2.8
3.	63-83	4	1	4	3.3
4.	Dourado Precose	5	2	2	3.3
5.	OS 6	4	3	4	3.8
6.	IRAT 13	5	3	3	3.8
7.	ITA 116	3	2	4	3.2
8.	ITA 117	4	2	6	4.5
9.	ITA 119	3	2	3	3.2
10.	ITA 122	7	3	7	5.7
11.	ITA 150	5	2	3	3.5
12.	Tough C24	4	2	3	3.3
13.	IR 5	7	6	8	7.0
14.	IR 1416-131-5	5	5	7	6.2
15.	Suakoko 8	7	3	7	5.7
16.	6869	8	7	9	9.0
	Mean	5.1	3.1	4.9	4.3

**Scoring scale 1 to 9; 1 = All roots are thicker than 2 mm; 9 = All roots are thinner than 1 mm.*
L = irrigated lowland; H = hydromorphic; D = dryland.

Traditional upland cultivars have a higher proportion of thick roots; whereas, the reverse is true in improved irrigated lowland cultivars. Root scores of newly released IITA cultivars range from 3 to 6 in a 1-9 system: 1 = roots thicker than 2 mm in diameter and 9 = roots thinner than 1 mm in diameter. In general, roots are thicker under hydromorphic conditions than under irrigated lowland or dryland conditions. No reasons are apparent as yet why root scoring was lower in hydromorphic and higher or similar in irrigated lowland and dryland.

These results suggest that the root thickness plays a more important role in drought resistance than the root volume or the proportion of root to total dry weight.

Rice varieties and drought resistance

Thirty-six rice cultivars, including advanced dryland selections from IITA, OS 6 and IRAT 13, were evaluated during the dry season. Sprinkler irrigation was used to create 4 moisture treatments corresponding to the growth stages of OS 6, viz, (1) no drought, (2) 18-day drought at tillering, (3) 12-day drought at booting and (4) 18-day drought at tillering and 12-day drought at booting.

Leaf water potential and stomatal conductance were measured with a pressure chamber and Delta-T automatic diffusion parometer, respectively, on the third leaf from the top. Dry weight of roots and shoots and root to shoot ratios were determined at the maximum tillering stage.

The water potential measurements showed that ITA 122, ITA 119, ITA 169 and IRAT 13 maintained higher values than that of OS 6 under moisture stress at both the vegetative and reproductive stage (Table 56).

The leaf diffusive resistance did not vary much among varieties, and no variety showed a high degree of stomatal control. Root to shoot ratios were different among varieties and ranged from 0.11 to 0.41.

Table 56. Critical water potential values (ψ) for selected rice cultivars at tillering and booting stages.

Cultivar	Tillering stage	Booting stage
ITA 119	16.6	16.6
ITA 122	21.5	19.1
ITA 169	23.5	18.2
IRAT 13	22.2	19.4
OS 6	23.3	20.8

However, no clear relationship was apparent between those values and that of water potential.

High positive correlation at the 1 percent level was observed between grain yield and 1.000 grain weight, weight per single panicle, harvest index, plant height, panicle number and panicle exertion, in that order (Table 57). The data suggest the extreme importance of the grain filling under drought stress. In contrast, 1,000 grain weight is the least variable yield component under irrigated conditions.

Another important observation is that plant height and panicle exertion, which are morphological expressions of cell elongation, are correlated with grain yield. As such, good panicle exertion has been a major breeding objective for dryland rice improvement.

Desiccation and heat tolerance tests

Among several screening techniques to determine drought resistance, heat tolerance has been reported to be useful, particularly in sorghum. The relationship between drought and heat tolerance is based on the observation that during moisture stress, the increase in stomatal resistance results in raising the leaf temperatures and causes leaf desiccation in susceptible varieties.

The method principally measures cell membrane integrity following heat stress. Heat tolerance is expressed as a percentage of extracted electrolytes at a specified temperature over total amount of electrolytes extracted when all the cells are destroyed by heat. The data on percentage injury by desiccation of some cultivars grown under irrigated lowland and dryland conditions is presented in Table 58. Varietal differences in percentage

Table 58. Desiccation tolerance in rice cultivars grown in dryland and irrigated paddy conditions.

	% Injury by desiccation	
Cultivar	Lowland	Dryland
OS 6	4.2	5.5
63-83	4.9	8.2
IRAT 13	5.6	11.6
ITA 116	4.8	6.0
ITA 119	4.0	5.0
Suakoko 8	11.8	7.1
IR 5	8.4	5.6
LAC 23	8.1	3.0
Moroberekan	5.6	3.5

Table 57. Correlation Matrix between selected plant parameters of 36 varieties under 4 drought treatments.

Plant parameter	Plant height	Panicle exertion	Panicle number	Grain weight	1,000 Grain height	Weight per panicle
Plant height (CM)	1.0					
Panicle exertion (CM)	.45*	1.0				
Panicle number (per hill)	.01	.06	1.0			
Grain weight (G/hill)	.46*	.28	.30	1.0		
1,000 Grain weight (G)	.46*	.27	.28	.87*	1.0	
Weight per panicle (G)	.45*	.29	.11	.86*	.87*	1.0
Harvest index (%)	.26	.10	.07	.49*	.48*	.44*

**Significant at 1% level.*

Recognizing that thick roots are associated with drought resistance and short stature with high yield potential, IITA scientists are developing semi-dwarfs with thick roots for upland rice.

injury and the relationship with the growing conditions were not clear. The appropriateness of this test for evaluating rice varieties for drought resistance needs to be further studied.

Seedling selection for root thickness

Research at IITA on plant type suitability for dryland rice has indicated that for improving lodging resistance and yield potential, short to intermediate statured cultivars are superior to traditional, tall cultivars.

Observations on African, traditional, dryland cultivars show that they have deeper and thicker roots, compared to the paddy varieties. It appears that deep-rooted varieties generally have a larger proportion of thicker roots than shallow-rooted varieties. The data reported under plant type under different ecologies (Figs. 6 and 10) suggest no relationship between root dry weight or proportion of root to total dry weight and grain yield obtained in dryland. However, the thick roots seem to have an advantage over the thin roots under dryland conditions. Recent studies at IRRI showed that the mean diameter of roots among 35 rice cultivars was significantly correlated with the field drought resistance score. Observations on the selected segregating populations in dryland show that plants with thick roots generally have better panicle exertion and grain filling compared to plants with thin roots.

Considering that evaluating for root thickness by visual scoring is simple and that it is related to drought resistance, it appears that selecting for root thickness rather than the tedious process of rooting depth is desirable. However, for breeding purposes, where the size of the F2 population needs to be large, there are no convenient methods available yet to evaluate for root thickness but to pull out individual plants and observe. As such, the possibility of evaluating plants for root thickness at seedling stage itself was explored so that selection for both plant height and root thickness could be conveniently done.

The appropriateness for selecting for short height at seedling stage is already known and widely practiced by several breeders.

The F2 seeds from cross TOx 936 (IR 1529-430-3/Iguape Cateto) were sown thinly on upland nursery beds. For the first 2 weeks, no N was applied and water was limited to encourage root development. After that, N and water were adequately supplied to promote short growth. Three weeks after sowing, the seedlings were carefully uprooted and the roots were washed.

The vigorous seedlings were separated and grouped based on their height and root thickness. They were then transplanted and at maturity, their plant height and root thickness score were recorded.

The correlation coefficients between any pair of characters for plant height and root thickness were inconsistent. Therefore, the linear regression equation between plant height (y) and root type (x) for all the F2 plants was calculated. The equation $Y = 0.318X + 147.7$ and $R = 0.025$ was not significant. This indicated that plant type and root type behave as independent characters.

Further, the comparison of grouping done at seedling stage with that done at maturity for root thickness showed 95 percent fitness. Thus, it appears that selection for short stature and thick roots should be possible at the seedling stage itself, which will increase the probability of obtaining desirable plant type for dryland. However, because the selected seedlings need to be transplanted in paddy for establishment, while the material is meant for dryland, further selection at maturity should be limited. Critical evaluation and selection should be initiated from the F3 stage under dryland conditions. More detailed studies are being conducted in this area.

Grain Legume Improvement Program

Introduction

During its early years, the Institute explored the possibility of genetic improvement of a number of grain legumes, including pigeon pea and lima bean, that might prove useful in farming systems of the humid and subhumid tropics. The Grain Legume Improvement Program has, however, been consolidated gradually and now concentrates primarily on cowpeas, which absorb about 60 percent of available resources and in second place on soybeans.

Cowpea diseases are among the most conspicuous constraints in humid tropical environments. Sources of resistance to most of the important diseases have been identified and combined into breeding lines. All of the 92 elite lines distributed in international trials since 1976 have high levels of combined resistance to the principal bacterial fungal and virus diseases.

Insect pests remain the main constraint to increased and stable production of cowpeas, particularly in Africa. The priorities in the eighties are, therefore, toward the development of resistance to the succession of insect pests that attack the crop.

The main objectives in the improvement of soybeans is to develop varieties that combine good seed storability, compatability with African rhizobia and yield capability. Poor seed storability and incompatability with indigenous rhizobia are the 2 principal factors that have prevented the development of soybeans as a commercial crop in Africa.

Genetic improvement in cowpeas and soybeans is reinforced by parallel research on symbiotic N-fixation. There have been few studies of the population of rhizobia in tropical soils, and, therefore, little is known about their diversity, survival in adverse environments, host range or effectiveness in symbiosis with selected crop hosts in terms of N-fixation. With the cost of N fertilizer escalating, the importance of study of these topics is clear.

Grain legume improvement projects in Upper Volta, Tanzania and Brazil complement the work done at IITA and are centers for development and utilization of improved lines in the countries they serve. Reports on these projects are included under the sections on crops, and individual annual reports are available from the respective organizations.

Cowpea

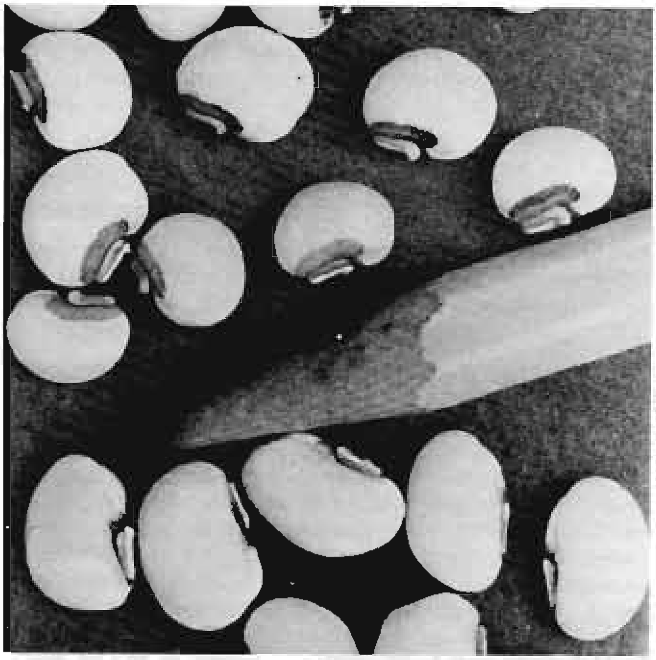
Cowpea breeding concentrated on 2 main objectives; first, to increase the seed size and improve the seed coat characters in high-yielding, disease-resistant lines; second, to incorporate resistance to bruchids. Research is also carried out on the sources of resistance to the other major insect pests of cowpea: flower thrips that cause flower bud shed; *Maruca testulalis*, a pod borer that damages stems and pods, and hemipteran pod-sucking bugs that can cause extensive damage within a short time.

Genetic improvement

Seed quality

Cowpea breeding concentrated on increasing the seed size and improving the seed coat characters in the high-yielding, disease-resistant backgrounds. Large (18-25 g/100 seed), white, rough seed lines were taken from the germplasm collection and screened in the field for tolerance to diseases. The more tolerant lines were selected, but all were substantially less resistant to disease than the elite lines. Therefore, when these large-seed donors were used in a breeding program, special care was needed to maintain the yield and multiple-disease resistance of the elite lines.

A large, white, rough seed with a small eye is strongly preferred in the West Africa savannah. The testa can be removed easily when the seed is soaked in water, which is the first step in the preparation of traditional recipes for korsai, akara and moi-moi. In parts of West Africa near the coast and in other regions of the world, colored seeds are acceptable. The initial program to improve seed quality was to transfer the large, white, rough seed characters from TVu 6203 (Bambey 26, Senegal) to the VITA-4 and VITA-5 genetic backgrounds by backcrossing. After 3 backcrosses, 3 advanced selections, TVx 4291-2C-01D (VITA-4 backcross), TVx 3671-01D (VITA-5 backcross) and TVx 3671-11C-01D (VITA-5 backcross), with seed that is 20-40 percent larger than the recurrent VITA parent were included in an international trial in 1980. Two selections, TVx 3671-3C-01D and TVx 3671-



Cowpea seed from backcrosses with VITA-5 are 20-40 percent larger than the original VITA-5 seed.

7C-01D, were also included in Nigerian national trials in 1980.

During the year, additional sister lines from these 2 crosses were evaluated, and 4 were identified that combined large seed, multiple-disease resistance and yield potential equal to the recurrent parent (Table 1). The selections will be included in an international trial next year.

VITA-4 and VITA-5 have white seed and so do the large seed selections from them. VITA-5 and its progeny (the TVx 3671 series) have a rough seed coat, but VITA-4 and its progeny (the TVx 4291 series) have a smooth seed coat.

In addition to the VITA-4 and VITA-5 backcrosses as a source of new lines with large seed, a number of large, white seed donors with moderate disease resistance were crossed with elite lines, most of which had small, colored, smooth seed. The reaction to disease of some of the large-seed donors and elite lines is shown in Table 2. Fifty F_6/F_7 selections from simple crosses and 1 backcross to the elite parent were evaluated in both an inoculated nursery and a uninoculated yield trial in the 1980 second season. Twenty selections with medium or large (14-21 g/100 seed) smooth seed, good disease resistance

Table 2. Disease rating of large, white, seed donors and elite lines used in breeding for improved, large-seeded lines.

A. Large, white seed donors (18-25 g/100 seed)	Reaction to humid zone diseases (CYMV, Anth, BB, BP, Cerc, Phak rust).
TVu 8440 = (Acc. 70002)	- MS
TVu 6203	- MR-MS
TVu 4573	- MR-MS
TVu 4563	- MR
TVy 6945	- MR-MS
IAR lines	- MR but MS for CYMV and Anth.
TVx 881-3C	- MR but MS for Anth.
B. Elite lines (10-15 g/100 seed)	
VITA-4	R - MR but MS for CAMV'
VITA-5	R - MR but MS for BB and Scab'
VITA-7	R - MR but MS for BB, Scab, CAMV and Anth.
TVx 12-01E	R - MR
TVx 33-1J	R - MR
TVx 1193-10F	R - MR

'*Savannah zone disease (rating unavailable for large white seed donors).*
Phak = Phakospora pachyrizi
BB = Bacterial blight
Anth = Anthracnose
CAMV = Cowpea aphid-borne mosaic virus
Cerc = Cercospora
R, MR = Resistant, Moderately resistant
S, MS = Susceptible, Moderately susceptible

Table 1. Agronomic and disease characters of large, white, seed selections out of third backcross to VITA-4 (TVx 4072) and VITA-5 (TVx 3671) from large, white, seed donor, TVu 6203 (IITA and Ilonga, 1980).

	Yield as % of recurrent (VITA) parent	Seed size g/100 seeds	Disease reaction				Days to 50% flowering
			CYMV	BB	Anth	Pod blotch	
VITA-4*	100	9.3	R	R	R	R	51
TVx 4072-1C-01D	130	12.4	R	MR	R	R	51
VITA-5*	100	10.9	R	MS	R	R	50
TVx 3671-3C-04D	140	15.2	R	R	R	R	42
-7C-02D	100	14.2	R	MS	R	R	43
-14-01D	122	14.3	R	MR	R	MR	49
LSD (5%)	500 kg/ha (55% of VITA parent)	1.6					8.0

**Mean of VITA-4 and VITA-5 over 3 trials.*
R, MR = Resistant, moderately resistant.
S, MS = Susceptible, Moderately susceptible.
CYMV = Cowpea yellow mosaic virus.
BB = Bacterial blight.
Anth = Anthracnose.

and agronomic characters were multiplied in 1980 and will be included in an international trial next year. They include white, tan, red and black seeded selections.

Other advanced lines with large seed, good disease resistance and agronomic characters were selected from crosses between elite lines (Table 3). These also will go into an international trial next year.

New F_1 lines were formed from 3-way and simple crosses between donors of large seed and the large seed derivatives of TVx 4291 and TVx 3671 (VITA-4 and VITA-5 backcrosses, respectively) to increase seed size still further and combine it with a rough testa and small eye. Disease susceptible plants were removed in the F_2 generations, and then bulk selections were made by cross for seed more than 18 g/100 seed. Other F_1 crosses were made to combine large, white, rough seed and photosensitivity into improved lines for the West Africa savannah.

Bulk selection for large seed was made in the F_3 breeding nursery that contained crosses between elite lines. Seed had been bulked by cross in the F_2 to provide 115 F_3 entries, 25 of which were selected. The nursery also included 262 F_3 progeny rows derived from large seeded selections of F_2 and backcross F_1 plants of 12 crosses (6 elite × 2 donors of large seed, TVu 6203 and TVx 881-3G). Seed from each progeny row was harvested, bulked and then sorted for seed more than 18 g/100 seed. Further selection within the between bulks gave 66 lines with large, white seed. When both parents had white seed (e.g., crosses of VITA-5 (11-13g/100 seed) with TVu 6203 (22g/100 seed) and TVx 881-3G (25g/100 seed), the proportion of progeny rows with large, white seed was higher, and the backcrosses to the large-seed donor gave a large proportion of large seed progeny (Table 4). There was evidence of genetic linkage among the white. rough testa and hilum-ring or small eye characteristic. Thus, 59 out of the 66 white seed selections had a rough or semi-rough testa, whether they were segregants within a line (23) or an entire line (36), and all but 6 showed hilum-ring or small eye. In contrast. none of the 33 lines with large but colored seed that were selected had a rough testa. Ten of the large, white seed selections from backcrosses had larger seed (24-27.3 g/100 seed) than the large-seed donor, TVu 6203 (22 g/100 seed). They also had a rough seed coat and small eye. Clearly selection for large seed appears to be more successful in the F_3 and backcross F_2 generations than in the earlier generations. A genetic study of the F_2 progeny of the 12 crosses indicated that the white, rough testa. hilum-ring and small eye characteristics are governed by recessive genes.

Table 3. Agronomic and disease characters of large seed selections from advanced trials (IITA and Ilonga, 1980).

	Yield as % of standards	(IITA/Ilonga) range over 2 sites kg/ha	Seed size g/100 seeds	Seed coat color	Days to 50% Flowering
Standards*	100	(460-1,510)	13.2		
TVx 3372-02K	89		16.0	White	41
TVx 3236-01G	121		14.0	White	54
TVx 3928-015F	138		16.0	Tan	48
TVx 4255-01F	92		16.0	Tan	49
TVx 2724-01F	172		15.0	Tan	46
TVx 3408-02J	94		17.8	Tan	47
TVx 410-02J	74		18.5	Tan	44
TVx 3871-02F	126		15.6	Tan	42
TVx 3777-04E	112		16.5	Tan	41
LSD (5%)	500 kg/ha (50% of standards)		1.6		8.0

**VITA-1*
VITA-4
VITA-5

Table 4. Percentage of progeny rows with large, white seed in F_3 and backcross F_2 generations for 12 reciprocal combinations of 6 elite × 2 large seed donors (IITA, 1979).

Type of cross	No. of combinations	No. of entries	F_3	F_2 of BC (S)	F_2 of BC (L)	Total with large, white seed
VITA-5 × L.W.R.	2	46	85.7%	38.5%	61.5%	27
VITA-4 × L.W.R.	2	27	33.0%	20.0%	63.2%	14
S.C.Sm. × L.W.R.	8	189	33%	1.6	39.4%	26
Total No.		262				66

S = Small seed
W = White seed
R = Rough
VITA-5 = S.W.R. seed
VITA-4 = S.W.Sm. seed

L = Large, >> 18 grm/100 seed
C = Colored
Sm = Smooth

BC(S) = Backcross to small seeded parent
BC(L) = Backcross to large seeded parent

In a genetic study of seed size in the F_2 and backcross F_1 generations of the same 12 reciprocal combinations, which generated the above F_3 and backcross F_2 progeny rows, broad sense heritability estimates ranged from 48 to 90 percent with a mean over crosses of 76 percent. The inheritance of white seed coat is governed by a recessive allele at 1 locus out of the 4 loci that control seed coat color. The hilum-ring or small eye that are preferred were shown to be controlled by recessive alleles at 2 or 3 loci but with epistatic interaction from a locus for color also occurring. The rough seed coat character either did not segregate or only at low frequency (4 percent) in 1 F_2 population of 300 plants involving semi-rough seeded (VITA-5) and rough seeded (TVx 881-3G) parents. A smooth seed coat occurred in 80-97 percent of F_2 segregrants. All these findings confirm the results of other workers and show that the combined expression of the white, small eye and rough seed characters is likely to be hidden by the dominant colored, large-eye and smooth-seed characters. The linkage between the preferred seed characters permits effective selection for them in the F_3 generation.

Breeding for disease resistance

Lines from preliminary and advanced trials and disease-resistant subpopulations were evaluated in the 1980 first season for resistance to humid-zone diseases. At Onne, cowpea golden yellow mosaic virus (CGYMV) and web blight (WB) were screened in the field; at IITA, cowpea yellow mosaic virus (CYMV), anthracnose (anth), protomycopsis (Proto) and fusarium root rot (Fus) were screened in the field while bacterial blight (BB), cowpea aphid borne mosaic virus (CAMV) and cowpea mottle virus (CMeV) were screened in the screenhouse. To select for resistance to the savanna-zone diseases, preliminary and advanced trials and selections from the disease populations were inoculated in the field at Funtua, Nigeria.

The trials were assessed for resistance to Septoria (Sept), scab, colletotrichum pod blotch (Coll), BB and Anthr (Table 5).

The incidence of diseases was lower in 1980 than 1979 with correspondingly larger variation in the data obtained from the trials.

Ways to improve the methods of field inoculation and, hence, the reliability of field screening were studied. Comparisons were made between arrangement of spreader rows, inoculation methods and selection levels. The study was conducted on an F_2 population of crosses for resistance to CYMV and Anthr. Individual plants selected on the basis of the different selection levels applied were grown in progeny rows in the 1980 second season. The study is expected to provide useful information on which to base modifications to the present screening procedures, specifically these concern spreader row configurations in relation to test materials and level of selection intensity required for satisfactory resistance.

Breeding for resistance to bruchids

The only germplasm accession found so far that has seed resistance to bruchids is TVu 2027. It is an unimproved local cultivar strongly photoperiod sensitive and extremely susceptible to CYMV. Elite lines and germplasm accessions with CYMV resistance were used in crosses from which selections were made for combined bruchid and virus resistance.

In the 1980 second season, 25 F_6 derivatives selected for bruchid and CYMV resistance in F_2, F_3 and F_4 generations were evaluated at IITA for agronomic characters. The most promising entries will be multiplied for wider testing next year. Their resistance to bruchids is similar to that of TVu 2027.

The expression of resistance in the seed is governed mainly by the maternal genotype; thus, all seeds from an individual plant have similar resistance. However, there is some evidence of a paternal effect that indicates that the genotype of the embryo may also influence resistance of a seed. For screening early generations, samples of 20 seeds per plant were used in each of 4 replications. Each sample was infested with eggs by exposure to 2 pairs of bruchids for 105 hours. Subsequently, any undamaged seed in samples derived from resistant plants (no adults emerged/no eggs = < 0.2) were grown with remnant seed from the same plant to provide an adequate sample of the progeny. The viability of damaged seed from which even only 1 adult has emerged is low. Two of these selections, TVu 4031-6B-01C (TVu 1193-9F × TVu 2027) and TVu 4409-11B-01C (TVu 408-P_2 × 2027), show resistance similar to that of TVu 2027 on the basis of the number of adults emerged, the time taken to emerge and the rate of increase per

Table 5. Pathology evaluation breeding trials 1980. Entries with multiple disease resistance, scored on 1-9 scale.

Standards	CGYMV[1]	WB[1]	CYMV[2]	Anthr[3]	BB[3]	Pod Bl[3]
VITA-7	1.7	3.0	1.0	5.0	5.0	5.8
Ife Brown	1.3	3.3	5.3	5.3	4.3	5.0
TVu 6507	9.0	4.3	6.3	5.0	3.3	2.0
New Entries						
TVx 3356-04F	1.7	4.0	1.0	1.0	1.0	7.0
TVx 3368-06F	1.7	1.0	1.7	3.0	2.3	1.8
TVx 3408-03J	1.7	2.3	5.3	3.7	1.5	1.8
TVx 3928-018F	2.3	1.0	1.7	2.7	2.3	2.0
TVx 4248-05F	4.3	2.7	1.0	1.0	2.8	1.0
LSD (5%)[4]	1.5	2.0	2.5	1.5	2.5	4.0

1. *The IITA Onne substation, 1980 first season*
2. *IITA, 1980 first season*
3. *Funtua, 1980 second season*
4. *Average estimates over trials*

Table 6. Bruchid resistance characteristics of improved, virus-resistant selections (IITA, 1980).

	Mean No. of eggs/20 seeds	Mean percent adults emerged	Mean No. of days to emergence	Natural rate[1] of increase
TVx 4031-6B-01C	30.5	39.8	34.2	1.67
TVx 4409-11B-01C	30.8	47.6	33.0	1.92
TVu 2027[2]	33.5	38.6	35.2	1.64
Ife Brown[3]	38.3	90.6	28.5	2.3
LSD (5%)	7.8	11.0	1.9	

1. *Natural rate of increase = No. of eggs/(No. of eggs—No. of adults)*
2. *Resistant check*
3. *Susceptible check*

generation (Table 6). The rate of increase must be less than 2 if resistance in storage is to be effective.

TVx 4409-11B-01C has medium-sized, white seed and is resistant to CYMV and CAMV. TVx 4031-6B-01C has medium-sized, red seed, and is moderately susceptible to CYMV but resistant to CAMV. Both lines have been multiplied for distribution in 1981. In 1979 and 1980, they were used in place of TVu 2027 as donors of burchid resistance in the breeding program.

Some F_3 plants of an improved virus and bruchid resistant line crossed with TVu 625 already combine large, white, rough seed and bruchid resistance. Further selection will be made to recover resistance to CYMV in the progeny.

Table 7. Lines selected from 1979 advanced trials 1, 2 and 3 that possessed pod-wall resistance to Callosobruchus maculatus (IITA, 1980).

	Av. No. eggs per pod	% hatch	% survival	% damaged seed	No. exit holes/ pod
Ife Brown	26	94	52	66	10
VITA-5	35	92	27	56	4
TVx 3384-027D	28	89	10	6	2
7R-0189-D	24	87	9	7	7
TVx 3336-040E	36	87	2	5	1
TVx 3356-04F	18	94	3	5	4
VITA-4	34	90	5	3	4
LSD (5%)	-	-	16	19	3

Pod-wall resistance to *Callosobruchus*

Cowpeas are commonly stored in the pods and threshed as the grain is needed. If cowpea pods do not dehisce, the pod wall serves as physical barrier, which lowers the survival of *Callosobruchus.*

In 1980, a study was completed that identified several cowpea lines possessing another mechanism of resistance to *Callosobruchus.* This mechanism is thought to be a toxin that the newly hatched larvae consume when penetrating the pod wall. Pods from the 1979 advance trials 1, 2 and 3 were screened for pod-wall resistance. Ife Brown and VITA-5 were used as susceptible standards. To insure that bruchids reached the seed only through the pod wall, the tips of pods were dipped in paraffin to seal the opening left when a pod is removed from its peduncle. The pods were then placed in plastic containers (15 cm × 35 cm) with 15 pairs of adult bruchids. After 5 days, the adults were removed, the eggs counted, and the percentage that hatched recorded. All tests were replicated 6 times. Adults that emerged from the pods were collected daily. The numbers of exit holes and of damaged seed were recorded at the end of the test period, which was 42 days. Table 7 shows that 5 lines exhibited good levels of resistance when compared to the 2 standards. The percentage survival, damaged seed and number of exit holes were significantly less than for the 2 standards.

Sixteen other lines from the advance trials showed pod resistance, but they tended to shatter, which destroys the protection through pod-wall resistance.

Table 8 summarizes the results of another test to compare pod wall and seed resistance to *Callosobruchus.* Pods of TVu 625 and TVu 4200 do not dehisce and, thereby, provide some protection while TVu 2027 has resistant seed. Worthmore, which is resistant to the cowpea curculio *(Chalcodermis aeneus)* was included to determine if it has pod resistance to bruchids as well. In this test, the number of eggs was kept the same in each of the 6 replicates. As shown in Table 8, the percentage of insects that survived on TVu 625 and TVu 4200 and

Table 8. Pod-wall resistance on selected lines, and its impact on population suppression and damage (IITA, 1980).

	Av. No. eggs per pod	% egg hatch	No. larvae penetrating pod wall	Larval survival	No. adults emerged/ pod	% damaged seed/pod	Exit holes/ pod
Ife Brown (Std.)	17.1	100	16.3	63.5	10.8	62.71	8.8
TVu 625	17.1	99.9	13.4	46.5	8.0	51.08	5.1
TVu 4200	17.1	97.4	13.7	46.3	7.9	55.13	5.3
TVu 2027	17.1	100	14.5	19.4	3.3	24.41	1.6
Worthmore	17.1	98.5	14.3	6.9	1.2	6.98	0.7
LSD (5%)	-	-	-	16.82	3.0	16.56	2.64

the damage caused were only slightly less than on Ife Brown, the standard. The seed resistance of TVu 2027 was effective in significantly reducing survival and damage. Survival and damage were least on Worthmore.

If the pod-wall resistance of Worthmore can be combined with the seed resistance of TVu 2027, more than 98 percent of the insect population would be suppressed. The combined resistance of 2 different mechanisms would be an advantage because it would diminish the risk of *Callosobruchus* overcoming resistance that depended on a single factor.

The F_1 generation of several crosses that involved the bruchid and virus resistant parents, large seeded selections (especially the VITA-5 backcrosses) and several sources of pod-wall resistance to bruchids were grown in 1980 with the object of combining the seed and pod-wall resistance.

Breeding for thrips resistance

Single plant selections were made in a field nursery infested with thrips in the 1980 first season. The nursery contained 90 F_2 populations of 400 plants each derived from crosses between elite lines resistant to thrips or to ethylene spray (a treatment used to mimic thrips damage) and 461 F_3 progeny rows and 16 F_3 bulks. These consisted of crosses between 2 sources of thrips resistance (TVx 3236-01G and TVu 1509), 3 lines resistant to ethylene (TVu 7133, TVu 2870 and TVu 6507) and various elite lines. Only 1 to 2 percent of the plants were selected to be advanced as single plant progeny in the 1980 second season. Fewer plants were selected from crosses involving TVu 7133.

The F_3 and F_4 progeny of these selections were evaluated in unreplicated progeny rows in the second season when the infestation of thrips was greater. Only 6 percent of the entries were selected. More progeny, 22 and 27 percent from 2 of the resistant parents, TVx 3236-01G and TVx 5390-01F, respectively, were selected than from other parents. Progeny from 3 of the elite lines, TVx 3218-03D, TVx 1836-015J and TVx 3040-02D, gave 10, 15 and 10 percent selections, respectively, but there was no close association with selection in the previous generation, which suggests that some of the selections may simply be escapes. Only 24 lines were selected, but their resistance remains to be confirmed.

From more than 500 advanced lines evaluated for differences in thrips damage in 1979, 410 lines were reexamined in the 1979 second season. The best 26 lines were selected and reexamined in a replicated trial with and without insecticide in the 1980 first season, and the 6 showing least damage were selected. Values of t were calculated for the probabilities of the difference between the means of the sprayed and unsprayed treatments of a single cultivar for each of the following variables: visual damage score, first and second flower and pod counts and yield. Based on the ranking of the mean t values, the best 6 cultivars were selected. Four of them, TVx 5995-02C, TVx 5995-07C, TVx 6011 and TVx 6017-02C, are derived from the thrips-resistant parent TVu 1509. The others, TVx 6013-06C and TVx 6015-03C, are derived from TVu 7133, which is moderately resistant to thrips and tolerant to ethylene.

The remaining 384 lines were grown in a replicated nursery. Of 38 lines selected in the first season, only 3 lines, all of which derived from TVu 1509, appeared to have resistance equal to TVu 1509 when reexamined in the 1980 second season.

All advanced breeding lines were evaluated for thrips damage in the 1980 first season. A large majority of the lines were significantly more susceptible than susceptible standard Ife Brown. The results underline the need to screen breeding lines routinely to eliminate the most susceptible.

Priority is being given to the development of better techniques for the screening of breeding materials for tolerance to thrips in the field and screenhouse. Foremost in this is the need for better methods to maintain thrips populations at predetermined levels, to monitor the distribution of insects and prevent selection of escapes.

Identification of new sources of resistance to thrips

In 1979, 650 cowpea germplasm lines were screened for thrip resistance. Every tenth entry in the test was Ife Brown, which was used as a standard. Twenty-nine entries were given a damage score of less than 2.5 on a 1-5 scale by all 4 evaluators. To overcome the problem of differential flowering, the lines were grouped into 4 categories based on time to flower:

Group A = Less than 45 days
Group B = 45-55
Group C = 55-70
Group D = More than 70

In the 1980 second season, the 29 lines were screened in 3 replications. Ife Brown was used as a standard and TVx 3236 and TVu 2870 as resistant standards. VITA-1 and VITA-3 were used as susceptible standards in a test of late flowering lines. As predicted on the basis of probability of escapes, 9 lines gave scores of less than 3 when rated by 3 independent evaluators (Table 9). These 9 lines were as effective as the resistant standards in averting thrip damage. They are from widely different locations, which increases the probability that they possess different mechanisms of suppression.

During the 1980 second season, an additional 630 germplasm lines were grown and evaluated for thrips resistance. As before, a standard was sown every tenth entry, lines were grouped according to the time taken to the first flower and a visual damage score (from 1 to 5) was assigned for each entry by 3 independent observers. A total of 44 lines were given scores less than 3; the standards averaged 4.6. In 1981, the 44 lines will be reexamined in replicated plots to verify the presence of mechanisms that suppress flower thrips.

Resistance to pod bugs

Laboratory and screenhouse evaluation. Using a laboratory bioassay method described in the following Entomology section in which the number of feeding punctures on the pods of Ife Brown used as a standard is compared to the number on test lines, several hundred lines have been screened. Forty-five accessions in the germplasm collection and 33 elite lines, including some from the insect subpopulation, have been selected with 60 percent or less feeding punctures than Ife Brown (Table 10).

Table 9. Germplasm lines with confirmed levels of thrips suppression (IITA, 1980).

	Visual damage rating	Origin
	TEST A	
Ife Brown (Standard)	3.9	-
TVx 3236 (Resistant Standard)	3.8	-
TVu 2870 (Resistant Standard)	2.3	India
TVu 2726	2.9	India
TVu 7683	2.9	Mali
TVu 7731	2.6	Ivory Coast
TVu 8029	2.7	Nigeria
TVu 8064	2.7	Ivory Coast
	TEST B	
Ife Brown (Standard)	3.9	-
TVx 3236 (Resistant Standard)	3.0	-
TVu 7606	2.6	Mali
TVu 7704	2.7	Mali
TVu 8063	2.9	Ivory Coast
	TEST C	
VITA-1 (Standard)	4.7	-
VITA-3 (Standard)	4.8	-
TVu 8079	2.7	Ivory Coast

The promising lines were then planted in replicated tests in a large screen cage (20 m × 40 m) and subjected to a known population of *Clavigralla tomentosicollis* or *Riptortus dentipes*. Counts were made of insect numbers. Lines from the screen cage tests were then evaluated in replicated field plots. Table 11 shows the results of an independent test of the relationship of the different screening methods. This suggests that the laboratory screening method can be used to detect lines that will be useful in a host-plant-resistance study.

Field evaluation. During the 1980 first and second seasons, 11 field tests of resistance to pod bugs were conducted at IITA. In the first season, *Clavigralla shadebi* was the only pod bug that appeared in significant numbers. This bug does not reproduce on cowpea, but adults migrate into the crop from unknown hosts. Lines that reduced populations of *C. tomentosicollis* had no impact on *C. shadebi*. The adults were found dispersed in equal number on the entries being evaluated. The green stink bug, *Nezarus viridula*, was present in small numbers, but data suggest no difference between entries. Therefore, it would appear that cross resistance does not occur between these species of pod bugs.

In the 1980 second season, 7 additional field tests were planted to evaluate selected lines against *C. tomentosi-*

Table 10. TVu and TVx lines showing reduced feeding punctures in laboratory tests (IITA, 1980).

TVu 1	TVu 2870
TVu 57	TVu 3346
TVu 191	TVu 3417
TVu 503	TVu 3511
TVu 577	TVu 3742
TVu 612	TVu 3752
TVu 751	TVu 4539
TVu 906	TVu 4557
TVu 984	TVu 4586
TVu 1023	TVu 4596
TVu 1053	TVu 4600
TVu 1220	TVu 4609
TVu 1283	TVu 4620
TVu 1560	TVu 6559
TVu 1796	TVu 6566-2
TVu 1846	TVu 6627
TVu 1856	TVu 6641
TVu 1890	TVu 6863
TVu 1962	TVu 6904
TVu 2000	TVu 7072
TVu 2640	TVu 7134
TVu 2845	TVu 7138
TVx 2940-01D	7E-143[1]
TVx 1319-03F	8EN-185-2-1
TVx 3368-021E	7E-56
TVx 3343-03E	7E-176-5
TVx 3335-03F	7E-95
TVx 3404-012E	7E-65-5
TVx 3210-05E	7E-165-5
TVx 3368-01F	7E-178-4
TVx 3920-09C	7E-36-5
TVx 3859-2D	7E-80
TVx 3373-011H	
TVx 3901-5D	
TVx 3943-014D	
TVx 3878-01C	
TVx 1843-1C	
TVx 309-1J	
TVx 2921-04D	
TVx 2394-01F	
TVx 3122-06D	
TVx 5931-01E	
TVx 5929-01E	
TVx 5930-1E	
TVx 3368-01F	

[1]E lines—from 1977 and 1978 insect subpopulation.

Table 11. Comparison of methods used in screening for resistance to pod bugs (IITA, 1980).

		Laboratory Tests		Screen cage		Field tests
		Feeding punctures % of Ife Brown		No. adults/ M row		No. adults/ M row
	Pod color	1st test	2nd test	1st test	2nd test	
Ife Brown (Standard)	Light green	100	100	4.3 a	2.3 a	1.9 a
TVx 3878-01C	Dark green purple	18	26	.7 b	.9 c	.7 c
8 EN-185-2-1	Dark green	22	34	3.5 a	1.2 b	1.2 b

collis. The continuing rains suppressed the population until late in the season when the crop was approaching maturity. However, 2 tests did sustain damage. While the populations of pod bugs in the tests shown in Tables 12 and 13 were low, the accumulated damage did result in significantly different levels of damage. Pod bug damage was significantly reduced on TVx 3878-01C. but differences between it and Ife Brown are low, and differences would be obscured by high populations. However, when additional characters are found that reduce pod bug populations and then combined with TVx 3878-01C, the differences could be useful.

Table 12. Pod-bug populations and resulting damage on selected cowpea lines (1980).

	No. Clavigralla/ M row		% damaged pods	Seed Wt. g/3 m row
	Total	*Clavigralla*		
Ife Brown	7.5	6.0	45	110
TVx 3878-01C	7.8	4.0	15	190
TVx 3878-03F	8.0	4.3	15	227
TVu 1	5.5	2.8	19	90
TVx 3908-01E	7.3	2.0	17	97
TVx 3928-012E	8.3	3.8	65	47
TVx 3368-09H	6.3	2.5	37	89
L.S.D. (5%)	NS	NS	16	NS

Table 13. Pod bug populations and resulting damage on selected cowpea lines (1980).

	Av. No. *Clavigralla*/ M row	% damaged pods	Seed Wt. g/3 m row
Ife Brown (Standard)	.6	45.2	33
8 EN-50-5-3	.5	18.2	138
8 EN-185-2-1	.5	25.4	159
8 EN-202-3-3	.2	25.8	121
TVx 3236	.2	53.8	90

Entomology

Biology of cowpea bruchids

The biology of cowpea bruchids on resistant and susceptible cowpea was studied over a period of 6 months. The total number of eggs laid per female, progeny produced and the time taken from egg to adult is shown in Table 14. The natural rate of increase on Ife Brown was 3 times that on TVu 2027. As explained previously, the rate of increase must be less than 2 if resistance is to be effective. There was no significant difference in the number of eggs laid per female, but there was a significant difference in the number of adults that emerged. The time from egg to adult was longer on TVu 2027 (31.2 days) than on Ife Brown (24.0 days). During the 6 month period, there were 5 complete generations on TVu 2027 compared to 6 on Ife Brown. The cumulative increase in the number of F, progeny from the 2 varieties is shown in Fig. 1.

Adults began to emerge sooner and more rapidly from Ife Brown than from TVu 2027. The average rate of emergence was 8.5 and 2.0 adults per day, respectively, with a maximum of 13.4 adults per day for Ife Brown compared to 3.2 adults per day for TVu 2027.

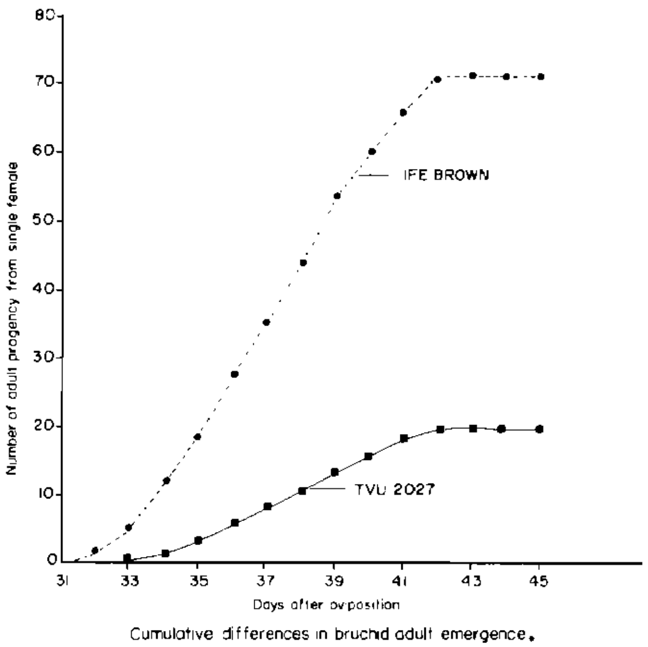


Fig. 1. Cumulative differences in bruchid adult emergence.

Table 14. Biology of cowpea bruchid on resistant and susceptible cowpea cultivars (IITA, 1980).

Cultivar	Number of eggs laid/ female	% adult emergence	Duration in days from egg to adult	Natural rate of increase*
TVu 2027	80.0	25.0	31.2	1.33
Ife Brown	71.9	84.0	24.9	4.08
LSD (5%)	10.2	7.3	1.1	

**Natural rate of increase = No. of eggs/(No. of eggs— No. of adults).*

Damage score and thrips population on Ife Brown at different locations

Ife Brown was planted at different locations. Data was collected on damage score and thrips per plant (Table 15). Thrips population varied considerably at the different locations in Nigeria. Highest populations were observed at IITA in the 1980 second season.

Table 15. Thrips population and damage score on Ife Brown at several locations in 1980: 35 days after planting.

Location	Damage score (scale 1-5)	No thrips/plant
IITA 2nd season	5.0	81.6
Ilora	4.0	46.8
IITA 1st season	4.2	46.4
Funtua	2.0	16.8
Mokwa	-	3.6

Economic threshold studies for thrips

Studies were begun in the 1980 second season to develop economic threshold studies of thrips by planting Ife Brown in large plots of 20 m × 30 m. Application of 0, 25, 50, 75, 100, 125, 150 and 175 g monocrotophos/ha a.i. at 32 and 38 days after planting obtained different levels of thrips per plant. Uniform protection was given against *Maruca* and pod bugs, and their populations were well controlled. Thrips populations were counted at 35 and 45 days after planting. Thrips per plant and cowpea yields were judged against the cost of application of insecticide, and gain from insecticide application was calculated (Table 16). Even at a low dosage of 25 g/ha a.i., gain from insecticide application was observed.

Distribution of thrips in field plots

A characteristic of field screening to recover plants or progenies that exhibit resistance to thrips has been by a high incidence of escapes, which suggests an uneven distribution of thrip population within the field. The observation that a high percentage of the lines selected was located on the margin of the fields supports this view.

The border effect seemed to be independent of the distance from surrounding pigeon pea hedges, which were established to increase thrip populations.

Table 16. Thrips population and cowpea yield (IITA, 1980).

*Insecticide dosage g/ha a.i.	Insecticide cost/ha ($)	Thrips per plant (35 DAP)	Yield kg/ha	Gain from insecticide ($)
0	0	59.9	300	-
25	23	49.0	460	137
50	26	39.6	540	214
75	29	35.3	600	271
100	33	30.6	700	367
125	36	24.6	800	534
150	39	20.4	990	651
175	43	15.8	1000	657

**Monocrotophos applied at 32 and 38 days after planting.*

In the 1980 second season, 10 peduncles were collected from each of the plots of Ife Brown that had been sown every tenth entry through the germplasm nursery, and the number of thrips present was counted on 2 dates, 10 days apart. On the first date, damage scores were also taken.

Table 17 shows that the number of thrips present on the Ife Brown was variable, evidence that the population of insects was not uniformly distributed throughout the field.

In another experiment, VITA-6 and VITA-7 seeds were mixed in equal proportion and sown to observe the distribution of thrips in a mixed population similar to that of a segregating breeding nursery. VITA-6 has normal leaves and VITA-7 has strap leaves so the plants can be easily identified. Fifteen samples at each of 5 spots were taken 42, 46 and 50 days after planting and the number of thrips per plant were counted. There were no flowers, only flower buds at 42 and 46 days after planting, but there were flowers at 50 days after planting.

Table 17. Variation of thrips in Ife Brown plots (IITA, 1980).

	Sample No.		Sample No.	
	1st	2nd	1st	2nd
Mean No. thrips	109	14	76	23
Range	51-184	4-31	27-201	5-55
S.D.	47	9	42	16

There was no significant difference in the number of thrips per plant at 42 and 46 days after planting, but at 50 days after planting, there was a difference in the numbers on the 2 varieties (Table 18).

Table 18. Distribution of thrips in VITA-6 and VITA-7 plots (IITA, 1980).

	Cultivar	
	VITA-6	VITA-7
Plant age	Thrips/Plant	
[1] 42 DAP	43.9	42.9 ns
SE ±	1.9	1.9
[1] 46 DAP	22.9	24.6 ns
SE ±	1.8	1.7
[1] 50 DAP	140.3	173.0
SE ±	3.9	7.3

[1] *Thrips/plant*

There were differences in the number of flowers per plant in the 2 varieties at 50 days after planting, and this is known to have affected the number of thrips per flower. The variation in the counts of number of insects per plant was much less than the variation in the number of thrips counted on 10 peduncles in the first experiment.

Development of precise thrip screening procedures. A high priority has been given to the development of dependable screening procedures that would permit the recovery of resistant plants from segregating progenies. The procedure must be sufficiently precise and independent of seasonal variation in thrips population so that it serves throughout the year but simple to operate with available resources.

Biology of pod bugs and field populations

Field observations indicate that *Clavigralla tomentosicollis* adults do not feed on the flower buds even though they are present in the field in large numbers prior to formation of pods. The feeding is restricted to the functional nectaries on the peduncles until pods are formed.

Within a 4-day period, females laid 5 egg masses/m of row and averaged 17 eggs per cluster.

An untreated cowpea field near Funtua had 29 *C. tomentosicollis* and 3 *Mireperus jaculus* adults per meter of row plus hundreds of nymphs. While these populations

Table 19. ***Composition and density of the pod bug population (IITA, 1980).***

	Avg. no. bugs/m.	% of total population	Avg. no. bugs/m.	% of total population
Clavigralla shadebi	3.08	82	.70	17
Clavigralla tomentosicollis	0	0	1.21	29
Riptortus dentipes	0.3	8	-	0
Aspavia armigera	4	9	1.64	40
Nezara viridula	-	-	.57	14
Anoplocnemis curvipes	-	-	-	-

may not be typical of the entire cowpea growing area, they do indicate the difficulty in designing control methods against populations of this magnitude.

A preliminary survey for wild hosts that may serve as reservoir plants for *C. tomentosicollis* was negative, but *M. jaculus* and *N. viridula* were observed feeding on a species of *Cassia* and on *Dicrostochys cinaria.*

The pod bugs population was monitored in untreated plots during the 1980 first and second seasons at IITA. As shown in Table 19, *C. shadebi* accounted for 28 percent of the total population, which was measured 6 times during the pod formation period. However, during the second season, several species were involved, but *Aspavia armigera* predominated. Whether this represents an aberrant make up is not known but needs to be determined in order to establish realistic priorities.

During the 1980 first and second seasons, the efficiency of the drop-cloth procedure and visual observations were compound for sampling pod bug populations. The drop-cloth procedure consists of placing a cloth 1 m long between 2 rows and vigorously shading the plants in order to deposit the insects on the cloth. As shown in Table 20, the drop-cloth procedure was more than 3 times as efficient as visual observations. In addition to being more efficient, the drop-cloth is faster and, therefore, it should be used whenever possible; however, it is difficult to use this method to monitor populations on indeterminate plant types that spread close to the ground.

Table 20. ***Comparison of sampling methods for measuring C. tomentosicollis populations (IITA, 1980).***

Treatment	Av. No. bugs/m Drop cloth	Visual
Control I	5.7	
Control II	2.9	.9
Cymbush	3.0	.9
Dursban	2.5	.7
Mean bugs/m	3.53	1.05
S.E. ($\bar{x}$)	0.73	0.22

Economic threshold studies for pod bugs

Pest populations fluctuate from season to season or from year to year. Therefore, it is important to know when damages resulting from this pest population are greater than the cost of the control measures.

In the 1980 first season, a test was carried out to establish economic thresholds for pod bugs. Thiodan (endosulfan) was used to obtain different population densities. Populations were monitored by the use of the drop-cloth procedure. The number of bugs present on 4 m of row in each plot were measured before and after treatment. Nine population counts were totaled during the crop season.

Table 21 shows that the thiodan dosages resulted in a pod bug population ranging from 3.88 to 2.06 bug/m where losses ranged from 214-598 kg/ha. Based on the data presented in Table 21, it was estimated that the threshold level was about 3.0 bugs/m of row.

In the 1980 second season, this test was repeated, but there were few pod bugs until the crop was nearing maturity, and they did little damage so that the effect of dursban on yield was small (Table 22).

At Funtua, *C. tomentosicollis* occurred in the IITA yield trials. Insecticide treatments were applied whenever the insect concentration reached 2 bugs/m and losses were kept low; whereas, in the 2 previous years, at very much higher populations, the crop was a total loss.

Table 21. ***Pod bug economic threshold (1980 First season).***

Thiodan (g)	Yield kg/ha Total	Yield kg/ha Loss	Value of seed N*	Losses due to insects N	Cost of insecticide N	Cost of losses and insecticide N	Profit N	Av. No. bug/pod
1,000	1,051	—	630.60	—	46.20	46.20	584.40	2.06
500	837	214	502.20	128.40	23.10	151.50	350.70	2.20
250	750	301	450.00	180.60	11.50	192.15	257.22	2.71
125	633	418	379.80	250.80	5.78	256.58	123.22	2.98
62.5	509	542	305.40	325.20	2.89	328.09	−12.69	3.58
0.0	453	598	271. 0	358.80	00	358.00	−86.20	3.88

N1.0 = US$1.80.

Table 22. Pod bug economic threshold (1980 Second season).

Dursban (g)	Av. No./pod bugs/m	No. soil bugs/m		% control all spp.	Yield kg/ha
		Clavigralla	Aspavia		
960	2.14	1.11	.89	48	698
480	2.74	1.25	1.09	34	733
360	2.77	1.40	1.00	33	704
240	2.53	.96	1.24	39	672
120	2.96	1.38	1.20	29	786
0	4.14	1.89	1.61	-	693

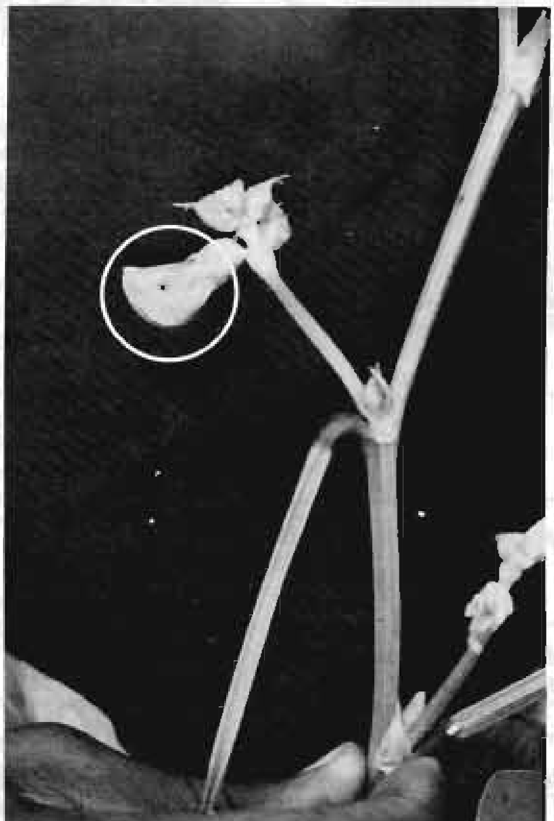
Field screening for resistance to *Maruca*

A standardized technique for screening cowpeas for resistance to the legume pod borer, *Maruca testulalis*, (IITA Annual Report 1979) was modified during 1980 to include some additional parameters, bringing the total number to 10 (Table 23). These parameters were examined in several different ways. Based on the importance and reliability of the data, time and labor efficiency, the following were selected as most dependable in the evaluation of pod borer resistance:

STEM —percent infested plants per row.
FLOWER —number produced per meter row.
—number larvae per sample (usually 5-10/m-row).
PODS —percent infestation (25-50 pods per replication).
—number of entry/exit points per pod (same sample as above).
SEEDS —estimation of seed damage from 5 plants randomly selected.

Typical damage to cowpea stem (top) and peduncle (bottom) by **Maruca.**

Cowpea flower showing entry-exit point of **Maruca** *larvae. (See circle around flower.)*



Pod damage by **Maruca.**

Table 23. Parameters studied in the development of a field screening technique for cowpea resistance to M. testulalis, IITA, 1980.

I STEM:
- (a) Number of holes per plant.
- (b) Percent infested plants.

II FLOWERS:
- (a) Number produced per meter row.
- (b) Scores (based on percent infestation).
- (c) Number of larvae per unit sample.

III PODS:

Infestation
- (a) Percent infestation (in field—no pods collected).
- (b) Percent infestation (in laboratory—from a sample of collected pods).

Damage severity
- (c) Number of holes on all pods on peduncle (in field).
- (d) Number of holes on collected samples of pods (laboratory).

IV SEED:

Damage index

The technique was modified further to eliminate scores that tended to mask slight differences between cultivars, and the results were expressed instead as percentages. The modified technique was used to evaluate several cowpea lines in 1980. In these tests, TVu 946 and VITA-3 were used as resistant and susceptible standards, respectively. The increase in the population of *Maruca* larvae in these 2 cultivars had been studied already (Figs. 2 and 3). Results from the varietal evaluation tests are shown in Table 24, for the best 5 and the worst 5 entries only. TVu 946 was consistently better than other varieties in all but 1 measure while VITA-3 was the worst in all but 1 measure. This supports the choice of these cultivars as checks. Four other cultivars were selected as potentially important sources of resistance.

These were TVu 1, Kamboinse local (Upper Voltan), TVx 3890-010F and VITA-5. An important parameter included in this year's study was the measure of actual seed damage. This was expressed as the seed damage index (Isd), computed as follows:

$$Isd = \frac{Sd \times P \times 100}{ST^2}$$

where Sd is the number of seeds damaged by pod-borer larvae, P is the total number of plants and ST is the total number of seeds obtained from the plant. This index is important as a means of combining more than 1 parameter, viz, actual damage suffered by the seed and the productivity (in terms of seed number) of the cultivar. An assessment of seed damage is considered important since it affects economic yield.

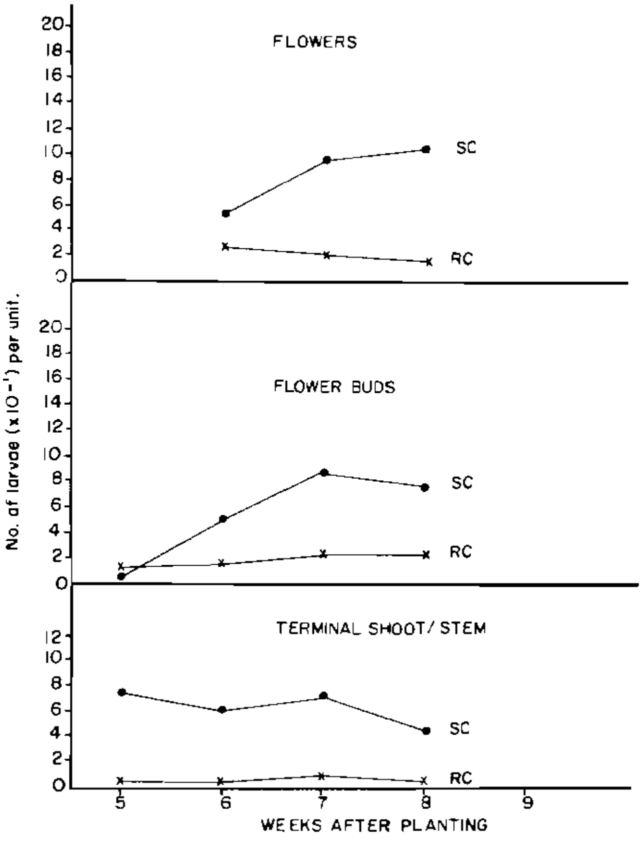


Fig. 2. Differences in the population of M. testulalis larvae in a susceptible SC (=VITA-3) and a resistant RC (=TVU 946) cultivar 1979, First season.

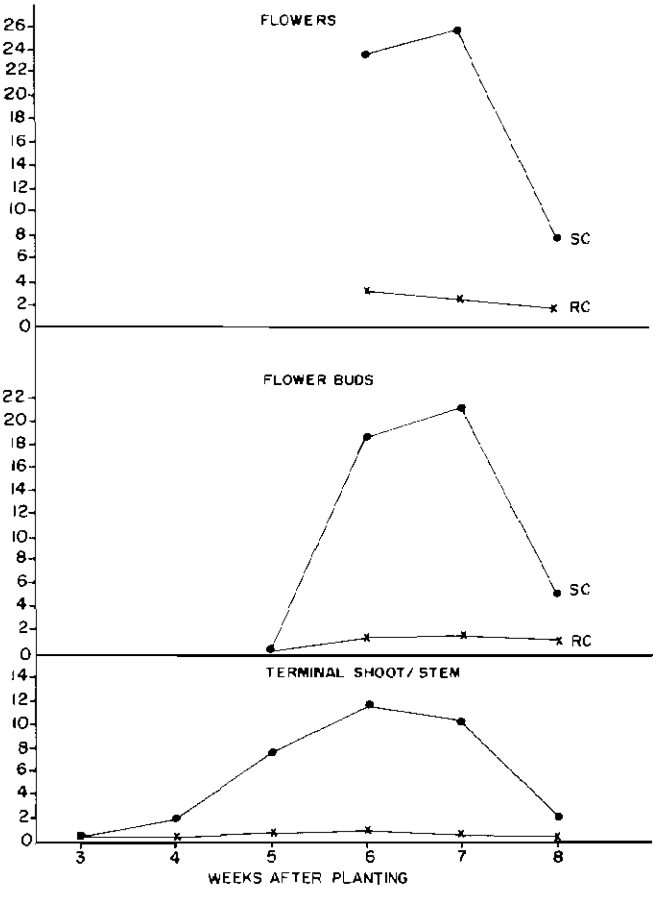


Fig. 3. Differences in the population of M. testulalis larvae in a susceptible SC (=VITA-3) and a resistant RC (=TVU 946) cultivar 1979, Second season.

Table 24. Measurements of different parameters used in screening for cowpea resistance to M. testulalis in the field, (IITA, 1980 Second season).

Serial No.	Cultivar	Stems: No. holes/ plant	Stems: % Plants infested	Flowers: Score	Flowers: No. larvae/ 10 fl.	Pods: % Infestation: Field	Pods: % Infestation: Lab.	Pods: Damage severity: Field (holes/ pod.)	Pods: Damage severity: Lab. (holes/ 10 pods)	Seed damage index ($\times 10^{-2}$)
1.	TVu 946	0	0	1.4	2.0	9.9	1.3	0.2	0.3	0.8
2.	Kamboinse local	0	0	1.6	7.0	18.0	4.0	0.2	1.0	6.8
3.	TVu 1	0	0	2.7	8.7	16.2	13.3	0.2	1.0	5.4
4.	TVu 4557 (VITA-5)	0	0	3.0	8.2	22.0	14.7	0.2	2.0	5.0
5.	TVx 3890-010F	0	0	4.5	12.5	16.4	9.3	0.3	1.0	0.4
6.	TVx 3906-02F	1.30	66.7	3.8	13.6	29.8	24.0	0.7	3.0	3.9
7.	TVu 9837	0.13	13.3	4.2	19.5	27.4	45.3	0.8	6.0	3.9
8.	TVu 9912	0.13	13.3	4.1	18.5	39.0	49.3	0.5	6.0	2.7
9.	TVu 9927/28	0.60	26.7	4.3	24.5	34.7	34.7	0.7	4.0	3.6
10.	VITA-3	2.40	93.3	4.3	25.7	62.7	52.0	1.2	8.0	14.8

An expression for estimating the index for overall plant resistance (Ipr) was developed, which combines all the measures of damage. It is computed as follows:

$$Ipr = \frac{EW_1 + MW_3}{\Sigma W_i} + TW_2$$

Where E, M, T are weighted measurements of stem (E), flower (M) and pod (T). Seed damage assessment can be included in this equation and given a weight of 2. Weights given to other measurements are 1. 2 or 3 as shown.

Table 25 gives some of the results obtained using this plant resistance expression. The plant-resistant index shows the same 5 cultivars to be best. TVu 946, a parent of all the TVx lines, and TVx 3890-010F rank among the best 5 entries.

Using the field screening technique described (IITA, Annual Report. 1979), TVu 946 has been selected as the best resistant source to date and will be the basis of IITA's resistance breeding for the pod borer until other sources of resistance are found. The population of larvae in flowers in this test is shown in Table 26. Usually, of all the feeding sites, flowers have the highest number of eggs and larvae (IITA Annual Report, 1979). It is important that a measure of the population of larvae in flowers accompany every measure of resistance so that results can be compared. Other promising lines, particularly Kamboinse local and TVu 1, will be reexamined in 1981 as this is the first time they have been in tests at IITA. Two out-crosses from TVu 946 (TVu 946-1E and TVu 946-2E) identified in 1980 will also be reexamined. They have larger seeds than TVu 946. (up to 1.5 times) and TVu 946-2E has a more acceptable seed color.

Table 26. Estimated total larval population in flowers per unit of area of a resistant check (TVu 946) and a susceptible check (VITA-3) (IITA, 1980 Second season).

Cultivars	Av. No. of flowers/ m.row	Av. No. of larvae/fl.	Total popul./ m.row
TVu 946	16.3	0.2	3.7
VITA-3	10.0	2.6	26.0

Table 25. Indices of resistance to M. testulalis (IITA, 1980 Second season).

Serial No.	Cultivar	Plant resistance index, Ipr[1]: I	II	III
1.	TVu 946[2]	1.4	1.7	1.5
2.	Kamboinse local	2.8	5.8	6.1
3.	TVu 1	8.8	10.5	9.1
4.	TVu 4557 (VITA-5)	9.0	10.8	9.1
5.	TVx 3890-010F	9.4	11.2	8.1
6.	VICAM-1/SP	13.6	14.6	12.5
7.	TVu 3629	14.0	16.8	38.5
8.	TVx 3892-05F	14.6	14.8	12.8
9.	TVx 9845/46	14.7	16.3	12.7
10.	TVx 3901-013F	15.5	13.6	10.0
11.	TVu 1456	17.0	17.7	14.1
12.	TVx 3903-01F	17.2	16.7	13.4
13.	TVu 9863/64/65	17.8	19.4	14.5
14.	TVx 3901-05F	17.9	18.8	14.3
15.	TVx 3904-02F	18.6	16.3	12.3
16.	TVx 3904-04F	19.9	19.9	14.9
17.	TVu 9886	20.6	20.1	16.7
18.	TVu 199	21.2	18.2	29.2
19.	TVx 3901-016F	21.9	18.3	13.7
20.	TVu 772	22.8	16.7	13.4
21.	TVu 9811/12/13	23.0	23.6	18.9
22.	TVx 3906-01F	23.3	22.6	17.5
23.	TVu 8392	24.2	29.0	24.4
24.	TVu 9884	24.9	28.5	22.6
25.	TVx 3906-02F	25.9	17.8	13.8
26.	TVu 9837	27.1	29.8	22.4
27.	TVu 9912	27.9	30.8	22.8
28.	TVu 9927/28	28.3	28.6	21.4
29.	TVu 1190 (VITA-3)[3]	45.7	36.2	30.1

[1]The lower the PRI value the greater the resistance.
[2]2Resistant check.
[3]Susceptible check.
Ipr - I based on stem, flower, and pod measurements.
II based on flower and pod measurements.
III based on flower, pods, and seed damage measurements.

This screening technique is recommended only for non-segregating lines. A bioassay is being developed for the screening of segregating material. The amount of material to be screened may make a detailed evaluation impossible at first.

The field screening can be conducted as follows:

- Step 1. Assess damage to stems and pods only (large number of cultivars).
- Step 2. Eliminate most susceptible lines from further testing-negative screening.
- Step 3. Include flowers, pods and stems in second screening (with a more manageable number of entries).
- Step 4. Assess resistance of best lines in more controlled laboratory or screenhouse assays.
- Step 5. Use best lines from step 4 as parents in the breeding program.

Management. If there is a flower thrips problem, all entries should be sprayed with 200 g nuvacron/ha a.i. Also, if pod bugs are a problem, all entries should be sprayed with nuvacron at pod set/pod fill.

Economic threshold studies for *Maruca*

During the 1980 first season, a population of *M. testulalis* developed in an experiment that was originally designed to study pod bugs. The pod damage cause by *Maruca* was monitored throughout pod development. While the test was not designed as a *Maruca* threshold study, it provided information on damage and yield losses at different populations of *Maruca*.

Table 27 shows that the insect population and the yield loss varied with the amount of thiodan applied. Surprisingly, the yield loss in the untreated check was only 16.1 percent even though over 40 percent of the pods were infested with *Maruca* larvae. To examine losses more closely, 600 pods that were infested with *Maruca,* but did not show visible signs of being damaged, were collected and compared with 600 pods that were uninfested. The loss in weight of seed from pods that were intested was 49.3 percent.

This agrees with previous estimates of losses caused by *Maruca*. However, more data is needed before economic thresholds can be established for this pest. Available evidence suggests the threshold may be much higher than expected.

Table 27. Estimated seed yield losses from different levels of infestation of M. testulalis (IITA, 1980).

Thiodan Dosage (g)	Av. Infestation %	Seed yield losses %	Seed yield losses Kg/ha
1,000	3.8	.07	7.4
500	7.6	4.17	43.8
250	15.5	6.20	65.2
125	20.5	9.45	99.3
62.5	26.7	13.71	144.1
0.0	41.9	16.09	169.1

Field variability. Lepidopterous insect populations are unevenly distributed in the field, and, therefore, a large number of replicates are required to obtain reliable estimates. Based on the variability in this experiment, it was calculated that 20 replicates would be needed to show differences of 10 percent between treatments while 6 replicates would be needed to show 20 percent differences.

Upper Volta food legumes program

Genetic improvement

Improvement of local photosensitive cowpea varieties. Traditional varieties in a subsistence farming system are usually day length sensitive and specifically adapted to flower at the end of the rains in the locality where they are grown, but they are low yielding. Much larger yields can be obtained in the savanna and Sudan-sahelian regions of West Africa with early-maturing photoinsensitive varieties of cowpea. But to obtain the high yields, they must be protected with insecticides.

In Upper Volta, cowpeas are grown in mixtures with maize, sorghum or millet, and they are usually planted at the same time as the cereal crop soon after the first rains. Photoinsensitive varieties planted early in this manner would mature in the middle of the rains, and even if farmers adopt them and spray insecticides, they could not grow them in their present crop production system. In other words, to adopt high-yielding, early-maturing varieties, farmers would have to adopt a cropping system in which cowpeas are either planted late in an earlier established cereal crop or planted as a sole crop. Such change is not likely to take place quickly.

Efforts are, therefore, being made to improve the traditional photosensitive cowpeas while retaining their good seed quality and adaptation. The main improvement aimed at is the introduction of the seed resistant to bruchids from TVu 2027.

Incorporation of insect resistance into promising varieties. Damage caused by insects is a major constraint in cowpea production. Aphids, flower thrips, *Maruca* and pod sucking bugs in the field and *Callosobruchus* in the store are the most important insect pests of cowpea in Upper Volta.

The use of insecticides to control them is too costly and difficult for farmers to adopt. The alternative is to identify and incorporate genetic resistance into new varieties.

Known sources of resistance to aphids (VITA-4 and B-27), *Callosobruchus* (TVu 2027-seed resistance, Worthmore-pod resistance) and *Maruca* (a local cultivar from Kamboinse) are being used as parents in the breeding program.

Yield trials conducted at different sites in Upper Volta have shown that KN-1 will give high yields in areas where rainfall is more than 700 mm. Local Gorom-Gorom is the best line available for dry areas. Both the varieties are susceptible to damage caused by insect pests. The major objective of the program, therefore, is to incorporate resistance against important cowpea insect pests into these varieties.

KN-1, Kamboinse local and local Gorom-Gorom have been crossed with sources of resistance to aphids, *Maruca* and bruchids (both seed resistance from TVu 2027 and in pod resistance from Worthmore).

The F_2 population of crosses involving KN-1 and Kamboinse local will be grown at Kamboinse and those involving local Gorom-Gorom will be grown at Gorom-Gorom. In the crosses for insect resistance, 2 of the parents, TVu 2027 and local Kamboinse, are photosensitive, and from the segregating populations a range of photosensitive insect resistant lines will be selected.

Breeding cowpeas for dry climates. During the last 2 years, research results from dry areas in Upper Volta have consistently shown that material originating from southern latitudes does not perform as well as material originating from northern latitudes. Efforts are being made by IITA to understand the mechanisms of drought resistance in cowpeas and ensure that introduction of new lines does not erode the resistance of local varieties.

In Upper Volta, work in 1980 included the evaluation of cowpea collections that originate from latitudes of 12°N and northward, together with evaluation of crosses between local varieties and improved selections. The work was carried out at Saouga, which is representative of the driest location in the country (latitude 14° 23'N, rainfall 371 mm).

There were 80 germplasm lines, 68 of which came from IITA, 4 from Senegal and 8 from Upper Volta. Observations were recorded on 5 randomly selected plants in each plot for each variety. Twenty-one early flowering lines produced seed yield. They included all the entries from Senegal and Upper Volta, and 10 entries from IITA. All other lines either flowered after the rains stopped or did not flower at all. Yields of the 21 lines that did flower are presented in Table 28.

There was large variation between lines in days to flowering, pod length, seeds per pod, seed weight, pods per plant and seed yield. Among the germplasm lines, TVu 7641 produced the largest seed yield (37.8 g/plant). It also had the highest number of pods per plant (39.7). Other promising germplasm lines were TVu 7650 (27.6 g/plant) and TVu 7608 (25.1 g/plant). Among the improved lines, TVx 1948-01F produced the largest yield (67.5 g/plant). It also had a high number of pods per plant. Other lines that did well were VITA-4 (48.8 g/plant), TVx 1999-01F (42.5 g/plant), TVx 1999-02E (28.0 g/plant) and local Gorom-Gorom (27.0 g/plant). These are lines that have produced consistently good yields at Saouga in previous years. Seed of the promising lines will be increased for more extensive testing next year.

Development of high-yielding, early-maturing cowpea varieties. From the beginning of the project, most of the research work has been devoted to the development and testing of high-yielding, early-maturing (photosensitive) cowpea varieties. Early lines give a harvest when food is scarce, and this has attracted interest in the drier parts of the country. Several large scale farming projects have also shown interest in such varieties for use as a rotation crop. Whereas KN-1 has been recommended for cultivation in areas with adequate rainfall (700 mm or more), others, notably TVx 1948-01F and TVx 1999-02E, have been found to perform well in drier environments.

Other varieties that gave high yields across locations included TVx 33-81-02F, TVx 3337-015E, TVx 3385-029D, TVx 3337-1C-1K, TVx 3934-2E-1K, TVx 3934-3C-1K and TVx 3920-2C-1K.

Regional cowpea testing program. A regional cowpea variety trial was sent for the first time to 23 locations in 13 different countries participating in the SAFGRAD project. This extended the scope and the responsibilities of the cowpea program in Upper Volta.

Semi-Arid Food Grains Research and Development Project (SAFGRAD)

Entomology

Research on insect pests of cowpea as a part of the SAFGRAD project began in 1979. A survey conducted in 1979 indicated that flower thrips, *M. sjostedti*; pod borer,

Table 28. Performance of germplasm lines and other promising varieties (Saouga, 1980).

Line	DFF	Pod length (cm)	Seeds/pod	100 seed weight (g)	Pods/plant	Per plant seed yield (g)
TVu 7601	44	11.8	8.4	13.7	22.1	21.9
TVu 7605	45	10.0	6.5	10.2	12.4	8.9
TVu 7606	45	11.7	7.6	9.2	19.2	13.8
TVu 7609	44	10.6	7.6	11.0	28.0	25.1
TVu 7621	52	11.5	6.7	13.0	19.4	15.6
TVu 7626	51	9.4	6.1	13.0	11.6	8.6
TVu 7641	44	11.1	9.7	9.9	39.7	37.8
TVu 7650	44	11.7	9.1	9.7	33.9	27.6
TVu 8273	49	10.4	7.5	9.7	15.0	10.7
TVu 8419	44	11.6	8.0	10.2	21.2	16.0
Local Gorom-Gorom	50	9.5	7.5	13.0	26.0	27.0
VITA-4	44	11.5	11.8	9.2	67.6	48.8
Ife Brown	44	12.0	8.7	10.8	47.6	39.1
TVx 1999-01F	46	11.8	9.6	9.3	43.1	42.5
TVx 1999-02E	45	11.6	10.1	9.7	32.0	28.0
TVx 1948-01F	45	15.2	12.4	11.6	63.6	67.5
TVx 309-1G	44	10.8	9.1	9.4	27.7	21.3
Bambey 21	44	10.3	5.2	12.1	18.6	25.1
Mounge	46	13.6	8.3	11.9	24.9	21.4
N'Diambour	44	12.3	8.0	11.7	33.8	28.1
58-57	45	11.5	9.2	8.6	19.3	14.3

M. testulalis; cowpea aphid, *A. craccivora;* and several species of pod bugs appear to be important pests of cowpea.

In 1980, field trials were conducted to estimate the losses caused by pests, determine the effect of date of planting on pest incidence, evaluate cowpea cultivars resistant to flower thrips and compare the efficacy of insecticides.

Estimation of losses due to cowpea pests. Combinations of insecticide applied to KN-1 as seedlings, at flowering and after flowering were compared. Tests were conducted at 3 locations, Saouga (14.3°N), Kamboinse (12.3°N) and Farako-Ba (11.1°N), that represent 3 ecological zones in Upper Volta. Yields were lowest without insecticide. Insecticide applied at flowering gave the largest increase in yield; application after flowering gave a smaller increase.

Resistance to flower thrips. Twelve cultivars were compared for resistance to flower thrips. The population of thrips on flower buds and flowers, and the flowers produced per plant were recorded (Table 29). There was no significant difference in the number of thrips per flower bud. The number of thrips on flowers of KN-1 was significantly higher than on other cultivars. Based on the number of flowers produced without insecticide, TVx 3236 selections appear to be better than other cultivars.

Effect on flower thrips and grain yield of monocrotophos applied at different dosages. The relationship between the number of flower thrips and grain yield was studied on cowpea cultivar KN-1. Different dosages of monocrotophos were applied at 35 days after planting. Thrips populations were low and no clear relations between number of thrips and grain yield could be established.

Efficacy of insecticides against cowpea pests. Six different insecticides were compared against cowpea pest damage and yield (Table 30). Synthetic pyrethroids applied at low dosages appear to be effective against flower thrips and produced significantly higher yields.

Table 31 shows the number of thrips on buds and flower and the grain yield obtained when low dosages of insecticide were applied twice (35 and 50 days after planting). TVx 3236 derivatives had significantly higher yields than the other cultivars, including the local variety and KN-1.

Table 29. Evaluation of cowpea lines for resistance to flower thrips (Kamboinse, 1980).

Entry	Flower thrips: Per 10 buds	Flower thrips: Per 10 flowers	Flowers per plant
ER 1-1	4.3	67.7	24.7
ER 5	5.3	46.0	29.7
ER 7	4.5	47.0	20.9
TVu 946	0.0	76.5	27.4
TVu 1509	4.3	98.3	30.0
TVu 2870	6.3	49.7	37.7
TVx 3236 1-1-1	12.3	48.7	36.7
TVx 3236 F7-P1-1-2	10.0	87.0	38.7
TVx 3236 F7-P1-2-1	6.7	66.3	42.0
TVx 3236 F7-P1-2-2	6.7	32.3	50.3
KN-1	15.7	161.7	29.0
Kamboinse local	10.3	82.0	18.0
LSD (5%)	N.S.	36.8	11.5

Table 31. Thrips population and grain yield of 9 cowpea varieties treated 2 times at 35 and 50 DAP with decamethrin (Kamboinse, 1980).

Entry	Flower thrips: Per 10 buds	Flower thrips: Per 10 flowers	Grain Yield (t/ha)	Rank
VITA-4	14.0	10.3	893	8
VITA-5	3.8	12.7	967	6
VITA-7 (KN-1)	14.3	26.0	906	7
ER-7	9.0	25.3	1025	4
TVu 1509	5.3	11.2	983	5
TVx 2839-1-1	2.3	23.2	1391	2
TVx 3236-1-1	7.5	7.0	1367	3
TVx 3236-1-2	2.5	11.0	1633	1
Kamboinse local	10.7	87.0	250	9
LSD (5%)	7.4	28.8	147	

Table 30. Comparison of synthetic pyrethroids with other insecticides applied at high volume for control of cowpea pests (Kamboinse, 1980).

Insecticide	No. of application	Dosage g.a.i./ha/ application	Thrips per 10 buds	Thrips per 10 flowers	No. of flowers/ meter	Yield kg/ha
Synthetic pyrethroids						
Decamethrin	2	20	4.5	8.3	93	1865
Decamethrin	3	20	0.8	4.3	91	1865
Cypermethrin	2	40	0.0	4.0	82	1775
Cypermethrin	3	40	1.5	3.8	79	1760
Other insecticides						
Fenvalerate	2	50	1.8	15.8	88	1688
Fenvalerate	3	50	0.3	14.5	85	1782
Fenitrothion	2	400	0.8	16.3	82	1557
Fenitrothion	3	400	1.3	19.0	93	1635
Endolsufan	2	400	6.0	28.5	75	1635
Endosulfan	3	400	0.8	18.6	76	1502
Monocrotophos	2	400	0.3	3.0	85	1752
Monocrotophos	3	400	0.8	1.0	81	1698
Untreated control	-	-	13.3	19.8	53	885
LSD (5%)			2.7	11.9	18.4	170

The number of thrips on flowers was significantly larger on the Kamboinse local variety.

Survey of cowpea weevil infestation in cowpea in local market in Ouagadougou, Upper Volta. Samples collected monthly from the local market were observed for the percentage of infested grains and their weight. The infestation was lowest between October and December. This period coincides with the harvest. Infestation was greatest from June to September after a long period of storage.

Agronomy

A SAFGRAD cowpea agronomy research program began in 1979. In the first year, a number of exploratory trials were conducted. From the results of these trials, it was possible to identify several research areas that appeared promising, and these were pursued in 1980.

Time of planting. Results from a multilocational exploratory trial conducted in 1979 to identify factors limiting growth and yield in the semi-arid zone indicated that time of planting was a factor of great importance. To obtain more information on this factor, a regional trial was conducted in collaboration with SAFGRAD cooperators at 16 locations. The results show that for maximum yield, cowpeas should not be planted later than 2.5 months before the end of the rains. Also, highest yields (3 t/ha) of VITA-4 (spreading plant type) and VITA-6 (erect plant type) were obtained with the earliest planting (4 months before end of rains). However, the yield was obtained over 150 days (planting to final harvest) and required 10 insecticide applications. The pattern of grain production over time shows that a practical production goal under these conditions would be 2t/ha produced in 90 days with only 3 insecticide applications. To achieve this, VITA-4 can be planted about 75 days before the end of the rains. Planting has to be earlier to obtain the same yield from VITA-6, 100 days before the end of the rains.

Despite a difference of 75 days in planting dates, all plantings of IAR 1696 (photoperiod-sensitive local cultivar from northern Nigeria) reached inactivity within a 3-week period. The highest yield of this cultivar (2 t/ha) was obtained from the planting made 2.5 months before the end of the rains.

This planting (and all other plantings of IAR 1696) reached inactivity after the rains had ended. In contrast, it does not appear possible to plant VITA-4 or VITA-6 at such a time that maturation will occur after the rains end and still obtain 2 t/ha.

The interval between flowering and the production of a 2t/ha grain yield was approximately 3 weeks less for IAR 1696 than VITA-4 or VITA-6. Since the major field insect problems occur between flowering and harvest, this could possibly be very important in terms of insect control. It would appear that for varieties with a growth pattern like IAR 1696, the period during which insect protection is required and the time available for insect populations to build up is significantly less than for varieties like VITA-4 and VITA-6.

Relay cropping maize and cowpea (planting cowpea into maize so that the 2 crops overlap for only a portion of their life cycles) appears to be a promising practice for the Guinea savanna. When planted 2.5 months before the end of the rains, IAR 1696 flowered 2.5 weeks later than VITA-4 and VITA-6. Thus, as a relay crop, a photoperiod sensitive variety can continue vegetative growth after the maize is removed and before reproductive development begins, thereby, increasing the number of reproduction nodes eventually produced.

Soil fertility. A multilocational exploratory trial conducted in 1979 to identify yield limiting factors showed P to be limiting at several locations. To determine the extent to which P and other nutrients limit yield, a regional fertility trial was sent to 13 locations. From the results of 5 locations, there was a response in growth and/or yield to 1 or more of the nutrients tested: P (10 kg P_2O5/ha), K (60 kg k_2O/ha) and S (10 kg S/ha). Growth and grain yield increased with addition of P at Kambo, Upper Volta, and Sotuba, Mali. At Koporokenie-Pe, Mali, P increased yield but had little effect on growth.

At Ina, Benin, yield increased with additions of both P and K. At Oipassi, Upper Volta, applications of both K and S increased growth, but these did not affect grain yield, probably because of drought at the end of the season.

In addition, 1979 results had shown that the response to P (150 kg P_2O5/ha) depends on plant type. An erect variety shows an increase in yield; a spreading variety shows no response, and a local photoperiod sensitive and vegetated vigorous plant shows a reduction in yield. A trial was conducted to study, in more detail, the response to P of different plant types. A range of soil solution P levels was established based on P adsorption isotherms. Plant growth (measured as fresh weight of whole plants 45 days after planting) of the spreading variety, VITA-4, and the local photoperiod sensitive variety, Kamboinse local, increased with increasing levels of P over the range of levels used. In contrast, the response of the erect variety, VITA-6, was significantly smaller, and it did not increase further above 0.08 ppm P.

The effect on grain yield was markedly different. The yield of VITA-6 increased over the entire range of P levels although 90 percent of the increase was produced with 0.02-0.04 ppm P. The yield of VITA-4 also increased with increasing P up to 0.04 ppm but then declined, the yield at 0.32 ppm being the same as the control (0.01 ppm). The local variety showed a consistent decrease in yields with an increase in P levels.

The balance between vegetative and reproductive growth clearly is important in determining the effect of P on yield of different types of cowpea plants.

Plant population. A trial was conducted at 3 sites in Upper Volta, Fanakoba, Saria and Saouga, to determine the effect of plant population on different plant types in different rainfall zones.

VITA-6, VITA-4 and a local variety of the area (prostrate and photoperiod-sensitive, except at Saouga where it is probably relatively insenstive to photoperiod) were planted at densities ranging from 22,000 to 155,000 plants/ha. At Fanakoba, yield of VITA-6 increased with the plant population with an optimum population of between 100,000 and 150,000 plants/ha. At the same site, an optimum density for VITA-4 appears to be between 50,000 and 100,000 plants/ha. IAR 1696 gave its highest yield at the lowest density, and it appears that the optimum is less than 22,000 plants/ha. At Saria, yields were low because the rain ceased early, and the effect of plant population on yields was small.

However, the optimum appeared to be between 50,000 and 100,000 plants/ha for VITA-6 and between 50,000 and 75,000 for VITA-4. The yield of Kamboinse local tended to increase with increasing density over the entire range of densities. The difference in response between Kamboinse local in Saria and IAR 1696 in Fanakoba indicates a need to investigate the response of a range of photoperiod sensitive varieties to density under different environmental conditions within their zone of adaptation.

At Saouga, plant populations were less than planned because of mortality of seedlings following a sand storm shortly after emergence. However, over the range of densities obtained (20,000 to 75,000 plants/ha), there was a marked increase in yield of all 3 varieties with an increase in density. This was more pronounced than the responses observed at the other locations. It agrees with results obtained in the cowpea management trial conducted in 1979 at Kamboinse, Kaya, Ouahigouya and Saouga in which there were significant yield differences between densities of 50,000 and 100,000 plants/ha only at Saouga.

It may be that under the harsh, hot, dry environment of Saouga, plant growth is limited more than in favorable environments and that when plants are small, yields increase with plant population.

Position in toposequence. Some of the most important soil variables in the Sudan savanna are associated with position on the catenary slope from plateau to valley bottom. Soil depth over ironstone or compact subsoil, texture and water holding capacity all vary. To determine how position on the slope affects growth and yield of cowpea, 2 varieties, KN-1 and Kamboinse local, were planted at 2 dates (July 14 and July 31), at 5 different positions in toposequence at Kamboinse. Very marked differences in yield were associated with position. These differences were probably caused by factors other than soil fertility since 75 kg P_2O_5/ha was applied uniformly. The yield of KN-1 in the first planting increased progressively from 800 kg/ha on the upper slope to 2,400 kg/ha on the lower slope. The second planting of KN-1 and both plantings of Kamboinse local only gave acceptable yields on the lower slope. The local variety showed no special adaptation to poor soils. The choice of location is clearly important, and it is only on the better parts of the slope that yields justify the cost of insecticide. Most cowpea trials tend to be sited on the middle and lower slope and to this extent, they may be representative of a large part of the production area, most of which corresponds more closely to the upper slope.

Tanzania food crops research

Genetic improvement

Collection, evaluation and maintenance of germplasm. From the start, efforts were made to collect, evaluate and maintain cowpea germplasm lines from different sources. This local collection is used to develop new varieties. Most cowpea lines were obtained from IITA. However, a wide variety of land races are cultivated in Tanzania, and there are many naturally growing wild cowpeas. A systematic collection of them was organized and completed in 1979. To date, 1,636 cowpea lines have been collected, evaluated, and all are being maintained. The promising lines have been used in variety trials and as parents in the breeding program.

Multilocation varietal tests. Sixteen different types of variety trials were conducted at from 1 to 12 locations depending upon the nature of the trial to identify high yielding and widely adapted varieties. The trials included newly developed breeding lines combining high yield and resistance to disease and pests. Inadequate rainfall affected the yield at several places.

A Tanzania cowpea uniform variety trial consisted of 12 varieties selected on the basis of their superior performance in the previous years. The trial was conducted at 9 locations, representing the major cowpea growing areas. The performance of individual varieties differed from location to location, but, overall, TVx 2907-02D, SVS-3, TVx 1948-01F, TKx 9-16D and TKx 9-11-D gave the best yields across locations. Some of the varieties had been evaluated at different locations in 1979. The mean performance of 7 selected varieties in both years is shown in Table 32. TVx 1948-01F gave the highest yield, closely followed by TKx 9-11D, TKx 9-16D and SVS-3. These 4 varieties gave consistently good yields at most of the locations. The remaining 3, TVx-01B, TVu 1502 and TVx 33-IJ, showed more variation and gave lower yields averaged across sites. There was variation in the relative ranking of varieties with location and season. The trial at Hombolo gave the largest mean yield in 1979 but the smallest in 1980. At all locations out of 15, the mean yield was more than 1 t/ha.

The variation in yield of the varieties was analyzed (Table 33). Based on this analysis, a stable variety is one with a large mean yield and regression yield against site yield in which the slope is less than or equal to 1, and the deviations from the linear regression are small. Based on

The cross of this early-maturing, high-yielding cowpea variety was made at IITA and selected in Tanzania. Cross 1-6E-2 reached maturity in 65 days and yielded 1.5 to 1.9 t/ha. Large scale testing of this variety on farmers' fields has been scheduled for 1981.

Table 32. Seed yield (kg/ha) of promising cowpea breeding lines at different location in Tanzania (1979-80).

	Ilonga	Gairo	Mlingano	Ukiriguru		Lubaga	Hombolo		Bihawana		Ismani		Miwaleni		Tumbi	
Variety	1980	1980	1979	1979	1980	1979	1979	1980	1979	1980	1979	1980	1979	1980	1980	Mean
SVS-3	1253	858	1151	1314	1313	943	2107	824	1269	1654	1166	2068	1163	1162	1520	1318
TVx 1948-01F	1247	1219	982	1661	1284	1231	2198	726	1305	1388	1716	1798	1282	1162	1798	1400
TKx 9-11D	1349	1030	1410	1327	1326	1136	2335	683	1390	1168	1390	1945	1310	1315	1790	1393
TVx 966-01B	1259	1089	616	1301	961	347	1799	232	716	994	967	1636	1102	1136	1695	1056
TVu 1502	1071	680	982	1430	870	608	2240	704	1380	1294	1028	1357	1208	1238	1495	1175
TVx 33-1J	1124	955	862	1398	960	673	1561	709	1087	877	955	1355	1245	1085	1235	1072
TKx 9-16D	1231	938	1156	1240	1311	1296	2258	750	1045	1439	1590	2111	1380	1340	1580	1377
Environment Mean	1198	954	921	1348	1153	879	1962	709	1098	1322	1103	1770	1149	1238	1386	1213
LSD (5%)	NS	NS	427	221	184	307	NS	286	573	NS	154	207	NS	349	489	

Table 33. Stability parameters of 7 cowpea cultivars.

Variety	Mean yield kg/ha	bi	S^2d
SVS-3	1318	1.10	1.46
TVx 1948-01F	1400	0.98	3.69
TKx 9-11D	1393	1.06	3.61
TVx 966-10B	1056	1.23	5.2
TVu 1502	1176	1.09	4.61
TVx 331J	1072	0.66	1.9
TKx 9-16D	1377	1.09	3.53

these criteria, SVS-3 TVx 1948-01F, TVx 9-11D and TVx 9-16D appeared to show the most stable performance. They gave reasonably good yields in poor environments. The other varieties were more variable. They gave poor yields in poor environments and differed considerably in their response to good environments.

Stability of yield is an important character for a variety to be released to farmers. It is associated with the inherent capability of a variety to adjust to variation in the environment. SVS-3 is a variety widely grown in Tanzania. Apparently, it has been selected for its stable performance.

The other varieties show an interesting relation between parents and stability. SVS-3 was a parent in the crosses from which TVx 9-11D and TVx 9-16D were derived. Similarly, all the varieties with stable performance have SVS-3 or its relative as a parent. All less stable varieties were from crosses that involve exotic parents only.

Even though SVS-3 has a high-yield potential and fairly stable performance, it is susceptible to major diseases and may suffer serious yield losses in years of disease epidemic. TKx 9-11D and TKx 9-16-D are resistant to CAMV and moderately resistant to top necrosis. Similarly, TVx 1948-01F is moderately resistant to CAMV. Based on their superior performance and disease resistance, TKx 9-11D and TVx 1948-01F were recently accepted for release as TK-1 and TK-5, respectively, by the Seed Release Committee of the Ministry of Agriculture.

Two hundred and fifty-two newly developed breeding lines, including SVS-3 as a check, were evaluated in 1 initial and 3 preliminary trials at Ilonga and Miwaleni. Based on their yield and disease resistance, a number of lines appear to be better than SVS-3. The most promising were TKx 179-02D-2, TKx 14-01D, TKx 169-35D, TKx 133-38D-1, TKx 43-06E-2, 1ET-120 and cross 3-16E-1. These lines will be evaluated further at several locations in the coming season.

Trials sent from IITA included 2 cowpea international trials, 5 advance trials and 3 preliminary trials. They were conducted at Ilonga to identify the best lines. The 2 international trials were also conducted at Miwaleni. In all, 469 new breeding lines developed at IITA were evaluated in these trials. As expected, a vast range of diversity in plant type, maturity, disease reaction and yield potential was observed, and a number of lines appeared extremely promising. The best among them were TVx 3380-042E, TVx 2724-01F, TVx 3866-05F, TVx 3790-01F, TVx 3882-05F, TVx 1843-01C, TVx 4619-01E, 8R-86-01E, TVx 3912-07F, TVx 3384-01E and TVx 4677-014D. These will be evaluated in multilocational trials next season.

Breeding for extra early cowpeas. Parts of Tanzania have 2 rainfall seasons. The short rains start in October or November and end in late December or in January depending upon the region. A dry period for about a month follows after which the main rains start and continue for about 75-90 days. Farmers plant maize or cowpea with the start of the short rains in October-November, but none of the varieties they possess of either crop are early enough to mature within the short rain period. Consequently, unless the short rains are unusually extended, the farmer loses his first crop. For this reason, extra early varieties of cowpea are being developed that will be suitable not only as a crop for this short season but also as a relay crop to follow a main crop, usually of maize in areas where there is a single, longer growing season. A number of new selections, including early lines from IITA, were evaluated in the short as well as the long rains at Ilonga. The crosses 1-6E-2 and TKx 133-16D-2 were found to be most promising in terms of yield and maturity. They mature within 65 days and yield from 1.5 to 1.9 t/ha. In addition, they are resistant to top necrosis and CAMV. Flowers are all produced within a short period so that pods mature for a single harvest. They can be harvested by cutting the plants and beating or threshing them when dry like soybean. This reduces significantly the labor of harvesting. Seeds of the varieties have been multiplied for village trials and farmer demonstrations.

Breeding for disease resistance. A number of diseases attack cowpeas in Tanzania. The most common are CAMV, top necrosis, bacterial blight and *Phytophothora* stem rot. If infection occurs in the seedling, any of these diseases can cause a complete crop loss. All the currently grown local varieties, including SVS-3, are highly susceptible to these diseases. Therefore, incorporation of resistance into local varieties and new breeding lines is a major objective.

Cowpea germplasm lines, including the newly developed breeding lines, were screened for resistance. The important sources found are shown in Table 34.

Table 34. Sources of resistance to different diseases in cowpea.

Disease	Resistant breeding lines
Top necrosis	TVx 966-01B, TVx 1193-54C, TVu 3629, TVx 1836-397, Cross-3-13-E-2, 1ET-120, TKx 528-06D, TVx 3747-02D, TKx 43-06E-2, TVx 3780-10, 8R-43-03E, Cross 1-6E-2.
CAMV	TVu 410, 8R-43-03E, Cross 1-6E-2, TKx 133-16D-2, TKx 9-11D, TKx 133-35D-3, TKx 133-43D-2, Cross 3-13-E-2, 1ET-120, TKx 179-04D-5.
Bacterial blight	Cross 3-13E-2, Cross 1-6E-2, TKx 133-43D-2, TVx 3866-06D, 1ET-120, TKx 177-10D-2, TKx 133-35D-3, TKx 179-04D-5.

A severe outbreak of *Phytophothora* stem rot was observed in the experimental plots of cowpeas at Ilonga in 1979. Most cowpea varieties were highly susceptible and dried prematurely. An experiment was, therefore, begun to identify sources of resistance to be incorporated into new breeding lines. Lines from the germplasm collection, including Chinese red and Black Eye 5 identified to be resistant in Australia, were planted in single row plots in March, 1980, in the same block of land on which *Phytophothora* had appeared in 1979. The International Cowpea Disease Nursery (ICDN), consisting of 145 lines, was also planted in the same block. The disease appeared in severe form about 5 weeks after planting. To ensure a uniform spread of the disease, a water suspension of spores from the diseased plants was sprayed on 2 occasions, 1 week apart, over the whole field. This caused almost a 100 percent infection of all the susceptible lines. The typical symptoms included large, water-soaked, light brown spots on the leaves followed by stem rot at the nodes. The susceptible plants died within 20-25 days of inoculation. From the 1,636 germplasm lines and 145 ICDN lines, only 2 (Ku 235 and TVu 3861) were found to be moderately resistant. These lines did not develop any symptoms, even after the second inoculation. They were, therefore, sprayed with a high concentration of spores. About 1 week after the third inoculation, they showed a hypersensitive type reaction on the leaves and very slow rotting of the stems. The leaf spots were small compared to those found on susceptible lines and quickly became necrotic, preventing further spread of the fungus. Interestingly, the growth habit and seed characteristics of both lines are similar, indicating these to be duplicates bearing different numbers. These lines will be further tested in the coming season and used as parents in a crossing program.

Breeding for insect resistance. Many of the same insect pests that attack cowpea in West Africa are found also in East Africa and if not controlled by frequent sprays of insecticides, may cause complete crop loss. The most common insect pests in Tanzania are Ootheca beetles, foliage and flower thrips, *Maruca,* pod sucking bugs, flower beetles, aphids and bruchids. The attack of foliage thrips and aphid is more severe in the dry seasons. Recently a new pest, a leaf miner (*Liriomyza trifolii*), has been observed in several parts of Tanzania, including Zanzibar. The larvae make serpentine tunnels in leaves and cause premature senescence.

Insect resistant lines from IITA were evaluated at Ilonga to determine whether they are also resistant to pests in Tanzania. Resistance to thrips and *Maruca* was done in field trials using thiodan and nuvacron to control populations of other pests. Preliminary data indicate a few cultivars are resistant to these pests. From the differential reaction of aphid resistant lines identified at IITA, it was found that lines resistant to strain A of aphids were resistant at Llonga which suggests that the aphids present may be the same at IITA biotype A, and not B.

The field infestation of leaf miner during the dry season permitted screening of cowpea varieties for resistance to this pest. None of the varieties were free from leaf miner, but there was variation in their reaction.

These lines, Cross 1-6E-2, Cross 2-2, TVx 4762-01E, 4R-0267-1F and TVx 3404-01J appeared tolerant, but TKx 133-16D-2 was highly susceptible. Most of these insect resistant lines are being used in the hybridization program.

Development of new breeding lines. To combine disease and insect resistance with suitable agronomic characteristics, a large number of crosses were made among the selected parents. During the main season of 1980, a total of 118 F_1, 375 F_2, 86 F_3 and 76 F_4 populations were evaluated, and a large number of individual plants/progenies with desirable characters were selected. These are being advanced and reselected in the dry season under irrigation. Greater emphasis is being placed on selection of better plant types, which will respond to high plant population.

Studies on wild cowpeas. Wild cowpeas grow in abundance along the roads in several parts of Tanzania. They show great diversity in leaf type, but all have small black pods with small darkly speckled seeds. They correspond well with the description for *Vigna unguiculata* spp. *dekintiana*. A number of them were collected from around Ilonga in 1979 for possible use in hybridization.

All wild types are prostrate with medium size leaves that have different patterns of white banding on the lamina. Flowering starts about 60 days after planting. Normal size (similar to cultivated cowpeas), purple flowers are borne on fairly long peduncles that protrude above the canopy. Clusters of pods develop on the tip of the peduncles in an upright position. Pods mature 15 days after flowering and shatter with considerable force when mature, scattering the seeds all around the plants. Normally pods are black and their size varies from 7 to 9 cm with 14-18 seeds per pod. The mean weight of 100 seeds is 1.8 g. The seed is mostly dark-brown with black specks, but occasional black seeds are found. Seeds have a hard seed coat and do not germinate immediately on harvest unless scarified.

Artificial sap inoculation with CAMV and top necrosis in the screenhouse showed that these wild cultivars are susceptible to both diseases. However, whereas local varieties such as SVS-3 die 10 days after inoculation with top necrosis, wild cowpeas show only typical MYMV symptoms. They are, therefore, nonlethal, susceptible to top necrosis. Most of the wild cowpeas are susceptible to *Phytophthora* stem rot. When sprinkled with a suspension of spores prepared by macerating diseased plants in water, the leaves developed typical, large, water-soaked, brown spots with subsequent stem rotting. The plants died within 20 days of inoculation.

A bulk sample of wild cowpeas was also screened for insect resistance along with a number of cultivated cowpea lines in a replicated experiment conducted with differential chemical protection. The reaction of wild types was similar to that of local variety SVS-3. Wild cowpeas appear, therefore, to be as susceptible as SVS-3.

Laboratory screening showed that wild cowpeas are more susceptible to bruchids (*C. maculatus*) than cultivated ones. The dry weight loss caused by bruchids 35 days after infestation was 48.6 percent in wild cowpeas compared to 41.75 percent for SVS-3 and 9.81 percent for TVu 2027.

Crosses between wild and cultivated cowpeas can be made almost as easily as crosses between cultivated forms. However, the F_1 plants show partial male and female sterility as shown by shorter pods and fewer seeds per pod than would normally be expected. The possibility for natural crossing between wild and cultivated cowpeas may permit limited introgression of genes in both directions.

Though susceptible to major diseases and insect pests, the wild cowpeas thrive in nature, probably because plants are isolated and grow among natural vegetation.

Brazil cowpea program

Elite lines selected from trials and nurseries conducted in the northeast of Brazil during the past 3 years are beginning to move into commercial production. A selection, 4R-0267-01F, from IITA's cowpea population improvement program is being multiplied for 1000/ha to be sown in Amazonas in September, 1981. It is planned that more than 10,000/ha of this variety will be grown on the alluvial soils of the Amazon valley around Manaus in 1982.

In Ceara, the state government has multiplied seed of VITA-7 and TVx 1836-013J for commercial distribution under its own variety names of IPACE-1 and IPACE-6 (IPACE = Institute do Pesquisas Agropequarias do Ceara).

These accomplishments follow the placement of an IITA cowpea breeder in Brazil and the continuous and substantial support that EMBRAPA has given to the national cowpea improvement program since it began in 1978.

Soybean

IITA's soybean improvement program has concentrated on improving seed storability and developing varieties capable of nodulating with indigenous rhizobia. Unimproved varieties possessing these characters have been identified, and the breeding program has focused on incorporating these characters into genotypes with superior agronomic traits. Selection of promising material from these crosses continued in 1980. Numerous progenies were recovered that combine good seed storability and promiscious nodulation with improved agronomic characters. Seeds of these selections (F_5, F_6 and F_7 generations) are being multiplied and will be tested for yield next year.

Several new areas of research were initiated in 1980. Studies on methodology for predicting seed storability revealed that methanol stress (soaking seeds for 2 hours in 20 percent methanol) can be used to identify breeding lines with good inherent storability, but the method may cause the breeder to reject an occasional line that possessed good storability but is hypersensitive to methanol stress. Various methods for evaluating vigor of stressed seeds were investigated. Seedling emergence appears to be the most efficient method for breeding purposes.

Screening methodologies were refined for identifying genotypes resistant to field weathering—a serious problem if temperature and humidity are high during seed maturation. Several lines were selected from a germplasm screening that appear to be quite resistant to field weathering of seeds.

F_4 and F_5 lines derived from crosses of promiscuously nodulating parents, high-yielding parents, and, in some cases, with parents having good seed storability were tested at 4 locations in Nigeria for their potential and ability to nodulate with indigenous rhizobia. Many lines were identified that nodulated without inoculant at 2 sites in northern Nigeria—fewer lines nodulated well at southern sites.

However, some lines nodulated well at all locations, and are being multiplied for multilocation yield testing next year.

Management practices (trap cropping) that can be used to control pod-sucking bugs with the judicious use of insecticides were studied. The use of early-maturing soybeans or cowpeas as insect "traps" resulted in an 80-90 percent reduction in the amount of insecticides required for protecting the crop from stink bugs. Also, investigations were conducted on soybean varieties that cause nymph mortality to stink bugs—the major pod sucking pests of soybeans.

Management trials were established to isolate the environmental factors responsible for large variation in plant growth in different regions of West Africa. In the Guinea Savanna region of West Africa, plant growth is often variable. P and K applications alone do not appear to alleviate the stress, but when applied in combination with secondary and micro-nutrients, growth is sometimes greatly enhanced. Good growth appears to be associated with areas where there is a relatively high-clay content in the subsoil, which may be a source of nutrients or water or both.

Methodology for screening soybean varieties for tolerance to high levels of soil A1 was refined. Genotypes tolerant to soil acidity were identified, and promising varieties will be confirmed next year.

Genetic improvement

Seed quality studies

Varietal evaluation for storability. Seed storability of breeding lines was based on seedling emergence after subjecting freshly harvested, unweathered seed to conditions of 40°C and 75 percent relative humidity for 6 weeks as previously described (IITA Annual Report, 1977, 1979). During 1980, 34,520 seed lots were evaluated. The majority of tests involved the screening of breeding nurseries for lines with superior storability in combination with other important traits, such as promiscuous nodulation, high yield and resistance to lodging and pod shattering (Table 35).

Following seed storability tests, remnant seeds of the superior lines were sown in nurseries at Mokwa, Nigeria, to determine their agronomic merit and confirm their superior storability. From an unreplicated F_4 and F_5 nursery of 2,440 lines, 298 selections are being multiplied for yield trials next year. Similarly, from a F_3 family nursery of 2,995 lines, 365 lines are being multiplied.

The entries in the soybean uniform trials were evaluated for storability. TGm 618, TGm 120 and TGm 579 showed moderately good storage characteristics, except TGm 579 from Ikenne, Nigeria, that did not store well presumably because of severe web blight infection (Table 36).

Seven parents being used extensively in the breeding program as sources of promiscuous nodulation were evaluated for storability to determine if lines from single crosses involving these parents and high-yielding, U.S.A. materials are likely to give progeny with good storability (Table 37). These entries were harvested under very dry conditions in December, 1979, and seedling emergence prior to storage was very high. Twenty-five seeds were subjected to the hot-water, stress test (Seeds soaked at 70°C for 70 seconds) (IITA Annual Report, 1979) and to 8 months of ambient storage at Mokwa and IITA. A check variety, TGm 737p (Indonesian), that was previously identified to have superior storability had a mean emergence score following ambient storage of 66 percent; whereas, the best promiscuous lines, TGm 618 and TGm 119, had only 30 percent and 24 percent emergence, respectively. Although there appears to be varietal differences among the promiscuous parents for storability, none of the lines store as well as TGm 737p. The hot-water, stress test predicted storability rather well, except that TGm 107 (Malayan) and TGm 80 (Bossier) were intermediate in the

Table 35. Emergence tests to determine seed storability or resistance to field weathering of soybean lines (1980).

Source	Location	Season	Families evaluated
Breeding lines			
F_3 seed quality nursery	IITA	1979S	740
F_4 seed quality and nodulation nursery (D.S.M.)	Mokwa	1979F	1,810
F_4 and F_5 nodulation nursery; single plants from selected bulks	IITA	1980D	1,950
F_3 and F_5 seed quality nursery	IITA	1979F	13,500
F_4 seed quality nursery	Mokwa	1979F	9,660
F_3 seed quality nursery	Mokwa	1979D	200
Other experiments			
Assessment of yield trial entries	IITA	1979S	100
Heritability studies	IITA	1979S	5,200
Storage methods experiments	IITA Mokwa	1980D	160
Field weathering experiments	IITA	1979F	1,200
		Total =	34,520

Table 36. Entries in soybean uniform trial with the best storability. Seeds from 4 trials were subjected to 2 weeks of accelerated ageing (40°C, 75 percent relative humidity, 1980).

Variety	Location = / Planting Date =	IITA May 26	Ikenne May 14	Mokwa July 25	IITA July 30
		% Emergence and Rank			
TGm 618		92 (1)	80 (2)	82 (1)	92 (2)
TGm 579		84 (5)	50 (12)*	70 (3)	98 (1)
TGm 120		86 (3)	74 (5)	75 (2)	84 (4)
Checks					
Bossier		66 (17)	20 (21)	63 (5)	80 (7)
Jupiter		34 (21)	38 (14)	59 (6)	90 (3)
Trail Mean		72	52	55	76
Entries		21	21	12	12
Replications		2	2	3	2
LSD (5%)		22	16	19	19

Plants had severe web blight infection.

Table 37. Storability evaluation of 7 parents used as sources of promiscuous nodulation and 3 check varieties. (IITA and Mokwa, 1980).

	Unaged	Hot water[1] stress	Ambient[2] storage
	% emergence		
TGm 737[P]*	98	92	66
TGm 618	92	86	30
TGm 119	94	70	24
TGm 120	90	12	12
Malayan	96	42	10
TGm 344	94	10	10
TGm 577	90	30	8
Bossier*	78	46	6
Jupiter*	88	14	6
TGm 579	98	12	6
n	3	3	16
$S(\bar{x})$	92	40	18
LSD (5%)	10	16	6

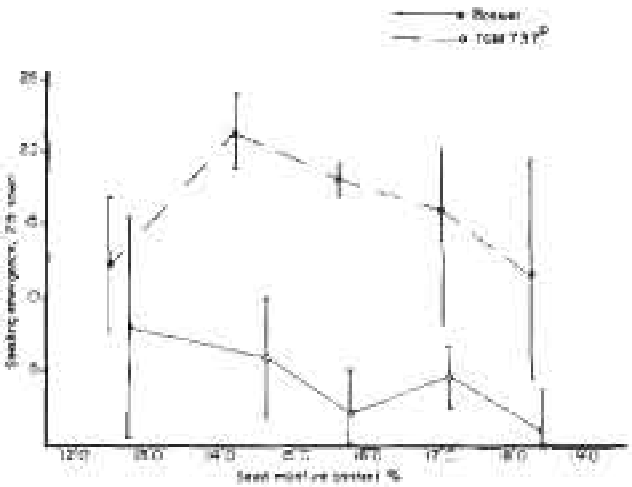
[1]*Dipped in water at 75°C for 80 seconds.*
[2]*Mean over 2 locations stored for 8 months.*
**Check varieties: 737[P] has good storability; Bossier and Jupiter have poor storability.*

hot-water, stress test, but both stored poorly under ambient conditions. In the same experiment, seed was stored 8 months under ambient conditions either threshed or unthreshed. The mean emergence of the unthreshed seed (21 percent) was significantly higher than the threshed seed (15 percent).

The average emergence of seed stored at Mokwa was only 8 percent while that at IITA was significantly higher, 28 percent. Unfortunately, the temperature and relative humidity during storage were not monitored. More research is needed to determine the degree of storability required to give good emergence year after year in the different West African regions where soybeans are being grown or will likely be grown in the future.

Selection methods in screening for improved seed storability. To predict inherent seed storability of breeding lines without waiting for 6-12 months required in ambient storage tests, a modified accelerated aging test (seeds stored at 40°C and 75 percent relative humidity for 6 weeks) and the hot-water, stress test (seeds soaked at 75°C for 70 seconds) both predict seed viability after ambient storage fairly well (IITA Annual Report, 1979). There are, however, some lines that perform poorly under these tests that give good emergence following ambient storage. Seed physiologists in the U.S.A. have recently found that soaking seeds in a 20 percent solution of methanol for 2 hours caused deliterious changes in seeds similar to those observed in storage or following accelerated ageing. To test whether methanol stress could be used to predict inherent storability of lines, 51 germplasm lines with seedling emergence from soil of 80 percent or better were subjected to methanol stress and accelerated ageing. Though the correlation (0.60**) of emergence scores between methanol stress and accelerated ageing was not excellent, it appears that methanol stress might be a functional screening method for seed longevity. However, using this method, it appears likely that a few lines with good storability may be discarded based on sensitivity to methanol. All lines that performed well following methanol stress also performed well following accelerated ageing.

It needed to be determined if the seed moisture content at the onset of either accelerated ageing or hot-water, stress test has a large effect on the degree of seed deterioration. Thus, freshly harvested seeds of 2 varieties, Bossier (poor storability) and TGm 737[P] (good storability), were equilibrated to 5 moisture levels by suspending seeds over water in a refrigerated humidifying chamber. Seedling emergence scores were recorded for unstressed seeds and seeds following accelerated ageing and hot-water, stress test. Seed moisture content had no significant effect on emergence scores before stress or following either accelerated ageing or hot-water, stress test. Fig. 4 shows emergence results of the 2 varieties at 5 moisture contents following accelerated ageing. Therefore, it does not appear necessary to carefully equilibrate all seeds to the same moisture content prior to accelerated ageing or hot-water stress test.



Brackets around the mean indicate 95% confidence interval

Fig. 4. Relationship between seed moisture content and seedling emergence after accelerated ageing (40°C, 75 percent relative humidity. Brackets around the mean indicate 95% confidence interval.

After seeds are subjected to stress, such as ambient storage, accelerated ageing, hot-water, stress test or methanol stress, the effects of the stress are assessed in a test of seedling emergence from soil in a screenhouse. Although results are quite consistent, methods are being tried to further reduce unwanted variability in screening. Commercial seedsmen often use a laboratory germination test for this purpose that is not practical for a large breeding program because it would require many seed incubators to accommodate the volume of breeding lines being tested. Some seed physiologists assess the effects of stress by soaking seeds in distilled water and then monitoring the solute content in the leachate that is thought to reflect the degree of membrane deterioration caused by the stress treatment. Leachate characteristics, such as conductivity or optical density (OD), appear to be useful in comparing seed lots of the same variety, but it has not been demonstrated that this assessment method would serve in a breeding program to evaluate different lines. If seed characteristics, such as seed coat color or seed size influence the results, then the merit in using seed leachate for a breeding program is doubtful.

To test this, the leachate conductivity and the OD were compared for 2 varieties, black-seeded TGm 618 and yellow-seeded TGm 579. Removing seed coats caused a similar increase in conductivity for both the black-seeded and yellow-seeded varieties, suggesting that seed pigments in the leachate do not greatly affect conductivity scores. As expected, the seed pigments had a large effect on OD readings, which increased when seed coats were removed from TGm 579 but decreased when seeds coats were removed from TGm 618. This indicates that for OD assessment of leachate on varieties with different seed pigments, it would be necessary to remove seed coats, but this is very time consuming.

To mimic the effect of differences in seed size, the conductivity of the leachate was tested for the same 2 varieties over a range of seed numbers. Conductivity values were 119, 151, 189 and 203 u moh for 8, 10, 12 and 14 seeds, respectively. By dividing the conductivity score by seed number or by the weight of the seed in the test, then the values are similar. This suggests that to use conductivity for assessing seed vigor of varieties with differing seed size, the samples should be weighted before soaking for adjusting conductivity scores.

To determine if varietal differences in the rate of seed imbibition can influence leachate conductivity, seeds of 5 lines that imbibe water slowly and 5 lines that imbibe water rapidly were freshly harvested. Those lines with slow imbibition had lower conductivity scores than those with rapid imbibition (Fig. 5). Thus, to use either leachate OD or leachate conductivity readings in assessing seed vigor in a breeding program, weighting the seed samples and removing the seed coats are necessary. These time-consuming operations are not necessary if the seed vigor is assessed by emergence tests in uniform soil.

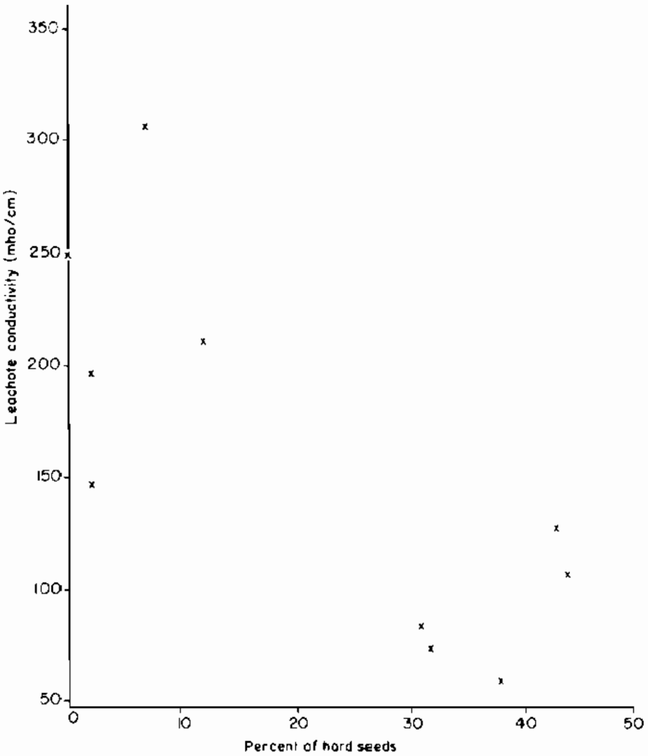


Fig. 5. Effect of slow imbibition on conductivity of seed leachate. Ten soybean varieties were soaked for one hour in distilled water (mean of 2 replications).

Screening of soybeans for resistance to field weathering. Seventy-six germplasm lines were sown adjacent to a spreader row, which was sown 3 weeks earlier. The spreader row provides a source of a broad-spectrum of fungal pathogens involved in seed weathering. At the onset of pod-fill, overhead irrigation was used for 2 hours every afternoon to provide humid conditions for seed weathering. Each variety was harvested twice, once when 80 percent of its pods were dry and again 2 weeks later. Before threshing, plants were hung in a shed until all pods were dry. Seedling emergence scores were recorded for 100 seeds for each of 3 replications. Some lines were very tolerant to the adverse conditions (Table 38). Emergence from the 2 harvest dates were highly correlated ($r = 0.76^{**}$). Several of the lines, TGm 737, TGm 685, TGm 693 and TGm 623, resistant to weathering were identified to have superior seed longevity in storage in previous studies. Small seeded varieties tended to have highest emergence scores following field weathering ($r = 0.67^{**}$). Varieties with a high percentage of hard seed (unimbibed seed after 1 hour soaking) also were generally resistant to weathering, but varieties with a low percentage of hard seed also were resistant; the correlation between percent hard seed and emergence was only 0.24.

Studies on screening method for resistance to seed weathering. During 1979 and 1980, field experiments were carried out to improve screening precision for varietal resistance to field weathering by use of overhead irrigation, *Phomopsis* inoculation and preplanting of disease spreader rows. Both overhead irrigation and spreader rows increased the level of seed deterioration, but neither improved the experimental precision (IITA Annual Report, 1979); they did not reduce the size of experimental errors. There are 2 sampling difficulties in screening for resistance to field weathering. The first is that lines do not mature at the same time and, consequently, are subjected to different environmental stress. The second is that on a given plant, all pods do not mature at the same time, especially for varieties with indeterminate growth habit.

It might be possible to overcome both of these problems by removing a sample of pods from plants as the pods just begin to change color from green to yellow and place the pods in a uniform environment that would permit seed weathering. An initial experiment was conducted to see if seeds would 'weather' if pods were placed on metal incubator trays and kept at 30°C and 80-90 percent relative humidity. Pods from 7 varietal entries of a yield trial were harvested at the onset of yellowing, at 2-weeks delayed harvest and at 4-weeks delayed harvest. The pods harvested at yellowing were either dried at 28°C and 50 percent relative humidity or placed in the incubator for controlled weathering. Averaged across 7 varieties and 6 replications, the seedling emergence scores were 60 percent, 40 percent, 20 percent and 16 percent for prompt harvest (unstressed), 2-weeks delayed harvest, 4-weeks delayed harvest and 1-week controlled weathering, respectively. The controlled weathering clearly resulted in severe seed deterioration.

Table 38. Seedling emergence of 15 soybean lines most resistant to field weathering out of 76 lines tested. Plants were subjected to humid conditions at onset of seed fill and harvested at maturity and again 2 weeks later (IITA, 1980).

IITA Acc. Number	Name	Emergence (%) First harvest	Emergence (%) Second harvest	Seed color	Seed size g/100 seeds	% hard seed 1 hr. soaking
TGm 1171	AVROC 8457	97	91	black	6.1	70
TGm 737P	INDO 243	94	81	black	8.3	42
TGm 705	INDO 169	94	83	yellow	10.6	5
TGm 715	INDO 195	93	79	yellow	10.2	0
TGm 712	INDO 188	92	71	yellow	9.3	0
TGm 706	INDO 173	92	81	black	9.7	63
TGm 693	INDO 153	91	72	black	9.6	79
TGm 623	INDO 9	90	83	yellow	9.6	0
TGm 685	INDO 131	90	84	black	10.3	60
TGm 730	INDO 226	91	84	black	9.3	15
TGm 737W	INDO 243	91	77	black	15.3	23
TGm 742	INDO 255	93	71	black	9.3	48
TGm 1063	AVRDC 3477	90	80	green	8.1	0
TGm 993	AVRDC 2106	89	84	yellow	12.2	0
TGm 918	ORBA	89	78	yellow	14.7	12
TGm 80	Bossier*	67	40	yellow	19.2	0
TGm 479	Jupiter*	47	27	yellow	17.5	2
TGm 7	Improved Pelican*	54	11	yellow	15.2	3
Mean		68	55	(61 yellow)		
Range		22-97	11-84	(12 black)	8.3-19.2	0-79
LSD (5%) = 21				(1 brown)		
*Checks				(2 green)		

Because there were no varietal differences for resistance to weathering in this experiment, correlations between true field weathering and controlled weathering were not calculated. Further studies on screening methods are planned next year.

Selection for promiscuous nodulation. By screening the IITA soybean germplasm at numerous locations from 1976 to 1978, several varieties were identified that consistently nodulated effectively with the indigenous rhizobia—cowpea cross inoculation group. Numerous crosses were made to incorporate the promiscuous nodulation character into high-yielding backgrounds. In 1979, F_2 populations and F_3 families were screened for acceptable agronomic type and effective nodulation on soils low in N at Mokwa. The selections were reevaluated during the 1979-80 dry season at IITA. In 1980, 890 F_4 and F_5 bulk populations from the pedigree breeding program were evaluated for their ability to nodulate with indigenous rhizobia at 4 locations in Nigeria: Onne, Ikenne, Mokwa and Gusau. Nodule number, size and color were scored for 5 plants dug at both ends of 2-row plots of 6 m lengths. In general, less nodulation was observed at Ikenne and Onne than at Mokwa or Gusau. There are several possible explanations for this location difference. First, the entries were selected for promiscuous nodulation in earlier generatons at Mokwa and perhaps selection resulted in some site specificity. This is not a likely explanation because even cowpeas, which were grown as checks, did not nodulate well at Ikenne or Onne. Second, it seems more likely that high levels of N from previous cropping and mineralization may have inhibited nodule development. N deficiency symptoms did not occur on poorly nodulated lines at Ikenne and Onne but were noticeable at Mokwa and Gusau, which supports this hypothesis. Of the 890 populations tested, 318 were reselected based primarily on their across site nodulation and, in a few cases, on having very good nodulation at specific sites. A few single plants from each family of the promiscuous nodulating material were tested for their seed storability. Lines exhibiting both promiscuity and good seed storability were selected.

Another breeding procedure being used to incorporate both promiscuous nodulation and seed storability is Diallel Selecting Mating (DSM). From the DSM program, 1,827 F_4 double-cross derived breeding lines were evaluated for nodulation at Ikenne and Mokwa. Over half, 983, of the lines nodulated well at both sites and are being multiplied for replicated yield testing next year. A second cycle of seed storability evaluation is also being made on the selected DSM lines. In 1981, the promiscuous lines from both the pedigree and the DSM programs will be made available to national and international collaborators.

Yield trials

Uniform trials. The IITA soybean uniform trial was sown in 3 locations in Nigeria: IITA in both the first and second season and Ikenne and Mokwa. Twenty-one entries were to be sown at all locations but droughty conditions during and following planting at both IITA in the first season and Mokwa, resulted in poor stand establishment. Because of the lack of seed when trials were resown, some of the original entries were not included in the second season planting at IITA and the resowing at Mokwa. Four lines that performed well at more than 1 sowing are listed in Table 39. In addition to their high-yielding potential, TGm 17-2G and TGm 182-1D are also very resistant to pod shattering.

On-farm yield testing. Six varieties were grown with fertilizer (200 kg 7:25:18/ha) and without fertilizer by 5 small-scale soybean growers in eastern Nigeria. Four of the 6 varieties are parents (donors of the promiscuous nodulation characteristic) being used in the breeding program at IITA. TGm 479 (Jupiter), a parent with high yield potential under good soil fertility conditions, and Malayan, a local check, were also included. All varieties except Jupiter were well nodulated. Jupiter and the early-maturing line, TGm 618, had poor yields while the late-maturing lines, TGm 579 and TGm 119, had good yields, (Table 40). Unfortunately, Malayan, which is a very late maturing line (160 days) was not harvested from 3 of the 5 locations and, therefore, not included in the analysis. All varieties responded similarly with modest yield increases to the fertilizer treatment.

Large plots of a wider range of varieties were sown on a mechanized farm in south-central Nigeria, near Agenebode (Table 41). Even though 300 kg 15:15:15/ha fertilizer was applied, the nodulation of IITA's promiscuous parental lines, TGm 579, TGm 119, TGm 344 and Malayan, was very good. There were virtually no nodules on

Table 41. On farm soybean yield trial in south-central Nigeria (Tiffany farms near Agenebode, 1980).

Variety	Yield kg/ha
TGx 252A-1-2	1,414
TGm 579	1,275
TGm 119	1,264
TGm 344	1,175
TGx 187-2G	1,109
TGx 26-23D	1,026
Malayan (Local)	993
TGx 17-2G	975
TGx 174-5E	837
Mean	1118
N	3
S.E. ($\bar{X}$)	131
LSD (5%)	393 (N.S.)

Table 39. Yield (kg/ha) and average rank of 4 promising breeding lines compared to varieties Jupiter and Bossier from soybean uniform trial (1980).

Location: Planting Date:	IITA May 26	IITA July 30	Ikenne May 14	Mokwa July 25	Ave. Rank
TGx 17-2G	1387 (1)	2304 (2)	1228 (4)	664 (7)	3.5
TGx 182-1D	1076 (6)	2564 (1)	1290 (2)	843 (3)	3.0
TGx 11-3E	1202 (4)	-	1266 (3)	-	3.5
TGx 26-23D	1036 (11)	2014 (3)	995 (10)	907 (1)	6.25
Jupiter (check)	1205 (3)	1635 (8)	783 (18)	814 (4)	8.25
Bossier (check)	1049 (10)	934 (12)	-	594 (9)	10.33
Trial Mean	1007	1709	984	684	
Entries	21	12	20	12	
Reps	4	4	4	4	
LSD (5%)	252	621	384	392	

Table 40. Yield (kg/ha) of 5 promiscuous inoculating parents compared to 1 nonpromiscuous variety, Jupiter, from on-farm soybean yield trial (1980).

Variety	Fertilizer* treatment	Anonguku Farm	Shasha Egum Farm	Kyaior Igyira Farm	Kwaghbura Asarsuen Farm	Iorgirim Utsu Farm	Variety means
TGm 119	1	2,040	1,668	910	678	1,480	1,104
	2	1,060	542	678	875	1,110	
TGm 579	1	2,040	1,223	446	1,767	1,443	1,228
	2	1,170	1,362	428	1,767	610	
TGm 618	1	1,610	500	178	625	1,147	720
	2	1,080	389	142	928	592	
Jupiter	1	1,580	361	410	785	555	628
	2	1,070	305	142	892	185	
TGm 120	1	1,380	1,334	1,178	1,414	666	1,060
	2	1,030	862	803	1,196	740	
Malayan	1	1,230		1,624			
(Local)	2	1,240		1,481			

*Fertilizer treatments: 1 = ~ 200 kg/ha 7:25:18; mean = 1097.
2 = no fertilizer; mean = 799.
LSD (5%) = 430 for comparing variety or fertilizer means.*

the other entries. TGm 579 and TGm 119 performed relatively well, which is consistent with results on fields of small farmers in eastern Nigeria. TGm 252A-1-2 also yielded well but is very susceptible to pod shattering.

Entomology

Trap cropping for control of stink bugs

At the initiation of IITA's soybean program 7 years ago, insects were not considered to be a major problem. However, during the last 2 years, pod sucking insects have been observed in sufficient populations to require insecticidal control. The most commonly observed pod sucking insects are stink bugs. Although the composition is complex, 3 stink bugs are frequently encountered in Nigeria, *Nezara* spp., *Piezodorus guildinii* and *Aspavia sp. Nezara viridula* appears to be the most common stink bug in the drier zones (Mokwa); whereas populations appear to be equally divided among *Nezara* spp., *P. guildinii* and *Aspavia sp.* in the wetter zones (Onne).

Due to their importance in other areas of soybean production, the biology of the stink bugs, especially *Nezara spp.*, has been extensively studied. The insects have a wide host range, and a reservoir population is maintained on many wild leguminous plants and other weeds. They normally migrate into a soybean field in relatively small numbers, but the population rapidly increases as eggs are deposited on the crop. One female can lay as many as 600 eggs, and the nymphs start feeding on soybean pods approximately 2 weeks later. The behavior of the insect may lend itself to some novel methods of control.

During 1980, experiments were conducted to evaluate the effectiveness of 'trap cropping' as an economical means of controlling stink bugs. This method is based upon directing the initial invasion of the insects. The migratory pattern may be influenced by providing a food source at a time when the main soybean crop does not have pods. Since the insect is attracted to a food source, it could be effectively trapped and the population controlled by spraying insecticides only on the trap crop.

Early-maturing soybeans or other legumes, which form pods earlier than the main soybean crop, could be employed as a trap. This may reduce the amount of spraying; the trap occupies less than 20 percent of the field.

The experiments consisted of 5 treatments and were planted at 2 locations in Nigeria: Mokwa and Onne. The treatments were as follows: 1) an unsprayed control, 2) a sprayed control, 3) an early-maturing soybean trap, 4) a cowpea trap and 5) a cowpea preference plot. The trap of soybean and cowpea trap treatments were sprayed with an insecticide while the trap of cowpea preference treatment was not. By the nature of the experiment, each treatment had to be separated by large distance (~ 300 m). The plot size was large (~ 1.0 ha) in order to simulate a practical situation. Consequently, only 1 replicate of each treatment was sown at each location.

Mokwa. The 5 treatments with plot sizes are shown in Table 42. Jupiter, which matures in approximately 110 days, and TGm 577, which matures in approximately 120 days, were used as the main soybean crop.

The soybean trap was designed by planting 15 rows of TGm 686, which matures in approximately 75 days, on each side of the main crop (100 rows) on the same planting date as the main crop.

The cowpea trap was planted like the soybean trap, except that 10 rows of cowpeas were planted on each side of the main crop and in the center. Since cowpeas have a short pod-filling period, 5 plantings were required in order to maintain fresh pods on the trap during the reproductive period of the soybean. The cowpea preference treatment was planted like the cowpea trap.

The sprayed control was sprayed with 1.0 kg endosulfan/ha a.i. at 67, 72, 77, 82, 92 and 97 days after planting. The soybean trap was also sprayed with 1.0 hg endosulfan/ha a.i. at 50, 57, 63, 68 and 72 days after planting. Since cowpeas will not set pods unless thrips are controlled, 2 applications of a synthetic pyrethroid were applied to the cowpea trap and the cowpea preference treatment during the flowering period (40 and 47 days after planting). The cowpea trap was also sprayed with endosulfan at 50, 55, 62, 68 and 72 days after planting.

Insect populations were evaluated using the drop cloth method at 2 stages of crop development at several sampling points (Table 42). Also, the number of aborted pods that fell on the drop cloth and the insect populations on the cowpea trap and cowpea preference treatment were counted.

Table 42. List of treatments, plot sizes and number of sampling points for trap cropping trials (Mokwa and Onne, 1980).

	Plot size (ha)		No. of sampling points	
Treatment	Mokwa	Onne	Mokwa	Onne
Unsprayed control	0.25	0.25	12	24
Sprayed control	0.25	0.50	12	15
Soybean trap	1.0	1.0	48	42
Main crop	0.78	0.80	48	42
Trap	0.22	0.20	0	0
Cowpea trap	1.0	0.5	56	32
Main crop	0.78	0.4	44	24
Trap	0.22	0.1	12	8
Cowpea preference	1.0	0.4	56	32
Main crop	0.78	0.32	44	24
Preference	0.22	0.08	12	8

Large differences in the insect populations and number of aborted pods were observed in the various treatments at 77 days after planting (Table 43). At this stage, Jupiter was in the early pod fill period while TGm 577 was in the early pod formation period. The unsprayed control had 4.1 stink bugs/2m row with equal populations in Jupiter and TGm 577. Based upon economic threshold studies conducted in the U.S.A. and Brazil, this insect populaton is at the economic threshold level. The sprayed control had no stink bugs as the crop had been treated 3 times with endosulfan.

Both the soybeans and the cowpeas were effective traps; only 1.8 and 0.8 insects/2m row were counted in the main soybean crops, respectively. The cowpea preference treatment was also an effective trap, 1.6 bugs/2m row were counted in the main soybean crop while 11.1 insects/2m row were counted on the cowpea trap.

The insect populations and number of aborted pods were measured again at 91 days after planting the main soybean crop. At this stage, Jupiter was in the rapid bean fill period, and TGm 577 was in the mid-pod fill period. In the 2-week period between samples, the unsprayed control almost doubled its insect population, (Table 44).

This insect population is also approximately double the economic threshold level. The sprayed control had no insects while the soybean and cowpea traps maintained the main soybean crop below the economic threshold level with 3.8 and 0.8 insects/2m row, respectively. The cowpea preference treatment had 6.5 insects/2m row. The first sampling of the cowpea preference treatment showed that the stink bugs had been trapped on the cowpea; however, the second sampling showed that all the cowpeas pods had been consumed by the stink bugs. Since the stink bugs were not killed, they proliferated tremendously, destroyed the entire trap and moved into the main soybean crop for food.

Nymph populations also were observed to provide information as to the source of the adult populations in the main soybean crop. The unsprayed control had 6.8 nymphs/2m row; whereas, the main soybean crop of the 2 trap treatments had few or no nymphs. This shows that the adult stink bugs in the main soybean crop in the soybean trap treatment moved in from outside of the plot; few nymphs were inside, (Table 44). This also shows that the timing between the maturity of the trap and the

Table 43. Stink bug populations and pod abortion at 77 days after planting of 2 soybean cultivars grown under various methods of insect control (Mokwa, 1980).

Cropping System	Insecticide	No. of adult stink bugs/2 m	No. of aborted pods/2 m
Soybean monocrop	None	4.1 (0.3	24.2 (3.9)
TGm 577		4.1 (0.5)	13.4 (2.2)
Jupiter		4.0 (0.3)	38.8 (3.3)
Soybean monocrop	Endosulfan	0 (0)	5.6 (0.8)
TGm 577		0 (0)	4.7 (0.9)
Jupiter		0 (0)	6.5 (1.2)
Soybean trap	Endosulfan on trap only	1.8 (0.3)	5.0 (0.8)
TGm 577		2.1 (0.4)	6.4 (0.7)
Jupiter		1.6 (0.5)	3.5 (0.5
Cowpea trap	Endosulfan on trap only	0.8 (0.2)	8.2 (0.6)
TGm 577		0.6 (0.1)	7.5 (0.6)
Jupiter		1.0 (0.3)	9.1 (1.1)
Cowpea		2.1 (0.3)	-
Cowpea preference	None	1.6 (0.2)	12.1 (0.9)
TGm 577		2.0 (0.3)	8.8 (1.0)
Jupiter		1.3 (0.2)	15.3 (1.1)
Cowpea		11.1 (2.1)	

Values are means followed by standard error of mean in parentheses.

Table 44. Adult and nymph stink bug populations and pod abortion at 91 days after planting of 2 soybean cultivars grown under various methods of insect control (Mokwa, 1980).

Cropping System	Insecticide	No. of adults/2 m	No. of nymphs/2 m	N. of aborted pods/2 m
Soybean monocrop	None	7.4 (0.9)	6.8 (0.5)	35.4 (7.0)
TGm 577		9.5 (1.2)	7.5 (0.7)	20.8 (3.6)
Jupiter		4.7 (0.5)	6.0 (0.5)	54.8 (11.6)
Soybean monocrop	Endosulfan	0	0	4.0 (0.5)
TGm 577		0	0	2.8 (0.4)
Jupiter		0	0	5.1 (0.5)
Soybean trap	Endosulfan on trap only	3.8 (0.6	0.8 (0.1)	4.1 (0.5)
TGm 577		5.8 (0.8)	1.1 (0.2)	3.8 (0.5)
Jupiter		1.9 (0.4)	0.6 (0.1)	4.5 (0.8)
Cowpea trap	Endosulfan on trap only	0.8 (0.2)	0.1 (0.02)	4.5 (0.7)
TGm 577		1.0 (0.3)	0.1 (0.02)	2.0 (0.3)
Jupiter		0.6 (0.2)	0.1 (0.02)	7.6 (1.3)
Cowpea		0	0	-
Cowpea preference	None	6.5 (0.5)	10.0 (0.6)	28.9 (1.7)
TGm 577		7.7 (0.6)	12.2 (0.8)	20.1 (1.9)
Jupiter		5.6 (0.6)	8.3 (0.6)	36.2 (1.6)
Cowpea		12.2 (2.2)	100+	-

Values are means followed by standard error of mean in parentheses.

main crop is important. If the trap matures too early, a secondary invasion of adults can occur and initiate a new population that could produce serious damage to the main crop. In this experiment, the soybean trap matured when the main soybean crop was starting to pod, which appears to be close to the optimum timing.

The cowpeas in the cowpea preference treatment had more than 100 nymphs/2m row, indicating that the cowpeas were the source of the adult populations observed in the main soybean crop. This illustrates a potential problem with the trap cropping concept. If the insect population is not controlled on the trap, the trap serves as a breeding ground resulting in an uncontrolled population that would migrate into the main crop once the food supply in the trap has been exhausted.

As observed at 77 days after planting, the amount of pod abortion observed at 91 days after planting was generally in close agreement with the insect population (Table 44). Very little abortion was recorded in the sprayed control and the 2 trap treatments (Table 44). The insect populations in the unsprayed control and the cowpea preference treatment were about equal (7 insects/2m row), and pod abortion was similar. However, Jupiter consistently aborted more pods than TGm 577 even though the insect population was lower in Jupiter. It appears that TGm 577 may possess more tolerance to stink bug damage (as measured by pod abortion) than Jupiter, but TGm 577 can still incur severe damage.

Pods damaged by stink bugs normally do not fill if the bean is punctured during early development. In order to obtain an estimate of insect damage (besides yield), the number of unfilled pods was evaluated (Table 45). Sampling consisted of randomly selecting 3 plants at each sampling site at physiological maturity and counting the number of pods with and without seeds. In the unsprayed control, 4 insects/2m row at early pod fill and 7.4 insects/2m row at mid-pod fill resulted in 75 percent of the pods without seeds. The damage was higher on Jupiter (98 percent) than TGm 577 (58 percent). The effectiveness of the trap treatments is clearly shown; pod damage in the soybean and cowpea traps was equal to the sprayed control.

Furthermore, the economic threshold values derived in the U.S.A. and Brazil of 2 and 4 insects/m row at early pod development and mid-pod fill respectively, are close estimates in these trials. Neither of the trap treatments exceed these values, and there was no measurable pod damage. However, pod damage in the cowpea preference treatment was severe (78 percent) and equal to the unsprayed control.

Seed yield was determined on 3 rows each 5 m long at several sampling points. The yield data were generally in close agreement with the insect counts and pod damage estimates. The unsprayed control and the cowpea preference treatment suffered severe yield losses (85 percent) due to stink bug damage (Table 46). The 2 trap treatments gave yields equal to the sprayed control. Also, the sprayed cowpeas in cowpea trap treatment yielded, 1,564 kg/ha.

Onne substation. The same 5 treatments were established at Onne in the second season. Due to the short season, early-maturing soybean, TGm 686, was planted as the main crop. The early-maturing soybean trap, TGm 686, was planted 27 days earlier than the main crop. Difficulties were encountered in establishing the cowpea trap and cowpea preference treatments because of the early maturation of the main soybean crop. Cowpea was planted 10 days later than the main soybean crop. However, this was too late to function as a trap. The cowpeas did not form pods until approximately 10-14 days after the main soybean crop.

The control was sprayed with 1.0 kg endosulfan/ha a.i. at 50, 55, 60, 65, 70 and 75 days after planting. The soybean trap was sprayed with endosulfan at 50, 55, 60, 65, 70 and 75 days after planting the trap. The last spray was

Table 45. Evaluation of pod damage at physiological maturity of 2 soybean cultivars grown under various methods of insect control (Mokwa, 1980).

Cropping System	Insecticide	No. of pods per plant	No. of pods/ plants with seeds	No. or pods/ plants without seeds	% of pods without seeds
Soybean monocrop	None	236 (23)	43 (10)	193 (30)	75.0 (6.0)
TGM 577		185 (22)	72 (8)	113 (21)	58.0 (5.0)
Jupiter		305 (27)	5 (1)	300 (27)	98.0 (0.3)
Soybean monocrop	Endosulfan	142 (10)	135 (10)	6 (1)	4.6 (1.0)
TGm 577		151 (13)	144 (12)	8 (1)	5.0 (1.0)
Jupiter		132 (15)	127 (11)	5 (1)	4.0 (1.0)
Soybean trap	Endosulfan on trap only	158 (4)	152 (4)	6 (1)	3.7 (0.5)
TGm 577		165 (6)	158 (5)	6 (1)	3.8 (0.6)
Jupiter		151 (5)	146 (5)	5 (1)	3.6 (0.7)
Cowpea trap	Endosulfan on trap only	146 (5)	138 (5)	8 (0.7)	6.0 (1.0)
TGm 577		140 (5)	133 (5)	6 (0.3)	4.4 (0.4)
Jupiter		154 (10)	144 (9)	10 (1.7)	6.0 (0.7)
Cowpea preference	None	185 (6)	39 (6)	148 (9)	78.0 (3.0)
TGm 577		171 (8)	59 (8)	114 (10)	66.0 (5.0)
Jupiter		197 (9)	19 (4)	176 (11)	89.0 (7.3)

Values are means followed by standard error of mean in parentheses.

Table 46. Seed yield of 2 soybean cultivars grown under various methods of insect control (Mokwa, 1980).

Management system	Insecticide treatment	Yield kg/ha	% of sprayed control
Soybean monocrop	None	255 (45)	15.1
TGm 577		358 (52)	18.1
Jupiter		116 (25)	8.2
Soybean monocrop	Endosulfan throughout pod-fill	1688 (97)	100
TGm 577		1977 (77)	100
Jupiter		1400 (60)	100
Soybean trap	Endosulfan on trap only	1545 (55)	91.5
TGm 577		1797 (77)	90.9
Jupiter		1319 (44)	94.2
Cowpea trap	Endosulfan on trap only	1679 (53)	99.5
TGm 577		1846 (47)	93.4
Jupiter		1536 (71)	109.7
Cowpea		1564 (13)	-
Cowpea preference	None	179 (36)	10.4
TGm 577		316 (38)	16.0
Jupiter		54 (19)	0.04
Cowpea		0	-

Values are means followed by standard error of mean in parentheses.

applied when the main soybean crop was 48 days old and initiating small pods. The 27 days difference in maturity between the soybean trap and the main soybean crop was similar to the soybean trap treatment at Mokwa. The cowpea trap was first sprayed with endosulfan at 54 days after planting the trap when the main soybean crop was 64 days old and already in mid-pod fill. The same lack of proper synchronization also occurred in the cowpea preference treatment. Even though it was evident that the cowpeas could not serve as a trap, insect counts were still taken on the treatments as the information could be useful to illustrate the effect of improper timing on establishing the trap. Also, these treatments could provide information on whether stink bugs have a preference for cowpeas.

Insect populations and pod abortion estimated at 60 days after planting the main soybean crop are shown in Table 47. The unsprayed control had 3.8 insects/2 m row even at this early stage. The unsprayed control had no

Table 47. Stink bug populations and pod abortion at 60 days after planting of TGm 686 grown under various methods of insect control (Onne, 1980).

Cropping system	Insecticide	No. of adult stink bugs[1] per/2 m	No. of aborted[1] pods/2 m
Soybean monocrop	None	3.8 (0.3)	3.5 (0.4)
Soybean monocrop	Endosulfan on entire field	0 (0)	0.9 (0.3)
Soybean trap	Endosulfan on trap only	0.9 (0.2)	1.4 (0.2)
Cowpea trap[2]	Endosulfan on trap only	4.1 (0.3)	2.7 (0.4)
Cowpea preference	None	3.6 (0.3)	4.0 (0.6)

[1]Values are means followed by standard error of the mean in parentheses.
[2]At this sampling date, few pods were present on cowpeas. Consequently, endosulfan had not been applied.

insects. The soybean trap treatment had only 0.9 insects/2 m row.

The soybean trap had already matured and had not been sprayed for 2 weeks prior to these observations. Due to the late establishment of the cowpeas in the cowpea trap and cowpea preference treatments, the insects were not trapped, and the population of stink bugs in the main soybean crop for these 2 treatments was equal to the unsprayed control. Very few pods were present on the cowpeas at this sampling date, and endosulfan had not been applied to the cowpeas in the cowpea trap treatment. The number of aborted pods of the main soybean crop varied according to the insect population. The amount of pod abortion in the soybean trap treatment was equal to the sprayed control, and the cowpea trap treatment and the cowpea preference treatments were similar to the unsprayed control. However, pod abortion of TGm 686 was consistently lower than the 2 varieties used in the Mokwa experiment.

The stink bug population in the unsprayed control was 8.7 insects/2 m row at 68 days after planting (Table 48). During the 8-day period between counts, the insect population in the unsprayed control doubled. The soybean trap treatment maintained the population below the economic threshold level with 2.9 insects/2 m row. The cowpeas in the cowpea trap treatment were profusely podded at this sampling time and had been sprayed twice with 1.0 kg endosulfan/ha a.i. between 60 and 68 days after planting. No stink bugs were present on the

Table 48. Adult and nymph stink bug populations and pod abortion at 68 days after planting of TGm 686 grown under various methods of insect control (Onne, 1980).

Cropping	Insecticide	No. of adults/2 m	No. of nymphs/2 m	No. of aborted pods/2 m
Soybean monocrop	None	8.7 (0.4)	4.5 (0.3)	5.7 (0.6)
Soybean monocrop	Endosulfan at 5 days	0 (0)	0 (0)	0.6 (0.3)
Soybean trap	Endosulfan on trap only	2.9 (0.4)	0.5 (0.2)	1.5 (0.3)
Cowpea trap	Endosulfan on trap only	6.3 (0.4)	2.2 (0.2)	3.0 (0.5)
Cowpea Preference	None	5.2 (0.4)	3.2 (1.0)	5.8 (0.6)

Values are means followed by standard error of mean in parentheses.

cowpeas at 68 days after planting, but the population on the main soybean crop was 6.3 insects/2 m row, which is well above the economic threshold level but less than the unsprayed control. The stink bug population on the soybean in the cowpea preference treatment was also above the economic threshold level but less than the unsprayed control.

Nymph counts indicated that very little population buildup was occurring in the soybean treatment (0.5 nymphs/2 m row). Also, there were fewer nymphs in the cowpea trap treatment than the unsprayed control. This indicates that after the cowpeas formed pods, they were trapping some of the stink bugs that migrated into the field in the later stages of the crop development. The number of nymphs in the cowpea preference treatment was equal to the unsprayed control. Pod abortion at 68 days after planting was related to insect population.

Pod damage was evaluated by counting the number of unfilled pods at physiological maturity (Table 49). Even though TGm 686 has an effective pod-filling period of only 20 days, severe damage occurred in the unsprayed control, cowpea trap treatment and cowpea preference treatment. Reduced damage occurred in the soybean trap treatment and sprayed control. Pod damage was generally consistent with the insect counts.

Stink bugs are not considered a serious pest on cowpea in Africa, but data from the cowpea preference treatments at both Mokwa and Onne showed very high populations on the unsprayed cowpeas (Tables 50 and 51). Also, the data indicates that stink bugs as well as other pod sucking bugs may prefer cowpeas over soybeans.

Conclusions. By spraying the early-maturing soybeans planted on the edges of the main soybean crop, the stink bug population can be maintained below an economic threshold level in the main crop as illustrated in experiments conducted at Mokwa and Onne. The differences in maturity between the early-maturing trap and the main crop is critical. At Mokwa, the trap matured in 75 days, and the 2 varieties in the main crop matured in 110-120 days. Consequently, a difference of 35 days appears to be about optimum. If the trap matures too late, the insects will not concentrate on the trap and escape control. If the trap matures too early, the insects from the trap will migrate into the main crop and can build up a new population that could cause serious damage, especially if the main crop is very late in maturation.

At Onne, the same variety was used as the trap and main crop, but the trap was planted 27 days earlier. This procedure also was successful but required 2 plantings and may not be feasible on a large scale.

Another important consideration is that the initial insect population that concentrates on the trap must be controlled. Failure to spray the trap properly can be devastating as the population on the trap multiplies and serves as a reservoir for invading the main soybean crop.

There may be some advantage in using cowpeas as a trap. There is evidence indicating a preference by stink bugs for cowpeas over soybeans. The use of cowpeas as a trap may be a very economical method for growing cowpeas. Cowpeas must be sprayed for control of pod

Table 51. Insect composition of unsprayed cowpea and soybean at Onne[1]

Crop	Insect: Stink bugs	Riptortus
Cowpea	18.2 (2.8)	2.3 (0.6)
Soybean	5.2 (0.4)	1.0 (0.2)

[1]*Data from cowpea preference treatment. Cowpea grown on edges of soybean. Values are means followed by standard error of mean in parentheses.*

Table 49. Evaluation of pod damage at physiological maturity of soybean grown under various methods of insect control (Onne, 1980).

Cropping system	Insecticide	No. of pods without seeds/ 3 plants	No. of pods with seeds/ 3 plant	Total No. of pods/3 plants	% of pods without seeds
Soybean monocrop	None	79 (6)	101 (6)	180 (8)	43.8 (2.2)
Soybean monocrop	Endosulfan throughout pod develop.	14 (3)	161 (16)	175 (18)	8.1 (0.9)
Soybean trap	Endosulfan on trap only	26 (2)	116 (7)	172 (8)	13.8 (0.6)
Cowpea trap	Endosulfan on trap only	56 (3)	132 (7)	188 (9)	38.1 (1.7)
Cowpea preference	None	118 (9)	106 (6)	224 (12)	51.4 (2.0)

Values are means followed by standard error of mean in parentheses.

Table 50. Insect populations on cowpea and soybean at 2 times of evaluation at Mokwa.[1]

	Evaluations at 77 DAE			Evaluations at 91 DAE		
	No. of Insects/2 m			No. of Insects/2 m		
Crop	Stink Bugs	Clavigralla	Others	Stink Bugs	Clavigralla	Others
Cowpea	11.1 (2.1)	10.3 (1.4)	1.0 (0.5)	12.2 (2.2)	21.2 (2.6)	0.7 (0.2)
Soybean	1.6 (0.2)	0.1 (0.1)	0.2 (0.2)	6.5 (0.5)	0.20 (0.2)	0.1 (0.1)

[1]*Data from cowpea preference treatment. Cowpea grown on edges of soybean. Values are means followed by standard error of mean in parentheses.*

sucking regardless of whether they are used as a trap or grown in monocultures. Consequently, by growing the cowpeas on the edges of the soybeans, one is effectively controlling the stink bugs in the soybeans "free of charge." Such a system produced yields of 1,564 kg/ha of cowpeas and 1,679 kg/ha of soybean as compared to yields of no cowpea and 225 kg/ha of soybeans when not sprayed.

Host-plant resistance of soybean to stink bugs

Stink bugs normally migrate into a soybean field in relatively low numbers, but the population soon exceeds an economic threshold level due to their multiplication in the crop. Consequently, if the initial population can be prevented from multiplying, perhaps severe damage can be prevented. This could possibly be accomplished by identifying soybean cultivars that cause nymph mortality of stink bugs. Reports from the USA indicate that a few soybean cultivars may possess characters that cause nymph mortality to *N. viridula*. In 1980, the nymph mortality of *N. viridula* and *P. guildinii* caused by selected cultivars was tested.

In the first experiment, nymphs at 2 stages of development were exposed to 4 cultivars for 12 days. The procedure consisted of placing 10 nymphs in a Petri dish containing 5 pods of each cultivar. The pods were changed every 2 days, and nymph mortality was recorded at 6, 9 and 12 days after initial exposure. Different treatments consisted of intact and open pods.

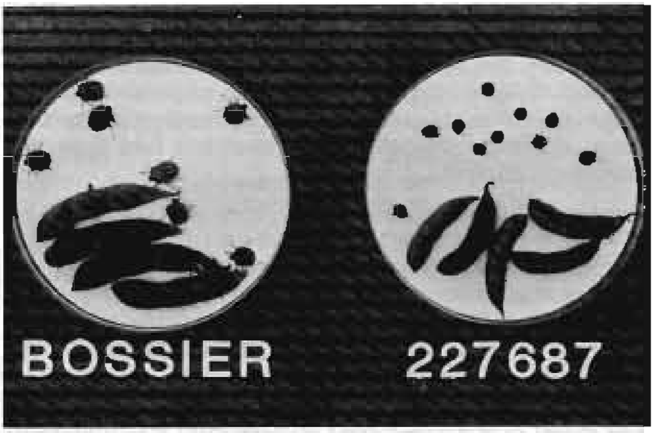
With intact pods, accession PI 227687 and cultivar ED 73-308 killed 85 percent of the second instars (Table 52). With open pods, cultivar ED-73-308 killed only 35 percent. This indicates that 2 mechanisms may be invo'ved in the nymph mortality of ED- 73-308. The first mechanism may be due to pubescence of the pod. ED 73-308 is a progeny of PI 229358, which has long, erect, leaf trichomes. Perhaps this character was transferred to ED 73-308. The second mechanism may be due to toxin of the seed. Some nymph mortality (35 percent to second instars) was observed to open pods, which indicates that the seeds may contain a toxin or that the nymphs were not feeding.

ED 73-371 is a sister line of ED 73-308 (both from crosses of PI 229358 × Bragg) but did not exhibit nymph mortality (Table 52). Likewise, Bossier did not exhibit nymph mortality.

PI 227687 produced 85 percent mortality to 3-day-old 2° instars and 70 percent mortality to 1-day-old 3° instars. While ED 73-308 produced 88 percent mortality to 3-day-old 2° instars but only 20 percent mortality to 1-day-old 3° instars. This narrow range of instar susceptibility to ED 73-308 makes this cultivar less attractive than PI 227687. ED 73-308 also possesses limited nymph mortality to *P. guildinii* (Table 53).

Table 52. Nymph mortality of N. viridula *on 4 soybean varieties (IITA 1980).*

Variety	% mortality 2° nymphs	3° nymphs
PI 227687	85	70
ED 73-308	88	20
BD 73-308-open	35	0
ED 73-371	10	0
Bossier	5	0
S.E. = 5.6		



Nymph mortality of* Nezara *spp. on resistant soybean, PI 227687, compared to susceptible Bossier.

In the second experiment, 24-hour-old 3° instars were placed in Petri dishes containing intact and open pods of PI 227687 and intact pods of Bossier. After 9 days, both intact and open pods of PI 227687 caused high nymph mortality to *N. viridula* which Bossier did not (Table 54). PI 227687 appeared to produce slightly more nymph mortality with open pods than intact pods, which suggests that either the nymphs were not feeding or the seeds contain a toxin.

Table 53. Nymph mortality of P. guildinii *on ED 73-308 and Bossier (IITA, 1980).*

Variety	% mortality 3° nymphs
ED 73-308	43
Bossier	10
S.E. = 12.9	

Table 54. Effect of exposing seed on nymph mortality of N. viridula *on PI 227687 (IITA, 1980).*

Variety	% mortality 3° nymphs Days of exposure 6	9
PI 227687	65	72
PI 227687-open	75	90
Bossier	12	22
S.E. = 4.9		

The practical use of nymph mortality under field conditions will be accessed next year. The mortality character of PI 227687 may significantly reduce stink bug reproduction. If this is the case, the nymph mortality gene(s) will be incorporated into material that possesses improved seed quality and the ability to nodulate with indigenous rhizobia.

Egg masses for the nymph mortality studies were collected from several crops in the field at both IITA and the IITA Onne substation. A serendipitous finding was the presence of a parasitic wasp that hatched from eggs collected from Onne. Ninety percent of the eggs collected from Onne were parasitized, and few sink bug nymphs emerged. The potential use of the wasp for biological control of stink bug reproduction needs further investigation.

Agronomy

Fertility trials

Fertility trials were conducted at 4 locations in Nigeria: Mokwa, Agenebode, Lessel and Gusau. Gusau is in the northern Guinea Savannah. Mokwa and Lessel are in the southern Guinea Savannah over sandstone parent material (probably Alfisols). Agenebode is on the southern edge of the Guinea Savannah on what may be alluvial deposits over sandstone. The effective CEC of the surface 15 cm is particularly low in the 3 southern-most sites: 2-3 me/100 g soil at Mokaw, 3 me/100 g soil at Agenebode and 1 me/100 g soil at Lessel. The Gusau soil is only slightly better. around 4-9 me/100 g soil. The pH fluctuated slightly above 6 at Mokaw and Agenebode and slightly below 6 at Lessel and around 6 at Gusau. Bray 1 available P levels are low to moderate at all 4 locations.

A trial was conducted at Mokwa, Agenebode and Lessel to determine the response of soybeans to P with and without K and with and without a combination of secondary and micronutrients, Mg, S, Zn, B, Mo, Fe and Cu. Two varieties were used, TGm 579, a moderately early-maturing variety (115 days), and TGm 344. a moderately late-maturing variety (130 days). Both varieties are promiscuous nodulators and were nodulated at all sites without the use of inoculants.

Only in Lessel was there a marked response with both varieties to P applied alone (Table 55 and Fig. 6). This may be because the soybeans followed fertilized maize at Mokwa and Agenebode while only a portion of the field had contained fertilized tobacco in 1979 in Lessel. At Agenebode, TGm 579 responded to 25 kg P/ha, but

Table 55. Response of soybeans to P. secondary and micronutrients at 3 locations in Nigeria (1980).

Location:	Mokwa		Agenebode		Lessel	
Fertilizer treatment *Variety:*	TGm 579	TGm 344	TGm 579	TGm 344	TGm 579	TGm 344
No fertility	1,630	1,460	690	890	1,040	760
25 kg p/ha	1,550	1,120	1,080	1,010	1,320	1,000
25 kg p/ha and secondary and micronutrients	1,640	1,360	1,100	1,110	1,330	1,470
50 kg p/ha	1,660	910	850	960	1,380	1,100
50 kg p/ha and secondary and micronutrients	1,910	1,420	1,580	1,600	1,810	1,740
LSD (5%)	242 (ms)	361	510	400	552	327

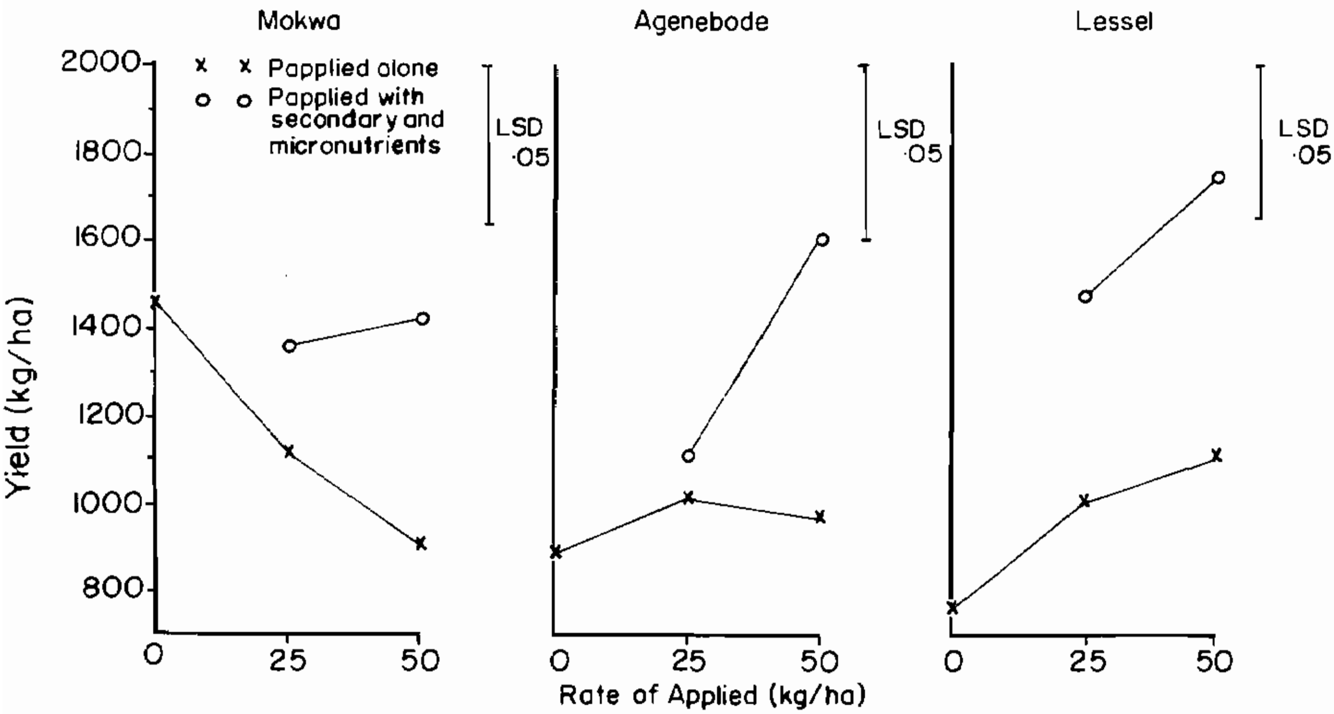


Fig. 6. Response of TGm 344 to P, secondary and micronutrients at 3 locations in Nigeria (1980).

TGm 344 was unaffected by this P rate. At Mokwa. TGm 579 was unaffected by P rate while the yield of TGm 344 actually declined with increasing P. K applied with P had very little effect on yield. However, application of secondary and micronutrients in conjunction with P was beneficial at all locations. At Lessel and Agenebode, applications of secondary and micronutrients together with 50 kg P/ha increased yields 30-90 percent more than yields of plots receiving 50 kg P/ha alone. At Mokwa, application of secondary and micronutrients mitigated the detrimental effect of P fertilization on TGm 344. This suggests that when secondary or micronutrients are limiting, P fertilizer alone may actually reduce yields. If P fertilizer is applied in large quantities on these soils, it appears that it should be supplemented with secondary and micronutrients.

The effect of combining K with secondary and micronutrients and P was not consistent, and further analysis is required before conclusions can be drawn.

A second trial was conducted using variety TGm 618 at Mokwa, Agenebode and Lessel to determine the effects of Ca, Mg and S on soybean yields. P, K and micronutrients, B. Mn, Zn, Mo, Cu and Fe, were applied uniformly to all plots. Treatments were not significant; however. the trend at Lessel was for higher yields when secondary nutrients were applied in combination while the trend at Agenebode was the reverse; Ca. Mg and S tended to decrease yields when applied in combination.

Experiments were conducted to examine the response of soybeans to application of $MGSO_4$, Zn, and Mo at Mokwa and K, $MgSO_4$, Zn and Mo at Gusau. At both locations, variations in plant growth and yield were unrelated to fertilizer treatments applied. A mid-season drought and early cessation of rains at Gusau resulted in very poor yield: 680 kg/ha for TGm 618 and 440 kg/ha for TGm 344.

In a Mokwa trial, variabilities in plant growth were extreme; individual plot yields ranged from 200 to 2,200 kg/ha. Plots containing vigorously growing plants were located over pockets of clay, approximately 25 cm below the soil surface. Plots containing stunted plants were located over sandy-textured soil to depths greater than 75 cm.

This phenomenon also has been observed to a lesser extent at Lessel and Agenebode. and soil samples have been collected to document this.

Yields of 2 t/ha and more in some plots at Mokwa, Agenebode and Lessel suggest that soybean production is feasible in the southern Guinea Savannah of Nigeria.

Variatal tolerance to acid soils

There are large areas in the tropics environmentally suitable for soybean cultivation, but production is limited due to soil acidity. Soil acidity is often comprised of many factors including Al and Mn toxicities and Ca and P deficiencies. However, a common feature of acid soil is toxic levels of exchangeable Al. Attempts have been made to identify soybean genotypes tolerant to Al toxicity, but little progress has been made because, in most soils, it is difficult to isolate Al toxicity as the only growth limiting variable.

The soils of Onne are of coastal sediment formation (Oxic Paleadult) and are acid due to weathering. These soils are unique in that P is not limiting (low P fixation), and Mn is not present at toxic levels. These conditions allow for testing genotypes with only Al toxicity/Ca deficiency limiting the plant growth. Although Onne soils are, in general, acid, the acidity is variable. Attempts to screen cowpeas for acid tolerance in the field have not been successful due to large variation in acidity. Pockets of severe acidity are present in low areas where more leaching has occurred and in isolated spots where the subsurface soil has been brought to the surface. Areas that have a deeper A-horizon profile are also less acid.

It was necessary to uniformly acidify an area in Onne before measuring the acid tolerance of soybean varieties. In March, 1979, a one ha field (200 m × 50 m) was divided into 4 m strips each 200 m long. An alley 2 m wide was demarked between each 4 m strip. There were 5 pairs of strips. A pair consisted of one strip that was acidified and an adjacent control strip that was limed. Acidification of the stress strips was accomplished by applying 625 kg $(NH_4)_2\,SO_4$/ha and 200 kg Kcl/ha.

Five composite soil samples were taken from each strip and analyzed for Al and Ca at regular intervals. The chemical changes in the acid strips over time are shown in Fig. 7. Before acidification. the soil in the acid plots contained 1.03 meq Al/100 g soil (± 0.32, 95 percent confidence interval) and 1.01 meq Ca/100 g soil. With a CEC of 3.1, this represents approximately 33 percent Al saturation. Two months after the applications of $(NH_4)_2\,SO_4$ and Kcl, the Al increased to 1.49 meq/100 g soil, and Ca decreased to 0.91 meq/100 g soil. This represents approximately 48 percent Al saturation. During the heavy rainy period (July-October), the acidity further increased and became more uniform, reaching a level of 1.8 meq Al/100 g soil (± 0.14, 95 percent confidence interval) and 0.75 meq Ca/100 g soil (± 0.09, 95 percent confidence interval). In summary, in a 7-month period, the Al toxicity increased from 1.03 meq/100 g soil (32 percent Al saturation) to 1.8 meq/100 g soil (56 percent Al saturation). The field was left fallow for 10 more months, which included another rainy season. In August, 1980, the acidity levels in the acid strips were analyzed, and Al had increased to 1.98 meq/100 g soil (62 percent Al saturation), and the Ca had decreased to 0.55 meq/100 g soil. Also, the Al levels in the acid strips became more uniform reaching a level of 1.98 meq/100 g soil (± 0.12, 95 percent confidence interval).

In October, 1980, the entire field was fertilized with 300 kg 15-15-15/ha and 100 kg magnesium sulfate/ha. A mixture of 500 kg hydrated lime/ha plus 1,500 kg dolomite limestone/ha was applied to the control strips. Each variety was planted across the 4 m acid and limed strips. Consequently, each cultivar could be evaluated by comparing its growth in the adjacent limed strip. This made the evaluations easier and also reduced the variation due to factors other than acidity. The field was harrowed. and small ridges constructed across the field with 50 cm between ridges. A small ditch was made to separate the acid and limed strips. A total of 660 genotypes were planted, 433 entries had 3 replications, 149 had 2 replications and 178 entries were planted only once. These entries represent IITA's tropical soybean germplasm collection, which are varieties adapted to low altitudes of high temperature and neutral days. Generally, these varieties are late maturing (Group VII-X) and photosensitive. Fifteen standard lines were planted after every 100 entries. The standards were chosen to represent geno-

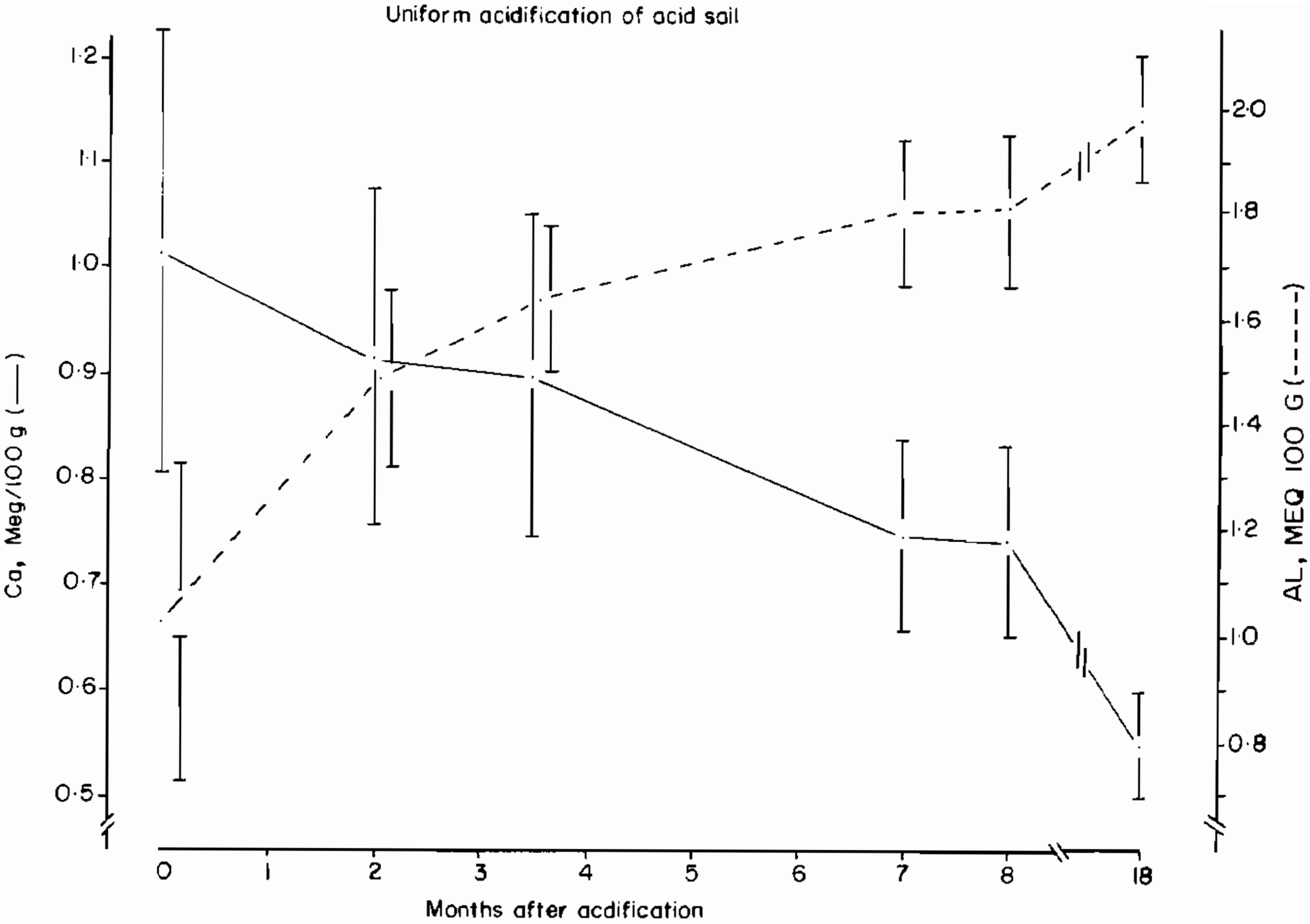


Fig. 7. Chemical analysis of soil after treatment with 625 kg $(NH_4)_2SO_4$/ha and 200 kg Kcl/ha.

types with various degrees of tolerance (as reported in the literature) and assist in measuring field variation. Fifty days after planting, the entries were evaluated for acid tolerance. Acid tolerance was determined using both visual ratings and fresh weight measurements.

Two types of visual ratings were recorded: the first based upon toxicity symptoms and vigor in the acid plots (absolute growth rating) and the second based upon a comparison between growth in the acid and the limed plots (relative growth rating). Absolute growth was rated using a 1-5 scale: 1 = severe toxicity symptoms with severely stunted or dead plants; 2 = toxicity symptoms only on lower leaves of stunted plants; 3 = no toxicity symptoms on leaves but plants were stunted; 4 = no toxicity symptoms and plants had vigor and 5 = no toxicity symptoms and plants were very vigorous.

Relative growth was rated visually using a 1-5 scale: 1 = plants in acid plots were 20 percent as vigorous as the plants in the limed plots; 2 = plants in acid plots were 20-40 percent as vigorous as the plants in limed plots; 3 = plants in acid plots were 40-60 percent as vigorous as the plants in limed plots; 4 = plants in acid plots were 60-80 percent as vigorous as the plants in limed plots and 5 = plants in acid plots were 80 percent or more as vigorous as the plants in limed plots.

Plant fresh weight and number of plants in the center 2 m of each plot was recorded at 50 days after planting. Fresh weight in the acid strip as a percent of weight in the limed strip provided a quantitative measure of relative growth. The 2 visual ratings combined with the fresh weight determinations gave a subjective evaluation of acid tolerance and a quantitative measurement. Absolute growth ratings and fresh weight in the acid plots are measurements of growth under acid conditions, which indicates general adaptability to low-altitude, tropical environments. Relative growth ratings and fresh weight as a percent of the limed plots are more precise measurements of acid tolerance. Consequently, combinations of these measurements allow for the identification of genotypes that are tolerant to high levels of soil Al and are also adapted to tropical environments.

The distinction between acid tolerance and acid tolerance combined with adaptation is necessary in order to identify the most useful parents for a breeding program. There are nontropical environments where soil acidity is a problem. For these areas, genotypes that possess the genetic character for acid tolerance would have to be grown in the particular environment to identify the genotypes most agronomically suitable. If acid tolerant material is to be developed for tropical environments, it would be desirable to commence a breeding program using genotypes as parents that are tolerant to high levels of Al and also agronomically adapted to tropical environments.

Results. The correlation matrix between visual ratings and quantitative measurements is shown in Table 56. Absolute growth ratings were highly correlated with fresh weight in the acid plots (r = 0.7). Usual relative growth ratings were also significantly correlated (r = 0.53) with fresh quantitative relative growth measurement plots. Significant correlation between the above 2 sets of variables would be expected as both are measurements of the same parameters, i.e., 1 visual and 1 quantitative.

This illustrates that the visual ratings were reasonably accurate measurements of growth under acid conditions. This is important in that visual ratings are rapid and nondestructive, both of which would be required if breeding material were to be evaluated for acid tolerance.

The standards did not exhibit differential tolerances as expected (Table 57). Earlier trials at Onne indicated that TGm 2, TGm 344 and Jupiter may be tolerant; whereas, TGm 51 and TGm 119 were sensitive, but they all appear to be about equal. Likewise, standards developed at North Carolina State University, U.S.A., all appeared to react similarly to soil acidity. The data from the 15 standards planted at 23 locations in the field indicate that the field was not as uniform as the soil analysis indicated (Table 57). The coefficient of covariation was lower (24 percent) for the visual ratings and higher (35 percent) for both fresh weight per 2 m in the acid plots and fresh weight as a percent of the limed plots. The unaccountable variation in growth in the limed plots was 25 percent even though the plots were uniformly nonacid.

Table 56. Correlation matrix (N = 193s) between visual growth ratings and fresh weight measurements (Onne, 1980).

	Variable	1	2	3
1.	Absolute growth rating	1	-	-
2.	Relative growth rating	0.67	1	-
3.	Fresh wt., acid plots	0.70	0.63	1
4.	Fresh wt., % of control	0.37	0.53	0.57

It was estimated that about 30 percent of the random variation in the acidified strips was due to variance in soil acidity. As a result of the uncontrollable variation, more emphasis should be given to replicated entries.

The reaction of the varieties to 1.98 meq Al/100 g soil fit normal distribution curves, especially for the quantitative measurements (Fig. 8). Generally, the frequency distributions illustrate that the stress of 1.98 meq Al/100 g soil was adequate to separate cultivars for tolerance. The means for all entries was 2.4 for absolute growth rating, 2.3 for relative growth rating, 357 g/2 m for fresh weight in the acid plots and 35.8 percent for fresh weight as a percent of the limed plots. The percent of the population selected varied with the parameter used for evaluation.

Entries were selected that had a relative or absolute rating of 3.5 or more, a fresh weight in the acid plots of 500 g/2 m or more and fresh weight as a percent of the limed plots of 50 percent or more (Table 58).

Two types of acid tolerant genotypes are desired. Varieties that possess the genetic character(s) for tolerance to high levels of Al can be identified by comparing the growth in the acid plots with growth in the limed plots. It is necessary to have a nonstressed plot to clearly identify acid tolerance; many varieties gave 500 g/2 m or more fresh weight only because they are vigorous genotypes and not truly acid tolerant. Of the 102 entries that gave

Table 58. Selection of acid tolerant soybeans based upon various criteria and the percent of the population selected according to each criteria (Onne, 1980).

Selection criteria	Limits	No. of lines selected	% of population selected
Absolute growth rating	>3.5	48	7.3
Relative growth rating	>3.5	25	3.8
Fresh wt., acid plots	>500 g/2 m	102	15.5
Fresh wt., % of control	$>50\%$	74	11.2

Table 57. Visual ratings and growth measurements of 15 standard varieties planted at 23 sites in the acid screening field. (Onne, 1980).

	Parameter			
Variety	Absolute growth rating, 1-5	Relative growth rating, 1-5	Fresh wt. acid plots, g/2 m	Fresh wt. % of control
TGm 2	3.4 (0.19)	2.5 (0.18)	396 (32)	35 (2.1)
TGm 51	2.7 (0.17)	2.3 (0.19)	399 (42)	37 (3.6)
TGm 119	2.4 (0.19)	2.2 (0.19)	286 (43)	34 (5.0)
TGm 120	3.0 (0.21)	2.5 (0.19)	383 (40)	37 (3.2)
TGm 344	3.2 (0.20)	2.8 (0.19)	467 (45)	35 (3.1)
TGm 479	2.8 (0.17)	2.4 (0.19)	345 (35)	35 (3.3)
TGm 618	2.4 (0.19)	2.2 (0.23)	344 (43)	35 (4.0)
TGm 801-76	2.2 (0.15)	2.0 (0.18)	326 (30)	38 (3.1)
TGm 806-76	2.2 (0.07)	2.2 (0.17)	366 (24)	39 (3.0)
TGm 929-78	2.0 (0.10)	1.9 (0.16)	320 (29)	35 (3.1)
TGm 939-78	2.3 (0.16)	2.1 (0.2)	382 (32)	37 (3.1)
TGm 811-76	1.8 (0.13)	2.4 (0.20)	235 (19)	43 (4.5)
TGm 808-76	2.3 (0.15)	2.2 (0.16)	390 (34)	36 (3.7)
TGm 815-76	2.3 (0.17)	2.2 (0.14)	321 (29)	34 (2.5)
TGm 817-76	1.7 (0.16)	2.3 (0.19)	220 (31)	46 (6.6)

Values are means with standard error of mean in parentheses.

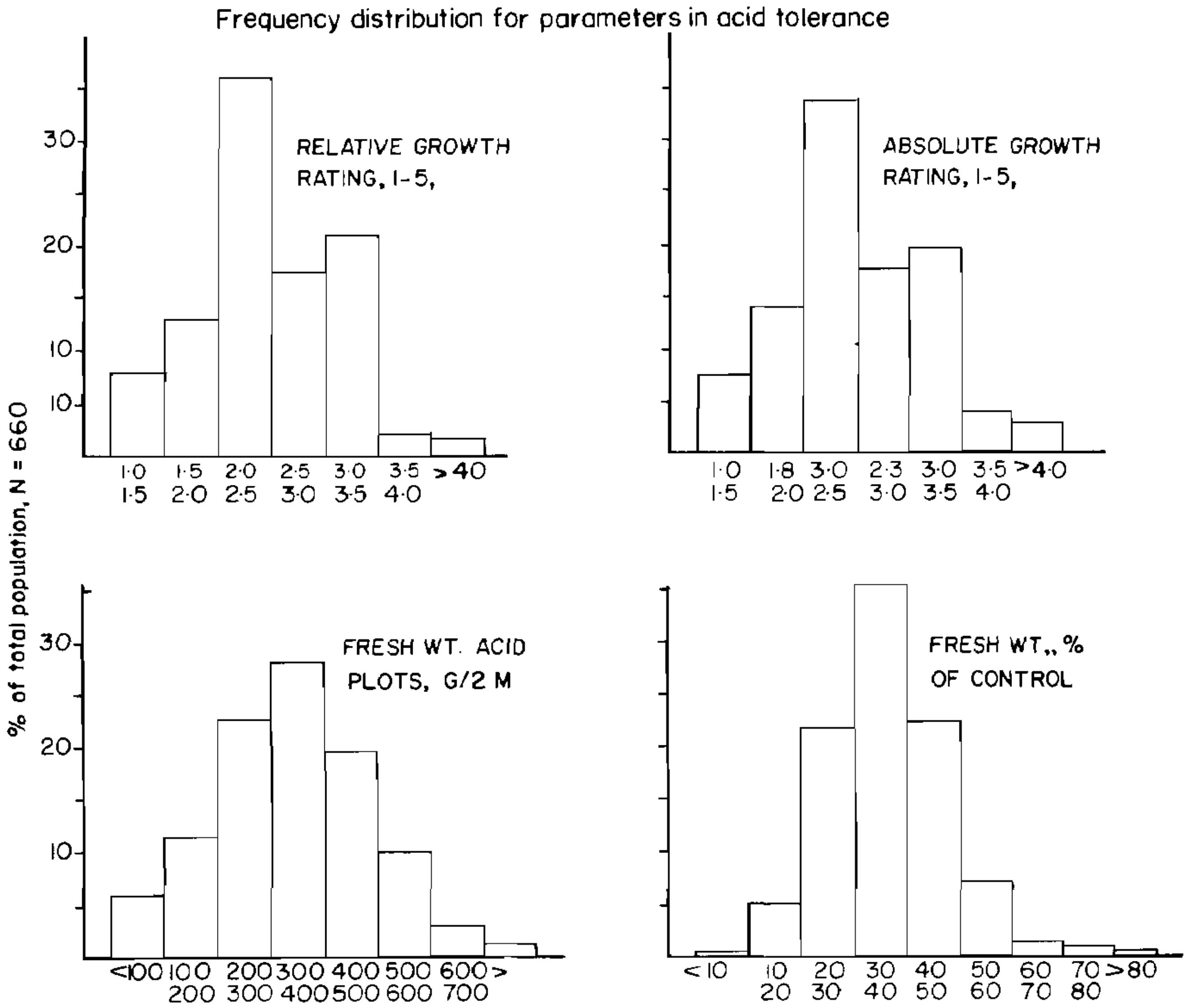


Fig. 8. Frequency histograms of parameter used to evaluate genotypes for acid tolerance.

500 g/2 m of fresh weight in acid strips, only 31 had relative growth of 50 percent or more. Consequently, if selections for tolerance were made only under acid conditions, 70 percent of the material would be escapes, i.e., they exhibit vigor under acid conditions only because they are large genotypes. By combining visual and quantitative relative growth measurement, selection precision may be increased.

The criteria for tolerance to 1.98 meq Al/100 g were defined as a relative growth rating of 3.5 or more *combined* with a fresh weight as a percent of the limed plots of 45 percent or more or a relative growth rating of 3.0 or more *combined* with a fresh weight as a percent of the limed plots of 50 percent or more. There were 14 entries that were planted in 3 replications that satisfied these criteria (Table 59). Ten entries with 2 replications and 11 entries with 1 replication also met the criteria for acid tolerance (Table 60).

The second type of genotypes sought are entries that are acid tolerant and also adapted to low-altitude, tropical environments. This character can be identified by taking into consideration the growth in acid strips. Entries that met the criteria for acid tolerance and had a fresh weight in the acid plots of 500 g/2 m or more were characterized as acid tolerant and environmentally adapted.

There were 10 entries with 3 replications, 10 entries with 2 replications and 5 entries with 1 replication that appear to be acid tolerant and adapted to low-altitude, tropical environments (Table 61).

Next year, the most promising material will be reevaluated in large plots with several replications. The most acid tolerant material will be made available to national soybean programs in other environments. The material that exhibits both acid tolerance and adaptation will be used as parents for developing acid tolerant material for tropical environments.

Herbicide trials

Weed control in soybean is particularly difficult due to the lack of broad-spectrum selective herbicides and the

Table 59. Most acid tolerance varieties based upon relative growth rating of 3.5 or more and fresh weight as a percent of control of 45 percent or more or relative growth rating of 3.0 or more and fresh weight as a percent of control of 50 percent or more (Onne, 1980).

Entry (decreasing order)	Relative growth rating, 1-5	Fresh wt., % of control	Fresh wt. acid plots, g/2 m
3 replications			
TGm 790	3.3	75.4	361
TGm 975	3.7	64.2	526
TGm 971	3.3	61.3	586
TGm 533	3.3	61.2	527
TGm 801	3.7	59.2	803
TGm 910	3.0	59.1	380
TGm 745	4.0	49.9	825
TGm 316	3.0	58.8	565
TGm 313-13	3.3	57.4	501
TGm 1168	3.0	57.3	575
TGm 629	3.3	56.3	540
TGm 756	3.3	55.9	761
TGm 998	3.0	55.8	483
TGm 767	3.7	46.5	753

slow initial growth of the crop. Weeds in soybean must be controlled for at least 40 days at which time the crop forms a canopy and can successfully compete. There are many preemergence herbicides that give excellent control of grass weed species and are well tolerated by the crop. However, many broadleaf weeds are resistant to these herbicides and must be removed by mechanical or manual cultivation.

The most difficult weeds to control at IITA are *Euphorbia* spp. and *Commelina agraria.* In 1980, 2 herbicides, RH-2817 and Blazer, that have been reported to control these weeds were evaluated for weed control efficiency and crop tolerance.

RH-8817 was applied preemergence on the soil surface after planting at a rate of 3.0 and 6.0 kg/ha. The chemical gave acceptable levels of control for *Euphorbia* spp., but the crop was only marginally tolerant to these rates (Table 62). More research will be conducted to find the most optimum rate to control *Euphorbia* and determine the degree of crop tolerance.

Blazer was applied postemergence at 2 stages of crop development and at 3 rates; 1.00/ha liter or more was required to obtain adequate control, but 2.00/ha liter or more (Table 63) did not appear to increase control. Blazer is a contact herbicide; consequently, the efficiency of control depends upon good foliar coverage. More effective weed control is obtained with high volumes of water and the use of a surfactant in order to increase foliar absorption.

Soybeans appear to tolerate Blazer even though a noticeable amount of leaf burning is produced (Table 63). However, the crop completely recovered as the chemical is not translocated. Soybeans appear to be more tolerant in the earlier stages of growth (third trifoliate leaf stage). The application of 2.01 l/ha at the fifth trifoliate leaf stage resulted in severe leaf burning, and the crop did not completely recover. Also, *Euphorbia* appears to be more resistant to Blazer in later stages of growth, and this is probably due to less foliar contact.

In another trial, Blazer was applied at a rate of 0.75 l/ha between soybean rows when *Euphorbia* was in the third

Table 60. Best soybean varieties with 2 or 1 replications for tolerance to high levels of soil Al based upon relative growth rating and fresh weight as a percent of the control (Onne, 1980).

Entry	Relative growth rating, 1-5	Fresh wt., % of control	Fresh wt. acid plots, g/2 m
2 replications			
TGm 1172	3.5	84.8	670
TGm 737 W	3.5	63.0	430
TGm 904	3.0	59.6	372
TGm 1037	3.0	59.1	535
TGm 749	3.5	58.5	535
TGm 1001	4.0	56.9	620
TGm 372	3.5	55.9	497
TGm 714	3.0	53.5	425
TGm 628	3.0	53.3	367
TGm 346	3.5	45.6	747
1 replication			
TGm 713	5.0	82.3	420
TGm 1185	3.0	85.4	350
TGm 1175	3.0	82.4	560
TGm 1039	5.0	75.4	980
TGm 263	3.0	80.3	610
TGm 1196	3.0	64.1	705
TGm 1189	3.0	54.9	335
TGm 1167	4.0	51.6	330
TGm 1111	3.0	52.3	450
TGm 1122	4.0	47.5	190
TGm 1133	4.0	44.1	150

Table 61. Best soybean varieties with 3, 2 or 1 replications for tolerance to a low-altitude, tropical environment (Onne, 1980).

No. of replications	Best entries (decreasing order)
3	TGm 745, 801, 756, 767, 971, 1168, 316, 629, 533 and 975.
2	TGm 346, 1172, 1001, 749, 1037, 372, 737W, 714, 904 and 628.
1	TGm 1039, 1196, 263 and 1175

Table 62. Effect of RH-8817 herbicides (preemergence) on Euphorbia spp. and soybean growth (IITA, 1980).

Treatments	Fresh wt. of soybean plants at 50 days g/m²	Fresh wt. of weeds at 50 days g/m²
No herbicide	710	351
3 RH-881* kg/ha	661	57
6 kg/ha RH-8817	420	17
LSD (5%)	260	197

Table 63. Effect of Blazer herbicide (postemergence) on **Euphorbia** *spp. and soybean growth (IITA, 1980).*

	Weed control[2]		Crop injury[3]	
	Days after application			
Treatments[1]	10	20	10	20
Control	1.0	1.0	1.0	1.0
1.0 l/ha at 3rd trifoliate	7.5	7.0	2.5	1.5
2.0 l/ha at 3rd trifoliate	8.5	8.5	3.5	2.0
4.0 l/ha at 3rd trifoliate	8.5	8.5	4.5	3.0
2.0 l/ha at 5th trifoliate	5.5	4.0	5.5	2.5

[1]*Application made between rows using 220 l/ha plus 0.2 percent v/v surfactant.*
[2]*Weed control ratings: 1 = no control, <7.0 = commercially acceptable.*
[3]*Crop injury ratings: 1 = no injury, <3.0 = commercially unacceptable.*

trifoliate leaf stage. Although the weeds were severely burned, recovery of weeds was almost complete. Blazer was also applied at rates of 1.5 l/ha and 3.0 l/ha between the rows and over the top of cowpea (third trifoliate leaf stage). Over the top applications resulted in severe leaf burning, but the crop completely recovered. Weed control was better and crop injury minimal when the chemical was directed between the rows. Consequently, for effective weed control, 1.5 l/ha appears to be the optimum rate, and this should be directed between the rows when the crop is in the third trifoliate leaf stage and weeds have less than 3 fully developed leaves.

Tanzania food crop research

Genetic improvement

Tanzania soybean uniform variety trial. Twelve promising varieties, including Bossier as a check, were evaluated in a trial at 7 locations. The mean performance of different varieties at 5 locations are presented in Table 64. The performance of varieties differed from location to location, but, in general, Bossier and 30120-38-78 yielded consistently high at all locations. None of the varieties proved superior in yield potential to Bossier.

INTSOY preliminary observation trial. A trial, consisting of 24 new breeding lines from different countries, was conducted at Ilonga in collaboration with the International Soybean Program (INTSOY) of the University of Illinois, U.S.A. The general growth of all varieties was adversely affected because of prolonged dry weather immediately after emergence. However, a number of varieties appeared quite promising. UFV-1 (BP-1) gave the highest yield closely followed by ICAL-125, F67-S132 and ICAL-124. These varieties yielded over 1,700 kg/ha compared to 1,253 kg/ha for Bossier. These lines will be evaluated in multilocation trials in the coming season.

Development of new breeding lines. Twenty-eight F_2 and 78 F_3 populations involving parents with better seed quality and free nodulation characteristics were evaluated at Ilonga. A number of individual plants with desirable characters have been selected for progeny testing and further selection.

Previous work done in Tanzania has identified varieties that nodulate freely without inoculant. Details of the work have been reported previously.

Microbiology

The microbiology work continues to exploit the legume *Rhizobium* symbiosis to optimize cowpea and soybean yields. Cowpea rhizobia were collected from many environments in order to select effective strains that can withstand the diverse constraints of the African continent. Inoculation trails with soybeans have shown that once introduced into the soil, rhizobia can survive a 2-year fallow period and sustain good soybean yields after the fallow. Also, some strains of rhizobia were found to be more competitive than others. The screening on tolerance of rhizobia to acidity and high temperature stresses continues.

Environmental diversity in cowpea rhizobia

An important step toward maximizing cowpea production through improved N-fixation is to isolate the indigenous rhizobia and identify the most effective competitive strains for use as inoculants. In 1979, the cowpea-rhizobia symbiosis was studied at 3 locations selected to pro-

Table 64. Grain yield (kg/ha) of 12 soybean varieties evaluated in the Tanzania soybean uniform variety trial at 5 locations (1980).

S.N.	Variety	Ilonga	Ukiriguru	Nachingwea	Mbeya	Ismani	General Mean
1	Bossier	1121	458	1439	2181	1709	1382
2	Blyvoor White	1574	391	1050	1815	1403	1247
3	Hokaido-48	1314	377	1111	1954	1345	1220
4	P_2-L_2	1406	471	1036	2287	1266	1393
5	40149-0-10	1029	394	944	2199	1496	1212
6	30120-38-78	1104	400	1308	2214	1554	1316
7	30106-2-1	1143	352	1297	748	1532	1014
8	30252-11	1367	454	1394	780	1614	1122
9	30271-6-66	899	430	1225	2089	1519	1232
10	L_7	1273	514	1261	1414	1051	1108
11	188-2	1658	464	1217	1581	1260	1236
12	L_4	1406	516	1183	1646	1453	1241
	LSD (5%)	N.S.	N.S.	284	435	272	

vide diversity in climatic and edaphic factors (IITA Annual Report, 1979). About 500 cowpea cultivars were evaluated in terms of relative effectiveness based on fresh shoot weight. About 45 good and 15 poor cultivar —*Rhizobium* combinations were selected at each location and nodules collected from the hosts. Cowpea rhizobia were isolated and purified from the nodules to provide a diverse collection of about 750 strains. Most have been authenticated by the plant infection test and placed in storage. Duplicate cultures were sent to collaborating scientists at Boyce Thompson Institute, U.S.A., and Cornell University, U.S.A., for further characterization.

Nodules collected from cowpea and soybean sown this year to identify the best cultivar and *Rhizobium* combinations in poor soils provided 250 rhizobia isolates. Ten percent of IITA isolates, 29 percent of Onne isolates and 87 percent of Maradi (Niger) isolates form pin point small (diameter < 2 mm) colonies that are usually dry after 7 days on yeast extract-mannitol agar. The remaining isolates form large colonies that are watery or gummy, usually translucent, confluent with irregular margins.

The colony morphology type of 20 dry and 20 slimy isolates, 13 from IITA, 17 from Onne and 10 from Maradi, have been tested on plates containing mannitol, gluconate, glucose, sucrose or mannose as sole carbon sources.

The following was observed:

(1) All isolates that are dry on mannitol are dry on all other 4 carbohydrates;
(2) Maradi isolates that are slimy on mannitol are never slimy on glucose and sucrose but sometimes on mannose and often on gluconate;
(3) IITA isolates that are slimy on mannitol are either slimy on all 4 other carbohydrates or only on mannitol and gluconate and sometimes on mannose;
(4) Onne isolates that are large and slimy on mannitol are slimy on all 4 other carbohydrates, but isolates that are small and slimy on mannitol are dry on glucose and sucrose.

The significance of these different types of colonies in terms of N-fixation and adaptation to the environment was examined in detail. It has been observed that isolates that form dry colonies produce dark purple nodules on a number of cowpea cultivars in sterile sand and soil. Isolates that form slimy colonies produce beige nodules. Such distinctions may be useful in ecological work.

In pot trials using sterile sand and soil from Onne and Maradi, seeds of 3 cowpea cultivars, ER 1, TVu 1811 and TVu 1957, were inoculated with a mixed suspension, consisting of equal numbers (5×10^6) of cowpea *Rhizobium* IRc 409A (purple nodule forming isolate) and IRc 409C (beige nodule forming isolate) or IRc 344A (purple nodule forming isolate) and IRC 344B (beige nodule forming isolate). Less than 10 percent of the nodules formed were dark purple, indicating that the purple forming isolates were less competitive. In the field trials at Maradi (Table 65) where the frequency of dark purple nodules is the highest, 35 percent of the nodules in uninoculated plots of 6 cowpea cultivars were purple.

In plots inoculated with about 10^6 rhizobia/seed of IRc 409A, 49 percent of the nodules were purple, but in plots inoculated with about 10^6 rhizobia/seed of IRc 409C, only 14 percent of the nodules were purple. This indicates again that the slimy isolates forming beige nodules are more competitive (Table 65).

Table 65. Number and color of cowpea· nodules uninoculated or inoculated with Rhizobium (Maradi, 1980).

Inoculation treatment	Nodule number/ 3 plants	% purple nodules
Uninoculated	55	35
IRc 409 A	49	49
IRc 409 C	44	14

·*Means of 6 cowpea cultivars.*

Identification of host-strain combinations for 'problem soils'

Selection of host. Four cultivar-Rhizobium combinations were identified as the most effective in N-fixation at IITA, Onne and Maradi in 1979 (IITA Annual Report 1979). This suggested that there may be an advantage in selecting cowpea lines capable of effective symbiosis, particularly in 'problem soils' of tropical Africa.

To identify cowpeas and soybeans forming effective symbiosis in soils low in P and/or N, 7 soybean and 13 cowpea cultivars, including 2 that performed well in 1979, were sown at the above 3 locations. A basal application of 30 kg K/ha as muriate of potash was applied. The treatments were: N_0P_0 (low fertility level), N_0 P_1 (intermediate fertility level with P), N_1P_0 (intermediate fertility level with N) and N_1P_1 (high fertility level). N_0 and P_0 consisted of no N and P fertilizer added, respectively. P_1 consisted of 30 kg P/ha applied at planting. N_1 consisted of 100 kg N/ha applied at planting and 50 kg N/ha added at both 3 and 6 weeks after planting. The design was a split plot with fertilizer levels as main treatments and cultivars as subtreatments.

Responses to P and/or N were evaluated by comparing the fresh weight of 10 shoots at low or intermediate fertility levels with the fresh weight of 10 shoots at higher fertility levels in corresponding plots of the same cultivar.

Responses of soybean to fertilizers were not significant at IITA or Onne. Although germination was good, growth was extremely poor (< 30 cm) at 6 weeks after planting at Maradi. The reason is not clear. Fresh shoot weight of cowpeas improved with high fertilizer levels at IITA and Maradi (Table 66). It was not significantly changed with high-fertilizer levels at Onne, probably because of an inadequate supply of P (78 ppm in P_0 plots) (Table 66). Significant increases in fresh shoot weight were recorded for TVu 151 and VITA-4 as a result of P fertilization at IITA. Single superphosphate improved the growth of TVu 179, TVx 1952-01E and Dan Haoussa at Maradi. Dan Haoussa responded more to P alone than urea alone. In terms of grain yield, some cultivars responded more to P than N, but a combination of P and N gave the highest grain yield (Table 66).

From these observations, it is necessary to screen more germplasm in order to identify effective cultivar-*Rhizobium* combinations in soils low in both P and N. It is also necessary to design cultural practices suitable for mini-

Table 66. Comparison of fresh shoot weights (FSW, g/10 plants) or grain yields (g/10 plants) of selected cowpea cultivars at different fertility levels (IITA and Maradi, 1980).

Cultivars	Fertility level			
	N_oP_o	N_oP_1	N_1P_o	N_1P_1
Fresh shoot weight at IITA				
VITA-4	715	1570	960	1305
TVu 151	630	1710	1230	1535
TVu 5132	1625	1210	1210	1495
Fresh shoot weight at Maradi				
TVu 179	210	700	760	1500
TVx 1952-01E	380	700	580	1990
Dan Haoussa	420	1240	570	1995
Grain yield at Maradi				
VITA-4	68	137	83	300
TVx 1952-01E	41	125	46	143
Dan Haoussa	130	161	66	144

NB FSW IITA SD = 185
SED = 185 treatment
LSD = 370
SED between means = 197

FSW Maradi SD = 149
SED = 149 treatment
LSD = 300
SED between means = 143

Yield at Maradi SD = 47
SED = 39
LSD = 77 treatment
SED between means = 40

mizing cowpea dependence on N and P fertilization, particularly at Maradi where responses of cowpea to N or P are considerable.

Selection of rhizobia. Screening was initiated for effective *Rhizobium japonicum* strains that are tolerant to the following soil acidity factors: low pH and P and high Al. To screen large numbers of rhizobia for their ability to tolerate acidity factors, the defined Keyser and Munn's basal medium was used:

Control: pH 6.8, P 1,000 μM
Low pH: pH 4.5, P 1,000 μM
Low P: pH 4.5, P 5 μM
High Al: pH 4.5, P 5 μM, Al 50 or 100 μM

Twenty-one strains out of 84 tested (mostly from tropical soils) were highly acid tolerant (Table 67). Surprisingly, acid tolerant strains showed generally no close relation to the soil pH from which they were isolated; for instance, only 4 isolates out of 20 tested from the highly acid Onne soil were highly tolerant.

These acid tolerant strains will be tested for symbiotic effectiveness on soybean in pot trials, and the highly effective acid tolerant strains will be used for field testing at Onne.

Cowpea rhizobia were also selected. Small inocula of test strains were introduced onto agar plates containing Keyser and Munn's modified medium, and the plates were incubated at 30°C. Growth was measured visually and microscopically over a 10-day period. Corroborative tests were then conducted in liquid media with selected strains.

Table 67. R. japonicum strains highly tolerant to acid stress factors (IITA, 1980).

IITA Culture Collection No.	Origin
IRj 2119	Ivory Coast, G3
IRj 2120	Ivory Coast, G8
IRj 2128	Thailand, THA2
IRj 2129	Thailand, THA5
IRj 2004	IITA Onne substation, Nigeria, cv. Malayan
IRj 2002	IITA Onne substation, Nigeria, cv. Malayan
IRj 2007	IITA Onne substation, Nigeria, cv. Orba
IRj 2123	USDA, 31 lb 138
IRj 2019	IITA, Ibadan, Nigeria, cv. Orba
IRj 2049	Samaru, Nigeria, cv. TGm 294
IRj 2052	Samaru, Nigeria, cv. Bossier
IRj 2039	Samaru, Nigeria, cv. Malayan
IRj 2025	IITA, Ibadan, Nigeria, cv. TGm 294
IRj 2109	University of Wisconsin, U.S.A., SM 61A76
IRj 2048	Samaru, Nigeria, cv. TGm 294
IRj 2035	Yandev, Nigeria, cv. Orba
IRj 2013	IITA, Ibadan, Nigeria, cv. Malayan
IRj 2020	IITA, Ibadan, Nigeria, cv. Orba
IRj 2038	Samaru, Nigeria, cv. Malayan
IRj 2033	Yandev, Nigeria, cv. Orba
IRj 2001	IITA Onne substation, Nigeria, cv. Malayan

Early work at IITA showed that many cowpea *Rhizobium* isolates were more tolerant to acidity than *R. japonicum*. Isolates that grew in acid media usually also grew in the presence of Al. Recent, detailed screening of cowpea *Rhizobium* isolates from IITA, Onne and Maradi has shown that 6 of the 16, 27 of 46 and none of 36 were tolerant from these locations, respectively. Four IITA isolates and 13 Onne isolates had higher tolerance.

The factors that confer high tolerance to acidity and Al among rhizobia are unknown. Only some isolates from acid soils are tolerant. It was observed that all tolerant rhizobia form "wet" colonies although not all wet colonies were tolerant. No "dry" colonies were tolerant. Forty-four, 17 and 97 percent of the IITA, Onne and Maradi isolates formed dry colonies, respectively.

Rhizobium inoculation effects on soybean

Fields inoculated with selected *Rhizobium* strains may be able to support good soybean yield for several years without additional inoculum or N fertilizer. This would be a definite advantage over the N fertilizer that is expensive and necessary to be applied every year for consistently good soybean yields of American-type cultivars. Therefore, an experiment was carried out at IITA in a field planted with inoculated seed in 1978, fallow for 2 years and replanted with uninoculated seed in 1980. For com-

Table 68. *Effect of planting inoculated seed in 1978 and subsequent planting of uninoculated seed in 1980 after a 2 year fallow period on the nodule dry weight (mg/plant at 6 weeks) and seed yield (kg/ha) of 3 soybean cultivars (IITA, 1980).*

	Cultivars					
	Bossier		TGm 294		Orba	
Treatments	1978	1980	1978	1980	1978	1980
	Nodule Dry Weight					
Uninoculated -N	14	74	46	68	287	208
150 N	46	68	30	72	275	135
Inoculated	485	155	378	163	514	193
Inoculated in 1980		367		392		584
LSD (5%) For comparison of means between different treatments: 1978 = 185; 1980 = 77.						
	Seed Yield					
Uninoculated -N	1643	1526	1079	1655	2124	1924
150 N	2726	2314	2682	2151	2671	1848
Inoculated	2970	2454	2824	2309	2370	1830
Inoculated in 1980		3031		2935		2205
LSD (5%) For comparison between different treatments: 1978 = 309; 1980 = 508.						

parison, an uninoculated treatment with N fertilizer (150 kg N/ha) and without N fertilizer and an inoculated treatment were included in 1980.

In general, there are significant increases in dry weight of nodules and shoots as well as the grain yield in the inoculated treatments with Bossier and TGm 294 but not with Orba. Considerable decrease in nodule weight was noticed in 1980 in those treatments inoculated in 1978, indicating a probable decrease in numbers and/or redistribution of rhizobia in soil during the 2-year fallow period. Yield increases in inoculated plots were significant with Bossier and TGm 294 but not with Orba. All the cultivars inoculated with *R. japonicum* SM 35 in 1980 had large nodule mass, shoot weight and grain yield comparable to that in 1978 (Table 68).

In 4 inoculant treatments, nodules formed were identified by a serological technique—the Enzyme Linked Immunosorbent Assay (ELISA) (Table 69). This revealed that Bossier and TGm 294 formed most of the nodules from the Rhizobium strains introduced in 1978. In Orba, *R. japonicum* SM 35 (IRj 2110) and SM 31 (IRj 2111) formed many nodules while *R. japonicum* 110 (IRj 2112) and 138 (IRj 2123) formed few nodules.

An experiment was conducted at Ikenne (in near neutral soils) to determine which of the *R. japonicum* strains are the best competitors. Four single *R. japonicum* strain

Table 69. *Percent nodules* formed by inoculant strains after 2-year fallow period (IITA, 1980).*

*R. japonicum*** strains	Bossier	TGm 294	Orba
SM 35	81	98	72
SM 31	93	100	78
110	98	88	16
138	90	94	45
SM 35 (1980)	100	100	100

**Based on 192 nodules/cultivar.*

***IRj numbers given in the text are IITA culture collection numbers.*

treatments, SM 35, CB 1809 (IRj 2114), 110 and 138 and 2 mixed *R. japonicum* inoculant treatments, SM 35 + 110 and SM 35 + 138 + 110 + CB 1809, were used. The mixed inoculants have *Rhizobium* strains in equal proportions, thus, giving a fair chance in terms of numbers. Two soybean cultivars, TGm 294 and TGm 119, were used.

All the nodules in TGm 294 were formed by the introduced strains. In TGm 119, only SM 35 and CB 1809 were responsible for nearly 100 percent nodulation while 138 and 110 formed about 70-80 percent of the nodules and indigenous strains formed the rest. In treatment SM 35 + 110 and SM 35 + 110 + 138 + CB 1809, the maximum proportion of nodules (70 percent) in both the cultivars were formed by strain SM 35. SM 35 appears to be highly competitive among the strains identified to be most effective (Table 70).

Table 70. *Percent nodules* formed by inoculant strains (Ikenne, 1980).*

R. japonicum Inoculant strains		Cultivars TGm 294	TGm 119
SM 35		100	94
CB 1809		100	97
138		100	71
110		97	81
SM 35 + 110	SM 35	66	78
	110	27	18
SM 35 + 110 + CB 1809 + 138	SM 35	66	78
	110	27	18
	CB 1809	10	10
	138	5	5

**Based on 192 nodules/treatment*

Trials were conducted in 1979 and 1980 second season in the highly-acid Onne soil to select elite strains of *R. japonicum* for acid tolerance and N-fixing efficiency as reflected in growth and grain yield parameters.

In the first planting, soybean seeds, Bossier (TGm 80), Malayan (TGm 51) and 3H/1, were inoculated with each of 4 strains identified as being highly effective in the near neutral IITA soil. Two of these strains were marked with antibiotic resistance (spectinomycin or streptomycin) to enable subsequent identification. Two uninoculated treatments were included, the first with N (90 kg N/ha) in 3 doses and the second without N.

In the first planting, response to inoculation in terms of nodule weight, N content in shoots and grain yield was noticed only in Bossier (Table 71). In Malayan and 3H/1, the response was not significant due to effective nodulation by indigenous rhizobia in the uninoculated plots.

In the second planting, response to nodulation was again noticed only in Bossier, but the introduced strains formed only 65 percent nodules in the second planting compared to 100 percent nodules in the first planting. Also, nodule mass was significantly reduced in Bossier during the second planting compared to the first planting.

Although no reduction in nodule dry weight was noticed in Malayan and 3H/1 between the 2 plantings, strains IRj 2114 str formed 50 percent nodules and strain IRj 2101 spc formed only 6 percent nodules in the second planting compared to 90 percent and 70 percent, respectively, in the first planting. No significant differences between the inoculated and uninoculated plots were noticed in shoot weight, N content in shoots or grain yield in all 3 cultivars. These results indicated lack of acid tolerance, poor survival and poor competitive ability of introduced rhizobia (Tables 71 and 72).

Rhizobium inoculation effects on cowpea

Cowpeas nodulate with a wide range of rhizobia of the cowpea—cross inoculation group, which are abundant in most tropical soils. To confirm additional benefits, if any, of inoculant use to improve the grain yield of cowpeas, 6 cowpea cultivars were tested for their response to inoculation with diverse rhizobia in the near neutral soils at IITA, the highly acid soils at Onne and the semi-arid conditions at Gusau and Maradi.

In 1979 field trials at Onne, liming at 0, 250, 500, or 1,000 kg/ha had no effect on soil pH, the NH_4 extractable calcium levels or Al levels, indicating probably high base levels of calcium already existing in the soil. Nodule dry weights in the inoculated treatments comprising strains from Onne, Maradi and Mokwa were significantly higher at some calcium levels compared to the uninoculated treatments. However, the mean values for all the inoculated treatments did not significantly differ from those for uninoculated treatments. Fifty kg N/ha reduced the nodule mass by 50 percent. Among cultivars, Ife Brown had the highest nodule mass. There were statistically significant increases in shoot fresh weight in a few inoculant–host combinations; 50 kg N/ha resulted in significant increases.

In terms of grain yield, inoculation showed no significant positive response. Although large increases in shoot weight were noted with N fertilizer, no such increases in grain yield were noted even with the additional 50 kg N/ha at flowering.

In 1980, the same experiment was conducted in soils that were under cultivation for a longer period, but no responses to inoculation and/or liming were obtained in terms of shoot weight or grain yield.

Experiments conducted at IITA and Gusau also did not reveal any significant response to inoculation in terms of plant growth and yield (Table 73).

Table 71. Nodule dry weight at first and second plantings and shoot dry weight, percent N content in shoots and grain yield at first planting* of Bossier inoculated with* R. japonicum *in the highly acid Onne soil (Onne, 1980).

Treatments	Nodule dry weight mg/plant First planting	Nodule dry weight mg/plant Second planting	Shoot dry wt. g/plant	N Content in shoots %	Grain yield kg/ha
Uninoculated	34	63	3.8	2.3	361
N Fertilizer (90 kg N/ha)	39	101	4.5	1.8	813
R. japonicum					
IRj 2101 spc	215	51	7.0	3.0	1511
IRj 2114 str	221	72	5.6	3.6	1292
IRj 2111	396	125	6.8	3.5	1745
IRj 2123	258	85	7.4	3.3	1161
LSD (5%)	102	39	2.0	0.4	606

**No significant difference between inoculated and uninoculated in shoot dry weight, percent N content in shoots and grain yield during second planting.*

Table 72. Percentage of nodulation by* R. japonicum *on Bossier, Malayan and 3 H/1 during first and second planting (Onne, 1980).

Treatments	Bossier First	Bossier Second	Malayan First	Malayan Second	3 H/1 First	3 H/1 Second
IRj 2101 spc*	98	64	68	9	67	7
IRj 2114 str*	98	65	89	46	89	46

**2101 spc and 2114 str are strains resistant to antibiotics, spectinomycin or streptomycin, respectively.*

Table 73. Effect of Rhizobium *inoculation and fertilizer N (100 kg N/ha) on nodule dry weight (Mg/plant), shoot fresh weight (G/plant) and grain yield (kg/ha) of cowpea grown in different locations in Nigeria.*

Field location	Nodule dry weight Uninoculated		Nodule dry weight Inoculated	Shoot fresh weight Uninoculated		Shoot fresh weight Inoculated	Grain yield Uninoculated		Grain yield Inoculated
	−N	100 N		−N	100 N		−N	100 N	
ONNE 1979	90	40*	107	117	151**	116	1867	2007	1875
ONNE 1980	ND	ND	ND	59	63	55	1277	1056	1153
GUSSAU	63	54	53	91	93	101	932	985	950
IBADAN	134	62*	116	143	186**	148	599	591	601

ND = Not Determined.
**Significant reduction   **Significant increase.*
Differences between other means of uninoculated (−N and 100 N) and inoculated treatments at each location not significant.

Using the ELISA technique, nodule typing was done for 2 strains in order to assess the extent of nodulation by introduced marked *Rhizobium* strains in the field trials at IITA, Onne and Gusau. Nodulation by introduced *Rhizobium* strains was poor at Onne and Gusau while fair at IITA. This may be due to the fact that both the marked strains were isolated from IITA (Table 74), and apparently they were competitive with indigenous rhizobia only at IITA.

Table 74. Percentages of nodulation by Rhizobium *cowpea strains, IITA 4557 and NCP, on 6 cowpea cultivars* at 3 different locations in Nigeria (1980).*

Rhizobium Cowpea Inoculant strains	Locations IITA	Onne	Gusau
IITA 4557	68	37	39
NCP	50	24	24

**Data based on 96 nodules/cultivar mean of 6 cowpea cultivars.*

Another set of experiments was conducted in 1980 using single strain and mixed inoculants and local and improved cultivars at 3 locations, IITA, Onne and Maradi (Table 75).

Table 75. Effect of inoculation and N fertilizer on fresh shoot weight (g/plant) of selected cowpea cultivars (1980).

Inoculation* Treatment	Cultivar and location: IITA VITA-4	Onne VITA-1	Maradi TVx 1850-01E	Maradi Dan Haoussa
Uninoculated	86	113	20	70
IRc 283	ND	ND	66*	91
IRc 838A	ND	ND	63*	51
IRc 409A	99	131	26	87
IRc 409C	60	153	27	98*
IRc 409A + C	62	181*	ND	ND
IRc 462A	74	185*	ND	ND
IRc 462D	143*	147	ND	ND
IRc 499A + B	ND	ND	38	142*
N fertilizer	196*	215*	103*	139*
LSD (5%)	42	50	23	23

**Significantly different from the uninoculated control according to the Duncan's Multiple Range Test.*

At IITA, the growth of VITA-4 inoculated with IRc 462D was lower than with fertilization but higher than the uninoculated control. It was noted that for cowpea ER-1, N fertilization was not significantly better than the mixed inoculant consisting of IRc 409A and IRc 409C. This suggests that the mixed inoculant forms an effective symbiosis with cowpea ER-1.

At Onne, only VITA-1 responded positively to inoculation with cowpea *Rhizobium* IRc 462A and with a mixed culture of IRc 409A and IRc 409C. Increases were recorded in fresh shoot weight of more than 60 percent over the uninoculated control, but increases were similar to those obtained with N fertilization. There was no difference among treatments for TVx 1952-01E. This may be an indication that, for this cultivar, indigenous and inoculant rhizobia are equally suitable for effective N-fixation.

At Maradi, inoculation with mixed cultures of IRc 499A and IRc 499B was as beneficial to Dan Haoussa as N fertilizer; also, IRc 409C in symbiosis with this crop showed yield increases of 40 percent over the uninoculated control. VITA-5 with IRc 383A, TVx 1952-01E with IRc 461 (unpublished data) and TVx 1850-01E with IRc 283 and IRc 383A yielded significantly higher fresh shoot weights than in the corresponding uninoculated treatments.

These results based on fresh shoot weight indicate that some cowpea cultivars, such as VITA-4 at IITA, VITA-1 at Onne and Dan Haoussa at Maradi, respond to inoculation with specific cowpea rhizobia, at a particular location. Careful screening of the cowpea rhizobia may lead to identification of suitable strains for inoculant use with the high-yielding cultivars of cowpea such as the VITA lines as well as with farmers' varieties like Dan Haoussa. *Rhizobium* strain isolated at a particular location is not necessarily a better inoculant at that location than isolates from another, different environment.

Training Program

While inquiries and requests for training were received in increasing numbers from around the world, the Training Program continued to enjoy a wide patronage from tropical Africa. Past participants of the IITA training programs, on return to their national establishments, offered even greater opportunities to IITA for the development of collaborative research networks and testing of IITA's technology and improved planting material.

The main objective of the Training Program is to increase the number of scientific, technical and extension personnel who are equipped and motivated to contribute to research and development of food production in the tropics. During 1980, the following priorities were kept in sight.

(1) Providing a means by which cooperative relationships can be established and maintained with universities for degree-related research supervised by the Institute's scientists.
(2) Providing an arrangement by which agricultural technicians and research workers can be upgraded in their skills and trained in new technology.
(3) Providing for training of extension personnel so that they may become more effective as trainers of those who extend to the farmers packages of new technology and agricultural practices.

An IITA research scholar and an IITA entomologist examine green spider mites on cassava leaves.

Training activities

Present facilities at IITA permit the training of 250-300 participants per year in its 4 main categories. The details by category pertaining to 1980 and a reference to totals over the years is indicated below:

Degree-related research training program. Forty-four M.S. students from 12 countries, 30 Ph.D. students from 15 countries and 2 senior research fellows from Ghana and Mali were engaged in research under the supervision of the Institute's scientists during the year. In all, 18 countries were represented, 13 of which were African. The largest number of research scholars and research fellows were from Nigeria; they numbered 16.

From the inception of training activities at IITA in October, 1970, to the end of 1980, a total of 108 M.S. students and 65 Ph.D. students have been conducting the research component of their degrees at the Institute. A wide range of research projects were listed under the works of the 1980 M.S. and Ph.D. students.

Non-degree-related research training program. By the end of 1980, the number of participants who were provided the opportunity to acquire additional research and production skills at IITA under the guidance and direction of the Institute's scientists rose to 191. Of this number, 35 participants were in residence partly or wholly during the calendar year. Feedback obtained from organizations that nominated and/or sponsored such individual research, extension and production workers reaffirm that such short-term exposures to the scientific study of specific problems pay ample dividends.

Vacation student research scholarships. Interests of faculties of agriculture of universities in East and West

Students from around the world participated in the 1980 Root and Tuber Production Training Course.

Africa in the vacation student research scholarship program continue unabated. During the year, 12 such students conducted 3-3.5 month research projects, thus bringing the running total of vacation students in this program up to 156. Selecting the individual's particular area of research interest with the research projects put forward by IITA's scientists are the key factors in getting the students to make an on time start at the Institute. Ghana, Nigeria, Sierra Leone and Uganda were represented by vacation students in the year.

Group courses program. In 1980, a total of 8 group training courses were conducted with the attendance of 163 participants. Three out of these were crop production courses, and the rest were on particular areas of special research and production interest such as soil-plant analysis and post-harvest technology. The bilingual nature of IITA's group training courses continues to increase and expand. During 1980, 5 of the 8 group courses were English/French, and the total number of francophone candidates who participated in the 5 bilingual group courses added up to a record of 66.

From a grand total of 1,457 training participants over the last 10 years, group courses contributed over 60 percent in number having trained 884 participants up to the end of 1980 in its different courses.

A research training associate conducts soybean longevity research at IITA under the guidance of an IITA plant breeder.

Research Support

Introduction

Research support units provide essential services to the research programs—developed land and field services at IITA's 2 major sites (Ibadan and Onne, Nigeria) as well as planting material services through the Genetic Resources Unit. Support facilities also include the Virology Unit, Library and Documentation Center, Conference Center and Communications and Information Office.

High-rainfall substation

Onne continued research in farming systems and crop improvement 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 to assist the 4 major research programs at IITA. During 1980, an additional 10 ha of land was cleared making a total of 51 ha of land available for research. The Onne substation placed emphasis during the year on research involving soil fertility and erosion and weed science as well as plantain, cassava, sweet potato, maize, rice, cowpea and soybean, the reports of which are contained under the previous farming systems and crop improvement sections.

Research station operations

Farm management continued to provide field support as required by the scientific staff at IITA and the Onne substation as well as other sites in Nigeria. It also assisted IITA's cooperative projects in Upper Volta and Tanzania in terms of improving their research facilities.

Emphasis was placed on the use of no tillage and cone seeders—to conserve the topsoil and reduce high labor costs, respectively.

At IITA, a soil survey was carried out on all agricultural research blocks (280 ha) to determine the degree of degradation resulting from up to 12 years of cultivation. This was to assess the need for fallowing. Soil depth and texture, organic matter, available P and K, soil pH and exchangeable Ca and Mg were sampled during this survey. In addition, road and drain work, especially in the rice paddy and west bank areas, was carried out.

Farm staff continued to have considerable involvement with training courses organized by the crop improvement programs, and, in addition, a tractor driving course was held with 10 successful trainees. Farm staff conducted many field tours and received numerous visitors who generally showed considerable interest in shear blade forest clearing and no-tillage farming.

Screenhouses and plant growth facilities

During the year, a second virology screenhouse was completed (IITA Annual Report 1979). The 6 conventional glasshouses at IITA, which are generally too hot to be suitable for virology research, are largely used for soil science pot experiments and germplasm maintenance of various crops.

Genetic Resources Unit

The Genetic Resources Unit (GRU) continued throughout 1980 to collect, manage and preserve the germplasm of food legumes, rice and root crops from sub-Saharan Africa. In 6 plant collecting missions, 1,734 germplasm accessions were gathered. 291 from western and coastal Kenya, 358 from southern Sudan, 763 from Madagascar (including 500 of rice from the national collection held at Tananarive), 211 from Togo, 360 from Malawi and 251 from northeastern Zambia. The exploration in Togo was conducted by the Togolese Department of Agronomic Research and in Malawi and Zambia by the International Board for Plant Genetic Resources (IBPGR). The IBPGR also was active in helping the GRU plan its exploration in Madagascar and providing IITA with a consultant in southern Sudan. Besides the germplasm gathered in plant exploration, the GRU received 1,612 new accessions as donations from collaborators all over the world, 805 of which were rice from the Institute of Tropical Agriculture and Food Crop Research (IRAT). Thus, the total of acquisitions in 1980 was 3,846 new accessions.

The explorations of 1980 brought to an end the first phase of the work of the GRU when the chief objective was germplasm collection. Since 1976, when exploration began, the GRU has mounted 38 plant collection mis-

Inside view of virology screenhouse developed at IITA.

sions in 18 African countries and gathered 20,346 germplasm accessions (Table 1). The following are the countries explored and the number of missions to each: Nigeria (11), Togo (3), Ivory Coast (1), Tanzania (2), Zambia (1), Benin (2), Ghana (2), Sudan (2), Madagascar (1), Upper Volta (2), Egypt (1) and Malawi (1).

Germplasm evaluation. The GRU evaluated 2,000 new accessions of cowpea and 1,500 new accessions of Asian rice for botanical characterization during the year. These data, together with information about the provenience of each accession, form the basic documentation of the collections. The evaluation of response to pests and pathogens is made by scientists of the crop improvement programs. For example, the cowpea pathologist studied the susceptibility of 2,000 cowpeas from the germplasm collection to diseases in the forest zone at the IITA Onne substation and in the savanna zone at Funtua, Nigeria; 715 wild and cultivated cowpeas were evaluated at IITA for thrips infestation. Both disease and insect resistant or tolerant accessions were identified.

The reaction of African and Asian rice germplasm to blast disease and yellow mottle virus was studied by the GRU and the Cereal Improvement Program. Preliminary results indicated that 54 accessions of *O. sativa* out of 1,132 tested showed horizontal resistance to blast disease. On the other hand, very few *O. glaberrima* collections tested showed high susceptibility to blast; the majority showed hypersensitive reaction or no reaction.

The yield potential of some of the *O. glaberrima* cultivars is comparable to *O. sativa* or better, particularly under low fertility levels. For example, *O. glaberrima* (Kolon Kallan) yields 2.0 t/ha against O.S. 6 check yield of 1.25 t/ha.

Rice germplasm collected in Africa and stored in IITA's "germplasm bank."

Table 1. Germplasm collections from 1976 to 1980.

	1976	1977	1978	1979	1980	Totals
Missions	2	9	13	8	6	38
Food legumes	340	918	4,645	3,231	1,208	10,342
Rice	242	1,436	2,276	1,083	2,172	7,209
Roots	126	382	166	82	36	792
Other crops		87	759	727	430	2,003
Totals	708	2,823	7,846	5,123	3,846	20,346

Germplasm documentation. Up-to-date computer data banks for cowpea and rice germplasm were completed using a new genetic resources data management system. The cowpea data bank has information on up to 68 descriptors, including seed stores records, for 10,471 accessions while the rice data bank has information on up to 71 descriptors for 3,886 accessions (1,143 are *O. glaberrima*). These data are available to all users for selective retrieval and analysis.

The first African germplasm catalog is ready for publication as a summary of the data stored in the computer. The African rice germplasm is less diverse than similar sized collections of Asian rice, but there are interesting variations in the components of grain yields, plant architecture and physiological traits.

Germplasm distribution. In 1980, the GRU responded to 538 requests for 9,670 samples of germplasm. Fifty percent of these requests (272) came from scientists at IITA, and 18 percent (96) came from research workers in Nigeria outside IITA. The remaining 32 percent (170) came from scientists in 45 other countries or institutes around the world.

In the future, new germplasm will continue to be collected as donations from collaborators and occasional explorations, but the GRU's chief objective will be to ensure the security of existing collections at IITA and promote their use with well documented evaluation and the maintenance of viable seed stocks, which are freely available to all users from the 'working collections.'

The 2 largest and most important collections are cowpea and rice. The sources of accessions of these 2 crops are listed in Tables 2 and 3. The large proportion of the cowpea germplasm, which comes from Nigeria and India, is justified because these are the 2 world centers of diversity of the crop, and Nigeria is within the area thought to be the center of origin. When new cowpea accessions now at IITA have been processed into the collection during 1981, the total number will have increased to 12,252.

Table 2. Country of origin of IITA cowpea germplasm.

Country of origin	Number of accessions
Nigeria	2,712
No information	1,960
India	1,238
U.S.A.	769
Selections from mixtures	704
Niger	550
Egypt	329
Tanzania	272
Benin	246
Ghana	228
Upper Volta	187
Mali	171
Malawi	155
Ivory Coast	129
South Africa	108
71 other countries	691
Total	10,471

Table 3. Country of origin of the IITA rice germplasm.

Country of origin	Sativa	Glaberrima*
Nigeria	365	549
Liberia	285	588
Sierra Leone	343	27
Ivory Coast	294	36
Mali	13	116
Ghana	63	32
Senegal	28	57
Upper Volta	44	36
Tanzania	67	0
Cameroon	12	28
Zaire	40	2
Chad	16	21
Egypt	32	0
Guinea	0	13
Gambia	1	6
39 other countries	364	0
Total	1,967	1,511

**A total of 37 wild rice samples are included in this column from the following countries: Nigeria (15), Mali (6), Cameroon (3) and Chad (13).*

The greatest demand was for the cowpea germplasm for which published documentation has been available since 1974. There were 362 requests for 6,615 samples of cowpeas, 185 of which were for the elite "VITA" lines.

Among other requests were 42 for 194 samples of winged beans; 35 for 38 samples of the "Cita" lines of pigeon pea and 16 for 1,578 samples of rice, 1,203 of which were distributed as part of a standing agreement to share rice collections with the International Rice Research Institute (IRRI), the West African Rice Development Association (WARDA) and IRAT.

Germplasm preservation. An important objective of the GRU is to preserve the world collection of cowpea and the African collection of rice in long-term storage at −20°C. The store was installed in 1980, and processing rice germplasm for packaging in aluminum cans began at the end of the year.

"Base collections" are presently kept at 5°C, and working collections of up to 1 kg seed of each of the rice and cowpea accessions are stored at about 15°C with 40 percent relative humidity. By the end of 1980, there were

10,375 accessions in the working collections. The total will quickly rise to around 20,000, some 13,000 of which will be of cowpeas, 1,500 of African rice and the rest of Asian rice.

Genetic resources training. The first genetic resources training course for anglophone Africa was organized in February-March, 1980, in collaboration with the IBPGR and the Department of Plant Biology, University of Birmingham, England. There were 13 participants, and they represented Ghana, Kenya, Liberia, Nigeria, Sierra Leone and Uganda.

Virology Unit

To facilitate the control of virus diseases causing economic loss in the crops under investigation at IITA, the virology unit continued studies on the etiology of virus diseases in cassava, yam, sweet potato, cocoyam, maize, rice, cowpea and soybean. In addition, epidemiological studies as well as studies on resistance screening and indexing methods are aspects of work covered by this unit.

Cassava

Cassava mosaic disease (CMD). Further attempts to transmit the agent isolated from cassava mosaic disease (CMD) infected cassava back to cassava both by means of sap inoculation or through the whitefly vector failed. Attempts to first mechanically transmit the virus from *Nicotiana benthamiana* to *Jathropha podagrica* and from this species back to cassava by means of approach grafting were also unsuccessful. Apparently, the agent does not infect *J. podagrica*.

It was also found that approach grafting between the diseased and healthy cassava plants did not result in transmission. Transmission studies with CMD from diseased to healthy cassava plants and from diseased cassava to *N. benthamiana* involving the parasite plant *Cuscuta subinclusa* (dodder) also did not result in any positive transmission. This confirms findings elsewhere that whitefly-transmitted viruses are not dodder transmissible. These observations also confirm the poor distribution of the CMD agent in infected cassava plants (IITA Annual Report, 1979).

Further attempts were made to purify biologically active virus from artificially infected *N. benthamiana* and produce an antiserum. Higher yields of virus were obtained from infected roots than infected leaves. Purification was easier from roots than leaves since fewer plant constituents, which are usually contaminants in virus purification, coprecipitated with this virus. In spite of 4 injections into a rabbit, no detectable levels of antibodies were produced.

Yam

Yam mosaic virus (YMV). Although clear virus symptoms are not visible all the time, *Dioscorea rotundata* (white yam) and *D. cayenensis* (yellow yam) are apparently always infected with a virus belonging to the Poty-virus group. Three methods were compared for initial purification of the yam virus from *N. benthamiana:*

(1) 0.1 *M* Tris-buffer (pH 8.4) and 0.5 percent 2-mercaptoethanol; 8 percent ether and 8 percent carbon tetrachloride were used as solvents.

(2) 0.25 *M* phosphate buffer (pH 8.5), 0.01 *M* EDTA, 0.001 *M* cysteine and 0.5 percent 2-mercaptoethanol; 25 percent chloroform and 25 percent carbon tetrachlcride were used.

(3) 0.1 *M* phosphate buffer (pH 7.7), 0.01 *M* EDTA, 0.001 *M* cysteine and 0.5 percent 2-mercaptoethanol; 25 percent chloroform and 25 percent carbon tetrachloride were used.

The highest virus yield was obtained by the first method. Electron microscopic examination of purified preparations showed typical Poty-virus particles. Attempts also were made to purify the virus directly from field infected *D. rotundata*. The virus was successfully purified and produced the same symptoms on *N. benthamiana*, but the yield was very low.

Sweet potato

Sweet potato virus disease (SPVD). Work on the sweet potato virus disease (SPVD) involved further studies to confirm its interdependent components (IITA Annual Report 1978, 1979). To facilitate these studies, a set of 15 seedling clones from the highly susceptible cultivar Tlb 8 were established and graft inoculated with the disease in order to obtain a susceptible clone persistently developing characteristic and prominent symptoms. This screening for high susceptibility was carried out using an approach graft technique.

It was found that 11 of the 15 clones were susceptible to the disease, developing symptoms in various degrees of severity; whereas, most of the clones initially reacted with a more severe shock reaction. The initially severe symptom expression faded into a mild to absent symptom expression in most of the clones. Only 2 of the 15 clones persistently developed prominent symptoms, including extensive patchy necrosis in the leaves and defoliation from the fifth to the tenth leaf onward.

One of these 2 clones, Tlb 8 clone 9, because of its reliable symptom expression as observed over a period of 8 months, was selected as the test clone for further work. It also was selected and used as a test clone for indexing purposes.

The interdependence mechanism of both components in sweet potato was further investigated by means of graft transmission studies. One part of Tlb 8 clone 9 was inoculated with the aphid-transmitted component and further propagated after positive infection had been confirmed by means of indexing to *Ipomoea setosa*. Another part of the clone was graft infected with the whitefly-transmitted component. This component was earlier found to be present in a sweet potato seedling clone, which had been grown under non-insect-proof conditions, and had developed severe symptoms on mechanical inoculation with the aphid-transmitted component (IITA Annual Report 1979).

Neither part of Tlb 8 clone 9 revealed any virus particles on electron microscopic investigation of crude juice samples; whereas, *I. setosa* grafted to the aphid-transmitted component infected part of Tlb 8 clone 9 revealed numerous Poty-particles and also showed the characteristic symptoms associated with the Poty component.

The sensitive ELISA serological technique was applied using an antiserum to the aphid-transmitted component. No positive reaction was obtained when either part of Tlb 8 clone 9 was tested. Thus, interdependence is not absolute since in *I. setosa*, the aphid transmitted component can multiply and develop symptoms. Interdependence in sweet potato, however, exists to some degree since propagation to electron microscope and ELISA detectable levels of Poty-particles as well as symptom expression apparently depends on the presence of the whitefly-transmitted component.

From sap inoculation experiments with the Poty-virus obtained and propagated in *N. benthamiana* (IITA Annual Report, 1979) to sweet potato, it could be concluded that infection does occur and is not dependent on the whitefly-transmitted component. This followed from a sap inoculation experiment involving 30 seedling clones of TIS 1499 origin. After 10 months and still being completely symptomless, these clones were indexed for positive infection by means of approach grafting to cuttings of a clone containing the whitefly-transmitted component. After 6 weeks, the first 2 clones started to develop symptoms, which means that infection with the Poty-component had occurred. Also, it proves that indexing by means of approach grafting to single component infected parts of susceptible clones seems to provide a reliable method of indexing for both components individually.

In 1979, the aphid-transmitted component was purified and an antiserum produced. Since sweet potato and *I. setosa* are very slimy on grinding, the commonly used microprecipitin test is difficult to conduct even after clarification of the juice. Therefore, ELISA was used as an alternative, sensitive test to identify the virus. The ELISA test was developed, and 50 field samples, which included plants with good symptoms, mild symptoms and healthy-looking plants were tested. Plants with good symptoms and mild symptoms as well as a few healthy-looking plants were positive by ELISA test.

In further experiments, attempts were made to detect the presence of virus in sweet potato when only the Poty-component was present. These tests were negative; however, *N. benthamiana* and *I. setosa* infected with the aphid-transmitted component alone gave positive results. The virus concentration in sweet potato infected with the Poty component alone is not sufficiently high to be even detectable by the sensitive ELISA technique.

Cocoyam

Dasheen mosaic virus (DMV). Results from serological tests performed at the University of Florida, U.S.A., with some isolates of the virus occurring in cocoyam in Nigeria have confirmed that dasheen mosaic virus (DMV) is involved.

Since obviously infected plants are rarely found in the field, a long-term observation on an artificially infected seedling population (25 plants) from a Nigerian cultivar was performed.

Initially, all 25 seedling plants developed prominent symptoms within 2 weeks after inoculation; however, gradually, symptom expression faded in the plants. Only 8, 6 and 5 plants showed symptoms after 4, 6, and 7 months, respectively. In a few cases, a single symptomatic leaf developed on the other plants, which, otherwise, remained symptomless throughout the period of observation.

Host range studies included inoculation of the only known alternate host, *Philodendron selloum*, and *N. benthamiana* and *N. glutinosa*. The latter 2 *Nicotiana* species, as found elsewhere, did not become infected.

Seedling plants of *P. selloum* were found to be unsuitable as a test plant for this virus since only about half of the plants in the population proved to develop some form of not very conspicuous and transient symptoms. Only about 2 percent of the plants developed severe chlorosis and distortion symptoms, which, like in the case of cocoyam, also tended to fade and fully disappear.

It is reported that *P. selloum* is a good source for virus purification. Attempts were made to purify the virus from this host. Systemically infected *P. selloum* leaves approximately 2 weeks after inoculation were used as virus source. One hundred g of tissue were homogenized in a blender in 200 ml of 0.1 *M* phosphate buffer (pH 7.7) and 0.01 *M* EDTA, 0.001 *M* cysteine and 0.1 percent 2-mercaptoethanol. Fifty ml of chloroform and 50 ml of carbon tetrachloride were added. The homogenate then was centrifuged at 7,700 g for 10 minutes. The aqueous phase was separated and centrifuged at 20,000 rpm for 90 minutes. After another cycle of low- and high-speed centrifugations, the virus preparation was layered on a 10-40 percent sucrose gradient. The virus peak was collected and concentrated by centrifugation. The purified virus preparation was highly infective, and typical Poty-virus particles were observed under the electron microscope.

Maize

Maize mottle/chlorotic stunt (MMCS). In greenhouse inoculation experiments, it was found that within the improved maize populations, TZB and TZPB, the maize mottle/chlorotic stunt disease (MMCS) syndrome may vary from a transient mottle of the young, unfolding, whorl leaves in most plants to severe chlorosis and complete growth check at an early stage in a few plants in the population. The latter leads to the young, emerging leaves sticking together in a tight bundle and becoming necrotic, which then leads to severe physical obstruction in further development of such plants, usually resulting in stem rots and complete die-back.

On closer monitoring, this phenomenon also was found to occur in field grown maize at all developmental stages up to tasseling. Shoot bending and "tailing" was a type

Symptoms of maize mottle/chlorotic stunt in sorghum producing many chlorotic and neucrotic tillers.

of symptom expression observed in infected plants in the greenhouse as well as field. Early infections occurred as transient mottle in the majority of the plants in the improved populations; in later stages of infection, varying degrees of severity of the "poor-growth" syndrome with progressively shortening internodes and a general deficiency-like interveinal leaf yellowing were observed.

This disease occurred throughout the southern Guinea savannah zone in Nigeria. Where maize production was practiced on a large scale with improved but streak (MSV) susceptible varieties, the maize mottle incidence (pure, without streak) exceeded 10-15 percent in the later part of the growing season. MSV incidence in the same fields exceeded 50 percent. In many cases, however, double infection with these 2 diseases, transmitted by the same leafhopper vector, was observed.

Some grasses in the vicinity of maize were commonly infected with streak (± 50 percent); whereas, those farther away were only occasionally infected. Obviously, epidemics of MSV in wild grasses can originate from maize crops nearby. Sorghum in farmers' fields around the maize was affected by a serious and epidemic disease of nearly 100 percent incidence. The disease manifesting itself solely in tillers, and from the general appearance of the symptoms, the disease was thought to be a manifestation of maize mottle virus. Further evidence for this was later obtained from artificial inoculations of millet and sorghum seedlings about 2-3 weeks after inoculation; however, symptoms were completely transient and newly emerging leaves did not develop any further chlorosis/necrosis. Similar to the symptoms observed in the field were the symptoms that later developed in the emerging tillers of the sorghum plants that were artificially inoculated. Many tillers showing severe chlorosis, distortion, leaf tip and marginal necrosis developed at the later stages of growth.

A disease of this kind in millet or sorghum in the major growing areas of these crops in northern Nigeria has not been reported yet. Large-scale introduction of a relatively new crop like maize into these areas, traditionally growing millet and sorghum, may in the future result in dramatic shifts in the ecology of the maize mottle disease, resulting possibly in a new disease similar to that observed in sorghum around large-scale maize production.

In leafhopper cage inoculation experiments of millet, the *Cicadulina* population was shown to build up on this graminaceous crop species without streak infection. Thus, millet may be a more suitable vector rearing host than maize, which will make rearing and maintaining streak-free, leafhopper cultures possible. So far, this was not possible because continuous reinfection of leafhopper colonies proved to occur in several attempts to eliminate streak contaminations from the rearing cultures. Another advantage of millet as a vector rearing host over maize proved to be the inability of aphids (*Rhopalosiphum maidis*), a severe pest of maize, to build up.

Maize dwarf mosaic virus (MDMV). Thirteen maize varieties and breeding lines were tested for resistance to an isolate of maize dwarf mosaic virus (MDMV). Some of these varieties and lines have resistances to other virus diseases, including MSV, maize rough dwarf virus and MDMV (Table 4).

IITA's MSV resistant TZSR—white population, earlier found to be resistant to maize mottle/chlorotic stunt and maize stripe virus (IITA Annual Report, 1979), only developed relatively mild symptoms in about half of the plants inoculated. It can, thus, be considered moderately resistant to MDMV.

IITA's MSV resistant TZSR—white population, thus, combines high levels of resistance to 4 different virus diseases of regional or continental importance in Africa.

MDMV was purified as previously reported (IITA Annual Report, 1979). The preparations were emulsified with an equal volume of Freund's incomplete adjuvant and injected into a rabbit at weekly intervals. Five intramuscular injections were given, and 2 weeks after the last injection, bleedings were started at weekly intervals. An antiserum with a titer of 1/1024 was obtained as assayed by a microprecipitin test.

Table 4. Reaction of a selection of virus resistant and other maize materials to infection with maize dwarf mosaic virus (MDMV).

Variety or line tested	Other resistances	Symptom expression with MDMV: Incidence 1)	Severity rating 2)
B 73		8/8	3-4
B 37		2/8	2
B 68 MT	MDMV; MMV-1	0/9	1
MO 17		5/5	4-5
IB 32 (S_3) × 14	MSV	4/12	2-4
IB 32 (S_3) – 8	MSV	1/2	3
OH 43 UT		7/8	4
H 95	MRDV	10/10	5
TZB		0/6	1
TZPB		4/13	1-3
TZSR—white	MSV	6/15	2
IB 32 × La Revolution	MSV	11/18	2/3
B14 AHT	MDMV, MMV-1	0/2	1

1) Number of plants developing symptoms/number of plants tested.

2) Severity rating 1-5: no symptoms—very severe symptoms.

MDMV—Maize dwarf mosaic virus; MRDV—Maize rough dwarf virus; MMV-1—Maize mosaic virus; MSV—Maize streak virus.

Cowpea

Cowpea virus diseases (CYMV, CAbMV, CuMV, CMeV, CGMV, and CMMV). A simple separation and differentiation scheme, involving a few selected test plants, was developed to identify cowpea mottle virus (CMeV), cowpea yellow mosaic virus (CYMV), cowpea aphid-borne mosaic virus (CAbMV) and cucumber mosaic virus (CuMV) in mixed infections. Specific susceptibility and resistance (immunity) to these 4 most important sap-transmissible cowpea viruses enables separation and preliminary identification (Table 5).

By serial inoculation to 3 test plant species in various sequences, separation of most double or multiple infec-

Table 5. Test plant differentiation scheme used to separate 4 cowpea viruses.

Test plant	Immune (resistant) from	susceptible to
Nicotiana benthamiana	CMeV	CYMV; CAbMV; CuMV
Nicotiana glutinosa	CYMV; CAbMV; CMeV	CuMV
Vigna unguiculata 'TVu 410'	CYMV (hypersensitive)	CAbMV; CMeV; CuMV

tions with the above mentioned viruses was possible. The scheme has also proved useful in routine checks for purity of the resistance screening isolates of these 4 viruses used in the cowpea improvement program and maintained by the virus unit.

Resistance screening for CAbMV and CYMV, with particular emphasis on segregation, was conducted with 55 advanced breeding lines and established varieties included in the 1980 large seed nursery No. 2 of the international testing program. It was found that quite a number of lines still show some form of segregation with regard to resistance. Mass selection within populations appears to be useful in removing the susceptible population fractions.

Susceptibility to CYMV was found to exist in 35 of the 55 introductions and at levels considered too high for these varieties to be safely grown in areas where CYMV occurs.

Massive infection with CuMV, not earlier considered to be of sufficient importance to specifically screen for it, was identified in the cowpea variety Ife Brown at Mokwa, Nigeria, in the southern Guinea savannah.

Preliminary attempts to purify CAbMV using different combinations of buffers and n-butanol did not yield any encouraging results. However, when the buffer and the solvents were changed, it was possible to get small quantities of virus. The following procedure was developed that gave satisfactory results: Infected leaves were homogenized in a blender with 0.25 *M* phosphate buffer (pH 8.5) and 0.5 percent Na_2SO_3 and 0.1 percent 2-mercaptoethanol. The resulting extract was filtered through a double layer of cheese cloth and 25 percent chloroform and 25 percent carbon tetrachloride were added. The mixture was stirred for 2-5 minutes. The emulsion was broken by low-speed centrifugation. Virus particles were precipitated from the supernatant by addition of 6 percent polyethylene glycol (PEG). The precipitate was collected by centrifugation at 10,000 rpm for 10 minutes. The resulting pellet was resuspended in 0.01 *M* phosphate buffer (pH 7.7) containing 0.001 *M* EDTA and 0.001 *M* cysteine. After another cycle of low-speed centrifugation at 20,000 rpm for 90 minutes in a Beckman 30 rotor, the virus was resuspended in 0.01 *M* phosphate buffer (pH 7.7) containing 0.001 *M* EDTA. The virus was further purified by centrifugation through sucrose density gradient columns. It gave a single virus peak, which was infective on inoculation to cowpea seedlings.

Cowpea aphid borne mosaic virus (CAbMV). CAbMV was transmitted through the seed of each of the 4 cowpea accessions (Table 6), all of which were known previously to be very susceptible to CAbMV infection. However, there appeared to be differences between accessions in the rate of seed transmission, ranging from a mean of 1.1 percent for TVu 37 to 12.0 percent for TVu 54 following artificial inoculation.

There was clear indication that seed-borne infection may lead to higher rates of seed transmission than artificial inoculation of seedlings (Table 6), and it seems probable that this is related to plant age at time of infection.

Table 6. Variation in the rate of seed transmission of CAbMV[1] in 4 cowpea accessions.

	Transmission (%)			
Accession	Artificial %	inoculation N[2]	Seed-borne %	infection N
TVu 22	1.8	165	7.1	127
TVu 37	1.1	91	6.3	179
TVu 54	12.0	25	18.3	60
TVx 309-1G	6.0	151	18.0	466

[1]*CAbMV-7132 in* N. benthamiana.
[2]*Total seedlings examined.*

There was some indication that CAbMV isolates may differ in their seed transmissibility (Table 7), but there was no evidence that isolates may become host-adapted since an isolate from the accession TVu 37 was transmitted at a lower rate through seed of that accession than were 2 other isolates from different sources.

The significant differences in seed transmission rates among varieties suggest there is a potential for screening against seed transmission of CAbMV.

Table 7. Effect of CAbMV isolate on seed transmission rate in cowpea TVu 37.

	Transmission (%)			
Isolate	Artificial %	isolation N[1]	Seed-borne %	infection N
CAbMV-37	0.71	274	3.5	66
CAbMV-54	4.0	126	3.8	420
CAbMV-7132	2.1	242	8.3	277

[1]*Total seedlings examined.*

Cowpea mild mottle virus (CMMV). Twenty-eight entries in the 1979 international cowpea trial, (see under soybean) all representing advanced breeding products, were tested for resistance to cowpea mild mottle virus (CMMV). None of the introductions developed any systemic symptoms, and no virus particles were found in any of the lines in electron microscope investigation.

Twenty-five germplasm introductions, representing a random cross section of cowpea genetic diversity were tested, and 4 introductions developed necrotic local lesions on the inoculated primary leaves, followed by systemic vein yellowing and/or necrosis. The vein necrosis reaction resulted in a prominent leaf curling and twisting, usually followed by abscission.

Among these, TVu 1582 was found to be a suitable indicator plant for this virus, developing well defined brown, necrotic local lesions followed by extensive systemic vein necrosis and leaf abscission in about 25 percent of the plants. All introductions developing visible symptoms were northern Nigeria cultivars. Virus particles were found in 14 of the 25 inoculated introductions.

Cowpea golden mosaic virus (CGMV). Virus-vector studies under greenhouse conditions indicated that the acquisition threshold for the Onne, Nigeria, isolate of the cowpea golden mosaic virus (CGMV) and the Ibadan, Nigeria, isolate of the lima bean golden mosaic virus (LBGMV), both transmitted by the whitefly *Bemisia tabaci Genn.*, was about 7 minutes. The inoculation threshold was about 2 minutes. The minimum latent period of CGMV and LBGMV were approximately 8 and 6 hours, respectively, with extrapolated LP 50 (the time 50 percent of whiteflies completed their latent period) of about 17 and 14 hours, respectively.

Both CGMV and LBGMV were persistently but erratically transmitted by *B. tabaci* that had a 24-hour acquisition access period on source plants. Under normal ambient conditions, maximum retention of infectivity of CGMV and LBGMV by female whiteflies were 21 and 9 days, respectively. Female adult whiteflies were more efficient transmitters (72 percent) than males (53 percent). Two to 3 adult whiteflies could cause 100 percent infection under greenhouse conditions. Preliminary studies suggest that virus may be acquired during the nymphal stages of development, thereby, making emerging adult whiteflies from infected plants viruliferous.

A southern bean mosaic virus isolate obtained from the University of Ife, Nigeria, and originally isolated from cowpea in Oyo State, Nigeria, was purified using 0.1 *M* phosphate buffer (pH 7.4) and 0.1 percent 2-mercaptoethanol. To the homogenates, 50 percent chloroform was added. The emulsion was broken by low-speed centrifugation. The virus particles were further concentrated from the supernatant by high-speed centrifugation at 28,000 rpm in a Beckman 30 rotor for 3 hours.

The pellet was resuspended in 0.01 *M* phosphate buffer (pH 7.4) and 0.003 *M* $MgCl_2$. After another cycle of low- and high-speed centrifugations, the virus preparation was layered on top of a sucrose gradient column. A single virus peak was obtained, which was collected and reconcentrated by centrifugation. The final pellet was resuspended in 0.01 *M* phosphate buffer (pH 7.4). A series of intramuscular injections were given to rabbits at weekly intervals. The immunized rabbits were bled every week starting 3 weeks after the last injection. The antiserum titer varied in agar gel diffusion tests, from 1/256 to 1/2,048, depending upon bleeding dates.

Soybean

Soybean Abuja virus. The spherical virus, earlier isolated from soybean in Abuja, Nigeria, (IITA Annual Report 1978), has some resemblance to tobacco streak virus (TSV). Serological tests were done using antisera to 2 different isolates of TVS—1 from tobacco in the U.S.A. and 1 from soybean in Brazil; however, no positive reactions were obtained with this soybean virus both in microprecipitin and in agar gel double diffusion tests. The ELISA test was developed using an antiserum earlier prepared against this virus, and the results are promising.

One of the CMMV isolates earlier described as causing a severe disease in soybean (IITA Annual Report 1979) was found to differ from other isolates of this virus, which are causing only very mild symptoms or none at all. Indications were obtained that "severe" isolates still contain another virus in addition to CMMV. This other virus is responsible for the severe symptom expression. Attempts to separate it by means of differential hosts have so far only yielded the mild type, being typical CMMV, by passage through *Phaseolus vulgaris*.

Initial purification attempts were made using frozen tissues and 0.25 *M* borate buffer + 0.5 *M* urea and 0.15 percent thioglycollic acid (pH 8.1). The extract was emulsified with a mixture of equal volumes of chloroform and carbon tetrachloride. The virus was precipitated by adding polyethylene glycol to 5 percent and sodium chloride to 1 percent. The virus yield was high using this procedure.

In addition to these 2 soybean viruses during the 1980 second season, a new Poty-virus was found to occur in soybean at IITA. Host range studies have shown that *N. benthamiana* can be readily infected with it, developing severe symptoms; whereas, both the severe and the sublatent type of CMMV were only found to infect *N. benthamiana* latently.

Canavalia ensiformis (jack bean, sword bean) and *Sphaenostylis stenocarpa* (african yam bean) were developing very prominent mosaic and distortion symptoms, strongly reminiscent of the virus diseases naturally occurring in these crop species (IITA Annual Report, 1977). No symptoms developed in the cowpea variety Ife Brown; thus, it is unlikely that cowpea aphid-borne mosaic virus is involved since Ife Brown is highly susceptible to that virus. Three known hosts of peanut mottle

Symptoms induced in sword bean (Caravalia ensiformia) with a new Poty virus from soybean.

virus, a Poty-virus described from soybean and other crops in East Africa and elsewhere, were tested. These hosts, *P. vulgaris* 'Top Crop,' *Phaseolus lunatus* and *Arachis hypogeia*, remained symptomless and uninfected; thus, it seems that still another so far unidentified virus is involved, possibly also causing the severe and common virus diseases of jack bean and african yam bean.

Nineteen soybean breeding parents with CMMV containing the severe component were tested; only TGm 344 and TGm 662 were found to be resistant (hypersensitive reaction) to this isolate though latent infection with the ordinary type of CMMV proved to occur.

These 2 introductions were tested with the new Poty-virus, and they were found to be susceptible developing the same prominent mosaic and leaf twisting symptoms as other introductions tested. Also, in the main growing season, another Poty-virus was isolated from soybean showing mosaic symptoms. On testing with antisera to soybean mosaic virus, positive reactions were obtained. This isolate was twice transmitted by aphids and electron microscopically checked for absence of the carlavirus, commonly found to occur in soybean.

A purification procedure was developed after testing several methods. Leaves of artificially inoculated soybean plants were collected and chilled. They were homogenized in 0.1 *M* phosphate buffer (pH 7.7) and 0.01 *M* EDTA and 0.001 *M* cysteine and 0.1 percent 2-mercaptoethanol. The extract was clarified by using 25 percent chloroform and 25 percent carbon tetrachloride. After low- and high-speed centrifugations, the pellet was resuspended in a 0.01 *M* phosphate buffer (pH 7.7) and 0.001 *M* EDTA. After another cycle of low- and high-speed centrifugations, the virus preparation was layered on top of a sucrose gradient. The single virus peak was collected, which was highly infective. The virus preparations have been injected to rabbits, and an antiserum is anticipated soon.

Analytical Service Laboratory

The Analytical Service Laboratory provided a range of analytical services to support research in all programs during 1980.

Assays routinely performed included chemical and physical analyses of soils, chemical composition analyses of water samples and nutrient content analyses of plant tissues. During 1980, the laboratory analyzed a total of 5,910 soil samples, 11,189 plant samples and 5,805 water samples. A total of 69,125 assays were carried out. The number of analyses for IITA has increased during the last few years.

Biometrical Unit

During 1980, the biometrician participated in 3 training courses. He gave lectures on the basic design of experiments, the analysis of experimental data and the interpretation of experimental results.

Besides the many consultations with IITA staff and students, the biometrician developed a theoretical approach to the use of the scores in selecting material for genetic improvement. It was stated that the technique is most useful in the case of large numbers of entries that must be screened for possible resistance to some pest or disease. Thus, work is in terms of a subjective probability, which may estimate and measure the belief of the scientists as to the closeness of any entry to the susceptible or resistant check. Finally, considerable headway was made in the analysis of long-range experiments on 5 crops and 22 mulches, which has lasted 5 years.

Conference Center

Conferences. The following conferences were organized during 1980:

- Leadership Conference for Agricultural and Allied Workers of Nigeria, 31 January-2 February.
- New Pests of Cassava Workshop, 10-12 March.
- Root Crops Symposium, 8-12 September.
- Petit Peste Ruminant (PPR) Workshop, 22-26 September
- Agricultural Development Projects Meeting, 29-30 September.
- International Potassium Conference, 8-11 October.

Visitors. IITA continues to attract a large number of visitors interested in the research programs and in planting material and seed of improved varieties. During 1980, approximately 200 secondary and university students in addition to approximately 90 church and other service organizations visited IITA. Technical college students now routinely visit IITA for discussions with scientists just prior to their final examinations. Many have expressed the desire to return to the Institute as part of an "industrial attachment" after graduation so that practical skills learned at IITA could be usefully transferred to the nation.

Seminar program. Thirty research seminars were presented during 1980, ranging from a series of 3 seminars presented by staff of the Plant Environmental Laboratory of the University of Reading, England, to a special seminar by the Director of the Land and Water Division of the Food and Agriculture Organization (FAO), Rome.

Library and Documentation Center

The Library and Documentation Center added 1,800 volumes of books and 1,700 volumes of periodicals to its collection during 1980. The collection in December, 1980, consisted of 17,600 books, 21,350 volumes of periodicals, 3,200 pamphlets and reprints, 3,414 microforms, 1,600 slides and 33 cassettes. The monthly indexed list of accessions as well as the monthly *Grain Legume Current Titles* were produced throughout the year.

Library use. Use of the library by IITA staff and trainees continues to increase. The library has become the major resource for the entire agricultural and biological research and training community of Ibadan. Over the years, use of the library by researchers, university lecturers, consultants, students and others not associated with IITA has increased tremendously (Fig. 1).

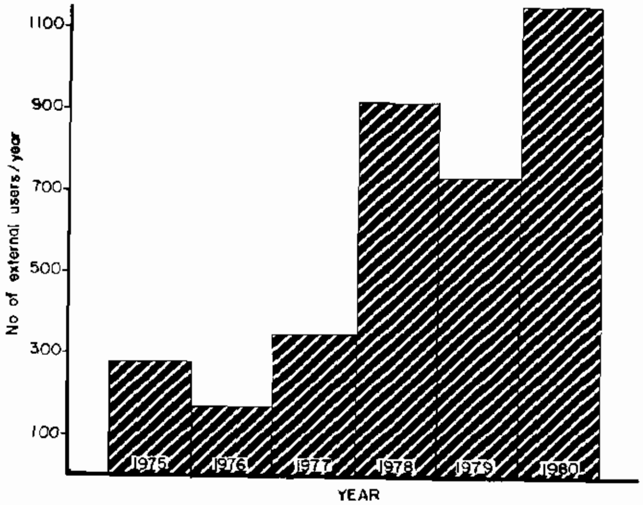


Fig. 1. Use of IITA Library by non-IITA staff.

International Grain Legume Information Center (IGLIC). The proposal for the second phase of the International Grain Legume Information Center was approved by the International Development Research Center (IDRC) during 1980. During this second phase, an IDRC grant will enable the information center to continue publication of the *Tropical Grain Legume Bulletin* as well as compile and publish the third volume of the *Abstracts of the World Literature on Cowpeas* and a manual on an aspect of grain legume research and development.

The information center will also continue to search the literature and provide photocopies for grain legume workers around the world. In 1980, the information center published 2 issues, Nos. 17/18 and 19, of the *Tropical Grain Legume Bulletin*.

Communications and Information Office

Editing and printing as well as audio-visual services took a substantial part of the time of the Communications and Information Office's staff.

Publications. Some publications that were edited during the year include the *IITA Research Briefs, Annual Report 1979, Research Highlights 1979* and journal articles.

Major publications edited and printed at IITA during 1980 include the following:

(1) Survey of Food Crop Farming Systems in the "ZAPI-EST" East Cameroon, IITA/ONAREST.
(2) Benchmark Surveys of Three Crops in Nigeria—Wheat, Millet and Sorghum.
(3) Evolution of the Program of the International Institute of Tropical Agriculture, 1967-1980.
(4) Crop Genetic Resources in Africa, AAASA/IITA.
(5) Tropical Grain Legume Bulletin, Nos. 17/18 and 19.
(6) Agronomy Training Manual for Agro-service Agronomists.
(7) Rapid Multiplication of Yam.
(8) Selected Methods for Soil and Plant Analysis (revised edition).
(9) Cocoyam Breeding by Flower Induction, Pollination and Seed Germination.
(10) Field Guide for Identification and Control of Cassava Pests and Diseases in Nigeria.

Major IITA publications edited at IITA and printed abroad during 1980 include the following:

(1) IITA Research Highlights 1979.
(2) Le point de la recherche a l'IITA 1979.
(3) IITA Annual Report 1979.
(4) Cowpea Pests and Diseases.
(5) Les insects nuisibles et les maladies due niébé.
(6) Parasitos y Enfermedades del Caupi.
(7) Weeds and Their Control in the Humid and Subhumid Tropics.

Translations. Several documents were translated from English to French and from French to English; the major translation accomplished was *Le point de la recherche a l'IITA 1979*.

Distribution. A total of about 20,000 copies of IITA's publications were distributed to about 4,500 requestors in 128 countries.

Training. One photographer from a Nigeria agricultural research institute received training for 3 months in IITA's photolab.

Fair. IITA participated for the first time in a science fair —Nigeria's First National Science and Technology Fair in Lagos. This fair offered IITA an opportunity to show its major achievements to the public, and a fair cross-section of the public was able to learn about IITA.

Nigeria's first National Science and Technology Fair was held in early December in Lagos, and IITA was present. The Communications and Information Office exhibited the Institute's improved crops and appropriate small tools to approximately 1,500 people during the show.

Special Projects

Introduction

Special projects are extra-core funded, medium-term projects (1-5 years) that contribute to the achievement of the Institute's research goals. Special projects fall into 3 categories: cooperative projects, training and collaborative research projects and core supplementary projects.

Cooperative projects

Cooperative projects involve cooperation between the Institute, a national government or regional body that requests IITA's involvement and, when necessary, a funding agency. The national or regional agricultural research and development program will generate scientific and technical information of relevance to IITA's research mandate and will incorporate a training component to prepare appropriate staff to assume overall responsibility for the program at an early date.

Cooperation with national programs

Sierra Leone. Since 1974, IITA has been under subcontract with FAO to execute a UNDP funded project aimed at strengthening rice research in Sierra Leone. Under the present phase of the subcontract which expires December 31, 1980, IITA has had a team of 2 scientists; an agronomist and an extension agronomist, undertaking a number of agronomic experiments and executing a program of on-farm trials of improved packages of rice technology.

Ghana. In June, 1979, IITA entered into a contract with USAID calling for IITA to place 2 scientists at Atebubu in Central Ghana to undertake studies aimed at improving food crop farming systems in the region. The 2 scientists are agronomists, and they are presently on site at Atebubu undertaking preliminary surveys of existing farming systems.

IITA is also collaborating with the Ghanian Grains Development Board scientists and their resident CIMMYT maize scientist on a program of cowpea improvement research. No full time IITA scientist is assigned to this effort, which is funded under a grant from the Canadian Government to CIMMYT.

Upper Volta. A grant from IDRC has enabled IITA to place since 1977, a plant breeder in Ouagadougou to assist the Government of Upper Volta in developing its National Cowpea Improvement Program.

Nigeria. IITA has been participating in the National Accelerated Food Production Project (NAFPP) since 1974, first under a grant from USAID and since July, 1977, under a grant from the Nigerian Government. Under the Nigerian Government grant, 8 IITA scientists were involved in supporting various aspects of the NAFPP. Since December, 1980, 1 IITA staff member, a communications specialist, remains and will serve under NAFPP till May 31, 1981.

Cameroon. IITA is involved in 2 projects in Cameroon, the Cameroon National Root Crops Improvement Program (CNRCIP) and the ZAPI-Est Farming Systems Research Project. Funds from the Belgian Government and IDRC enable IITA to provide 2 agricultural scientists, a plant breeder and an agronomist, to CNRCIP, which focuses on cassava, sweet potato, yam and cocoyam improvement. An IITA agronomist is stationed in eastern Cameroon under the IBRD funded ZAPI-Est Project to develop over a 3-year period a long-term plan for food crops research in the area. IITA is presently negotiating its participation under a grant from USAID in the Cameroon National Cereals Research and Extension (NCRE) Project. NCRE would cover maize, rice, sorghum and millet. IITA would seek ICRISAT's participation in the sorghum and millet aspects of NCRE.

Zaire. Since 1974, IITA has been assisting the Government of Zaire in developing its national cassava program, Programme National Manioc (PRONAM), first under a contract with the Zairian Government and since May, 1980, under a contract with USAID. With USAID support, IITA is to provide a team of 8; an agronomist, a plant breeder, an entomologist, 2 extension agronomists, a training officer, a physical-plant services officer and an administrator.

Tanzania. IITA and, through subcontractual arrangements, CIMMYT and ICRISAT are involved in strengthening food crops research in Tanzania and developing an improved food crops research station at Ilonga. IITA is providing an agricultural engineer, an agricultural economist and a team consisting of a plant breeder and an agronomist to work on grain legumes. CIMMYT is providing a plant breeder and an agronomist for maize improvement, and ICRISAT is providing a plant breeder to work on sorghum.

Sao Tome. IITA is assisting the Republic of Sao Tome and Principe (RSTP) in establishing a national food crop trials program involving rice, maize and grain legumes. IITA does not have a full time scientist assigned to RSTP, rather 2 Sao Tomeans have received concentrated training in establishing and evaluating food crop trials, and IITA scientists make several trips per year to Sao Tome to guide and evaluate the effort, which is funded under a contract with USAID.

Sri Lanka. An IITA agricultural engineer is assigned to Sri Lanka to develop an agricultural engineering program focused on developing small tools and machinery for low resource food crop farmers in the tropics. Although part of a national effort, tools and machinery developed would be relevant to food crop farming systems throughout the tropics.

Niger. Under a grant from IDRC, IITA is undertaking in collaboration with the Institute National de Recherches Agronomiques (INRAN) of Niger a study of drought tolerance in cowpea.

Regional Cooperation

SAFGRAD. Under a contract with USAID, IITA is providing 4 scientists to participate in the Semi-Arid Food Grains Research and Development (SAFGRAD) project. The scientists, all based in Ouagadougou, are a maize breeder, a maize agronomist, a cowpea agronomist and an entomologist. The cowpea agronomist works closely with the IITA cowpea breeder assigned to the Upper Volta National Cowpea Improvement Program. There are 24 African countries participating in the SAFGRAD effort.

Training and collaborative research projects

These projects supplement core allocations for training and establish collaborative research programs with other research institutes, scientists and universities.

Belgian Government Grant. Since 1973, the Belgium Government has been providing funds for training and for supporting collaborative research projects with Belgian universities.

Netherlands Government Grant. Since 1974, the Netherlands Government has been providing funds for the training of West African research and production agriculturalists.

Ford Foundation Grant for East African Trainees. The Ford Foundations East African Regional Office has since 1978 been providing funds to train East African agricultural scientists at IITA.

International Board for Plant Genetic Resources (IBPGR) Grant for Training. In 1980, IBPGR provided funds to provide 15 Africans with training in crop genetic resource conservation. The training emphasized food legumes and rice.

UNDP grant for Technology Transfer in Root and Tuber Crops. A UNDP grant enables IITA, CIAT and CIP to conduct training and conference activities designed to help transfer technology on root crops to national programs. The grant is being executed by CIAT.

Core supplementing projects

This category of special projects includes extra-core funded activities that supplement or expand various aspects of the on-going core research programs.

UNDP Nitrogen Contribution from Legume Rhizobia Grant. Funds from UNDP enable IITA to expand its research on N fixation by cowpea and soybean in order to determine the potential of the legume/rhizobia symbiotic system and devise methods for manipulating this system to improve grain yields and N accretion to farming systems. The Boyce Thompson Institute (USA), Cornell University (USA) and the University of Western Australia are collaborating with IITA on this project.

FAO African Rural Storage Center. This project's objective is to reduce on-farm, post-harvest, food crop losses in tropical Africa. The project is funded by the Danish Technical Aid Agency, DANIDA, and FAO is the executing agent. IITA is not directly involved in the project's execution; rather, IITA provides facilities and professional advice as required.

IDRC Grain Legume Information Center Grant. Since 1974, IDRC has been provided funds to establish at IITA a specialized information center on cowpea and other grain legumes of interest to the Institute.

USAID International Meloidogyne Project (IMP). With funding from USAID as administered by North Carolina State University (USA), IITA has been participating since 1976 in a project designed to gain knowledge of plant parasitic nematodes in the humid tropics.

IFAD Grant for the Biological Control of Cassava Mealybug and Green Spider Mite. In May, 1980, IITA and IFAD entered into an agreement whereby IITA will undertake over an initial 3.5 years, research and exploration missions aimed at the eventual biological control of 2 serious insect pests of cassava in Africa, the cassava mealybug and the green spider mite.

The International Federation of Institutes for Advanced Study (IFIAS) Grant for Soil Degradation Studies. IFIAS is providing funds to enable IITA to estimate the extent of soil degradation at 3 sites in tropical Africa and investigate the constraints restricting the application of techniques designed to prevent such degradation.

Texaco Grant for Cassava Mealybug and Green Spider Mite Research. Texaco Nigeria Limited has provided IITA a modest grant to enable IITA to expand its research on cassava mealybug and green spider mite control.

IDRC Agro Forestry Project. Since 1978, IDRC has provided funds to enable IITA to undertake research into tree crop/food crop farming systems in tropical Africa.

International Mineral and Chemicals Corporation (IMCC) Grant for Fertilizer Studies. An IMCC grant has enabled IITA to support research by students undertaking fertilizer studies in tropical Africa.

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M.A.O. Nwaogwugwu, *agronomy*
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Grain Legume Improvement Program

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(c) = Research Scholar (M. Phil. candidate)
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(e) = Research Training Associate

Publications

Farming System Program

Akobundu, I.O. 1980. *Live mulch: A new approach to weed control and crop production in the tropics.* Proceeding 1980 British Crop Protection Conference, 377-382.

Akobundu, I.O. 1980. *Weed control strategies for multiple cropping systems of the humid and subhumid tropics.* IITA Proceeding Series No. 3: 80-100.

Akobundu, I.O. and B.A. Olunuga. 1980. *Weed problems and control practices in field and vegetable crops in Nigeria.* IITA Proceeding Series, No. 3: 138-146.

Akobundu, I.O. and S.N. Utulu. 1980. *An evaluation of a CDA herbicide sprayer in a tropical environment.* IITA Proceeding Series, No. 3: 379-386.

Friesen, D.K., M.H. Miller and A.S.R. Juo. 1980. *Liming and lime-phosphorus-zinc interactions in two Nigerian Ultisols.* Soil Sci. Soc. Am. Journ. 44:1227-1236.

Getahun, A. 1980. *Agro-climates and agricultural systems in Ethiopia.* Journal Agricultural Systems, 5: 39-50.

Kang, B.T., K. Moody and J.O. Adesina. 1980. *Effects of fertilizer and weeding in no-tillage and tilled maize.* Fertilizer Research, 1: 87-93.

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Major Seminars

(Given at the Institute by IITA scientists or by visiting scientists during 1980)

7 March Research toward the integrated control of insect pests of cowpea . . . P. Matteson
14 March The role of *Leucena* in farming systems in South East Asia . . . J. Raintree
18 March Potentials and limitations of the symbiosis with *rhizobium* . . . F. Minchin
19 March Quantitative analyses of C-N interrelationships and implications for the formation of biological and economic yields . . . P. Hadley
20 March Toward the release of cultivars appropriately adapted to the environments for which they are intended . . . R. Summerfield
21 March Cocoyams—improvement potentials through disease resistance breeding . . . R. Volin
28 March Prospects of legumes in stable farming systems in the humid tropics . . . A.A. Agboola
11 April Problems of soil testing under native farming systems . . . A.A. Agboola
18 April The philosophy ot farming systems in the humid tropics . . . A.A. Agboola
25 April Field and greenhouse evaluation of ultra low volume sprayers and insecticide formulation against cowpea pests . . . T'Amma Moffi
2 May Identifying innovations for small farmers . . . C.D.S. Bartlett
16 May Rice and maize green revolution in Korea . . . S.K. Kim
20 May Studies on resistance of *Phaseolus vulgaris* to *Empoaska kraemeri* in CIAT . . . F.S. Eskafi
14 July Studies on weed interference in white yam (*Dioscorea rotundata* Poir.) . . . R.P.A. Unamma
15 Aug. Characterization of tropical rhizobia . . . A.R.J. Eaglesham
10 Sept. The importance of agro-ecological baseline data for research planning . . . R. Dudal
19 Sept. Cowpea host plant resistance: problems, progress and probabilities . . . M. Lukefahr
30 Sept. Breeding strategies of field peas in Canada . . . S.T. Ali-Khan
16 Oct. Rice specificity and durability of resistance to parasites . . . J.E. Parlevliet
22 Oct. Relationships of phyllosplane, silk and ear mycoflora to kernel infection of maize; resistance to aflatoxin production in maize . . . C.A. Martinson
4 Nov. Nitrogen fixation research in legumes and cereals at ICRISAT . . . P. Dart
14 Nov. State of art and future outlook of plantain research . . . E. DeLanghe
8 Dec. Problems of intensive cultivation of arable crops in the humid tropics . . . A.A. Agboola
23 Dec. Cropping systems of the southern Sudan . . . Q. Ng

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