International Institute of Tropical Agriculture

1976

ANNUAL REPORT

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International Institute of Tropical Agriculture

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FOREWORD

The food situation in developing tropical countries of the world remains serious because traditional agricultural systems are unable to support rapidly increasing populations. Even if population planning efforts are successful the world's demand for food in the year 2000 will likely be twice what it is today if present nutritional levels are to be maintained. It should be noted that the nutritional levels for much of the world's population need to be increased and not just maintained at present levels.

With the exception of the intensive rice production systems of Southeast Asia, yields of food crops in the humid and subhumid tropical zone have remained low. The predominant cropping systems involve intermittent cropping alternating with varying periods of fallow which in some areas have been shortened to the point of ineffectiveness by population pressures.

Continuous cultivation of tropical soils without fertilizers results in rapid loss of soil fertility. Leaving land under fallow for long periods not only keeps farmland out of production, but also increases the labor costs involved in periodic bush clearing. Clearing new land, still the most widespread method of increasing production in developing countries, exposes highly-weathered tropical soils with low inherent fertility to intense leaching, further loss of plant nutrients, and severe erosion. Once this happens, sustained yields of arable crops can be attained on a continuing basis only with costly inputs of fertilizers and pesticides, scientific land development and soil management.

If methods can be found to enable continuous food production in these areas without a decline in crop yields or soil fertility, a substantial addition to world food resources will be possible.

Although many constraints to increasing food production in the humid and subhumid tropics exist there is considerable scope for improvement. Studies by scientists of the International Institute of Tropical Agriculture and other institutions and agencies indicate that increased food production in the humid and subhumid tropics on a sustained basis is possible. Promising approaches include intercropping and multiple cropping, minimum tillage, mulches, improved high-yielding, pest- and disease-resistant crop cultivars, selection of improved crop lines with tolerance to adverse soil conditions, improved hand tools, small machines and appropriate technology that is accessible to the small farmers who constitute 95 percent of the farmers of the region to obtain and use.

This report includes the findings of research conducted by IITA scientists during 1976. Full details on research completed prior to that are not included. Interested readers are asked to refer to previous editions of IITA annual reports and are invited to contact the appropriate scientist or scientists involved.

William K. Gamble
Director General

INTRODUCTION

The humid and subhumid tropics are the largest underdeveloped region to which the world may look for increased food production to meet the needs of growing populations. Research scientists striving to develop the new and improved technologies that will ultimately unlock the food production potential of this vast region, however, face many constraints. Chief among them are these:

Small Land Holdings – Approximately 95 percent of the farmers of the region till less than two hectares of land annually.

Outmoded Systems of Cultivation – The outmoded systems of shifting cultivation and related bush fallow is still practiced on 36 million square kilometers – 30 percent of the world's exploitable soil resources, most of which lies in the humid tropics. This land supports more than 300 million people – 10 percent of the world population.

Poor Soils – Superficially fertile soils throughout much of the region lose productivity quickly under the hostile tropical environment.

Plant Diseases, Insects and Weeds – More plant diseases, insects and weeds that cause heavy crop losses are found in the humid and subhumid tropics than in any other region of the world.

Lack of Improved Cultivars – Sufficient plant varieties that are resistant to diseases and insects and that respond to better management are not yet available for farmers.

Lack of Adequate Credit Facilities – Farmers do not have access to adequate credit facilities and have limited resources to buy needed food production inputs which are often high priced and not easily available.

Lack of Trained Agricultural Manpower – Universities in the humid and subhumid tropics of Africa are still new and the number of agricultural graduates prepared to carry out research and extension programs is relatively low. Agricultural graduates from temperate-zone universities often lack experience with the crops and environment in which they return to work.

Labor Bottlenecks – Lack of available farm labor especially at peak periods limits the area a farmer can effectively cultivate.

Insufficient Food Marketing and Distributing Facilities – The infrastructure needed to market and distribute food produced to those who need it and to assure top returns for the farmer are lacking.

Farmers Fear Risks – The typical small farmer is in no position to take much risk and will not do so unless the chance of gain can be clearly demonstrated.

Overcoming these constraints for the betterment of farmers and through them all people of the humid and subhumid tropical region, is the ultimate goal of all IITA programs.

IITA's Mandate

At the April 1976 meeting of the IITA Board of Trustees certain modifications of the Institute's mandate were proposed. These changes were reviewed during the year and were approved by the Board at its April 1977 meeting. The mandate now reads as follows:

Within the system of cooperating international agricultural research institutes associated with the Consultative Group on International Agricultural Research (CGIAR) and provided funds are available, IITA will:

1. Conduct studies of and research on farming systems in the humid and subhumid tropical zone* in order to identify viable alternatives to shifting cultivation which will maintain the productivity of the land under continuous cultivation, with particular reference to food crops;
2. Accept worldwide responsibility, covering all climatic zones, for research directed to the improvement of cowpeas, yams and sweet potatoes;
3. Conduct studies and research, in the humid and subhumid regions of Africa, for the improvement of crops such as maize, rice, cassava, pigeon pea and soybean, for which other international institutes and organizations have special responsibility, cooperating in whatever ways may be appropriate with those institutes and organizations;

** The humid and subhumid tropical zone is taken to include those parts of the earth, in all continents, which lie between the Tropics of Cancer and Capricorn in which, on average, precipitation exceeds evaporation for five or more months in the year. In West Africa it thus includes the forest (Guinean) zone and part of the Guinea savanna zone, but not the Sudan savanna, the Sudanian or the Sahelian zones.*

THE WEATHER DURING 1976

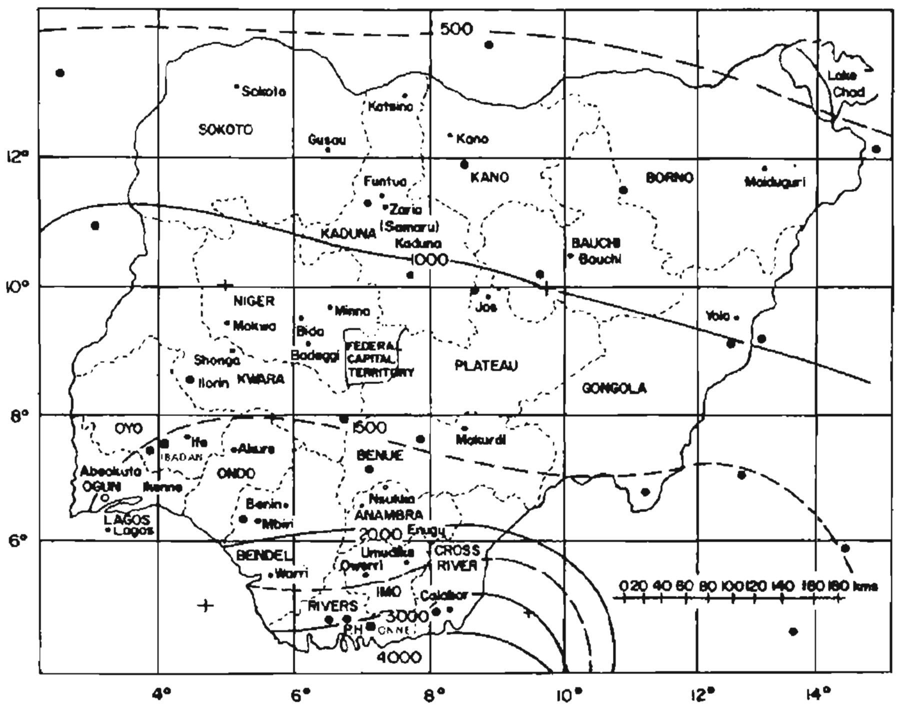


Fig. 1. IITA's administrative headquarters and main research facilities are located near Ibadan. Research work at the Institute's High-Rainfall Substation at Onne, near Port Harcourt, was begun during 1976. This publication also reports results of trials and experiments conducted under varying agro-ecological conditions at other locations within Nigeria (shown on this map) and in other African countries.

IITA's administrative headquarters and main research facilities are located about 16 kilometers north of Ibadan, the capital of Oyo State in western Nigeria. The 1,000-hectare site has an elevation of 250 m. and an average annual rainfall of 1,250 mm. per year, distributed in two wet seasons. Maximum temperatures are between 30 and 36 C most of the year. Minimum temperatures are between 20 and 25 C.

During 1976 experimental work was initiated at the Institute's substation at Onne, near Port Harcourt, in a high-rainfall area characteristic of the Niger delta region. There is, at present, no climatic station at Onne; the information presented here is based on data collected at Port Harcourt, 15 km. west-southwest (Table 1).

Average annual rainfall in the area is 2,400 mm. Although the rainy season shows two peaks — in July and in September — mean monthly rainfall during the low point — August

Table 1. Summary of data for Port Harcourt (04°51'N, 07°01'E)

	J	F	M	A	M	J	J	A	S	O	N	D	YEAR
Average Maximum Temperature* (°C)	31.6	32.6	32.0	31.6	31.0	29.1	28.0	28.1	28.0	29.6	30.6	31.3	30.3
Average Minimum Temperature* (°C)	20.8	21.4	22.3	22.4	22.6	22.1	21.8	21.8	22.0	21.9	21.8	20.8	21.8
Average Mean Temperature** (°C)	26.2	26.9	26.9	26.9	26.7	25.5	24.8	24.9	25.2	25.7	26.1	25.8	25.9
Average Mean Relative Humidity* (%)	79	78	83	84	85	88	89	88	89	87	85	80	85
Mean Daily Actual Hours of Bright Sunshine (1956-60), (Hours)	5.3	6.1	4.7	4.9	4.9	3.3	2.5	2.5	2.0	3.5	4.7	5.6	4.2
Mean Potential Evapotranspiration + (mm)	113	116	129	127	121	109	97	95	104	115	120	118	1364
Mean Rainfall** (mm)	29	68	187	175	249	269	332	278	442	266	93	32	2421

** 15-year average: 1951-1965 ** 1931-1960 normals + Determined on the basis of Turc's (1961) formula.*

– is still about 280 mm. Thus the "break" is not significant from an agricultural point of view, as it is in Ibadan and other areas of West Africa where two definite wet seasons occur.

The area enjoys an average of 179 raindays a year, with a mean maximum of 25 raindays in September, the period of highest mean monthly rainfall. Relative humidity remains high throughout the year, average values ranging from 78 percent in February to 89 percent in July and September.

Temperatures in the Onne-Port Harcourt area are generally moderate. February, March and April are the warmest months, averaging about 27 C; July is the coolest month, averaging about 25 C. Sunshine hours, based on 1956-60 observations, average 4.2 hours per day, ranging from 2.0 hours in September to 6.1 hours in February.

The soils at the main station in Ibadan are primarily Alfisols, Inceptisols and associated hydromorphic soils derived from basement complex rock. These are fairly fertile soils for the tropics, but have poor physical condition. Soil erosion is the major limiting factor for large-scale farming.

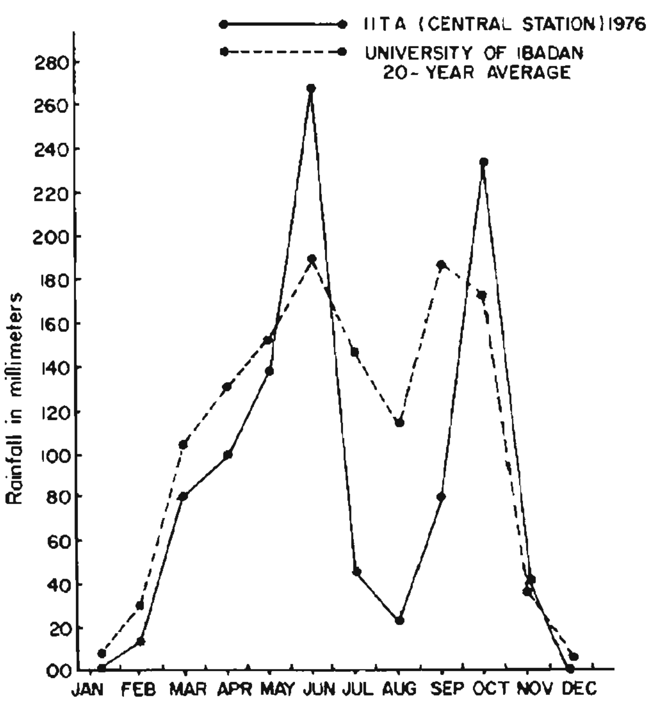


Fig. 2. Mean monthly rainfall.

The soils at the Onne high-rainfall substation are mainly Ultisols. These are strongly leached acid soils derived from coastal plain sediments. They have good physical properties, but chemically rate very poor. Nutrient deficiencies and soil acidity are the major limiting factors. Analytical data of the soils at the two sites are shown in Table 2.

Table 2. Soils at IITA, Ibadan, and at the Onne Substation

Properties	Ibadan Rainfall 1400 mm p.a. Oxic Paleustalf			Onne Rainfall 2600 mm p.a. Oxic Paleudult		
Horizon	A1	A3	11B2t	A1	A3	B22t
Depth, cm	0-12	12-20	42-92	0-7	7-16	45-160
% Clay	15	20	54	18	20	35
% Sand	66	71	37	67	74	60
pH (H_2O)	6.2	6.2	6.0	4.2	4.3	4.4
pH (KCl)	5.5	5.4	5.3	3.6	3.7	3.7
% Org. C	2.1	0.8	0.5	1.0	0.6	0.2
ECEC, me/100 g	10.8	5.4	5.3	2.9	2.7	2.2
Ca	6.2	3.1	3.4	0.3	0.2	0.2
Mg	3.4	1.6	1.2	0.09	0.03	0.02
K	0.4	0.2	0.2	0.07	0.02	0.02

Note: Both soils were sampled under secondary forest.

At Ibadan the year 1976 could qualify with justification, as the year without a growing season. A pronounced rainfall deficit in July, August and September following an earlier one in April drastically reduced the length of both the first and second cropping seasons. Insolation was also comparatively poor, and the weather was generally cooler.

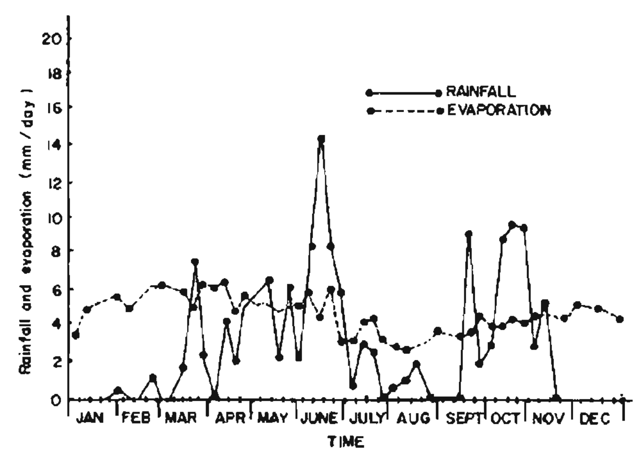


Fig. 3. Weekly mean rainfall and evaporation (IITA 1976).

Data collected at the IITA Ibadan site compared with 20-year average data from the nearby University of Ibadan indicate that cumulative rainfall for the year amounted to 1011.6 mm., about 20 percent below average. With the exception of June, October and November, the total rainfall in each month fell far short of the corresponding mean.

Daytime temperatures at Ibadan during 1976 were generally lower than normal as a result of the lower insolation. Minimum temperatures, however, were above normal averaging +1.2 C in December. Extreme temperatures during 1976 were 12.6 C on January 22 and 35.8 C on March 2. Higher relative humidities prevailed throughout the year. Climatic data collected at the IITA Ibadan site are summarized in Table 3.

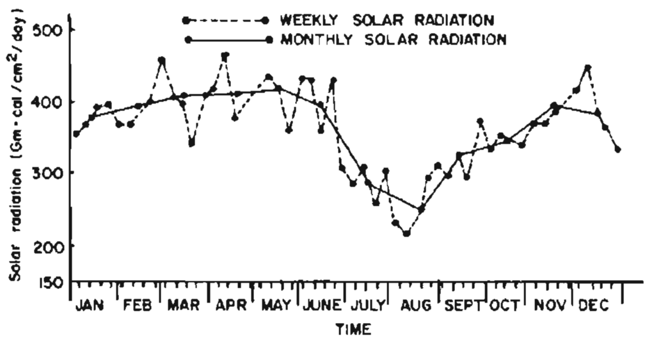


Fig. 4. Weekly and monthly mean solar radiation (IITA, 1976).

Table 3. Summary of climatic data for 1976, IITA, Ibadan

	Total				Average					
Months	Rain-fall mm	Evapo-ration mm	Wind Speed m.p.h.	Solar Radiation gm/cal/ cm_2/day	Temp. °C Min.	Temp. °C Max.	Rel-Hum % Min.	Rel-Hum % Max.	Mean Temp. °C	Mean Rel-Hum %
Jan.	Nil	149.52	2.00	375.7	19.5	31.3	36	95	25.4	66
Feb.	13.3	167.91	3.10	393.3	22.7	32.8	45	97	27.7	72
Mar.	79.7	180.10	3.02	407.1	23.2	32.9	46	97	28.1	72
Apr.	97.1	169.15	3.00	410.7	22.6	31.4	56	97	27.0	77
May	131.1	158.00	2.50	418.1	22.4	29.9	63	98	26.2	81
Jun.	265.3	142.27	2.53	398.6	22.0	28.7	66	97	25.3	82
Jul.	44.6	117.66	3.10	288.8	21.6	27.2	70	98	24.4	84
Aug.	22.0	91.78	2.90	250.3	21.1	26.3	72	98	23.7	85
Sept.	78.2	114.60	3.00	328.4	21.3	28.4	62	97	24.8	80
Oct.	232.6	130.82	2.54	345.1	22.1	28.7	66	98	25.4	82
Nov.	41.7	139.13	2.00	397.5	22.6	30.2	56	97	26.4	77
Dec.	Nil	150.94	2.10	384.2	21.5	31.5	40	97	26.5	69

CEREAL IMPROVEMENT PROGRAM

During 1976 the Cereal Improvement Program began to emphasize observation and analysis in various climatic and agronomic regions (ecosystems) as an essential first step in conducting genetic improvement and crop-environment interaction research. The goal of all research is to develop maize and rice lines able to produce high, stable and nutritious yields under tropical African conditions.

Although considerable research has been done on maize and rice — and dramatic increases in yields achieved in other areas of the world — African yields of both crops remain very low. Many of the constraints to increased production which IITA scientists are seeking to overcome are unique to the continent and materials and methods that are successful elsewhere do not perform well here.

Major problems include lack of improved cultivars for African conditions, poor crop-management practices, diseases and insects (many of which are specific to Africa) that severely damage both crops, iron-toxic and other problem soil conditions, heavy losses between harvest and consumption and low protein content and quality.

At IITA genetic improvement of both maize and rice is now focused on adaptation to the stresses of problem areas where yields are low. Genetic materials already available for areas where problems are minimal need little further genetic improvement. Research on long-term management required for sustained productivity in these areas is more relevant.

This philosophical change in approach to crop improvement has wide applicability in tropical agricultural research. In practice, it will result in fewer attempts to make cultivars and methods developed through research at arbitrarily located experiment stations fit different ecosystems where the fit is often poor. Instead, it will emphasize research within the defined problem areas themselves.

Maize

Genetic Improvement

Introduction, evaluation and utilization of germplasm. To broaden the sources of maize germplasm at IITA, about 400 materials consisting of inbred lines, composites, synthetics and hybrids were introduced from several countries and evaluated at IITA.

Materials introduced included inbred lines of Hawaiian and USA (Corn Belt) origins, composites and cultivars having resistance to European corn borer from the USA, composites of Guatemalan origin for tight and long husk cover and other high-yielding and high-protein-quality materials originating from Ghana, Tanzania, Upper Volta, Mexico (CIMMYT), Brazil, and the USA. All these introductions were grown, evaluated and multiplied by sib mating. Several materials found to be promising or potentially promising were incorporated and utilized in the various sub-projects of early maturity, resistance to diseases and insects, and tolerance to acid soils.

To combine the good plant type genes which exist in the Corn Belt materials with needed adaptability and tolerance to tropical disease-insect complexes, the selected Corn Belt entries were crossed to high-yielding tropical materials during early season, 1976. A total of 223 assorted crosses were planted in the second season and were advanced to F_2 generation by selective sib mating. Segregating populations are to be grown in the first season 1977 and selections will be made to combine the desirable characteristics of tropical and Corn Belt germplasm.

Plant type selection and low-density performance. Excessive plant height, leafiness and inefficient transfer of assimilates to the sink are considered to be important characteristics limiting yield in tropical maize. The plant architecture of high-yielding cultivars available now also seems to be unsuitable for mixed-crop farming systems widely practiced in the African tropics.

Selection has not been carried out previously at IITA for performance at low densities. Therefore, either for the African farmers' low plant population practice or for higher-technology intercropping, it has only been assumed that selection at high densities with high competition and inputs for sole crop maize would result in maize with high performance at low densities and mixed-crop farming systems.

In 1976, selection under low plant density was initiated for low ear placement and large ears, preferably on short plants. This approach followed observations that in a mixed-cropping, wide-spaced planting TZPB, the population varied greatly in plant and ear height and in ear size and productivity. Thus, it was apparent that within TZPB there was a greater genetic variability than was realized and expressible phenotypically under low density. From the open-pollinated population, 100 ears were selected from plants of short stature with large ears, and low ear placement. These were planted as ear-to-block during 1976 second season, at a spacing of 75 cm x 90 cm (14,800 plants/ha) to avoid inter-plant competition and to allow maximum expression of genotype on an individual plant basis. Results obtained are as follows:

1. The population was extremely variable and when allowed to express their genotypic potential through wide spacing, most of the plants were poor. Even if the population became tight, interplant competition among plants of differing vigor would become a major limitation to yield.

2. There was a high frequency of plants with very long peduncles producing secondary unproductive ears on the main peduncle.
3. Development of several unproductive ear shoots below the main ear occurred.
4. Some plants produced one large ear each with minimum expression of secondary and tertiary ear growths.
5. In some cases, plants produced two good ears with minimum expression of tertiary ears.

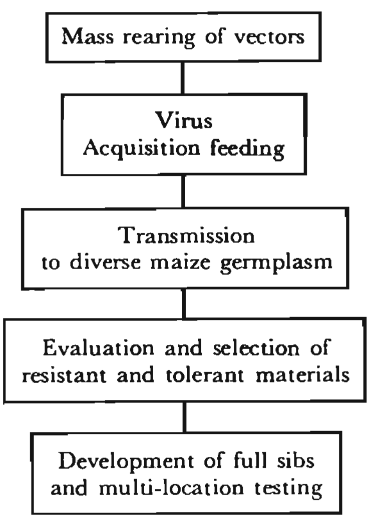
Thus, there appears to be a wide range of potentially different types, in terms of ear development and opportunity for accumulating genes for different types and numbers of ears.

Plants with ideal plant type of either one or two ears were at a very low frequency. Selection and crossing are underway to develop types with different ear expressions under low plant density.

Screening and development of disease and insect resistance. Efforts to develop methods to ensure identification and development of resistance to maize streak virus and the borers *Sesamia calamistis* and *Busseola fusca* were intensified during 1976.

Resistance to Maize Streak Virus

Screening system. The methodology developed during 1975 was greatly improved to enable the screening of large numbers of plants and to reduce inoculation variables. The following diagram illustrates the scheme used for evaluating the resistance of maize germplasm to maize streak virus:



Mass rearing of vectors. The vectors, *C. triangula*, and *C. mbila* are reared on healthy maize plants (cv. Upper Volta) inside cages consisting of three adjacent compartments. Young maize plants are first exposed for oviposition in one compartment where a large population of adult insects is maintained. After a five-day period the plants are transferred to another compartment where the eggs hatch and nymphs develop to adults. The life cycle is approximately 25 days and production of adults with our present facilities of six cages is about 10,000 per week.

Virus acquisition feeding. Adults are collected from the rearing compartments utilizing a vacuum pump. They are introduced into individual cages (500 adult insects/cage) and allowed to feed for 24–28 hours on maize plants infected with maize streak virus.

Transmission for evaluation of maize germplasm. After the acquisition period is completed, the adult insects are released into a large screenhouse (20 x 25 m) where maize materials for evaluation are planted in rows of 25 plants each (50 x 30 cm spacing). A susceptible check (Upper Volta) is planted every 10th row to monitor the level and timing of transmission, and the virulence of the virus.

Leafhoppers are reared for the maize streak virus study.

Uniform distribution of vectors is achieved by releasing them at different locations throughout the screenhouse. Additional vectors from the greenhouse cages are released at the rate of eight per plant, at five and 10 days after germination. All plants showing no streak symptoms 15 days after germination are reinoculated individually. These are covered for 48 hours with small cages each containing five viruliferous leafhoppers.

Evaluation and selection of tolerant materials. Under this screening system, the susceptible check (Upper Volta) is killed three weeks after germination. All susceptible materials are removed at this time and new materials planted. The tolerant plants are either selfed to develop inbred lines or crossed to generate full sibs. This system seems to be simple, accurate, and efficient. Sources of resistance have now been identified for use in the breeding program.

Host plant resistance evaluation. About 20,000 plants representing maize germplasm from many sources were evaluated in 1976 using the screening system described above. Sources of resistance were identified in materials from Nigeria, La Reunion Island, and Tanzania. Plants with various levels of resistance were identified in the TZ Yellow population which previously had shown some resistance under field conditions. The frequency distribution for reaction to maize streak virus in two generations of successive selfing in TZ Yellow population is summarized in Table 1.

Classification into the various classes is based on a rating scale of 0-5 for evaluating disease severity, where plants rated 0-1 are considered highly resistant, 2-3 are considered moder-

Maize streak virus incidence shown by IITA scientist.

Table 1. ***Frequency distribution for resistance to maize streak virus in TZ Yellow population and in S_1 and S_2 lines derived from it.***

Generation	Total plants tested	Severity rating (% of totals) 0	1	2	3	4-5
Parent TZY population	480	0	2	5	2	91
S_1 lines	1,188	0	7	15	66	12
S_2 lines	974	0	22	12	65	0.5

ately resistant, and 4-5 are from susceptible to highly susceptible. Classification into these classes is based on the frequency of streaks, leaf area affected, and degree of stunting. The term 'resistance' is used here for 'tolerance' to infection.

Several of the S_1 lines produced in the screenhouse segregated into various classes but some of the lines were uniform for a particular reaction. One of the lines (Ibadan 32) was uniformly tolerant in the S_1 and S_2 generations. This line is now being utilized as a resistant parent in breeding and inheritance studies. The data presented in Table 2 provide the frequency distribution of a few selected S_1 lines for their reaction to maize streak virus. Utilization of resistant plants with yellow and white grain to develop high-yielding maize materials with resistance to streak will be initiated during 1977. Meanwhile, by crossing selected plants, the full sibs have been generated from resistant plants and these full sibs will be available for African regional progeny testing trials in 1977.

Table 2. ***Distribution of selected S_1 lines for their reaction to maize streak virus.***

Material	Generation	Total plants	Severity rating (% of total) 0	1	2	3	4-5
TZ Yellow-32	S_1	32	0	100	0	0	00
TZ Yellow-33	S_1	32	0	69	0	0	31
La Revolucion-1*	S_1	48	0	53	10	29	8
Tuxpeno × Ilonga**	S_1	172	0	2	1	2	95
Upper Volta (susceptible check)		128	0	0 0	0	0	100

*Seed source: *IRAT — La Reunion; **Tanzania*

Inheritance studies. A resistant parent (Ibadan 32) was crossed to a susceptible parent (Upper Volta) and the F_1 and the two parents were grown in the screenhouse. All the 100 plants of Ibadan 32 had a rating of 1 while all the plants (100) of Upper Volta were rated as 5. The F_1 had all the plants (200) with a rating of 3. The F_1 has been advanced to F_2 and has also been crossed to both the parents to produce BC_1 and BC_2. All the six generations — P_1, P_2, F_1, F_2, BC_1 and BC_2 — have been planted as a randomized trial in the screenhouse. Data will be subjected to appropriate genetic analysis to study the nature of inheritance of resistance to maize streak virus.

Another plant, La Revolucion-1, which has been observed to possess even a higher degree of tolerance than Ibadan 32, has been crossed to Ibadan 32 and to the F_1 of Ibadan 32 × Upper Volta. This should determine whether or not these sources of resistance are carrying the same gene(s) for resistance.

Maize stem borers. During 1976 much effort was placed on developing methods for mass rearing of stem borers. Populations of *Busseola fusca* and *Sesamia calamistis* were developed inside large screenhouses (20×25 m) and attempts are in progress to explore suitable artificial diets for mass-rearing these two species. Also, locations were identified in Nigeria where natural infestations of these borers are very high and these are being utilized to evaluate maize germplasm for borer resistance.

Initial evaluations for resistance to this stem borer under controlled infestation conditions were initiated in 1976. A large population of *Busseola fusca* was first developed in a susceptible cultivar growing inside a screenhouse. Fifty materials for evaluation were planted to coincide with the emergence of adults from the multiplied population.

Each entry was planted in four-row plots of 25 plants each and every plant was infested with egg masses 25-35 days after germination. The larval infestation was very high, averaging 12 larvae per plant and most of the plants were destroyed before flowering. Individual plant selections were based on the ability of the plants to produce an ear, under these conditions, which was considered as a high degree of tolerance to this stem borer (Table 3).

Table 3. Number of plants selected as tolerant to Busseola from the most resistant of 50 lines.

Material	No. of plants infested	No. of plants selected
TZB	100	11
Ant. × Rep. Dom	100	4
W.H.E.0_2	100	3
Cogollero	100	3
Ant. Sel. Blanca	100	2

Among the materials tested were six synthetics resistant to the European corn borer. They were severely damaged and no selections were made. Their susceptibility to seedling blight and poor growth conditions may have influenced their reaction to this borer.

Evaluation of maize germplasm for resistance to this stem borer was conducted at Umudike (eastern Nigeria) where high populations of this borer occur, especially during August-December. Several materials (786) from various sources, mainly CIMMYT-Mexico, were evaluated. The infestation was extremely high 30 days after germination when 65 percent of the entries were completely destroyed or were severely stunted. Very few materials exhibited a high degree of tolerance to this borer (Table 4).

Table 4. List of promising maize materials selected under heavy infestation of Sesamia, Umudike, 1976.

Material	% Plant Survival
Tropical Intm. Yellow Flint Dent — Ear 1	63
Mezcla Amarilla × Comp. I — Ear 4	65
(Mezcla Amarilla P.B. × 8 Mats.) × Comp. I — Ear 1	88
TIYD × Comp. I × Phil DMR 1, 3, 5 — Ear 5	88
Ant. × Rep. Dom. × Comp. I — Ear 3	88

No. entries: 786; No. plants: 13,362; No. survivors: 1,129.

The 59 individual plant selections and the open pollinated bulk of the survivors have been planted at IITA to develop full sibs in two maize populations based on white and yellow grains. These materials will also be planted at Umudike during 1977, and recurrent selection will be made on both populations to increase the frequency of genes for resistance to this stem borer.

Early maturity. The objective of developing early-maturing populations is to develop cultivars which will fit into: (1) a second season in the forest zone, (2) a shorter rainy season in Sudan savanna areas, and (3) mixed and/or relay crop farming systems. This project was initiated in 1975 by crossing the early-maturing cultivar (Upper Volta) with several other cultivars and composites in IITA germplasm.

Since then, several other early-maturing materials originating from India, Indonesia, Philippines, Mexico and Africa have been utilized in developing early-maturing populations. Disease resistance and a reasonable yield of 3-4 t/ha with a maturity period of about 90 days are the final goals. From several hundred full-sibs developed in the F_3 generation during 1976 first season, 200 full-sibs were selected and planted as progeny rows in the second season. Full-sibs were again developed among the selected progenies from which populations have now been developed.

Table 5 gives the number of full-sib progenies selected in these populations that were planted during 1976 dry season for yield evaluation and for seed increase.

Table 5. Number of full-sibs selected in eight early maturity populations developed at IITA.

Sl. No.	Population Pedigree	Number of full-sibs
1.	TZ Early 1 Blancos Tropical Precoz × U.V.	27
2.	TZ Early 2 Precoz Blanco Indonesia × U.V.	17
3.	TZ Early 3 Amarillo Tropical Precoz D × U.V.	35
4.	TZ Early 4 Amarillo Tropical Precoz F × U.V.	20
5.	TZ Early 5 Mez. Am. PB × Phil DMR × U.V.	16
6.	TZ Early 6 Mez. Am. PB × Thai comp. × U.V.	17
7.	TZ Early 7 Indonesia Precoz Am. × U.V.	30
8.	TZ Early 8 Tropical Late White Dent × U.V.	4

Fifteen families and cultivars which were identified to be agronomically promising were grown out from remnant seed and have been crossed in various combinations to develop varietal crosses which would be tested in 1977.

Preliminary screening was initiated in 1976 under high rainfall, depleted acidic soil and the disease-insect complex existing in the ecosystem at the high-rainfall forest zone of Onne. In the first season, single rows of 400 maize cultivars were evaluated for general growth vigor on plots with and without lime. Several promising entries were selected. These included many local cultivars which seemed to have a measure of adaptation to acid soil and aluminum toxicity but had many other undesirable characters which need improvement.

In the second season, S_1 lines of TZPB and S_2 lines of TZB were grown and reselected. New materials were also introduced from Brazil and these were multiplied at IITA for testing in 1977.

Considerable interest is developing in certain African countries in large-scale farming where hybrid maize could be utilized to a great advantage, although a large majority of peasant farmers would continue to operate at subsistence level and the composite cultivars will be appropriate for such farmers. Therefore, it was considered appropriate to develop inbred lines suitable for potential utilization in the development of hybrid maize cultivars. Additionally these are required at IITA for uniformity trials in farming systems and agronomy-physiology research efforts. A total of 120 S_1 lines selected from TZB cycle 5 and S_2 bulks of 27 lines from TZB cycle 6 were planted in the dry season of 1976 for producing S_2 and S_3 lines. Selected plants in selected lines have been selfed. All the S_2 and S_3 lines will be crossed to two testers and good combining lines will be selected in 1977. In the meantime, inbred lines of India, Philippines, Hawaii, and Corn Belt origin are being evaluated in the introduction nursery and the promising lines would be utilized in crossing among themselves and with the top lines of TZB to develop single cross hybrids.

Initial screening of available germplasm to select promising populations for savanna and mid-altitude areas was also carried out during 1976. Nineteen experimental cultivars and 10 Opaque-2 cultivars from CIMMYT, along with TZB, TZO_2 and local check were planted at Mokwa and Samaru in the savanna area. Experimental cultivar Tlaltizapan 7322 yielded more than one ton higher than TZB and the local check at Mokwa and more than two tons higher at Samaru (Table 6).

Table 6. Promising entries from Elite Variety Trials 18 and 19 (ELVT 18 and 19) at Mokwa and Samaru.

		Grain	yield	kg/ha
		Mokwa	Samaru	Average
ELVT 18				
Tlaltizapan	7322	4480	7191	5386
La Maquina	7422	3640	5855	4748
Obregon	7328	2893	5982	4438
Pozarica	7422	3640	3542	3591
TZB (check)		2707	4815	3761
Mokwa composite (check)		3173	4001	3587
ELVT 19				
Across	7437	3453	5345	4399
Pozarica	7437	2520	5770	4145
TZO_2 (check)		3173	6385	4779
3123 (check)		3453	6597	5025

This cultivar requires immediate intensive testing and further development. Of the opaque materials, no cultivar appeared to be better than TZ opaque. In addition, an observation nursery consisting of promising materials originating from CIMMYT, Zaire, Cameroon, Tanzania, and the U.S.A. were planted at Samaru, Riyom, and Bokkos. Table 7 gives the performance of promising materials selected from the observation nursery at Samaru and Riyom, at an altitude of 65 m. and 1,250 m. respectively. At the higher altitude of Riyom (Jos Plateau), TZB yield was low owning to its susceptibility to highland diseases and other factors while Pioneer hybrids were relatively higher-yielding.

Table 7. Selected entries from observation nurseries at Samaru and Riyom

Pedigree	Plant height (cm)	Ear height (cm)	Days to 50% tassel	Stalk lodging %	Grain yield/ha (kg)
SAMARU					
Lote 1-Tuxpeno	192	90	70	4.5	4942
Lote 2-Mez-Trop-Blanco	200	105	70	7.5	4603
Blanco cristillano	195	93	69	9.5	4348
Amarillo cristillano 1	198	98	68	10.00	4263
RIYOM					
Madagasca selected	-	-	-	-	6787
Pioneer × 105 A	-	-	-	-	5897
Pioneer × 304 C	-	-	-	-	5430
Pioneer × 304 A	-	-	-	-	5403
TZB	-	-	-	-	3457

Population. The recurrent selection program to increase the frequency of desirable genes for higher and stable yields was continued this year at IITA in four base populations such as: TZB, TZPB, TZ Yellow, and TZ Opaque by recurrent selection. Yield evaluation of S_1 lines at different plant population levels was determined in a trial where plant density varied as a continuous function within a block.

TZB. One-hundred and sixty S_1 lines developed during the dry season of 1975 were grown in a yield trial in 1976 first season with two replications at Ibadan, one at Ikenne and two at Ilonga in Tanzania. Trial plots at Ibadan and Ikenne were planted with density varying as a continuous function from 20,000 to 120,000 plants/ha (IITA Annual Report, 1975). During the same season, these 160 S_1 lines were grown in a separate block and the selected plants were selfed to produced S_2 lines. Based on the trial data for yield, usable ears, ear height, tolerance to diseases and insects and based on their performance in the selfing plots, 27 S_1 lines were selected. S_2 ears from these lines were planted during 1976 second season for recombination. The selected recombined ears were planted in the dry season 1976-77 to develop a new set of S_1 lines for initiating the seventh cycle of selection. The bulk of selected recombined ears will be used as TZB (S_1) C_6, which can be offered to national programs for their evaluation and use.

TZPB. Composite TZPB was developed to satisfy the need for a short plant-type cultivar, which would resist lodging and fit better into a mixed-crop farming system. Selected S_2 ears from the recombination block were planted ear-to-row in the 1976 second season for selfing. Selected plants were selfed and the S_1 lines have been planted in the dry season for sibbing with a line to ensure sufficient seed for testing these lines at several locations and under stress situations during 1977 early season.

TZ Yellow. TZ Yellow composite was formed with similar objectives to TZPB from CIMMYT *Planta baja* yellow selections. The second cycle of selection in TZ Yellow composite was initiated during this year and the ears selected from the recombination block grown in dry season 1975 were planted ear-to-row in the first season 1976 and selected plants were selfed. The selected S1 ears were planted for sibbing to increase seed of S_1 lines for multi-location testing in international African maize trials.

TZ Opaque-2. Composites TZA and TZB were converted to an Opaque-2 (high lysine) version by three backcrosses in 1972. Other materials identified from CIMMYT trials have also been added to the base composite. The objective is to develop high-yielding, and high-protein-quality composite for tropical lowland Africa. A third cycle of recurrent selection using a modified S_1 method was carried out during 1976. A bulk reselected from all entries was used as the pollen source for recombination. The selected lines on the basis of yield and other plant and kernel characters will be planted in the first season 1977 for selfing to start a new cycle of selection.

Varietal development in the Tanzanian program. A major thrust of the breeding section is to improve level of disease resistance of presently available cultivars to increase yield stability. One major disease problem in the lower elevations of Tanzania is maize streak virus. During the past year, several progenies from six different cultivars were screened for resistance or tolerance to streak disease in the screenhouses at IITA in Ibadan, Nigeria. Of the more than 10,000 plants screened, only three plants survived to produce ears.

These three plants, all from the Tuxpeno cultivar, were selfed and the seed returned to Tanzania. The progenies of these plants will be integrated into the Tuxpeno cultivar and further tested under Tanzanian field conditions. Other cultivars tested with no positive result were Katumani, Katumbili, Lote 23, Lote 24 and Ukiriguru Composite A.

A new long-season, high-elevation maize cultivar, H6302 has received tentative approval for release pending the final year's testing. The new cultivar is a three-way hybrid developed by the East African Agricultural and Forestry Research Organization (EAAFRO) at Kitale. The cultivar is a replacement for the presently grown H613 and has outyielded H613 by about 25 during the past two seasons. A limited amount of seed is presently under increase for farmer use.

During 1976, Msimba Seed Farm grew 60 ha of Tuxpeno. The cultivar, released in 1975, was a top yielder again in the 1976 Tanzania Maize Variety Trial — low series.

An initial trial of quality-protein cultivars, compared to normal detasseled check cultivars, was grown at four locations. An improved selection of yellow hard endosperm opaque composite, yielded the same as the checks. If this result is substantiated in further testing, the cultivar has potential use for the stock-feed industry.

Physiology

Environmental and physiological factors limiting grain yield. Results of the West African uniform maize trials since 1967 have shown that maize yields in the guinea savanna are higher than in the forest or derived savanna. These differences have attributed to a combination of adverse biological factors in the forest areas with their high incidence of pests and diseases, and to physical environment differences, especially of lower light intensities in the forest. Although agronomic information is available, detailed physiological response of plants to environmental factor differences of forest and savanna is not fully documented or understood. A trial was therefore conducted in Nigeria with 12 maize cultivars, to test individual plant physiological responses to environments at Ikenne, Ibadan, Mokwa, and Samaru, representing a range of latitude from ca. 6° to 11° N.

Data average for all cultivars indicated a progressive yield decrease with decrease in latitude, except in the trial at Mokwa which was severely affected by drought stress, atypical for that location. Agronomically, the lower yield in the forest zone at Ikenne was loss of crop stand through lodging (Table 8), caused partly by stem borers and stalk rots. There also was "mechanical" lodging associated with taller, thinner plants with higher ear placement (a feature of plants grown in low light intensity).

Plant dry matter and grain production were recorded on individual plants from places in the plots where full stand occurred.

Total plant dry matter production decreased with decreasing latitude changing from 310 g at Samaru to 235 g per plant at Ikenne. The grain production per plant decreased with latitude, and this was attributable to a progressive decrease in grain number per ear. This was mainly due to a smaller number of kernels per row with a smaller decrease in number of rows per ear from an average of 15 at Samaru to 13.8 at Ikenne. A small increase in grain size (possibly due to less space competition on the cob) at lower latitudes could not compensate for the big reduction in grain number. Whilst the agronomic effects indicate almost a three-fold improvement in yield in the savanna, physiological potential was only 45 percent more grain weight per ear. This was realized through a 49 percent in kernels per row, 7 percent gain in average number of rows but offset by a decrease in kernel weight of 11 percent. Also, it was achieved with apparently no alteration in the partitioning of dry matter since harvest indices for forest and savanna sites were similar.

Climatic studies with particular emphasis on radiation were continued with the two cultivars TZB and TZPB in the first season and with erect and spreading leaf synthetics (see IITA Annual Report 1975) in the second season. Shading (c20 percent of normal daylight, a reduction similar to that encountered in forest areas) resulted in increased plant height and more lodging as compared with unshaded plants. Grain weight per plant was also lower, due to a decrease in grain numbers per ear in the shade treatments. This is consistent with the components of yield differences between Ikenne and Ibadan.

Variation in plant efficiency in composite populations. Previous experiments have indicated that a certain proportion of maize cv. TZPB, grown at relatively low densities, produce

Table 8. Yield and yield components grown at locations ranging from wet forest to savanna zone in Nigeria, 1976.

Location	Lat. o N	Averag. yield t/ha	Weight kernel/ ear, g.	No. of kernels/ ear	1000 grain weight, g	No. of ears/ 100 plants	% stand
Ikenne	6	3.5	88	397	259	71	49
Ibadan	7	5.2	115	460	248	75	76
Mokwa	9	3.1*	47*	334*	140*	72*	91*
Samaru	11	8.5	128	493	228	74	87

**Drought stressed at flowering.*

two ears. This proportion differs with the population pressure. For breeding and selection purposes, it is of interest to know whether two-eared prolificacy results in greater efficiency of converting current assimilates and preformed carbohydrates-reserves into economic yield, compared with single-eared plants. TZPB maize was planted at 75×75 cm (17,780 plants/ha) and plants with either two or only one silking ear, but of similar heights and uniform flowering dates, were selected. Serial sampling to determine the distribution of dry matter during ear development indicated a 42 percent higher grain yield per plant with two ears. Additionally, although they were of similar height, the double-eared plants had both greater leaf and stalk dry matter. Irrespective of the base of expression, the ratio of grain to other plant parts (Table 9), as efficiency indices, was higher in the double-eared plants throughout grain fill to maturity.

Table 9. A comparison of dry matter distribution of single- and double-eared maize plants TZPB.

	G/L		G/S		G/T×10-1	
DAF	1	2	1	2	1	2
7	0.13	0.20	0.06	0.08	0.003	0.034
12	0.38	0.57	0.16	0.26	0.07	0.10
17	1.09	1.33	0.47	0.59	1.61	1.89
27	2.05	2.48	0.56	1.15	2.75	3.11
55	3.17	3.73	1.00	1.69	3.34	4.01

DAF = days after fertilization; G = grain; L = leaf; S = stalk; T = total dry matter. 1 and 2—number of ears per plant.

Interestingly, more than 50 percent of the population produced two ears in this low-density planting. A heritability study of this characteristic and development of a population designed for higher plant efficiency offers a significant yield potential increase, particularly for low-density, intercropping situations. It remains to be determined whether a two-ear-based maize population would be more stable than single-eared material when considered for higher-density monocropping.

Comparisons of growth in acid and normal soil. For the management of highly leached acid soils such as the oxic Paleudult soil of the IITA high-rainfall sub-station at Onne, examination of the extent of genetic variability in types of growth response was commenced in 1976. The preliminary screen provided contrasting material for in-depth studies of the mechanism of acid soil and aluminum toxicity tolerance and susceptibility, which are just beginning. Selected lines from Onne, representing a range of plant responses, were grown in pots of Onne soil at IITA. Comparison was made of growth with and without balanced nutrition and the assessment of vigor agreed well with the field performance rating of the various cultivars. Cultivars Columbia 5 and Katumani were vigorous under both balanced nutrition and under N produced Ca deficiency. By contrast, TZPB was vigorous only under balanced nutrition. Poor seedling vigor of some entries was observed under both nutritional regimes; but for other cultivars, interaction occurred with the nutritional state. A subsequent study of 40 entries obtained from CIMMYT revealed a marked degree of genetic variability in seedling response to acid soil. Further studies are underway which include materials with specific genes for aluminum toxicity, tolerance and susceptibility, identified in the USA.

During 1976 second season, yield trials were conducted at Onne, without lime application, and the cultivars showed both good and poor responses in the screening nursery during the first season. Seven of the entries were grown at IITA at the same population density (33,000 plants/ha) for comparative purposes. The crop at Onne was heavily diseased and had a high incidence of stem borer and ear borer. Lodging was severe (70–84 percent) in all plots and grain yields were low (Table 10).

Rice

Varietal Improvement and Development

Germplasm introduction and distribution. During 1976 about 1,500 cultivars of rice were introduced into IITA from the Philippines (IRRI), India, Brazil, Colombia and some African countries. About 200 promising materials were introduced from Liberia and Sierra Leone from previous selections under dryland, hydromorphic and irrigated conditions. Some upland rice cultivars originated from Tanzania and Brazil. IRTP material from IRRI included the 1976 trials for IURON (185 entries), IRYN-M (32 entries), IRYN-E (20 entries), IRSATON (69 entries), IRCTN (137 entries), and IRON (330 entries). In addition, 460 cultivars were introduced representing the best blast resistant materials from IRAT's

Table 10. Comparison of maize cultivar yields in the ecosystems of Onne and IITA, second season 1976.

		ONNE			IITA		
Entry	Origin	No. ears/ 100 plants	Grain wt/ear g	Yield kg/ha	No. ears 100 plants	Grain wt/ear g	Yield kg/ha
Golden Crystal	Ghana	65	48	1472	50	144	5143
Western Yellow	Nigeria	56	54	1461	–	–	–
TZPB	IITA	58	54	1450	72	122	6399
TZB	IITA	51	61	1417	–	–	-
Composite W	Ghana	53	52	1261	49	138	4857
Composite 4	Ghana	52	47	1206	45	173	5570
Largo del Dia	CIMMYT	51	52	1205	60	111	4750
Batan 74	CIMMYT	49	38	656	56	94	3750
UCA	Tanzania	30	71	589	–	–	–
U.V. Yellow	Upper Volta	35	13	122	46	52	1714

Both local and improved cultivars are studied to improve rice.

collection of 4,500 in Ivory Coast. Segregating material was introduced for upland rice from Liberia (100 entries) and IRRI (28 entries), and for irrigated conditions, eight crosses of Mashuri.

In the Liberia rice project, 1,683 cultivars were introduced, including IRRI's trials of IRON, IURON, IBN and ISBN; African Rice Blast Evaluation Nursery (90 lines); WARDA Initial Evaluation Trial – lowland (40 lines) and WARDA Initial Evaluation Trial – upland (69 lines); and 295 cultivars from IITA's rice germplasm collection. Segregating breeding material in the F_2 generation was introduced mainly from IITA (46 populations for upland) and IRRI (32 populations for upland and lowland).

In Sierra Leone, 90 promising blast resistant cultivars were introduced from IRRI and AICRIP, India during 1976. Approximately 1,400 cultivars were sent from IITA headquarters to cooperators in Cameroon, Ethiopia, Ghana, Ivory Coast, Liberia, Sierra Leone, Zanzibar, Tanzania, WARDA, and IRRI. In Nigeria, cultivars were sent to 14 cooperators.

Hybridization and evaluation of segregating material. At IITA 173 crosses (TOX 51B to TOX 691) were made for different ecosystems. The crosses were for dryland, inland valley swamps (iron toxic and non-toxic conditions), for blast resistance in dryland, lowland valley swamps, boliland and mangrove swamps and for stemborer resistance. Multiple crosses were also made for multiple disease resistance.

Approximately 200 segregating materials were evaluated for upland conditions and eight F_2 materials for irrigation. Many advanced dryland materials, previously selected under Liberian dryland conditions were reselected at IITA and some were advanced to preliminary observation yield trial level. Selections were made under transition dryland at IITA and under marginal wet forest, dryland at Ikenne. In Liberia 27 F_2 populations, introduced from IRRI in 1975 for upland rice improvement, were screened in the blast nursery during the 1975-76 dry season. After 45-50 days, the blast resistant seedlings were transplanted into hydromorphic lowland conditions. About 300 plants with intermediate height, good tillering and long panicles were selected. On evaluating their F_3 families under dryland rainfed conditions during the wet season, it was observed that the majority of them were too tall to be selected further.

The 27 F_2 populations introduced from IRRI, were evaluated again under dryland rainfed conditions during the wet season, along with 46 F_2 populations received from IITA and 10 F_2 populations developed at Suakoko. From these variable populations 373 plants possessing intermediate height, high tillering, long and heavy panicle and disease resistance were selected. The crosses made at Suakoko of IR5×63-83, IR5× LAC 23, IR480-5-9-3-3×LAC 23, and some crosses made at IRRI often involving an African parent, (IR8084, IR8111, IR8121, IR8126, IR8231 and IR8233) gave a proportionately higher number of desirable segregates. Among the F_3 to F_6

Table 11. Characteristics and origin of some promising F_4 and F_6 families bulked for yield evaluation under dryland rainfed conditions, Suakoko, Liberia 1976.

Line	Cross	Height	Flowering	Grain
F_4 generation bulks				
LS (1) - 19 - 1	IR5994 (A6-10-37/LAC 5)	T	120	MB
LS (1) - 31 - 2	IR5894	T	118	MB
LS (10)- 1 - 1	IR6263 (MRC172-9/LAC 23)	T	117	MM
F_6 generation bulks				
LS (19) -4 - 2	TOX C1-13-1	I	110	MB
LS (19)- 1 - 1	"	T	116	MB
LS (19)- 2 - 1	"	T	116	MB
LS (19)- 2 - 2	"	T	116	MB
LS (20)- 3 - 3	TOX CI-18-1	I	114	MB

pedigree material 35 families appeared promising from which 63 plants were selected. Three of the F_4 families and five of the F_6 families (Table 11) appeared uniform enough to bulk for yield trials to be conducted in dryland rainfed conditions next year.

In Sierra Leone, crosses were made to incorporate blast and virus resistance into promising cultivars. These crosses were Fossagbe×CP4, Fossagbe×RCK7, OS6×ROK 1, and Mange 2×LAC 23 Moroberekan, Gbongoy, Durado Pracoce and Juma 1.

From a total of 106 segregating lines for dryland introduced from IITA in 1975, 53 were rated promising for good yield, blast and sheath blotch resistance. These were all from crosses TOXCI and TOX95. From 81 single plant selections in F_3 to F_5 of crosses TOX23 and TOXCI from IITA, evaluated under irrigated conditions, 10 that rated 'good' would be further tested.

Selection and screening of lines: Dryland. Two approaches were taken in 1976 to establish a broader, more analytical base for germplasm evaluation, (1) reexamination of many materials from the germplasm bank, to include especially IRAT, Brazilian and adapted African materials, and (2) development of a screening system which would evaluate many materials on a multi-locational basis, to obtain performance relating to spacing, and fertility on drought stress tolerance. In addition, a clear separation was made for performance under hydromorphic conditions as opposed to pure dryland conditions.

In Nigeria, in the first approach, the screen consisted of a 'special' dryland set, the 1975 IURON, 1975 IURYN, material from IITA and promising selections from Liberia and other African countries. The 'special' dryland material originated from several Far East countries. At Ikenne, a marginal wet forest site with moderate drought, 590 lines were screened; at IITA, a transition location, 630 lines, and at Onne in the depleted acid soil of the wet forest zone, 260 lines. At IITA, wet forest conditions were provided by overhead irrigation. At Ikenne, 47 lines, and at Onne, 31 lines were selected for further evaluation.

In Liberia 549 lines were evaluated under dryland rainfed conditions, consisting of 1976 IURON (185 lines), 1976 WARDA Initial Evaluation Trial (69 lines) and introductions from IITA's germplasm. Twenty-seven lines were selected as promising for peasant or commercial farming conditions. Fifteen were resistant to the major rice diseases in Liberia. Of the eight lines selected last year as promising for dryland rainfed conditions (Aus 61, Azmil 26 Azucena, IRAT 13, IR1752-F5B-1, IR1754-5B-16 and Juma), only IRAT 13 and Juma showed a high-yield potential in the observation yield trials in 1976. Because of their intermediate to loose panicle threshability, they are not suitable for peasant farming but may be useful for mechanical harvesting and breeding purposes.

In Sierra Leone, 1489 entries from collections and introductions were evaluated in different trials, with the objective of determining the best entries for total ecosystem adaptation. This included disease pressure as part of the criteria, thus eliminating resistant lines not otherwise adapted. Therefore all but 50 entries were eliminated for upland conditions.

Upland observational yield material: Nigeria. From previous upland screening in Nigeria plus information obtained elsewhere, 59 lines were selected for an observational yield trial. These were to be 29 of short duration and 30 of medium duration. Included along with sisters of crosses of TOX 7 (OS6×IR154) were some adapted African tall lines, Brazilian upland types, and IRAT 13, a mutant of 63-83.

The trial was conducted at six locations in Nigeria, covering dryland and hydromorphic conditions in savanna, transition and wet forest areas. In addition, 25 of the 60 cultivars were tested separately in five locations in Bendel State.

The rationale of this trial was to see if any lines previously screened could be considered sufficiently superior to the

Table 12. Cultivars in 1976 Nigerian upland observational yield trials comparable to OS6 in at least 50% of locations.

	Cultivar	No. times selected
Short duration:	IAC 25	5
	TOS 2300	4
	TOS 4103	3
	TOS 4120	4
	TOS 4138	4
	TOS 4148	3
	TOS 4688	5
Medium duration:	63-83	4
	IAC 1391	3
	IAC 5544	5
	Iguape Cateto	4
	IRAT 13	5
	Moroberekan	4
	OS6 (check)	6
	TOS 2583	3
	TOS 4106	3
	TOS 4153	4
	TOS 4620	3
	TOS 4622	3
	TOS 4631	4

checks; IAC25 for short duration and OS6 for medium duration. In general TOS2300, TOS4120, TOS4138 and TOS 4688 only are worth continuing among the short duration (Table 12). Within the medium-duration group the following will be re-evaluated and also used as parents TOS: 2581, 2583, 4106, 4153, 63-83 IAC 5544, Guape Cateto, IRAT 13, Moroberekan, TOS 4153, TOS 4631, TOS 2581, TOS 2583 and TOS 4106. The TOS lines are mostly early non-lodging with good grain quality.

In advanced yield trials eight medium-duration cultivars selected in 1974 and 1975 were evaluated against LAC 23. Several dwarf entries outyielded LAC 23, through high panicle numbers (Table 13). However, their short stature, small panicles and threshability are not appropriate for peasant farming. Entry 63-83 was vigorous but low-tillering and susceptible to sheath blotch. IR1754 may be useful for crossing for high panicle weight.

A yield trial of early-duration material revealed that several IRAT entries from Ivory Coast and TOS 2581 were highest-yielding (Table 14). The Ivorian lines had defects of threshability and susceptibility to sheath blight, sheath rot and husk discoloration.

Selection and screening of lines: Irrigated Rice. During 1976, general performance screening for irrigated rice cultivars in Nigeria was conducted at IITA, at Badeggi in collaboration with the National Cereals Research Institute (NCRI), and at Adani in collaboration with ADA rice.

In 1975 IRON and 106 other entries chosen from various IRTP trials on the basis of written information from Asia were screened at the above locations. In addition, 375 entries pretested in Africa were re-screened at IITA. From the first screening of 1975 IRON at IITA, 28 selected materials were re-screened, along with the other African-prescreened material.

A general conclusion from this work and field observations is that for typical normal irrigated conditions with good water control, there are many dwarf cultivars which will yield well under some West African conditions. Moreover, high-yielding cultivars, such as TOS 78, IR5, IR8, IR442, TOS103 and FARO 15 are already widely grown or available. Therefore, it is now necessary to examine the deficiencies of existing high-yielding cultivars in relation to specific problems and difficult areas, rather than continued massive general screening under well-irrigated conditions where there is low pressure from the environment.

The specific problems or needs for irrigated rice in different places in lowland West Africa are:

Neck blast	Sheath blight
Brown spot	Sheath blotch
Pale yellow mottle virus	Bakanae disease
Poor exertion	Dirty panicles (fungal)
Scald	Insect pests of various types
Soil nutrient imbalances	Soil toxicities
Continuously reduced soils	Low nutrients
Low light	Fluctuating water
Avoidance of transplanting	Quality needs
Good milling recovery	

Table 13. Yield and other agronomic characteristics of medium-duration cultivars evaluated under dryland rainfed conditions (Suakoko, Liberia, wet season 1976).

Cultivar	Yield kg/ha	50% fl.	Ht. (cm)	Pan. /m²	Pan. lt. (cm)	Pan. wt. (g)	Threshability	Grain	SB	SR	GD
IR2035-108-2	3444	98	65	500	20	0.75	7	LB	MR	I	I
IR937-55-3	2699	98	72	448	10	0.72	7	MB	MR	I	I
MRC 172-9	2451	112	93	402	20	0.72	7	MI	R	I	S
Juma 1	2377	97	101	328	21	0.83	7	MI	MR	I	I
IR480-5-9-3-3	2300	119	73	378	19	0.89	7	II	R	I	I-S
TOS 52-10-1	1896	109	119	335	21	1.14	3	MI	R	I-S	S
IR1754-F5B-23	1837	96	135	195	22	1.83	5	LS	R	MR	I
63-83	1474	90	121	180	21	1.44	3	MB	MR	S	I
LAC 23 (white)—check	172	104	130	227	24	1.41	1	MB	R	R	R

LSD (5%) 525 kg/ha; CV (%) = 19.5.

Table 14. Yield and other agronomic characteristics of early-duration cultivars evaluated under dryland rainfed conditions (Suakoko, Liberia, wet season 1976).

Cultivar	Yield kg/ha	Days to 50% fl.	Ht. (cm)	Panicle /m²	Pan. lt. (cm)	Pan. wt. (gm)	Threshability	Grain	SB	SR	GD
M18	2322	85	102	270	20	1.1	5	LB	I	S	MR
M55	2113	88	101	252	22	1.1	5	LB	I	S	MR
TOS 2581	2066	82	107	232	21	1.3	3	VLS	MR	I	R
M4	1969	84	106	225	22	1.1	7	LB	MR	I	R
TOS 4030	1788	86	107	230	20	1.5	3	VLS	MR	I	MR
TOS 2578	1673	86	105	278	20	1.0	3	LS	R	I	MR
TOS 2583	1658	89	107	252	20	1.2	3	VLS	R	R	R
T16	1509	90	109	220	18	0.6	1	MM	I	S	I
P14	1243	76	88	242	18	0.9	3	SB	I	S	I-S
Ikong-Pao	1219	82	72	372	19	0.3	5	SB	S	S	S
P20	1084	76	80	290	17	0.8	3	SB	I	S	I-S
P13	998	77	83	308	15	0.4	3	SB	I	I	I

LSD 5% = 658 kg/ha CV (%) = 34.8.

Most of the biological problems increase in the wetter, low-light areas of the deep forest ecosystem, especially in Sierra Leone and Liberia. Soil problems are present there as well as in savanna, and they differ by locations. Blast, sheath blight and some other diseases also are important in less wet areas.

Screening under irrigated conditions in Liberia. On the basis of their performance in 1975 dry season and 1976 wet season, 45 lines were identified as promising for inland valley swamps. Eighty-nine promising lines previously selected at Suakoko for lowland conditions were also evaluated at Mange farm, Sierra Leone under irrigated lowland condition. Thirty-two lines, including IR5, 2526, IR416-131-5 and TOS 78 were observed to be promising there, indicating that selections made in lowland at Suakoko, Liberia could be adapted in Sierra Leone.

In Liberian yield trials under irrigated conditions, IR1416 performed best and six others yielded similarly to IR5. Cultivar 2526 yielded slightly less than IR5 but it has superior grain quality and iron toxicity tolerance. IR1416 is too short

Table 15. List of lines identified as promising for inland valley swamps Suakoko, Liberia, 1976.

Line/Variety	Origin	Line/Variety	Origin
BR1-2B-40-3	Bangladesh	IR2035-290-2-1-3	IRRI
BR51-118-2	Bangladesh	IR2055-481-2-6-2	IRRI
BR51-199-1	Bangladesh	IR2061-628-1-6-4-3	IRRI
X 69-56-12-10-63	Burma	IR2068-65-3	IRRI
B 151-Kn-19-3-1	Indonesia	IR2070-834-1-2-2	IRRI
B 189b-528-3-1	Indonesia	IR2071-286-5-6	IRRI
B 441-b-24-4-5-1	Indonesia	IR2071-588-5-4-3	IRRI
B 453-b-49-2-4-3	Indonesia	IR2561-58-1	IRRI
Brengut	Indonesia	IR2588-5-1-2	IRRI
Mahsuri	Malaysia	IR2588-19-1-1	IRRI
Improved Mahsuri	Malaysia	IR2588-48-3	IRRI
Bahagia	Malaysia	IR2588-60-1	IRRI
C 168-134	Philippines	IR2588-132-1-2	IRRI
4414	Philippines	IR2797-115-3	IRRI
4418	Philippines	IR2823-74-3	IRRI
4443	Philippines	IR2851-41-3	IRRI
4445	Philippines	IR2865-1-6	IRRI
4467	Philippines	IR3265-112-1-2	IRRI
SPR 6726-134-2-26	Thailand	Ob 5. 677	?
CR 1113	India	KLG 6987-59	?
IET 2254	India	KLG 6987-133-2	?
IR1544-238-2-3	IRRI	TG 37	Indonesia
IR1820-52-2-4-1	IRRI		

Table 16. The most promising cultivars under irrigated conditions from newly introduced Indian material, wet season, 1976, Mange, Sierra Leone.

Cultivars Early duration	Grain yield kg/ha	Pan. no. m^2	Plant ht. cm	Leaf blast	Brown spot	Leaf scald	Iron tox.	Insect damage
CRM 13-3061	2829	165	65	3	1	1	1	1
CRM 13-3532	2553	165	55	4	1	3	2	2
BALA	2328	151	79	5	1	1	3	2
JBS 549 (5446)	2166	141	78	4	2	2	2	2
CR 113-84-2	2154	95	62	4	2	2	3	1
CRM-4-2-MTU-17-MUT	2142	117	107	2	1	2	1	2
Mid-Early duration**								
P X J 720. CR-1008	3517	207	101	4	4	3	1	1
CR-115-76	3392	174	79	3	1	2	2	2
S x S 55-296	3367	124	80	3	2	1	2	0
CR 138-802-10	3292	227	85	3	2	2	2	1
IR 2070-464-1-3	3283	140	82	4	2	3	3	1
S x S 55-304	3206	219	62	5	1	1	2	1
CR 44-118-1	3081	227	72	3	2	2	2	2
Medium-duration***								
CRS-95-JR 1512-6	3225	213	81	5	1	0	0	0
CR 139-1044-25	3142	123	98	4	2	2	2	0
DJ 684D	3083	141	85	4	2	2	1	1
CICA 4 X F 1 (IR665-23-3-1 x TETEP)	3042	108	97	3	2	2	0	2
BG 66-1	3042	195	97	2	1	1	2	0

*< 110 days. ** (110-125 days) *** (125-140 days).

and spreading for peasant adoption. Advantage can be taken of the diverse characteristics of these entries, including high panicle weights, in a crossing program.

In Northwest Liberia, entries IR1416, IR2071-105, IR2070-575 and IR2055-473 appeared to be best visually. But in the high-rainfall coastal area some of these performed well and instead, IR2071-77-9 and IR2035-654-3 yielded highest.

Among the early-duration (less than 130 days) cultivars evaluated in swamps at Suakoko, Foya and Johnsonville, IR2071-621-2, IR2035-120-3, CICA 4, IET 1996, CR12-178 and IR2053-407-2-1 appeared promising. All cultivars except IR2053-407-2-1 and IR2071-527-6-3 showed poor panicle exertion during the wet season. The earliest entries Hong Sun, and IR2071-559-2 which had good yields during dry season trials suffered from serious bird damage in this trial and they require further evaluation. Considering the amount and distribution of rainfall in the country, early-duration materials should be better suited for dry-season cultivation when there is a likelihood of water shortage during the latter part of the season.

Screening: Irrigated rice for soil toxicities and nutritional imbalances. In many locations of West Africa irrigated rice exhibits yellow-orange symptoms which are associated with high iron or moderately high manganese levels in leaf tissue. The high metal element levels are associated with low levels of N or P. Thus, the situation is one of nutritional imbalance.

Fifteen cultivars were selected earlier as tolerant to toxic soil conditions in Liberia with seven showing susceptible symptoms at IITA: twenty-four that were selected for general performance at IITA were grown under moderately toxic and non-toxic conditions at IITA. Differences in symptom expression and in yield and yield components under two soil conditions were measured and are being analyzed. However, based on leaf symptoms at vegetative stage and general performance before harvest, seven cultivars were selected for tolerance to toxic soil conditions: Mashuri, KLG 6986-161-7, SPR 6726-134-2-6-26, C 168-134, IR2061-228-3-9, IR2071-176-1-5-2, IR2153-550-2-6-3.

The first three were initially selected in Liberia, while the other four were previously selected at IITA. Three lines, the KLG, SPR and C showed yellow-orange symptoms initially, but later recovered. Gissi 27 and 2526 which were tolerant to iron toxic conditions in Liberia were not tested.

Table 17. ***Cultivars performing well under toxic shallow swamp conditions, Magbolontor, Sierra Leone, 1976.***

Liberia Selections	Sierra Leone Selections
BR51-199-1	Carrubamakassa
BR189b-29-4-3-1	Pa Panel
Mashuri	Banawo
IR2068-65-3	Bagbadin
IR2562-69-4-1	Bakutu
IR2854-23-4	Pamatis
IR2865-1-6	Parmatis
C168-134	Indian Panel
SPR 6726-134-2-6	Sokopent
IR1909-1-3-3	
BR1-2B-40-3	
BR51-243-1	
B 151d-Kn-19-3-1	
B 189b-29-4-3-1	
B 189b-52-8-3-1	

A rice line that performed well under iron toxic conditions.

Soil toxic swamp screening in Sierra Leone. Sixty-seven local and introduced lines were evaluated at Magbolontor inland swamp near Rokupr for performance under soil toxic conditions. The introduced lines had been found to possess tolerance to iron toxicity in Liberia. Twenty-four lines performed well (Table 17).

Iron toxicity. In Liberia, 573 lines were screened for tolerance to iron toxicity in inland valley swamps. Both Gissi 27 and 2526 were confirmed to be tolerant to moderately tolerant. The former showed purple pigmentation while the latter had orange discoloration. The purple pigmentation of Gissi 27 was observed to be correlated with the level of iron toxicity in the soil. This cultivar can be used as a marker to determine the relative iron toxicity levels in different parts of inland valley swamps which are generally heterogeneous for this soil problem. IR2035-654-3 was used as a susceptible check and 64 cultivars were identified as tolerant.

The following points were revealed: (1) Many tolerant lines were derived from at least one tolerant parent, suggesting that tolerance is heritable. (2) Crosses of IR5 and similar types with Gissi 27, 35, 26 and similar types should be carried out and evaluated. (3) Several lines from Sri Lanka, Malaysia and Indonesia were tolerant, suggesting that it would be useful to introduce more germplasm from these countries for screening and crossing for development of cultivars suitable for West Africa.

Screening: Specific problems: Irrigated rice with different low nutrients. At IITA, paddies were developed previously to investigate plant response to limiting nutrient levels, with separate paddies for each low element. These were utilized for determining if differences existed among 25 elite and other cultivars in performance under no application of N, P, K, S, or Zn or all nutrients, in comparison with normal complete (N, P, K, S, Zn added) fertility levels. The 25 cultivars (Table 18) were grown as the eighth crop without addition of the particular nutrient.

Table 18. Cultivars tested in paddies with different histories of nutrient status.

4421 from Colombia	** IR578-95-1-3
4440 from Colombia	IR1529-430-4
* BG 90-2	IR2035-242-1
Biplap	IR2071-179-304
* BPI 76/9 × Dawn	* IR2153-338-3
FARO 15	IR2153-550-2-6-3
IAC 1391 (TOS 4169)	IR2863-31-3
IET 1444	OS6
IET 2845	** Pelite 1-7
IR269-26-3-3 (TOS 78)	Pokkali
IR480-5-9-3-3	TOS 4106 (IR154-61-1-1×OS6)
IR503-1-91-3-2-1 (TOS 553)	TOS 4138 (IR154-61-1-1×OS6)
	* TOX 161-5-5

** Highest yielding under low N, P, K, and NPK*
*** Highest yielding across all low nutrient plots*

Striking differences among cultivars were obtained in growth and yellowing symptoms in the different minus-one nutrient paddies. Yield differences also occurred, showing interactions between nutrient deficiency and cultivar. The two cultivars yielding highest (more than 39 grams/plant) across all nutrient deficient paddies were Pelita 1-7 and IR578-75-1-3. Five others yielded moderately high (more than 24 g/plant) when either N, P, or K or all three nutrients were low. These were BG 90-2, FARO 15, IR2153-338-3, TOX161-5-5, and BPI 76/9 × Dawn. The experiment is being repeated to better quantify yield performance. However, the preliminary data indicate that varietal screening under different low nutrient levels would be useful for African conditions and should be carried out as a priority. The yield depression under missing nutrients was not consistently correlated with yield performance under high fertility.

Entomology

Screening for insect resistance. The major effort was on identification of rice cultivars having resistance to stemborers, whorl maggot, stalk-eyed fly, and rice gallmidge. The gallmidge screening trial was conducted in the north of Nigeria, while replicated stemborer screening trials were conducted in the east and central parts of the country and also at IITA. The stemborers at the east and central parts were *Chilo* and *Sesamia* spp., while *Maliarpha separatella* was the predominant species at IITA. The International Rice Observation Nursery (IRON from IRRI, 351 entries) was also screened at these three locations.

Field screening. Forty-seven rice cultivars were tested for field resistance to insect pests at three locations in Nigeria — the east (Adani), central (Badeggi) and southwest (Ibadan) of Nigeria. The cultivars were planted in a randomized complete block design with four replications. The level of infestation by stemborers, whorl maggot and *Diopsis* sp. varied according to location. The overall level of damage by stemborers and whorl maggot was highest at Adani. Infestations of *Diopsis* were low at all locations. Table 19 summarizes the response of some selected cultivars. The response of cultivars WC 1251, WC 1253, and WC 1263 is interesting in that these have been used as donors for stemborer resistance in Asia. Their response of susceptibility to the stemborer complex in Nigeria emphasizes that resistance to Asian borers does not necessarily provide resistance to African borers of the same genus.

The insect infestations at Adani were sufficiently severe to distinguish varietal differences to stemborers and whorl maggot. Cultivars IR2070-820-2-3 and IR2071-77-9-3-5 had the lowest percentage of damaged tillers. These also have good plant type and yield potential.

Table 19. A comparison of selected rice cultivars to various insect pests at different locations in Nigeria, 1976.

	Percent tillers damaged							
	Adani			Badeggi		Ibadan		
Cultivars	SB	WM	D	SB	D	SB	WM	D
IR2070-820-2-3	9	7	1	3	2	4	10	4
IR2071-77-9-3-5	13	8	0	5	2	3	9	3
TKM 6	22	12	1	22	9	5	6	5
WC 1251	24	9	0	4	2	3	7	7
WC 1253	24	9	1	3	1	6	6	7
WC 1263	16	4	2	4	1	3	4	5
BW 191	10	4	0	2	2	5	3	4
IET 2845	15	15	2	1	1	4	7	7
IR 8	15	28	0	2	3	4	8	4
OS6 (Local Check)	28	35	0	16	5	8	14	2

SB—Stemborers; WM—Whorl maggot; D—Diopsis thoracica

Gallmidge. Thirty-two cultivars, with various degrees of resistance to this insect in Asia, were planted at the Plateau State where heavy infestations normally occur during June — August. This test was to identify sources of resistance and to determine if resistance in Africa corresponded to resistance of the same materials in Asia.

The response of a few selected cultivars is summarized in Table 20. The cultivars WC 1263 and Ptb 18 showed the lowest levels of infestation and these two cultivars have also been reported to possess a high degree of resistance in India. However, RPW 6-12 which is resistant in India was not resistant here. Further screening will be directed toward the identification of other sources of resistance. Emphasis will be placed on screening elite breeding materials to identify good sources of resistance combined with good plant type and yield.

Table 20. Reaction of some of the rice cultivars screened for resistance to the gallmidge, Pachydiplosis oryzae, at Gangnum, Plateau State, 1976.

	Percent infected		Average number
Cultivars	Hills	Tillers	galls/40 hills
Ptb. 18	2	4	3
WC 1263	3	12	3
IET 2845	10	20	8
IR 8	18	18	10
OS6	8	26	13
IR2560-130-2	27	20	15
Pokkali	9	10	16
China 1039	8	4	17
Pelita 1-7	17	13	22
RPW 6-12	22	21	23

Observation nursery. The International Rice Observation Nursery, comprising 351 entries, was planted both during the dry season (January — April) at IITA and the wet season (July — October) at Badeggi and Adani. The trial at Badeggi did not yield any useful information on insect resistance due to the low insect pest infestation.

At IITA, an average infestation of 20 percent for *Hydrellia* spp. and 25 percent for *Nymphula* sp. was recorded, while infestation of *Diopsis thoracica* (4 percent) and stemborers *Chilo*, *Sesamia*, and *Maliarpha* spp., (less than 1 percent) was very low. Rice cultivar BW 191 was least damaged (2 percent tiller damage) by *Hydrellia* spp., compared with the most damaged cultivar, Sri Malaysia (54 percent tiller damage). Infestation of *Nymphula* sp. was lowest on BKN 6809-74-40 (4 percent tiller damage) and highest on JP 5 (85 percent tiller damage).

The insect infestations at Adani were also very low. The seedlings in nursery beds were infested naturally by *Hydrellia* sp. Scattered infestations of *Nymphula* sp. were observed and the most susceptible cultivars were IR1561-228-3-3, Biplab, OS6, and IET 2938. An average infestation of 17 percent was recorded for stemborers and the most susceptible cultivars were B151d-Kn-19-3-1, Tongil and Parwarnipur 1. Some of the cultivars having least stemborer infestation and also good plant type and yield potential were, B96-TK-23-5-5-2-2-2, Joachin A74, IR1857-103-2-2, BG 94-2 and IR26.

Insect screening: Caseworm. In Liberia, a field screening test of 100 cultivars indicated that cultivars LAC 23, Moroberekan, 2526, TOS144, TOS143, and IET1996, were less damaged than others. IR1416-131-5, Jaya, CICA 4, TOS 78, and Hong Sun were highly susceptible.

Insect screening: Leaf feeding beetle *(Epilachna similis)*. This insect has been observed to damage upland rice in the seedling and tillering stages. The insect feeds on the leaf surface and causes white streaks and patches. Entries in the Liberian leaf blast nursery, where the insect population was high, were rated for damage. Forty-four percent of the lines were grouped in the least damaged category. Among the lines adapted to upland conditions, MRC 172-9, ROK 3, 63-83, TOS 2581, ARC10372b, IR2734-F, B-20-1, IR3839-1 were less affected than others. Some adapted upland lines were very severely affected: IR3880-29, IR5179-2, Dinalaga, Kinandang Patong, ARC 7060 b, ARC 7102 b, IRAT 9, IRAT 10, and IRAT 13.

Pathology

Disease screening: Sierra Leone. A major change was made in this year's disease screening trials by evaluating materials for total performance under disease pressures in the precise agroecosystem of intended use. This procedure of direct field screening eliminated several disease resistant materials inferior in other respects. Concerted efforts were directed to identifying a few superior selections from a large number of introductions and collections. It is envisaged that this approach will greatly accelerate the identification of adapted useful cultivars.

International African Rice Blast Screening Evaluation. In June 1976 a total of 90 promising, blast resistant cultivars and advanced lines from Nigeria, Liberia and Sierra Leone rice improvement programs were assembled, packeted and dispatched from Sierra Leone to Ghana, Ivory Coast, Liberia, Nigeria and Cameroon. The 90 cultivars were to constitute the first set of test materials of the African Rice Blast Screening Evaluation Program (ARBSEP), which was launched by plant pathologists in the West African Region with the following objectives: (1) to identify cultivars and breeding lines with useful blast resistance in Africa, (2) to better characterize blast reaction of recommended and potentially useful breeding lines through multilocation screening, and (3) to help insure the availability to and utilization of identified sources of resistance by national rice improvement programs.

The first set of 90 cultivars was what remained of more than 200 original nominees from the three countries after preliminary screening in April 1976 at Rokupr, Sierra Leone in order to eliminate obviously susceptible ones (readings of six or higher in the IRTP scale).

The ecosystem approach will be adopted starting with the 1977 ARBSEP. This approach involves grouping test cultivars and growing them following recommended agronomic practices in the appropriate agro-ecological condition. This approach is considered to be a more realistic characterization of field resistances in addition to enabling expression of total adaptation to the ecosystem pressures.

In Liberia, 1,839 lines were screened in a seedling leaf blast nursery, consisting of the African rice blast evaluation nursery, promising lines from Suakoko screening, IRRI's IBN, and IURON. The susceptible check IR5 was severely blasted, and IR1416-131-5 was consistently resistant. Many lines were not blasted, among them IR22, 28, 29, 32, 34, BG11-11, Juma 1, IRAT 8, 9, 10, 13, whereas others were, e.g., IR5, IR8, Jaya, IR30, 36, SE3026, CICA4.

Disease screening: Leaf scald. In Liberia, the leaf blast nursery was also used to screen for leaf scald resistance. Of the 839 lines, not one was free from scald. Eight lines were rated moderately resistant. The lines LAC 23, Ratna, BG11-11, IR5, CICA 4, IET 3236, SE 319G, and SE 322B were highly susceptible.

Many of the lines adapted to lowland conditions showed much higher susceptibility to blast and leaf scald diseases when these were evaluated in the dryland rainfed disease nursery. Similarly, several well adapted upland cultivars showed higher susceptibility to sheath blight, sheath rot and brown spot when screened in lowland conditions. It appears that for realistic performance it would be more accurate to screen for disease resistance in the same ecological condition for which one intends to use the cultivar.

Crop × Normal-Environment Interaction

Rice in West Africa is raised in many diverse ecosystems whose complexities are not well understood. Before stress areas are considered, the management required for rice culture in each ecosystem needs investigation. Under normal conditions, management of the major nutrients in depleted upland soils, management of high organic matter swamps, timely planting in relation to rainfall, light and biological factors, the relationship between plant density, fertility and soil moisture, and the role of rice in cropping systems are just a few of the many areas needing research in different representative locations. A limited beginning has been made on some of these points, mainly in our programs in Sierra Leone and at IITA. The details of the more extensive information from the Sierra Leone project are available in a separate report.

Upland rice. In Sierra Leone, large numbers of field experiments were conducted at Makassa near Rokupr and Kenema, in the Eastern Province, to determine agronomic factors affecting rice yield under dryland rainfed conditions.

Time of application of nitrogen. Under freely drained, light-textured upland soils, loss of nitrogen through leaching is a serious problem in high-rainfall regions (2,000 to 3,000 mm) of West Africa, particularly in Sierra Leone and Liberia. Investigations were undertaken to increase the efficiency of chemical nitrogenous fertilizers by split application, synchronizing with early tillering, late tillering, panicle primordial initiation and boot-leaf stages of growth. Fertilizer was applied in two, three, four and five splits, all at the rate of N_{80} kg/ha over a uniform basal dressing of P_{40} and K_{40} kg/ha. Two split applications gave significantly lower yield than three, four and five splits, there being no significant difference among the latter three treatments, confirming 1975 data.

Source and placement of phosphatic fertilizers. Studies on the relationships between soil and fertilizer contacts with respect to phosphatic fertilizers varying in water soluble and citrate soluble phosphorus were continued. Three sources of phosphorus (single superphosphate, rock phosphate and basic slag) were applied to the soil so that five soil to fertilizer contact ratios (10, 30, 50, 70, 90) were maintained.

Table 21. Yield in kg/ha as influenced by soil: fertilizer contact ratios.

	% Soil area receiving fertilizer				
Fertilizer	10	30	50	70	90
SSP	1919	2419	2614	2718	2515
Rock phosphate	1948	1971	1840	2163	2293
Basic slag	2260	2159	2310	2763	2537

The results (Table 21) clearly showed that water soluble single superphosphate should be placed with 50–70 solid contact while the water-insoluble form of phosphatic fertilizers (basic slag and rock phosphate) needed 70-90 soil contact to give maximum efficiency of the phosphate fertilizer in acid soils in Sierra Leone.

Time of application of potassium. Potassium is subject to leaching losses in freely drained, light textured upland soils under heavy rainfall. Optimum times of application to increase the efficiency of potassic fertilizer, applied in the form of muriate of potash were determined at Makassa and Kenema. Three split applications at early tillering to boot leaf stages both for K_{40} and K_{80} kg/ha had a distinct advantage over two split applications, there being no added advantage from further splitting. Times of application of potassium showed the same response trend as time of application of nitrogen and, therefore, it is possible to recommend economic top dressing of both nitrogen and potassium at the same physiological stages of plant growth.

Nutritional requirement of rice. The requirements of the three major nutrient elements alone and in combinations under upland conditions were again determined at Makassa near Rokupr. Balanced application of NPK gave significantly higher yield over all other treatments (Table 22).

The most interesting point is that the response to potassium over N and P combination was dramatically higher than the response to K alone or to all combinations without K.

Table 22. Grain yield of upland rice (LAC 23) as influenced by N P K fertilizers.

Dose of fertilizers	Grain yield (kg/ha)	% increase over control
N_0P_0K (Control)	367	–
N_{80}	764	108
P_{40}	697	90
K_{40}	621	69
$N_{80}P_{40}$	1,084	195
$N_{80}K_{40}$	1,140	211
$P_{40}K_{40}$	811	121
$N_{80}P_{40}K_{40}$	1,448	295
LSD 5% = 232		
CV = 18.2		

Date of planting. An experiment was laid out near Rokupr, Sierra Leone, in a continuous function design of 5 to 50 cm spacing between plants within a row, using three rice cultivars of different maturity durations and sown at fortnightly intervals starting from the first rain. The highest yields were obtained from end of May to mid-June plantings. Delay in planting up to mid-July resulted in 38 to 67 percent reduction in yield.

Factors limiting yield. An experiment was initiated at Makassa uplands near Rokupr on the third crop of rice after bush clearance to determine the factors limiting rice production under typical rain forest conditions. Treatments included weeding three times during crop growth, adequate fertilization (N_{80} P_{40} K_{40} kg/ha), line sowing and chemical plant protection.

Treatments minus one factor were compared with the complete treatment using two cultivars, ROK 3 and LAC 23 (Table 23).

Table 23. Response of upland rice (averaged for ROK 3 and LAC 23) to various production factors at Makassa, wet season 1976.

Production factors	Yield in kg/ha	Reduction in yield kg/ha	%
complete package	1624	–	–
minus weeding	531	1093	67
minus fertilizer	627	997	61
minus line sowing	931	693	43
minus plant protection	1158	466	29

Table 24. Response (kg/ha) of upland rice cultivars to different levels of nitrogen, Makassa, wet season 1976.

Cultivar	Control yield of (kg/ha)	kg/ha response to: N40	N80	N120	% increase over control N40	N80	N120
ADNY 11	1528	433	650	1411	28	43	92
ADNY 2	1278	733	911	1272	57	79	100
ROK 3	1167	289	678	522	25	58	44
ADNY 4	1095	366	966	777	33	88	71
ADNY 3	1078	749	1028	1361	69	95	126
ADNY 5	1067	-272	-34	-289	-26	-3	-27
LAC 23	1050	200	633	583	19	60	56
IRAT 8	761	324	439	639	44	58	84
IRAT 13	706	321	622	1094	46	88	155
ROK 2	528	117	428	644	22	81	122
IRAT 10	417	211	622	400	51	149	96
IRAT 9	378	378	389	994	100	103	263
TOS 2583	244	306	623	489	125	214	200
TOS 2581	233	323	434	495	139	186	213

LSD (5%) to compare cultivar means within level of N = 159.

The complete package gave the highest grain yield of 1624 kg/ha. Absence of weeding, and fertilizer, resulted in the greatest reduction in yield but even line sowing (vs. surface broadcast) and insecticide application gave significantly higher yields.

Nitrogen times cultivar interaction. Relative performance and differential response to four levels of nitrogen under uniform dressing of P_{40} and K_{40} were examined with 14 upland cultivars. Two cultivars, ADNY 11 and ADNY 2, had higher yields than the recommended cultivar ROK 3 both with and without fertilizer application (Table 24).

Cropping systems. Combinations of rice with maize and rice with cowpea were tested against the respective monocrops because upland rice in Sierra Leone is often grown as a mixed crop. Different proportions of rice (LAC 23) were grown, either with cowpea (VITA 5) or with maize (TZB-C5) under uniform fertilization at the rate of 80:40:40 N:P:K, following two years of continuous rice (Table 25).

Table 25. ***Yields of rice with maize and with cowpea as sole crops and mixtures, Sierra Leone, 1976.***

		Grain		yield kg/ha	
Rice	+ companion	Rice	+ cowpea	Rice	+ maize
100	0	1661	0	1431	0
75	25	974	114	1052	93
50	50	633	150	1014	146
25	75	593	204	594	217
0	100	0	373		363

Yields of both cowpea and maize were low, and better adapted cultivars to the Sierra Leone ecosystems are required. Rice alone gave higher gross economic returns than any proportion of the mixture, related to the poor performance of the other crops. However, 50 rice:cowpea gave a gross return close to 100 percent rice due to the high price of cowpeas.

Interaction between types of seedling and methods of fertilizer application. To eliminate the tedious process of transplanting, Matsushima in Japan has proposed the use of "broadcastable seedlings". As the use of broadcastable seedlings results in shallow or surface planting, methods of fertilizer application would need to be suitably modified.

Two types of seedlings — normal seedlings grown in wet-bed nursery, and broadcastable seedlings sown in seedling trays — were compared at IITA under three methods of fertilizer application. The ordinary seedlings were transplanted at 4 to 6 cm. The fertilizer was incorporated with power tiller for deep incorporation, raked for shallow incorporation and applied immediately after planting for surface application.

In general, the use of broadcastable seedlings resulted in higher yield irrespective of the method of fertilizer application (Table 26).

The greatest difference between the yield of the two types of seedlings resulted when the fertilizer was surface applied, favoring broadcastable seedlings. This method of fertilizer application is the most common and convenient to the farmers. Thus, the use of broadcastable seedlings appears to be advantageous not only to eliminate the tedious process of transplanting, but also to better utilize the top-dressed N fertilizer. The economics of the use of broadcastable seedlings under African conditions should be explored.

Growth analysis of two promising irrigated rice cultivars. An experiment was designed to evaluate two promising irrigated cultivars under irrigated transition forest conditions in Nigeria at four different levels of fertility and two spacings. The purpose was to determine the factors which limit yield at each fertility-spacing treatment. The cultivars used were FARO 15, an IR5-type developed in Nigeria at Badeggi and BG 90-2, an IR8-type developed in Sri Lanka. Spacings were 24×12 and 24×24 cm, with fertilizer levels of 40N, 40:20:20, 80:40:40, and 120:60:60, NPK. All fertilizers were applied at the time of planting except for the extra nitrogen for the two higher N treatments, which was applied half at four weeks after transplanting and half at panicle initiation.

Samples were taken for growth analysis every two weeks, starting at panicle initiation. Data, including dry matter partitioning and light penetration are being analyzed. The relationship between spacing and fertilizer level is shown in Fig. 1. At the wider spacing both cultivars yielded about the same and responded equally to increased fertilizer levels up to 80:40:40. At the highest fertilizer level, however, BG 90-2 significantly outyielded FARO 15, giving a yield of 7 t/ha. At the close spacing, the two cultivars were equal only at the lowest fertility level of N_{40} alone, otherwise BG 90-2 significantly outyielded FARO 15. The maximum yield of BG 90-2 was 8.1 t/ha; that of FARO 15 was 7.4 t/ha. The most likely reason for this lower level probably reflects a different canopy structure.

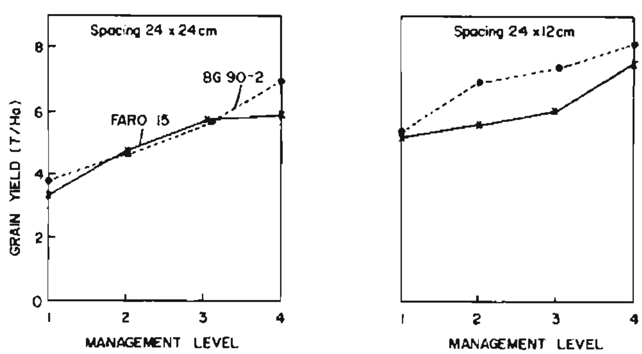


Fig. 1. Effect of cultural management on grain yield of two promising rice cultivars.

Table 26. ***Interaction of type of seedlings and method of fertilizer application on rice growth and yield.***

	Deep		Shallow		Surface	
Fertilizer incorporation Seedling type**	Normal	Broad- cast	Normal	Broad- cast	Normal	Broad- cast
Grain yield (t/ha)	6.1	6.8	6.3	7.1	5.8	7.4
Panicles/hill	8	9	7	8	7	8
Straw weight (g/hill)	24	24	21	22	21	21
Harvest index	0.47	0.49	0.51	0.52	0.49	0.53

**Deep incorporation with rotavator and shallow incorporation by raking.*

***Cultivar BG SO-2 grown in wet seed bed for "normal" and in seedling trays for "broadcastable" seedlings.*

GRAIN LEGUME IMPROVEMENT PROGRAM

Cowpea

Plant improvement. A strategy was developed to incorporate disease and insect resistance into several plant types and photoperiod reactions suitable for different ecological areas and cropping systems.

Three new series of crosses were initiated to improve the disease and insect resistance and seed quality of proven high yielders and to increase seed size of VITA-4 and VITA-5.

The breeding nursery was inoculated with the major pathogens and grown under minimum insecticide protection to facilitate selection for disease and insect resistance.

Preliminary and advanced yield trials were extended for the first time to off-site locations (Ethiopia, Tanzania, Puerto Rico and Nigeria). Minimum insecticide protection was given at IITA and, in addition, all entries were screened separately for disease and insect resistance.

In trials, VITA lines maintained their high disease resistance levels, but showed considerable fluctuations in yield over environments. Some preliminary and advanced lines outyielded the VITA-lines and showed good disease resistance levels.

In the population improvement, an insect resistant sub-population was synthesized and advanced to the F_2 generation. A new cycle of recombination was initiated in the disease sub-population and the different sub-populations were synchronized to permit free interchange of desirable genes among them. A system is being developed to integrate the disease resistance sub-population with the International Disease Nurseries.

There was progress in the development of green-pod, vegetable type cowpeas for the humid tropics. Several climbing types have shown good yield and disease resistance and will be more widely tested in 1977.

Two hundred and thirty-five germplasm and breeding lines were screened under maize for suitability for mixed crop conditions; several will be tested in replicated trials in 1977.

Studies of linkage relationships and of the genetics of anthracnose and root knot nematode resistance were initiated.

Plant protection. A special unit has been set up for multiplication, field inspection, roguing, treating and packeting of seed for international trials to ensure shipment of healthy seed.

A technique for a large-scale inoculation of early-generation cowpea breeding material was developed in screening for virus resistance. Serological techniques are now being used for identification of cowpea viruses. It was demonstrated that Southern bean mosaic and cowpea mottle viruses are transmitted in cowpea by beetles. There was progress in the identification of multiple virus resistance in cowpeas.

There was an apparent shift in the importance of cowpea diseases at IITA, with increased importance of *Phakopsora* rust and *Colletotrichum* pod blotch. Field surveys showed the importance of bacterial blight and *Septoria* widely distributed in the African savanna, the importance of *Ascochyta* zonate leaf spot in East Africa, the importance of web blight and *Sclerotium* blight in the high-rainfall areas of West Africa, the occurrence of a golden mosaic of cowpea in Nigeria and Tanzania and the importance of bacterial diseases of pulse crops in Ethiopia.

Techniques were developed for screening breeding materials to certain important pests. This included rearing and screening for resistance to *Maruca testulalis*, field techniques for screening for resistance to *Taeniothrips sjostedti* and Hemipteran bugs and preliminary work to screen some germplasm for resistance to *Aphis craccivora.*

Several sources of resistance to insect pests were identified: cultivars TVu 1509 and TVu 7274 were found to be resistant to *T. sjostedti;* TVu 7274 and VITA-4 showed resistance to the *Hemipteran, Acanthomyia* was confirmed. Identified sources of resistance to various insect pests were used to synthesize an insect resistant population. One early, determinate line (TVx 2869-2-2) showed resistance to several pests (leafhopper *Empoasca dolichi;* pod borer, *M. testulalis* and foliar thrips, *Taeniothrips sjostedti*). Large-scale trials on farmers' fields with ultra-low volume spraying have shown that Nuvacron gives effective pest control. Synthetic pyrethroids were found to be effective at very low dosages (50g. a.i./ha).

Growth and management. A study of nitrogen production and metabolism of field grown cowpea and soybean revealed that both utilize soil nitrate nitrogen as a primary nitrogen source in the vegetative period. Its importance declines as nodule nitrogen production becomes predominant in the late preflowering period. Estimates of nitrogen fixation by root nodules using amino-N content of the stem exudate were

Grain legume scientists carry out their research work in an inter-disciplinary manner.

closely correlated with the actual rate of accumulation of total reduced nitrogen in the plant. Whilst cowpea fixed more nitrogen per plant at flowering than soybean, rates also decline more quickly in the former. When nitrogen demand by reproductive organs, as measured by their rate of accumulation of nitrogen, exceeded the capacity of the plant to supply nitrogen to the pods, leaf senescence occurred. Foliar application of major nutrients (mainly N) after flowering only delayed senescence for a short time and resulted in only slight yield increases.

Experiments with artificial shading before flowering decreased leaf area, dry weight and branching at flowering, the effect on yield was small, except in the most severe treatment. Cowpeas sown under maize at tassel emergence showed differences in response to shade, but the responses were not always the same as those observed under artificial shading. To develop cultivars suited to intercropping, selection may have to be made under a cereal crop (maize, sorghum or millet).

Management experiments at several sites indicated that for intercrops and sole crops of cowpea, the most important input was two to four applications of insecticide.

Record yield for a vegetable type, climbing cowpea of 30 t/ha (3 tons dry weight) green pod was obtained in the first season at IITA from cv. FARV-13 grown on bamboo trellis. The greed pod yield was only 10 t/ha and the yield of maize was 4.7 tons compared with 6.1 t/ha for sole crop maize.

Soybean

Plant improvement. Eighty-one strains were developed from the breeding population and the preliminary testing showed that two lines TGx 16-2E and TGx 26-34D gave yields of more than 3 t/ha. The cross between TGm 22-1-2205 and TGx 13-3-2644 was particularly good; 15 progenies of this cross, now in F6 generation, have given good yields, have good seed quality and are resistant to lodging and bacterial pustule.

Plant protection. The cultivars were screened in the field for susceptibility to damage by leaf chewing insects *(Plathypena* sp. and *Trichoplusis* sp.). Cultivar TGx 13-3-2644 and six new lines showed the least damage. Varietal differences were observed in susceptibility to seed damage by *Cydia* sp., a pod borer.

Seed quality. The rapid loss in soybean seed viability is a main constraint in the tropics. Studies have shown that there is genetic variation that can be exploited in seed tolerance to weathering and to deterioration in store at high ambient temperatures and humidity. Seed quality at harvest influences seed viability during storage. Poor weed control and careless threshing contributed to poor seed quality at harvest. Good germination and resistance to weathering were associated with small, smooth seeds. Drying seed at 40 to 50 C helped to maintain viability in store; drying at 60 C or leaving seed undried markedly reduced viability.

Lima Bean

Plant improvement. New accessions have been added to the germplasm collection, mostly from Liberia (250) and Nigeria (120). A survey was conducted in southeast Kaduna State of Nigeria and samples were collected with various sizes and colors of seed.

Segregating lines that were tested (F_2) included the crosses between cultivated and wild forms of lima beans (Gembloux collaborative project).

A large nursery was screened against golden mosaic first in the field and then in the greenhouse. Forty lines showed good field resistance and of these, 12 lines were identified as highly resistant. Two of the resistant lines (TP1 10 and 111A) were previously included for yield trials.

First crosses have been made between resistant and susceptible lines. Some F_2 lines are now being tested in the field.

A sap-transmissible virus with filamentous particles has been partially characterized and tentatively named lima bean green mottle virus. The viny lima bean uniform trials at IITA averaged 2.8 t/ha for the seven best entries, with 88 percent of the harvest in less than 100 days. TPL 250B gave the best yield (3.2 t/ha).

Many interspecific crosses of *P. lunatus* with other selected wild species *(P. ritensis* and *P. polystachyus)* were carried out in Gembloux. Progeny from these crosses were backcrossed at IITA and field tested. Two results are particularly significant in this work. First, the percentage of successful pollinations (selfing or backcrossing) is higher in the F_2 than in F_1 generations. Second, at IITA in the first season the F_1 *P. lunatus* × *P. ritensis* and the parent *P. ritensis* showed no symptoms of golden mosaic.

Cowpea Improvement

Breeding

Four main sowings were made at Ibadan in 1976: the dry season (December to March) under irrigation, the first season (March to June), the first/late season (June to September) and the second season (September to December). Problems were encountered with the second season crop due to an extension of the mid-season dry spell from July to late September. Some trials were not sown and others, sown dry (in early September) did not emerge until 20 September with the first effective rains. Nevertheless, the rapid generation turnover possible with cowpea at Ibadan remains a major tool in increasing the rate of genetic improvement. For the first time, preliminary and advanced yield testings were extended to other locations.

Conventional varietal improvement

The numbers of populations and lines in the conventional varietal improvement program are summarized in Table 1. From the F_2 generation onwards, populations and lines were directly inoculated with suspensions of the major diseases: virus (CYMV, SBMV), anthracnose, bacterial blight, bacterial pustule, *Cercospora cruenta* and *C. canescens*. A minimum insecticide regime was applied and emphasis was placed on selection for disease and insect resistance while retaining different plant habits and other characteristics. Segregating populations and lines were advanced by single plants while uniform rows were bulk harvested for yield testing.

Recombination. Cross series 7 comprises 215 crosses between VITA lines and other elite material from the germplasm and breeding programs. Single plants were sown in the second season and seed of the uniform rows is being multiplied for preliminary trials in 1977.

Farmers visit IITA to see cowpea performance for themselves.

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Table 1. Numbers of populations and lines in breeding nursery (1976). Generations shown in parentheses.

Cross Series	Season: Dry	First	First/late	Second	Total
1	–	510(F_5+)	–	91(F_6+)	
2	–	1429(F_4)	–	220(F_5)	
3	5(F_2)	112(F_3)	–	24(F_4)	
4	495(F_3)	–	–	414(F_4)	
5	–	96(F_3)	–	287(F_4)	
6	–	100(F_2)	–	625(F_3)	
7	215(X)	215(F_1)	215(F_2)	673(F_3)	
8	–	19(X)	60(X)	60(F_1)	
9	–	–	–	30(X)	
Total 1976	715	2481	275	2424	5895
Total 1975	400	5079	–	4639	10118

Cross series 8 comprises a double cross series initiated in the first season to develop 60 populations combining high yield, seed quality and disease and insect resistance. Populations involving TVu 2331 and VITA-5 as the disease and insect resistant parents were found to be uniformly infested by CYMV, bacterial blight and pustule; they have been discontinued but more than 600 single plants were selected and are being multiplied for further testing in 1977. Cross series 9 involves five parents adapted to different ecological zones (SVs 3, Tanzania; White Wonder Trailing, Ethiopia; Kwara ex Kwoi, northern Nigeria; Ife Brown, Nigeria), and IITA elite lines. Crosses were made in the second season and the F_1 populations are being multiplied for advancing to F_2 generations in the first season 1977.

Advanced generation nursery. Crosses were made prior to 1976 between parents combining disease and insect resistance, various morphological characteristics, photoperiod and temperature insensitivity and seed quality. Approximately 300 rows have been selected for preliminary trials in 1977.

Population improvement

In population improvement the main objectives were the development of a system, the synchronization of the populations to facilitate the screening and interchange of material and the assessment of the performance of lines emerging from the main population. Progress made in 1976 is summarized in Table 2.

Disease resistance sub-population. The merged virus and disease resistant sub-populations were advanced from F_1 to G_3 generations. In G_3, 30 new disease resistant lines selected from the ICDN were introduced by crossing on to vigorous male steriles and disease free fertile plants were selected for further screening and multiplication before entering the pathologist's disease nurseries in 1977.

Insect resistance sub-population. The insect resistance sub-population was resynthesized in the first season by crossing 25 lines resistant to leafhoppers, thrips, hemipteran bugs, *Maruca* or *Callosobruchus* on to male sterile plants in the back-up population and advanced to the F_2 generation.

Protein quantity and quality. The protein sub-population, synthesized in 1975 by crossing 22 high-protein, high-S/N ratio lines on to male steriles in the back-up population, was advanced through F_1, F_2 and G_3 generations. Seeds of plants selected in F_2 and G_3 are being analyzed for protein content.

High yield sub-population. The high yield sub-population was screened for disease resistance in the F_2 and G_3 generations and is currently being merged with the back-up population.

Back-up population. The back-up population was sown only in the first season for synthesis of the insect sub-population and for the selection of single plants for disease screening in the second season. Lines combining good levels of disease resistance will be incorporated in the disease nurseries.

Main population. Yield tests of lines from the main population were unsuccessful. In the first season at Ibadan, emergence was poor due to low quality seed. In the second season, yields were reduced at Ibadan due to drought and at Onne due to heavy insect damage. In the Ibadan trial the seed yields of the lines ranged from 82 to 895 kg/ha compared with 596 kg/ha from VITA-4, the highest-yielding control line. Lines combining good yields and disease resistance will be tested further in 1977.

Yield testing

Lines from the breeding nursery are tested first in preliminary trials on the basis of which lines are selected for advanced and then uniform trials. The numbers of tests carried out in each of these categories in 1976 are shown in Table 3.

These represent a considerable increase over 1975. Formerly, preliminary and advanced trials were conducted only at Ibadan but this year were extended to other locations. Lattice designs were introduced to control variability in soils and other factors and were as much as 36 percent more efficient than randomized complete blocks when analyzed in yields. Minimum insecticide regimes were applied but resulted in increased variability due to spatial and temporal variations in insect infestations, the latter being partially confounded with varietal differences in time of flowering. Four standard

Table 2. Number of crosses and generations in population improvement 1976.

Sub-population	No. of lines	6D	6F	6S	7D
Virus resistance	19	–	S.P.S.	SPS(G_3)	400 lines
Disease resistance	19	(F_1)	3,831(F_2)		
	30	–	–	261(S)	(F_1)
Insect resistance	25	–	582(S)	(F_1)	(F_2)
Protein	22	(F_1)	8,297(F_2)	764(G_3)	Screen
High yield	83	–	29,980(F_2)	8,000(G_3)*	(G_4) Merge
Back-up	-	–	22,995(G_4)	200 lines	(G_5)
Total Crosses			65,685	9,025	

* *Estimated*

Table 3. Types of and numbers of entries in yield tests.

Type of trial	Number of replicates	Season First	Season Second	Total Tests 1976	Total Tests 1975
Preliminary	2	206	256*	462	-
Preliminary	3-4	99	50**	149	220
Advanced***	6	75	50**	350	215
Uniform	4	30	20**	50	60
Entomology	3	-	36	36	-
Total:				1047	495

** Also at Melka Werer, Ethiopia; Mayaguez, Puerto Rico; and Ilonga, Tanzania with and without insecticide.*
*** One trial not sown in the second season because of extended dry spell.*
**** Also at Onne, Port Harcourt in first and second seasons and Gusau, northern Nigeria in main season.*

cultivars — Ife Brown, VITA-1, VITA-4 and VITA-5 were included in all trials.

Records taken included days to 50 percent flowering days to 50 percent ripe pod, growth habit, disease and insect grades, pod and seed yields. Threshing percentages were determined. Where possible the trials were harvested at regular intervals to provide quantitative measures of earliness. Entries in all trials but the two replicate preliminary trials in the first season were screened. Photoperiod reactions are being determined by the physiologist and protein content by the biochemist.

Preliminary trials. Two types of preliminary trials were conducted: two replicate trials with single-row plots for preliminary assessment of the performances of large numbers of lines selected from the breeding nurseries in the dry and first seasons of 1976; and four replicate trials with standard four-row plots including lines selected in 1975.

In the first category, insect damage was severe in both trials, contributing to low and highly variable yields. In the first season the seed yields of 186 lines selected from cross series 4 in the dry-season breeding nursery were around 1,305 kg/ha

Cowpea cv. TVu 4557 (now VITA 5) produces high yields.

Table 4. Performances of entries in IITA preliminary trial 1, first season, 1976 (7×7 balanced lattice square, 4 replicates).

	Seed yield kg/ha	Maximum disease levels GH_1	V_2	A_3	BB_4	CCR_5
TVx 1193-10F	2001	E	3	1	2	1
TVx 33-1J(h)	1873	S	1	1	1	1
TVx 186-1G	1741	E	2	4	2	1
TVx 7-4K	1676	E	2	2	2	5
TVx 1193-9F	1615	E	1	1	3	1
TVx 12-01E	1592	E	1	1	1	1
Ife Brown	1317	S	3	4	1	1
VITA-1	2	S	2	1	1	1
VITA-4	490	S	1	1	1	1
VITA-5	575	S	1	1	2	1
Trial mean	152					
S.E.	147.1					
C.V.	31					

1. GH = growth habit. E = Erect, I = Intermediate, S = Spreading
2. V = Virus 3. A = Anthracnose 4. BB = Bacterial blight
5. CC = C. cruenta. Disease grades on a 1-5 scale where 1 indicates no disease symptoms. 6. h — hastate-leaf.

Table 5. Performances of entries in IITA Preliminary Trials — First and second seasons 1976 (each trial a 5×5 balanced lattice square, 3 replicates).

	Seed yield kg/ha Season First	Second	Mean	GH
TVx 289-4G(h)	1918	521	1220	S
TVx 1836-157G	1548	743	1146	E
TVx 234-2G	1343	924	1134	I
TVx 13-19E	1598	641	1120	E
Ife Brown	1263	397	830	I
VITA-1	0	701	351	S
VITA-4	1309	527	918	S
VITA-5	1466	438	952	S
Trial mean	1109	503	806	
S.E.	140.9	89.6		
C.V.	22.0	30.9		
Trial 3				
TVx 332-4G(h)	2414	491	1453	I
TVx 1999-LD	1603	643	1123	S
TVx 1989-5D	1798	438	1118	I
TVx 1997-3D	1826	359	1093	S
Ife Brown	1892	255	1074	I
VITA-1	152	739	446	S
VITA-4	1964	412	1188	S
VITA-5	572	211	392	S
Trial mean	1136	382	759	
S.E.	182.9	103.0		
C.V.	27.9	46.7		

1. For key to abbreviations, see Table 4.

each, accompanied by wide variations in other characters measured. Few lines approached the yield of the best control cultivar, VITA-4 which ranged from 1,017 to 1,799 kg/ha but 43 of the highest yielders with acceptable disease levels were carried forward to the second-season trial together with 196 lines selected from the breeding nursery and other trials in the first season. Seed yields of lines were again highly variable (0-540 kg/ha), due primarily to insect damage. In the second season VITA-1 was the highest-yielding control cultivar. Thirty-three lines combining good yield and disease levels are being multiplied as possible entries for advanced trials in 1977.

In the second category of preliminary trials, a trial of erect types was grown only in the first season and two trials comparing spreading types in both seasons. The data are summarized in Tables 4 and 5 where lines combining high yield with disease levels equal to those of the controls are underlined. In the erect trial (Table 4) significant differences between entries were recorded for most characteristics. Seed yields of the control lines ranged from 2 kg/ha for VITA 1, which is highly photosensitive, to 1,317 kg/ha for Ife Brown. Several lines outyielded Ife Brown, notably TGx 1193-10F and the hastate-leafed TVx 33-1J, the latter also exhibiting low disease levels.

The spreading types also gave high yields in the first season but these were reduced in the second season due to heavy pest damage (Table 5). As in the erect trial, several lines combined improved seed yields relative to the best controls lines with good disease levels lines with hastate-leaf shape yielded.

Advanced trials. Sixty-three advanced lines from the germplasm, conventional breeding and population improvement systems were included in three 5×5 balanced lattice square trials grown in five environments.

The performances of the highest-yielding lines in four of the environments are shown compared with the four controls in Table 6.

Marked interactions for seed yield occurred between lines and environments. Of the four controls Ife Brown was the most consistent, maintaining satisfactory yield levels even at Onne where many of the entries showed drastic yield reductions. The yields of the photosensitive VITA-1 line were poor in the first season. The yields of VITA-4, the most consistent yielder at Gusau were reduced at Onne, evidently because of acid soil conditions. VITA-5 also yielded poorly at Onne due to susceptibility to golden mosaic.

Several TVx lines were similar to or higher-yielding than the

Table 6. ***Yields and other characteristics of entries in advanced trials, 1976 (4 locations, each trial a 5×5 balanced square, 6 replicates).***

	Seed yield kg/ha					
	Ibadan (F)	Ibadan (S)	Onne (F)	Gusau	Mean	GH
Trial No. 1						
TVx 944-02E	1622	–	1435	1412	1490	I
TVx 7-3K	1730	–	1157	1200	1362	E
TVx 403-4E	1495	–	830	1468	1264	S
TVx 1836-90E	1671	–	1154	914	1246	E
Ife Brown	1279	–	918	1352	1183	S
VITA-1	251	–	399	1821	824	S
VITA-4	1070	–	258	1603	977	S
VITA-5	1071	–	212	1328	870	S
Trial Mean	1183	–	706	1094		
S.E.	68.7	–	76.7	120.3		
C.V.	34.9	–	26.7	26.3		
Trial No. 2						
TVx 30-01D	1761	521	1241	837	1090	E
TVx 1193-7D	1513	388	892	1362	1039	I
TVx 596-3D	1138	855	312	1813	1030	I
TVx 7-44	1150	246	1024	1334	1026	I
Ife Brown	1329	299	1050	1463	1035	I
VITA-1	64	682	375	1688	702	S
VITA-4	357	119	418	1909	701	S
VITA-5	779	296	261	1249	646	S
Trial Mean	756	348	574	1422		
S.E.	108.3	50.5	63.6	124.8		
C.V.	35.1	35.6	27.1	21.5		
Trial No. 3						
TVx 337-3F	2138	347	160	1777	1106	S
TVx 1843-1C	1261	707	653	1580	1050	I
TVx 1192-04D	1401	808	911	861	995	S
TVx 31-1G	1629	610	768	901	977	E
Ife Brown	1350	639	856	1149	999	I
VITA-1	78	860	311	1454	676	S
VITA-4	1771	554	455	1863	1161	S
VITA-5	800	526	120	1128	644	S
Trial	1030	488	545	1099		
S.E.	134.7	61.0	68.1	98.9		
C.V.	32.0	30.6	30.6	22.0		

controls. These tended to be lines yielding consistently across environments but at Onne reduced seed yields were recorded for TVx 337-3F probably due to acid soil conditions, and TVx 596-3D due to golden mosaic. Although all entries were susceptible to at least one of the diseases on which notes were taken, sources of resistance were identified and crossing programs are already in progress to incorporate these in the higher-yielding cultivars.

Uniform trials. In 1975, 32 sets of Trial I (10 entries) and 19 sets of Trial II (20 entries) were distributed. (See IITA Annual Report 1975.) The increased data now available, from 12 trials in each category, indicate the occurrence of marked interactions between cultivars and environments. VITA-4 and TVx 30-1G were the highest-yielding entries followed by VITA-1.

In 1976 distribution increased to 28 sets of Trial 1, 50 sets of Trial II and 36 sets of a new Trial III including 10 erect entries. At the time of writing no data had been received from off-site locations. Full accounts of all trials will be published elsewhere.

Intercropping. More than 200 cowpea lines with resistance to the major diseases and range of plant habits from germplasm and the breeding program were evaluated for suitability for intercropping. As seed and facilities were limited and since the aim was to identify gross differences in response, only a single replication was sown under a uniform crop of maize with no sole crop comparison.

The cowpea lines were single rows 5 m long arranged alternately with single rows of maize 1.5 m apart. In the first season cowpea and maize were sown on the same date. In the second season, the cowpea was sown at anthesis of the maize which was harvested and stalks removed when the earliest cowpea lines were flowering — a procedure more relevant to farming practices in the savanna areas. In both seasons VITA-5 was sown in every sixth row as a standard for comparison.

In the first season a wide variation was recorded for all plant characters. Small but significant positive correlations were recorded between plant vigor (60 DAP) and time to maturity and yield. Grain yield was determined primarily by pod number, pod length, seeds per pod and threshing percentage. Disease and insect damage were light but a significant, negative correlation was recorded between coreid bug damage and seed yield.

During the second season, 50 lines from the first-season screening and from the entomology unit were compared under mixed and sole-crop conditions in a split plot design with two replications. The intercrop comprised single alternate rows of maize and cowpea sown on the same date. Although insect damage on cowpea appeared less in the mixed than in the sole-crop, yield data were highly variable and the trial will be repeated in 1977.

Vegetable cowpeas. Vegetable cowpeas for green pod use are an important component of compound farming systems in the humid tropics. In the first season 123 lines were evaluated for disease resistance and pod characteristics including crude fibre content, and 12 were selected for a replicated trial in the second season. Two trellis systems, bamboo and maize were superimposed. Green pod yield, yield components and disease reactions were recorded and the data are summarized in Table 7.

Green pod yields were depressed by more than 50 percent where maize was used as a live trellis. Factors involved include competition for light and nutrients and increased incidence of disease and especially web blight under maize. Significant differences between cultivars were recorded for all characters. TVu 6642 gave the highest yields under both trellis systems with 12.42 and 6.25 tons of green pod per hectare. No correlation could be demonstrated between green pod yield and pod number probably due to the wide differences between lines in pod length. Virus infection reduced yields of lines such as TVu 1270 and TVu 7275. Six lines combining high yield and good disease resistance are being multiplied for a more extensive series of trials in 1977.

Crosses have been initiated between erect grain legume and vegetable types and climbing vegetable types. F_2 populations will be sown in the first season of 1977 at IITA and Onne.

Genetic studies. Crosses were made between lines carrying genes for different simply inherited characteristics to study linkage relationships and to assemble groups of genes for investigations of the inheritance of agronomic characteristics. Preliminary data indicate that the hastate-leaf, holly leaf and one of the male sterility loci are not linked.

Table 7. Mean performance of 12 cultivars of climbing vegetable cowpea for various agronomic characteristics under two trellis systems at IITA during second season (Sept.-Nov.) 1976.

	Green pod yield ton/ha		Green pod length (cm)		Pods per plant	
	B_1	M_2	B	M	B	M
TVu 6642	12.42	6.25	50.1	50.7	25.7	11.0
TVu 6644	12.02	3.97	42.8	43.8	30.0	11.7
TVu 3654	11.94	2.99	47.9	45.7	29.7	9.7
TVu 2176	11.47	3.25	25.9	24.2	63.0	20.3
TVu 1209	11.19	4.35	26.1	24.7	55.3	27.3
TVu 3398	11.00	3.53	29.2	25.3	49.0	18.7
FARV 13	9.85	4.20	36.3	33.1	36.7	18.7
TVu 6493	9.60	4.17	41.5	30.0	35.0	21.7
TVu 6643	7.65	3.76	49.3	51.8	37.7	10.7
TVu 3624	4.10	1.75	17.8	17.0	44.0	19.7
TVu 7275	3.83	1.79	49.8	43.4	17.0	7.0
TVu 1270	3.65	2.70	42.6	41.3	40.3	23.0
S.E. Cultivar	1.23		4.05		6.47	
S.E. Trellis	1.07		4.09		6.64	

1. B = Bamboo trellis 2. M = Maize trellis

Entomology

Host plant resistance in cowpea. Host plant resistance studies during 1974 and 1975 were concentrated on finding resistance to leafhoppers, *Empoasca dolichi*, a preflowering pest of cowpea, and developing simple rearing techniques for major post-flowering pests, pod borers, *Cydia ptychora*, and *Maruca testulalis;* and pod sucking bugs, *Riptortus dentipes*, *Acanthomyia horrida* and *Anoplocnemis curvipes*. During 1976, techniques were developed for screening a large germplasm of cowpea inside mesh houses against the pod borers. Cowpea germplasm found resistant in field screening, and several breeding lines, are now being screened in the mesh houses for resistance to leafhoppers and pod borers.

Resistance to pod sucking bug. *Acanthomyia horrida* is one of the common pod sucking bugs found feeding on cowpea pods in West Africa. Infested pods shrivel and dry prematurely, thus reducing cowpea grain yield. Selected cowpea cultivars and segregating cowpea lines were screened in the field.

IITA scientists appraise cowpea trials in Tanzania.

VITA-4 and TVu 7274 were identified as moderately resistant to pod damage. Table 8 indicates comparative percentage damage to pods by *A. horrida* in field trials.

Table 8. ***Resistance to pod sucking bug, Acanthomyia horrida damage to cowpea pods in four field trials.***

Cultivar	% Pod damage Range	Mean	Resistance rating
TVu 7274	30-50	37.5	MR
VITA-4	35-60	52.8	MR
VITA-1	90-100	97.1	S
VITA-3	90-100	97.5	S
VITA-5	60-80	71.5	LS
S.E. ±		1.3	
C.V.		7.2	

MR = Moderately resistant LS = Less susceptible S = Susceptible

Resistance to flower thrips. *Megalurothrips sjostedti* is a major pest of cowpea throughout tropical Africa. The thrips are shiny black and are found easily in cowpea flowers and do serious damage to flower buds. Severely infested plants do not produce any flowers. A diversified selection of cowpea germplasm and segregating lines were screened in the field for thrips resistance. TVu 1509 was identified as a resistant line. TVx 2869-P_2-2 (ER-1) escaped thrips infestation due to early flowering and was rated as moderately resistant. Table 9 indicates the percentage damage to flower buds by flower thrips in field trials.

Table 9. ***Resistance to flower thrips, Megalurothrips sjostedti damage to cowpea flower buds in three field trials.***

Cultivar	% flower buds damage range	Mean	Resistance
TVu 1509	15-30	23.3	R
TVx 28869-P_2-2	20-50	31.7	MR
VITA-1	95-100	98.3	S
VITA-3	95-100	99.2	S
VITA-4	50-85	62.9	LS
VITA-5	60-90	71.3	LS
S.E. ±		3.7	
C.V.		10.3	

R = Resistant, MR = Moderately resistant, LS = Less susceptible, S = Susceptible

Resistance to aphids. *Aphis craccivora* is a minor pest of cowpea in Africa but is an important virus vector of grain legumes including cowpea in Africa. It is a serious pest of cowpea in India, the Philippines and a few other countries in Asia. A greenhouse technique for rearing this pest and screening germplasm for resistance was developed. Initial screening of some of the disease resistant lines indicated that TVu 408 P_2 and TVu 410 are resistant to this pest. These two lines were earlier identified in India as resistant to *A. craccivora*.

Resistance to cowpea weevil: Cowpea weevil, *Callosobruchus maculatus*, is a serious field-to-storage pest. The initial infestation occurs in the field and after harvest multiplies in storage. World germplasm of cowpea consisting of 4,578/cultivars was screened for resistance to cowpea weevil in storage; so far one cultivar, TVu 2027, has been found resistant to weevil infestation in storage. Table 10 indicates the comparative F_1 progeny emergence in the resistant and susceptible cowpea cultivars from one cowpea weevil.

Table 10. ***Resistance to cowpea weevil,*** *Callosobruchus maculatus*, ***damage to cowpea in storage.***

Cultivar	Weevils*	Resistance rating
TVu 2027	8	Resistant
VITA-1	42	Susceptible
VITA-3	42	Susceptible
VITA-4	30	Susceptible
VITA-5	34	Susceptible

**F_1 progeny produced by a single female weevil.*

Combining resistance to different pests. In cooperation with the plant breeders, efforts were made to combine resistance to several insect pests by crossing insect resistant cowpea cultivars. Along with multiple insect resistance, selections were made for high-yielding erect plant types with early maturity and white seed with black eye. The selections, TVx 2869-P_2-2, TVx 2869-P_9-1 and TVx 2869 P_9-3-2, have been tested both inside and outside IITA and were found resistant to leafhoppers, and with some resistance to *M. testulalis* and *M. sjostedti* in field trials. The low susceptibility to damage is attributable mainly to early maturity and escape.

Insecticide and varietal resistance. In cooperation with the plant breeders and agronomist, VITA 1, 3, 4, and 5 and the yield of three recently selected multiple insect resistant cowpea cultivars mentioned above compared when given minimum insecticide protection was applied at 40 and 50 DAP only. Four trials were conducted, one in the first season and two in the second season at IITA and one on a farmer's field in the second season at Odo-Ogun, a village 50 km north of IITA. Results obtained are indicated in Table 11. The three multiple insect resistant cowpea cultivars had a higher yield than the VITA's.

Table 11. ***Performance of VITA 1,3,4,5 and three multiple insect resistant cowpea lines under minimum insecticide (0.5 kg Nuvacron at 40 and 50 DAP) application.***

Cultivar			Trial Number*			
			1	2	3	4
TVx	2869-P_2-2	(ER-1)	889	657	916	707
TVx	2869-P_9-1	(ER-5)	1026	773	607	628
TVx	2869-P_9-3-2	(ER-7)	1083	966	870	978
VITA 1			37	347	584	900
VITA 3			23	130	51	137
VITA 4			355	484	82	-
VITA 5			180	297	320	618

**1 = 1st season IITA, 2 = 2nd season Odo-Ogun, 3 = 2nd season Agronomy trial IITA, 4 = 2nd season breeding trial IITA.*

High volume insecticide applications. During 1976 emphasis was on identifying effective insecticides with low mammalian toxicity in order to find safer insecticides. Efforts were also made in identifying insecticides which are effective in controlling cowpea pests at lower dosages, so that the cost of insecticide may be reduced. Table 12 indicates cowpea grain yield obtained by treatments of various insecticides on Prima cowpea in a field trial. Insecticides were applied at 10 DAP and subsequently four more applications at 10-day intervals. The pest complex consisted mainly of leafhoppers and *M. testulalis.* Gammalin at 1000 gr a.i./ha per application and synthetic pyrethroid, Decis, which has low mammalian toxicity at a low dosage of 50 gr. a.i./ha per application had the best yields.

Table 12. ***Yield of Prima cowpea under different insecticide applications, second season, IITA.***

Insecticide	Dosage*	% Pod damage by Maruca	Yield kg/ha
Gammalin	1000	23.3	844
Decis	50	47.8	673
Nuvacron	500	34.3	415
Rogor	500	82.5	37
Thuricide	1000	85.3	23
Control		85.3	13
S.E. ±		7.2	20.4
C.V.		35.0	73.0

**Grams a.i./ha/application applied five times.*

Ultra-low-volume applications. ULV insecticide application appears to have some advantage over conventional high-volume spray (HV) in non-irrigated crops like cowpeas where water availability for spraying crops could be a problem. Therefore the comparative performances of ULV and HV insecticide applications on cowpeas were evaluated. A field trial was conducted in the first season of 1976 on Prima. Thiodan was applied as ULV at 800 and 400 gr. a.i./ha per application at 10 DAP and subsequently four more applications at 10-day intervals. Almost 17-fold increase in grain yield over the control plot was obtained with the Thiodan ULV treatment at a higher dosage (Table 13).

Table 13. ***Effect of two dosages of Thiodan ULV application on Prima cowpea, first season. IITA.***

Insecticide	Dosage*	Yield kg/ha
Thiodan ULV	800	672
Thiodan ULV	400	235
Control		40
S.E. ±		24.1
C.V.		39.0

**Grams a.i./ha/application, applied 5 times.*

Table 14. ***Comparative efficacy of Nuvacron and Thiodan applied as HV and ULV on VITA-5, second season, Odo-Ogun 1976.***

Insecticide*	% damage by			Yield kg/ha
	Thrips on flower buds	*M. testulalis* on pods	Hemiptera on pods	
Nuvacron ULV	4.5	14.0	34.0	846
Nuvacron HV	5.5	12.0	31.0	703
Thiodan ULV	28.8	11.0	39.0	304
Thiodan HV	33.8	6.0	39.0	200
Control	93.8	35.0	74.5	15
S.E. ±	4.6	1.9	7.3	24.4
C.V.	28.6	39.5	27.6	37.8

**500 grams a.i./ha. application, applied three times.*

IITA scientist inside a farmer's plot at Odo Ogun near Oyo, Nigeria.

Table 15. ***Comparative performance of VITA 1, 3, 4 and 5 and local checks under less insecticide (three to five applications) in four different countries.***

Cultivar	Yields kg/ha S. Nigeria	N. Nigeria	Ghana	S. Leone	Punjab, India
VITA-1	1308	2141	628	999	776
VITA-3	1469	2334	702	1075	876
VITA-4	1575	1620	229	1343	-
VITA-5	1309	1698	228	831	239
*Local check	1245	868	493	0	532
**Local check	658	525	235	633	334

**Ife Brown, Farinwake, Amatin, Black eye bean and cowpea 74 respectively.*
***Prima, Prima, Local red, Prima, Pusa dofasli respectively.*

In the second season a similar trial consisting of Nuvacron and Thiodan (ULV and HV) was conducted on the farmer's field at Odo-Ogun. Insecticide was applied at 500 gr. a.i./ha per application at 30 DAP and subsequently two more applications at 10-day intervals on VITA-5. Nuvacron applied as ULV and HV was superior to Thiodan treatments and control. There was no significant difference between ULV and HV treatments within the same insecticide indicating ULV applications are as effective as HV applications (Table 14).

Multilocation testing. Cowpea yields obtained under coordinated minimum insecticide trials by different entomologists in their respective countries are indicated in Table 15. No insecticide was applied in the pre-flowering plant growth stage of the crop and the insecticide applications (varying from three to five) were confined to the post-flowering pests. In general, pest resistant VITA yields were superior to local checks.

Pathology

The objective of the legume pathology sub-program continued to be the control of diseases causing economic crop loss through the identification and utilization of durable genetic resistance. During 1976, major emphasis was given to virus diseases and the development of serological techniques for their identification and to the adoption of large-scale field inoculation techniques for early-generation screening of cowpea breeding material. Work was initiated on the effects of intercropping on cowpea diseases.

Disease distribution and importance. An apparent shift in importance of cowpea diseases was noted at IITA during the year. *Phakopsora* rust, *Synchytrium* false rust, *Aristastoma*, and *Colletotrichum* brown blotch have increased in significance so that control measures may have to be sought. Field surveys have demonstrated the importance of bacterial blight, *Septoria* and cowpea aphid-borne mosaic in the savanna zone, while web blight and *Sclerotium* rot can be devastating in high-rainfall areas. *Ascochyta* zonate leaf spot is a major disease of cowpea in eastern Africa. A striking golden mosaic causes appreciable damage to susceptible cowpea cultivars at IITA's high-rainfall station at Onne; symptoms resemble those reported from Tanzania. Cowpea mottle virus has been identified from Mokwa, Ibadan and Nsukka, suggesting it is widespread in Nigeria.

The effect of time of virus infection on the nodulation and yield of cowpea was investigated in the second season 1976 at IITA. The trial was of a split-plot design, with three viruses (cowpea yellow mosaic and southern bean mosaic viruses, and a mixture) as the main plots and four times of inoculation (including an uninoculated control) as the subplots. The 12 treatments were replicated four times. The results (Table 16) show that early infection may reduce nodule weight, and that infection as late as 35 DAP can significantly reduce both top dry matter and seed yield. There were no differences between the virus treatments. Data analysis, following appropriate transformation, revealed relatively large variability in the results to which the non-uniformity of contamination of the uninoculated plots would have contributed.

Table 16. Effect of time of virus infection on cowpea IITA, 1976 second season.

Time of Inoc. (DAP)	Top dry matter (% reduction)	Nodule wt. (% reduction)	N_2 fixation* (% reduction)	Seed yield (% reduction)
15	96	77	86	96
25	95	42	73	91
35	70	22	-	77
Uninoc.	0	0	0	0

Data of Adnew, Allen & Ayanaba
**Micromoles C_2H_4/g dry nodules/hr*

Epidemiology

Southern bean mosaic and cowpea mottle viruses were transmitted by adults of laboratory reared *Ootheca mutabilis* following 24-hour acquisition feeds; the beetles remained viruliferous for 13 days with SBMV and at least five days with CMeV. The beetle, *Paraluperodes quaternus,* also transmitted CMeV. Serological techniques were used to check the virus freedom of the field collected *P. quaternus* and to confirm successful transmission. This is believed to be the first report of vector transmission of these viruses in Africa.

Preliminary and advanced disease screening

Preliminary Disease Nurseries (PDN). During the 1976 first season, 100 lines, including multiple insect resistant selections and entries from preliminary yield trials, were planted in unreplicated rows and evenly exposed to inoculation of 10 diseases by using susceptible spreader lines. Results from scoring at about 70 DAP are shown in Table 17.

A second PDN was grown at IITA in the second season in which high levels of *Phakopsora* and *Aristastoma* developed. Few of the 205 entries showed resistance to these diseases, as might be expected if comparable disease pressures had not previously occurred. Two lines possessed resistance to *Phakopsora,* 13 to *Aristastoma* and one to both. Two multiple insect resistant lines were found to possess fair disease resistance.

Advanced Disease Nursery (ADN). Multiple disease resistant lines identified from data analyzed at the Taximetric Laboratory of the University of Colorado, and selections from the 1975 PDN were planted in two replications during the first season at IITA. Results are shown in Table 17.

Table 17. Cowpea preliminary and advanced disease nurseries, IITA, 1976 first season.

	PDN	ADN
Total lines tested		
Resistant* to:	100	134
CCa CCr Anth Rust Cory BB BP Virus**	36	73
Multiple insect resistant lines	2	0
TVu entries	6	49
TVx entries	30	24

**Scores 1 or 2 (1-7 scale)*
***CCa : Cercospora canescens*
***CCr : Cercospora cruenta*
***Anth : Anthracnose*
***Cory : Corynespora target spot*
***BB : Bacterial blight*
***BP : Bacterial pustule*

Screening of breeding material. Considerable attention was paid to the large-scale production and application of pathogenic inocula to breeding material in the field.

A greater emphasis was placed on screening against bacterial blight than in previous years. The adoption of the use of a high-pressure paint sprayer for field inoculation with a virus 'cocktail' obviated the need for an abrasive (carborundum), was labor saving and permitted early roguing of susceptible plants.

Screening for resistance to web blight. One hundred and fifty-four lines were screened in three batches in the laboratory during March-April 1976. Pot grown four-week-old seedlings of the test lines were spray inoculated with a mycelial homogenate of *Rhizoctonia solani* and incubated at 23 C within a polythene moisture chamber for 3-4 days. Results showed that although all lines were susceptible, there was some variation in the degree of susceptibility. Further field testing of promising lines will be conducted during 1977.

Development of screening techniques against Pythium. Observations made during the dry season 1975-76 at IITA suggest that there is probably genetic variation in response to *Pythium* wet stem rot but, owing to vagaries in the natural distribution of the pathogen in soils, a successful screening technique should rely on artificial inoculation. Earlier attempts at artificial inoculation were unsuccessful when various methods of stem infection with both mycelium and zoospore suspensions were used. A technique, involving the addition of small leaf samples of various grass species to agar cultures of *P. aphanidermatum,* has facilitated the production of copious sporangia and zoospores which may constitute more appropriate inoculum. Future work will be directed to the soil application of zoospore suspensions under controlled conditions and to the examination of detached petiole techniques.

International Cowpea Disease Nursery (ICDN)

The ICDN program, now in its third year, was initiated in an attempt to identify broad-spectrum stable resistance to many different populations of pathogens (including some that do not occur at IITA) over various environments. In addition to providing information on varietal resistance and distribution of pathogens it also serves as a means of distributing useful germplasm to national breeding programs. The 1976 ICDN, with which the ICPMVN has now been combined, consisted of 166 entries and was sent to cooperators in Colombia, Ecuador, Brazil, El Salvador, Puerto Rico, Trinidad, USA, Nigeria, Ghana, Liberia, Zambia, Malawi, Tanzania, Uganda and Ethiopia. Though in need of cooperators in Asia, this represents a considerable expansion of the program.

Some cooperators will be examining specific diseases, either because of specialist knowledge or suitable localities. Results are to be summarized elsewhere.

The ICDN has been screened in the greenhouse at IITA to an Oyo isolate of southern bean mosaic virus (SBMV) obtained from Dr. S. A. Shoyinka in Nigeria. Results are presented in Table 18. Lines designated highly resistant showed neither local nor systemic symptoms but, since no attempt was made to recover the virus, immunity and tolerance cannot be differentiated. Resistant lines produced necrotic local lesions without the development of systemic symptoms, while plants which showed mild systemic symptoms were considered moderately resistant.

Table 18. Resistance to southern bean mosaic virus (SBMV); IITA Greenhouse, 1976.

Reaction	Number of lines
Total lines tested	80
Highly resistant*	3
Resistant	27
Moderately resistant	18
Susceptible	32

**TVu's 310, 1220 & 1271*

Results from virus inoculation either in the greenhouse or field have been obtained from various cooperators; they indicate that certain cowpea genotypes possess multiple virus resistance as shown in Table 19. Of the 12 shown, at least six of the lines also possess resistance to the major fungal and bacterial diseases at Ibadan. To be noted here is the combined resistance to CYMV, CMeV and SBMV (as in TVu's 310 and 393, 493) which would be of special value in the West African forest and sub-humid zone; and the resistance of TVu's 408-P_2 and 410 to both aphids and viruses (probably CAMV as well as CYMV) in the Tanzanian savanna.

Mechanisms and inheritance of resistance. Histological studies on the infection of cowpea lines susceptible and resistant to *Colletotrichum lindemuthianum* were continued in collaboration with Wye College, University of London, as part of an ODM/ARC project. Several mechanisms appear to restrict fungal growth, including failed penetration, penetration leading to encapsulation of hyphae within 'reaction material', failure of the primary vesicle to develop (associated with the appearance of a red halo in the cell wall around the appressorium) and cell death which leads to the cessation of fungal development. In an examination of 'field resistant' lines (TVu 76, 647, VITA-3), it was found that either the fungus was unable to produce secondary hyphae to cause the development of lessions, instead the host cells containing the primary vesicle became necrotic so inhibiting fungal growth (TVu 76, VITA-3) or that some infection produced well developed primary vesicles without causing necrosis and cell death until after the formation of secondary hyphae (TVu 647). The expression of field resistance apparently depends upon climatic factors, principally the alternation of wet and dry periods, and upon the maturity of tissue. Essentially, the mechanism of field resistance apparently differs from hypersensitive resistance and susceptibility in that when the primary vesicle eventually does kill the first-penetrated cell, the latter still has the capacity to produce a sufficiently antifungal environment to prevent the development of secondary hyphae. In contrast, the hypersensitive reaction is probably a very rapid response to infection by an incompatible race of the fungus while in a susceptible reaction, the fungus is compatible and thus the initial growth of the primary vesicle goes 'undetected' by the host cell.

Intercropping and disease

In a vegetable-cowpea intercropping trial planted at Ibadan during the first season 1976, the incidence of the beetle-transmitted cowpea yellow mosaic virus was markedly reduced when cowpeas (FARV 13) were intercropped with maize (TZPB) or when they were sprayed with Gammalin insecticide.

In collaboration with the entomologist in the Farming Systems Program, the incidence of disease was scored in a second-

Table 19. Summary of ICDN results: toward multiple virus resistance.

	CYMV	SBMV	CMeV	Virus (Tanzania)	Aphids	C_iAMV (India)	C_pMV (India)	TMV-CP (India)	CSMV (Puerto-Rico)	CSMV (Trin-idad)	CSMV (El Sal-vador)	CSMV (Brazil)
113	R/S	R	–	HS	–	–	R	–	S	R	S	S
238	R	R	–	HS	–	–	–	–	HS	–	–	–
274	R	R/S	–	S	–	–	R	–	HS	S	R	S
310	R/S	R	R	HS	–	–	R	–	HS	–	S	–
393	R/S	R	R	HS	–	–	–	–	–	–	–	–
408-2	R	–	–	R	R	–	–	–	–	–	–	–
410	R	S	–	R	R	–	R	R	S	S	S	S
470	R	R	–	HS	–	–	R	–	S	S	S	S
493	R	R	R	HS	–	–	–	–	HS	–	–	–
1190	R/S	R/S	–	R	MR	–	R	–	MS	S	S	HR
1948	R/S	R	–	R	–	–	–	–	S	–	–	–
2331	S	R/S	–	R	S	R	–	–	R	–	–	–

Notes:

CYMV = 4 Nigerian isolates of Cowpea (yellow) mosaic virus (Allen)
SBMV = 3 Nigerian isolates of Southern bean mosaic virus (Ladipo & Allen)
CMeV = 1 Nigerian isolate of Cowpea mottle virus (Robertson)
Virus = Field response; both CAMV and CYMV occur at Ilonga, Tanzania (Patel)
Aphids = A craccivora in India (Patel) and Nigeria (Singh)
C_iAMV = Chenulu's spherical aphid-borne virus in India (Patel)
C_pMV = Uncharacterized virus presumed to be related to Nigerian CYMV, in India (Patel)
TMV-CP = Chlorotic spot virus, related to Tobacco mosaic in India (Patel)
CSMV = Cowpea (severe) mosaic virus in Puerto Rico (Vakili), Trinidad (Haque), Salvador (Diaz-Chavez) & Brazil (Yohe & Wheeler)
R = Resistant, S = susceptible, H = highly, M = moderately, R/S = isolate specific resistance

season cowpea-maize intercrop planting at IITA that included two single rows per plot of a disease susceptible cultivar (TVu 76). Preliminary results indicate that *Rhizoctonia* web blight may be slightly reduced by intercropping cowpea with maize. This contrasts with significant increases in web blight which have been reported in cowpeas supported by maize.

Because light intensity can be a major factor limiting growth of cowpeas intercropped under cereals, attempts were made to assess the effect of light intensity on cowpea disease development. Light intensity was varied both by maize spacing and by artificial shade. Powdery mildew incidence increased significantly with increasing natural shade. Thus, preliminary results indicate that cowpea disease incidence may either be increased or decreased in a cowpea-maize intercrop, depending upon the interaction of microclimatic, biotic and host effects on the pathogen and, in certain cases, its vector.

Growth and management

Nitrogen uptake and fixation. In 1976, emphasis was shifted from bacteriological studies to the host part of the symbiosis: the plant. This approach was adopted because the plant governs the system by providing energy to maintain the symbiosis, and in most cases, the plant is the only segment of the system that is readily manipulatable.

To gain a basic understanding of the role of the plant, detailed studies were conducted in which forms of N utilization, rates of N accumulation and re-distribution were monitored throughout growth in both cowpeas and soybean.

N accumulation and metabolism. There appears to be three distinct phases of N accumulation representing the pre-flowering, early pod formation and rapid pod fill stages (Figs. 1 and 2). During the vegetative growth phase, much of the total plant N is produced. In TVu 3629 (indeterminate, intermediate growth habit), 43 percent of total N accumulation occurred during the pre-flowering stage (before 35 days after emergence). The determinate, erect cultivar TVu 4552 accumulated more than 50 percent of its total N during this stage of growth. In soybeans, the vegetative growth phase was slower and only 20-30 percent of the total N was produced during the pre-flowering phase. These experiments were conducted in soils where 30 kg/ha of N applied, and a different situation may arise in less fertile soils. In the early vegetative growth period most of the plants' nitrogen requirements were supplied by nitrate absorption from the soil. The relative amount of nitrate utilization was estimated by assaying for nitrate reductase (N.R.) activity in leaf tissue. The specific activity of N.R. was at a maximum at the early sampling dates and decreased drastically with plant age (Table 20). Although soybeans possess a specific N.R. activity twice that of cowpeas, the total N.R. activity in soybeans was only 50 percent that of cowpeas because of smaller soybean plant size. There also appear to be large differences in N.R. activity between soybean cultivars as TGm 280-3 had a higher activity than TGm 686. This was reflected in the total reduced nitrogen (TRN) content as TGm 280-3 contained 290 mg TRN/plant as compared to 190 mg for 686.

During the early reproductive phase both cowpea and soybean started depending upon symbiotic N_2 fixation to satisfy their N requirements. Atmospheric N_2 fixation is difficult to measure under field conditions because the standard procedure (acetylene reduction) requires excavating the host-nodule system intact. An alternative procedure was developed in which the quantity of N_2 fixed was estimated by determining the amount of amino-N present in the stem exudate. Results from both cowpea and soybeans demonstrated that the amount of amino-N in the stem exudate was closely correlated with the actual rate of TRN accumulation in the plant (Fig. 3).

In cowpeas, the maximum rates of TRN accumulation and N_2 fixation were observed at flowering and decreased rapidly

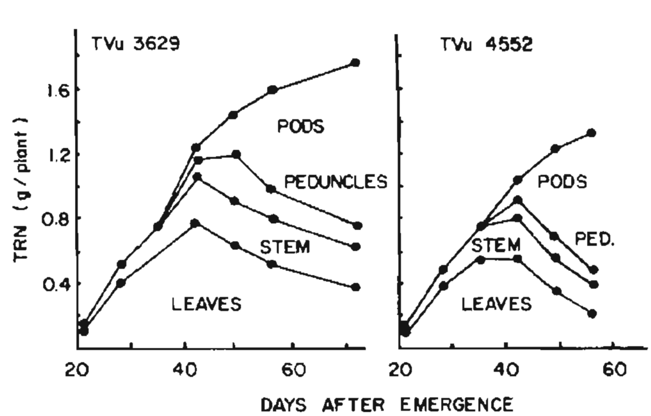

Fig. 1. Total reduced N accumulation in various plant parts of two cowpea cultivars. First season 1976.

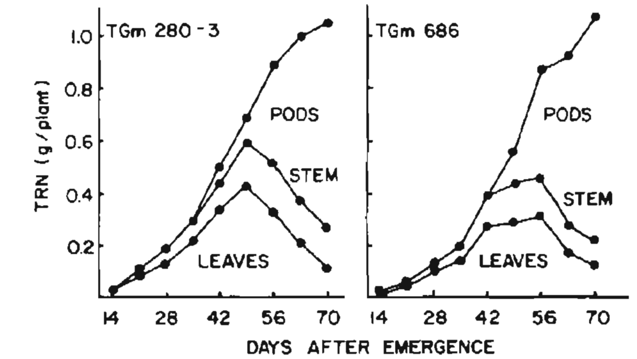

Fig. 2 Total reduced N accumulation in various plant parts of two soybean cultivars.

Table 20. Nitrate reductase activity of cowpeas and soybeans at different stages of plant development.

	Specific nitrate reductase activity days after emergence					
	14	21	28	35	42	49
	u moles NO2/1 g dry wt./hr					
TVu 4552	N.D.*	33.5±3.8	18.1±2.3	9.8±1.5	6.9±0.9	5.8±1.4
TVu 3629	N.D.*	27.7±2.4	18.5±3.4	7.6±1.2	7.8±0.7	6.2±0.3
TGm 280-3	89.5±8.7	58.3±5.1	38.8±7.2	26.5±0.9	6.6±1.8	5.1±0.7
TGm 686	63.9±8.6	37.1±4.0	22.2±4.9	18.7±4.1	4.9±2.2	3.2±0.7

**N.D. = not determined.*

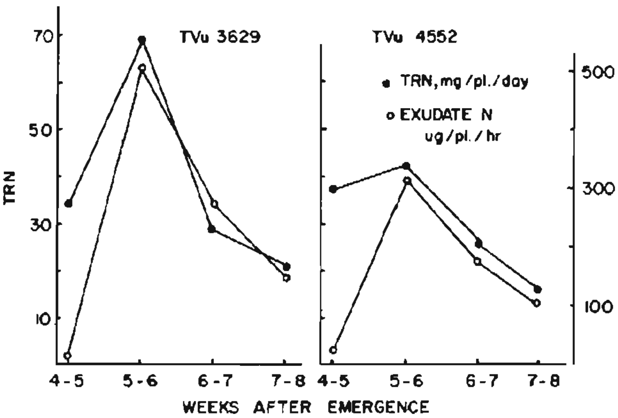

Fig. 3. Relationship between rates of TRN accumulation and amino-N present in stem exudate of cowpea.

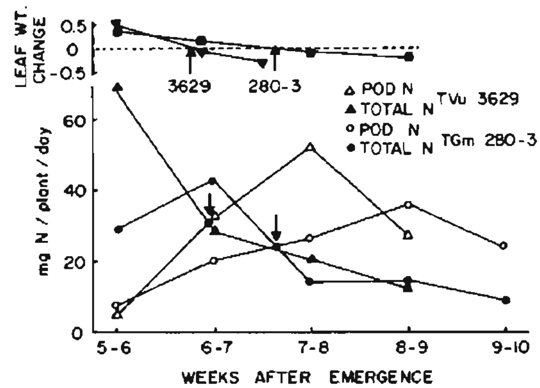

Fig. 4. Rates of TRN accumulation (supply) and TRN demand by seeds in relation to leaf senescence.

during pod development. TVu 3629 was capable of producing more than 40 percent of its TRN during the two weeks from flowering to start of rapid pod fill, whereas the same period only lasted one week for VITA-5 and resulted in 20 percent of its TRN accumulation. TVu 3629 not only reached a higher rate of fixation than VITA-5 but also maintained a moderate rate for a longer duration.

Soybeans had a lower rate of amino-N production – maximum rate of 90 ug amino-N/plant/hr – although they produce an equivalent amount of nodules compared to cowpeas. On a per plant basis, the nodule efficiency of soybeans was only 20 percent that of cowpea (Table 21). The low nodule efficiency of soybeans is probably a result of the shading effect produced at the close spacings. In the two weeks following flowering, TGm 280-3 accumulated 50 percent of its TRN and TGm 686 35 percent.

Table 21. Nodule efficiency of cowpea and soybean during pod development.

	Nodule efficiency days after emergence			
	35	42	49	56
	ug amino-N/mg nodule			
VITA-5	1.10±.07	0.73±.17	0.63±.28	0.53±.13
TVu 3629	1.97±.51	1.00±.26	0.78±.24	0.70±.27
TGm 280-3	0.22±.04	0.18±.04	0.06±.01	0.09±.01
TGm 686	0.32±.08	0.32±.09	0.16±.03	0.10±.01

The rates of TRN accumulation and the amino-N in the exudate greatly decreased during rapid pod development. The N requirement for pod growth exceeded the supply from N_2 fixation between 5-6 weeks after emergence for VITA-5 and one week later for TVu 3629 (Fig. 4). In soybeans, the rate of pod development was slower and the N demand did not surpass the supply until the eighth week. In both cowpea and soybean, the point at which the N demand by the pods exceeded the N supply coincided with leaf senescence, indicating that the N demand was being fulfilled by redistribution of N from other plant organs. Sources of seed N are shown in Table 22. In cowpeas, about 40 percent of the TRN in the seeds was re-translocated from leaf tissue and 45 percent synthesized during the pod-filling period. Soybean seeds received less of their total N from the leaves, especially TGm 686, but were capable of producing much nitrogen during pod fill. However at maturity, 40 percent of the TRN accumulated by cowpea remained on the plant whereas in soybeans, only 22 percent had not been translocated.

Even though the rate of TRN accumulation, quantity of amino-N in the exudate, and nitrate reductase activity were all very low during the pod filling period, most if not all of the TRN produced during this phase of growth was translocated directly to the seed.

Pod removal and N_2 fixation. As observed earlier, pod formation has a detrimental effect on N_2 fixation. This phenomenon was further studied in two cowpea plant types. In VITA-5 the pods comprise a large percentage of the total plant weight, and removal of flowers for two weeks after anthesis (delayed pod formation) allowed a continuation of N_2 fixation

Table 22. Sources of seed N at maturity and relative amount re-distributed from other plant organs.

	Cowpea				Soybean			
	VITA-5		TVu 3629		TGm 280-3		TGm 686	
Sources	mg/plant	%	mg/plant	%	mg/plant	%	mg/plant	%
TRN in plant	1320.7		1759.6		1057.3		1071.0	
TRN in seeds	841.9	63.7**	1001.6	56.9**	797.0	75.4**	859.1	80.2**
Sources of seed N:								
re-distributed from leaves	334.0	39.7*	390.0	38.7*	308.5	38.7*	175.3	20.4*
re-distributed from stem	72.8	8.6*	37.2	3.7*	39.6	5.0*	66.1	7.7*
re-distributed from peduncles	36.4	4.3*	136.7	13.7*	–	–	–	–
Produced during pod fill	398.7	47.4*	437.7	43.9*	448.9	56.3*	617.7	71.9*
TRN remaining in non-seed tissue	478.8	36.3**	758.0	43.1**	260.3	24.6**	211.9	19.8**

*** Percent of TRN in plant*
** Percent of TRN in seeds*

(Table 23). Pods were less of a drain on the leafy cultivar, TVu 1977, and subsequently pod formation only decreased N_2 fixation by 40 percent.

Foliar application of nutrients. Apparently, lack of an adequate N supply during pod development forces the plant to re-distribute N from other plant tissues. This in turn induces leaf senescence and results in a lack of metabolites necessary for N_2 fixation and nutrient uptake. If N is the limiting nutrient during pod filling, then the application of foliar N (urea) should increase yield and delay leaf senescence. This hypothesis was studied by applying foliar nutrients to grain legumes that have distinct patterns of pod development. Mung beans have a very short pod filling period and four applications of a nutrient solution containing N, P, K, and S (ratio 10:1:3:0.5) increased the yield of the indeterminate cultivar by 24 percent bud did not alter seed yield in the determinate type. At the higher concentration of foliar spray some leaf burning occurred. Using the same nutrient spray, cowpea responded only slightly to three applications during the pod filling stage. (Table 24). As noted in mung beans, application of foliar nutrients delayed leaf senescence. In the second season, the concentration of the foliar spray was reduced and applied during three phases of pod development.

Table 23. Effect of flower removal on the amount of amino-N in the stem exudate of cowpea.

Cultivar	Treatment	Exudate N ug-N/plant/hr
TVu 4552	–Pods	52.6
	–Pods	192.3
TVu 1977	–Pods	114.8
	–Pods	190.1
S.E. ±	5.5	
C.V.	8.0	

Table 24. Effect of foliar application of nutrients during pod fill on cowpea yield, (First season, 1976).

	VITA-5		TVu 3629
Treatment	kg/ha		kg/ha
Control	1822		1569
Spray soln. 1*	1860		1791
Spray soln. 2	1789		1509
S.E. ±		67.5	
C.V.		7.8	

***Spray soln. 1 - 12.5 kg/ha N; 1.3 kg P; 3.8 kg K: 0.8 kg S*
Spray soln. 2 = 2 × spray soln. 1.

Table 25. Effect of foliar nutrients applied at various stages of pod development on cowpea yield, (Second season, 1976).

	VITA-5		VITA-4
Treatment	kg/ha		kg/ha
Control	588		240
Flo. – Mat.**	632		273
Epf – Mat.	745		351
Mpf – Mat.	720		276
S.E. ±		46.5	
C.V.		19.4	

Table 26. Effect of foliar nutrients applied at different stages of pod development on soybean yield, (Second season, 1976).

	TGm 294-4-2371		TGm 686
Treatment	kg/ha		kg/ha
Control	1858		1605
Stage R-5*	2118		1600
Stage R-7**	2047		1773
S.E. ±		69.2	
C.V.		15.7	

**R-5 = beans can be felt in uppermost pods.*
***R-7 = leaves on bottom of plant are yellow.*

Four applications from flowering to maturity neither increased yield nor delayed senescence in either cowpea cultivar. (Table 25). However, applications commencing at early pod fill and continuing through maturity resulted in significant increases in seed yield in both VITA-5 and VITA-4. Applications during late pod fill were ineffective. Indeterminate soybeans also responded to foliar nutrients but only when applied during the period of rapid pod fill. (Table 26).

Generally, these results indicate that N is not the only limiting factor during pod development. Also the grain legumes studied are unable to support a high rate of N_2 fixation and rapid pod development simultaneously.

Since cowpeas appear to be inefficient in redistributing N compared to soybeans, more emphasis will be directed toward identifying plant types having the following characteristics:

1. early nodulation, thereby decreasing their dependency on soil nitrate during the pre-flowering stage
2. high nodule efficiency with the capability of maintaining an adequate N supply during pod fill and
3. efficient re-translocation of N in the late pod fill period.

Reading-ITTA Project. In cooperative studies carried out at Reading University, certain experiments were conducted on nitrogen nutrition of cowpea cv.K 2809 grown in pots in a greenhouse and inoculated with *Rhizobium* strain CB 756.

The results demonstrated that effectively nodulated plants grown without applied N were vegetatively equal to non-nodulated plants supplied daily with 60 ppm N throughout growth (88 days) and produced significantly greater seed yields. Nodulation promoted branching and improved pod set and retention compared with plants relying on applied N.

Average seed yields of effectively nodulated plants were 36 percent greater than those of non-nodulated plants when both received applied N at concentrations ranging from 60 to 240 ppm during one of three periods: emergence to first flower; first flower to mid pod fill or mid pod fill to maturity. Nodulation improved yields by 45 percent when plants received a 'basal' level of 30 ppm N during growth.

Maximum rates of assimilation of nutrient N and of symbiotically fixed N occurred during early pod fill in plants receiving 25 ppm N. Symbiotic fixation contributed significant amounts of nitrogen to seed production even after mid pod fill. Some N taken up before flowering was translocated to post flowering vegetative and reproductive components. Although there was little net change in vegetative dry matter during pod maturation, there was a large decrease in N content which contributed the bulk of N accumulated in fruits.

Inorganic N applied as a 'starter dose' (equivalent to 10 kg N ha_{-1}) had no significant effect on seed yield of nodulated plants but 40 percent of the starter taken up during the first three weeks of vegetative growth was located in seeds at maturity.

Rhizobium strains isolated from soils at IITA were shown to be superior to CB 756 in providing N for seed in several cowpea genotypes. The significance of cultivar-strain interactions and the potential of different strains for tolerating diurnal temperature extremes are being investigated. To quantify further the carbon-nitrogen interrelationships of cowpeas, a system for measuring root respiration continuously throughout the entire growth period has been developed and tested. Vegetative growth and reproductive development are almost identical for plants rooted in the respiration chamber and in conventional pots.

Stress physiology

Progress in screening cowpea cultivars for environmental sensitivity with respect to the onset of flowering and yielding potential has been accelerated with the establishment of an integrated field and glasshouse screening technique. Screening for photoperiod sensitivity using low intensity incandescent lighting to extend the natural daylength in the field at IITA is followed by a second stage at Reading University, where glasshouses are used to determine the effects of night temperature on time to first flower, and of day temperature on the rate of leaf senescence and components of seed yield. The integrated screening of the first batch of cultivars using this technique was completed in the summer of 1976.

Screening for photoperiod sensitivity continued in 1976 outdoors. As before, about half of the cowpea lines screened showed no variation in the date of the first flower due to natural versus a 13½-hour photoperiod. Of the 34 soybean lines, none was rated insensitive, with lines of Indonesian origin particularly sensitive. Of 27 climbing lima bean lines, 18 were insensitive, while none of the three winged bean *(Psophocarpus)* or three hyacinth bean *(Lablab niger)* lines flowered under a long photoperiod within 60 days. Mexican yam bean *(Pachyrrhizus erosus)* neither flowered nor produced tubers under a 13½-hour photoperiod.

Work on drought stress of cowpea and soybean continued so as to develop a field screening technique to detect varietal differences in susceptibility to drought. In a field experiment planted in October, 1975 irrigation was withheld from one soybean and three cowpea cultivars for two weeks starting at flowering. Although the cowpeas showed increased leaf stomatal resistance during the stress period compared to the well watered controls, plant moisture tension measured during the early afternoon was only slightly increased, and showed no increase with duration of the drought period (Fig. 5). Soybean, on the other hand, showed increased plant moisture tension as drought was prolonged. Thus

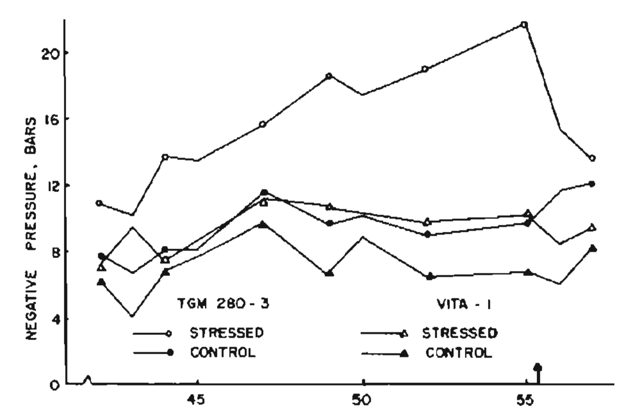

Fig. 5. Plant moisture potential (4) (measured by pressure bomb) of cowpea and soybean during a two-week drought stress period.

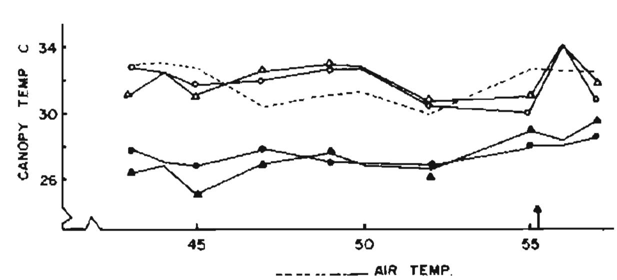

Fig. 6. Canopy temperatures of stressed and unstressed cowpea and soybean during a two-week drought stress period. Temperatures were measured with infrared thermometer.

plant moisture tension as measured by the pressure bomb can give indication of soybean drought stress but is less useful with cowpea. Canopy temperatures of stressed plots of both cowpea and soybean as measured by a hand-held infrared thermometer during the stress period were 5 C higher during the middle of the day than non-stressed canopies, with no significant difference among cultivars or species (Fig. 6). Under drought stress, high stomatal resistance prevented evaporative cooling of the canopy causing an increase in leaf temperature. This appears to be a useful criterion for differentiating drought stressed from non-stressed plots, but the instrumentation is at present too expensive to permit a large-scale use of this technique.

Seed yields of cowpea were not significantly reduced by the stress period (Table 27). Although pod numbers decreased slightly, a small increase in seed size compensated. In contrast, seed yields of soybean were reduced by 53 percent, primarily due to a 44 percent reduction in pod numbers. It thus appears that work on drought stress at IITA should concentrate on the more susceptible soybean rather than cowpea.

Table 27. Seed yields and yield components of three cowpea and one soybean cultivar after a two-week drought stress during early podfill.

	Yields g/m^2		Pod no/m^2		100 seed weight (g.)	
Cultivar	Control	Stressed	Control	Stressed	Control	Stressed
TVu 4552	75.6	69.6	88.9	75.3	11.28	12.83
VITA 1	115.8	120.7	66.8	62.1	13.12	14.68
VITA 5	115.3	99.8	133.6	108.3	9.51	10.39
TGm 280-3	142.2	66.7	550.1	309.6	17.30	15.41
	5.4					
S.E. ±						

A poorly drained soil can frequently lead to waterlogged conditions during an excessively wet growing season. To understand better the response of grain legumes to soil flooding, an experiment was conducted in the dry season with the soil physicist, in which soil flooding was applied to one cultivar each of cowpea, soybean and maize growing in Apomu or Egbeda soil in buried 250-liter drums. Flooding treatments of five-day duration were applied at three weeks after planting and at flowering. Measurements of stomatal resistance during the first flooding period indicated that only maize and cowpea experienced drought stress with flooding, but this was not measurable until the third day of waterlogging. Plant dry weight and leaf area were adversely affected by the first flooding treatment in all three crops. Seed yields showed most drastic decline for cowpea, with plants subjected to two flooding treatments yielding virtually nothing (Table 28). Soybean was less affected by waterlogging, although yields were also significantly decreased. Maize recovered from the effects of the early flooding and appeared to be less sensitive to flooding at tasseling, so that yields were not significantly different between treatments.

Table 28. The effect of one or two flooding treatments of five days duration on seed yields of cowpea, soybean and maize grown in buried 250-liter drums filled with Apomu or Egbeda soil.

Flooding frequency	Seed yields, g/plant		
	Cowpea	Soybean	Maize
0	29.0	32.8	103.2
1x	22.8	27.0	64.0
2x	5.4	16.6	91.2
S.E. ±	2.6	2.2	17.5
C.V.	23.3	18.4	35.3

In cooperative work at Reading, a defoliation experiment with vegetative cowpea plants, dependent largely on applied nitrogen for their total nitrogen requirement has shown that leaves which are from two to three weeks old contribute little to further vegetative dry weight increment. When parts of young cowpea leaves were removed plant dry weight increase was hardly affected as compensatory expansion of the remaining laminae took place. However, the removal of several young leaves (a reduction in total leaf area of 17 percent or above) was highly detrimental to subsequent plant growth. Thus, the outcome of defoliation depends not just on the absolute leaf area removed but also on the age of the leaves treated and whether or not loss of whole leaves or parts of leaves is involved. These results could be used as a basis for deriving rational 'scoring' criteria for estimating the depredation by pests in the field.

To understand cowpea growth and yield when intercropped with taller crops such as maize which can severely shade the cowpea, studies of the effects of shade *per se* were continued in 1976. Three levels of shade (50, 62 or 75 percent) applied, using metal frames covered with black polyethylene strips, were put on two cowpea cultivars growing in field plots, from emergence to flowering of the unshaded controls. Dry matter samples taken at the time of shade removal showed progressively more reduction in dry weight, leaf area index and branch numbers with increased shading in both TVx 1836 and VITA-4 used in the first season.

Similar results were obtained with TVx 1836 and VITA-5 in the second season. At least partial recovery was achieved by the shaded plants, particularly in the first season, when cool wet conditions permitted harvesting during a seven-week period. In the second season, yield levels were lower and recovery after shading, as indicated by seed yields, less complete. Variability was high but the results indicate that cowpea can recover from heavy shading and produce adequate yields as long as the reproductive period is long. Intercropped cowpea in the savanna zone of West Africa is frequently shaded by tall cereal crops during the vegetative growth stage.

Intercropping investigations

Intercropping is the main feature of cropping systems in Africa. Insect susceptible legumes such as cowpea are often grown in mixtures with cereals and other crops to avoid risks and uncertainty in obtaining yields. To better determine the performance of cowpea when intercropped with maize, sorghum or millet, several intercropping experiments were conducted. Effects of plant types, maize density, planting date and insecticide application on intercropped cowpea were examined in these experiments.

Comparison between artificial shade and maize shade. Six cowpea cultivars of contrasting growth habit were interplanted under three maize densities 0, 16,000 (60×100 cm) and 33,000 (30×100 cm) plants/ha. one week before the maize (TZPB) started tasseling.

The maize produced a leaf area index of 2.45 and 1.51 within two weeks after tasseling for the 30×100 and 60×100 spacings respectively. This corresponded to 67 and 51 percent light interception for the two densities.

Maize was harvested 10 days after the unshaded cowpeas started flowering. The ability of cowpea to regrow vegetatively after shade was removed was, however, limited by the cessation of rains four days later, so that final seed yield of cowpea was reduced 71 percent and 94 percent by intercropping under less dense and dense maize, respectively (Table 29). Significant varietal differences in cowpea yield occurred, with the erect cultivar Prima and a traditional cultivar (TVu 3231) of low yield potential producing least yield and VITA-1 and VITA-4 the highest yields in the trial. The cultivar × intercropping interaction was significant at the 5 percent level.

Table 29. Seed yields of cowpea cultivars when intercropped under maize at three densities. Cowpea was planted six weeks after the maize in second season, 1976.

Cultivar	Monocrop	Intercropped with maize 60×100	Intercropped with maize 30×100
		Yield, g/m²	
TVx 1836-19E	97.8	28.9	5.5
VITA-1	130.0	33.1	8.4
VITA-4	121.2	43.0	4.1
VITA-5	92.1	26.3	5.7
TVu 3231	86.8	26.5	4.8
TVu 76	70.9	16.5	3.9
Average	99.8	29.0	5.4
S.E. ±	6.2	6.2	6.2

Since the second shading experiment and the maize cowpea intercropping experiment were planted at the same time, using the same cowpea cultivars, a comparison of the effects of artificial versus maize shade is possible. Both types of shade delayed flowering of cowpea, particularly for VITA-4, in which a two-week delay resulted at the densest shade level. Plant morphology, as expressed by main stem length and internode length was, however, significantly different under maize from under artificial shade. Whereas increasing artificial shade led to greater stem length, due to longer internodes; stem length, node number and internode length were drastically reduced in VITA-5 under the densest maize shade level. The cause of this response requires further investigation, but from preliminary evidence may be attributed to competition for nutrients or moisture between cowpea and maize.

Planting date and maize plant type. The performance of VITA-5 cowpea intercropped with either TZPB or Upper Volta Early (UVE) maize was evaluated by planting it either simultaneously with maize or two months after the maize. The cowpea was planted between maize rows 1 m apart, with in-row spacing set at 15 and 30 cm for cowpea and maize, respectively.

Planting cowpea simultaneously with maize permitted vegetative growth of cowpea under unshaded conditions. Therefore, cowpea dry weight at flowering was only reduced by 25 and 42 percent by association with UVE and TZPB maize, respectively. Growth after flowering was more severely affected, however, and grain yields were reduced 50 percent by UVE and 60 percent by TZPB (Table 30). UVE had less effect on cowpea growth and grain yield than TZPB because it shaded the cowpea less. Leaf area index measured two weeks after tasseling was 0.9 for UVE and 2.3 for TZPB.

*Table 30. **Seed yields of VITA-5 cowpea and two cultivars of maize under monocrop or intercrop conditions when cowpea was planted at the same time as maize or two months later.***

Treatment	Maize cultivar	Cowpea Mono-crop	Cowpea Inter-crop	Maize Mono crop	Maize Inter-crop
		Seed yield (g/m^2)			
Cowpea + Maize	UVE	258	128.2	202.6	197.9
planted same time	TZPB	260	80.3	610.1	654.2
Cowpea planted	UVE	44	26.4	222.8	229.9
8 weeks after maize	TZPB	35	3.2	615.8	642.8
S.E. ±		7.8	7.8		

Maize spacing and nitrogen level. Maize density was varied from 10,000 to 30,000 plants/ha and nitrogen level from 0 to 120 kg/ha to determine the effect of these two factors on intercropped cowpea VITA-5 planted between rows of maize. Maize and cowpea were planted simultaneously with cowpea at 20 by 100 cm. Two spatial arrangements, 33 by 100 with 1 plant/hill and 100 by 100 with 3 plants/hill, were also compared. The latter arrangement is widely practiced by subsistence farmers.

Because the soil used was fertile, there was no significant effect of nitrogen on intercropped cowpea and maize. However, decreasing maize density increased percent light transmission, leaf area index and seed yield of cowpeas, but reduced maize yield (Table 31). Changing the spatial arrangement at 30,000 plants/ha did not have any effect on percent light transmission and intercropped cowpea and maize yields. In terms of Land Equivalent Ratio (LER), maize planted at 50 by 100 or 100 by 100 cm with 3 plants/hill was more productive than maize planted at 33 by 100 or at 100 by 100 cm with 1 plant/hill.

Spraying regime × cultivar interaction. An experiment was conducted at three locations in Nigeria, Gusau in the north, and Shaki and Odo-Ogun in the west, to determine the productivity of cowpea under two cropping systems and two spraying regimes. In all locations intercropped cowpea produced lower yields than sole cowpea under both spraying regimes (2 or 3 insecticide applications versus none) (Table 32). In the unsprayed plots the level of insect damage (leafhoppers, thrips, *Maruca testulalis* and coreids) on intercropped cowpea was about the same as on monocrops in any location.

*Table 32. **Effect of intercropping and insect control on cowpea yield in three locations within Nigeria.***

Location and cropping system	Monocropping Sprayed	Monocropping Unsprayed	Intercropping Sprayed	Intercropping Unsprayed
	Seed yield (kg/ha)			
Gusau*, with millet	775	16	121	31
with millet + sorghum	775	16	48	32
Odo Ogun**, with maize + sorghum	383	68	278	9
Shaki***, with maize	935	474	412	145

**Means of 4 cowpea cultivars. Sorghum and cowpea were planted 1 and 2 months after millet, respectively. Millet planting date was 21 May.*

***Means of 8 cowpea cultivars. Maize and sorghum planted 16 August, and cowpea on 1 September.*

****Means of 6 farmers' fields with VITA-5. The cowpea was planted 2-3 weeks after maize in second season.*

Intercropping did not reduce insect damage in cowpea. In the sprayed plots the low yields of intercropped cowpea were mainly attributed to light competition particularly when planted two months after cereals at Gusau. In Gusau, VITA-4 showed the least dry matter and yield reduction under millet compared to the other three cultivars. In Odo-Ogun, TVu 2616P-01D and VITA-4 were the best performers among the eight cultivars tested. As in the previous experiments, intercropping had higher total productivity than monocropping when the yields of both cereals and cowpea are considered.

Use of maize as a support for climbing cowpea. Vegetable climbing cowpea provides an important source of protein in humid areas where harvesting of dry seeds is difficult or unprofitable. Although trellising is necessary for high yield, trellising materials are frequently difficult to obtain. Maize was used as an alternative support to determine the effect of planting method, insect control and cowpea cultivars on cowpea and maize yields. Maize and cowpea were planted simultaneously in both seasons.

In the first season climbing cowpea FARV-13 planted 50 cm between rows of maize TZPB produced 700 to 800 kg/ha more green pods than planting in the same hills or alternate

*Table 31. **Effect of maize spacing on performance of maize (TZPB) and cowpea (VITA-5) in an intercrop experiment planted in first season, 1976, with cowpea and maize planted at the same time.***

Maize spacing (cm)	Maize Population, plants/ha	% Light trans-mission at 63 DAP	Cowpea LAI** at 60 DAP	Cowpea yield, kg/ha	Maize yield, kg/ha	LER*
33 × 100, 1 plant/hill	30,000	34.5	2.19	407	4719	1.16
100 × 100, 3 plants/hill	30,000	36.9	2.07	432	5131	1.25
50 × 100, 1 plant/hill	20,000	47.2	2.54	556	4365	1.24
100 × 100, 1 plant/hill	10,000	65.8	3.18	700	2775	1.11
Sole cowpea (20 × 100 cm)	–	–	6.77	1098	–	–
Sole maize (33 × 100 cm)	30,000	35.0	–	–	5974	–
S.E. ±			0.18	74	366	
C.V.			11	24	16	

**LER = Land equivalent ratio*
***LAI = Leaf area index*

Table 33. Effect of planting method and insecticide application on vegetable cowpea FARV-13 using maize TZPB as a support. Both cowpea and maize were planted 25 x 150 cm in first season, 1976.

Planting method	Cowpea pod yield (ton/ha)*		Maize yield (ton/ha)		Cowpea LAI	
	SPR**	UNS**	SPR	UNS	SPR	UNS
Cowpea + maize same hills	7.70	4.43	4.68	4.61	0.99	1.02
Cowpea + maize alternate hills	8.83	4.74	4.69	4.26	0.99	0.86
Cowpea between rows of maize	9.54	4.37	5.01	4.61	1.04	1.12
Cowpea/maize alone	30.05	8.87	6.14	5.60	1.69	1.59
S.E. ±	1.35	1.43	0.29	0.39	0.22	0.21
C.V.	8	44	8	14	33	32

**About 90% moisture content*

***SPR = spraying weekly from 21 DAP, UNS = No insecticide application.*

hills with maize but the yield differences were not significant (Table 33). When yields of both cowpea and maize are considered, however, the former method of planting was more productive (LER = 1.14) than the latter methods of planting (LER 1.02 to 1.05) provided the cowpea was sprayed and properly trained on maize. Without insect control planting method had no significant effect on cowpea and maize yields.

Green pod yield of FARV-13 growing on bamboo trellis with good insect control was 30 tons/ha with about 90 percent moisture. The yield of FARV-13 on maize support was reduced by 71 percent because of competition for light and possibly also water and nutrients. The leaf area index of cowpea was reduced from 1.7 in a sole crop to about 1.0 in the intercropping. Cowpea also reduced maize yield by 21 percent as a result of the reduction of maize leaf area exposed to solar radiation. Contrary to previous findings (IITA Annual Report 1973), maize lodging was not increased by the cowpea. Growing vegetable cowpea with maize in the first season had the advantage of additional yield of maize, lower costs in building trellises, and in the unsprayed plots, lower incidence of virus and *Maruca testulalis* damage on pods. Without insect control the first-season cowpea yielded 40 percent of the sprayed plots; this was considerable compared to the generally poor yields of second-season cowpea.

Harvesting the young tender leaves weekly or biweekly from 28 to 77 DAP reduced green pod yield of FARV-13 by 19 percent. This was probably due to low leaf area index of the cowpea (less than 2.0) even when no leaves were removed.

In the second season 12 vegetable cowpea cultivars were planted either with bamboo or maize trellis. Maize TZPB was planted 25×200 cm and the cowpeas at 25×100 cm. Two rows of cowpea were trained to one row of either maize or bamboo. Green pod and dry seed yields of cowpea under maize trellis were reduced by 61 and 66 percent respectively, mainly through the reduction in the number of pods/m^2 and pod length. There was a significant linear relationship between yield on maize and yield on bamboo trellis for both green pod ($r = 0.76^*$) and dry seed yield ($r = 0.93^{**}$). These results indicate that screening climbing vegetable cowpeas for high yield potential can be more simply done on maize than on bamboo trellis.

The conclusions from the above intercropping experiments show that:

1. Shading frames cannot be used for evaluating the tolerance of cowpea to intercropping with cereals since the intercropped species compete for moisture, nutrients and light.
2. Planting cowpea simultaneously with maize was more advantageous under Ibadan conditions than planting at six to eight weeks after maize.
3. Maize density and maize plant type had a pronounced effect on the growth of intercropped cowpea.
4. Leafy semi-erect VITA-4 performed better than other cowpea cultivars under intercropping, indicating the importance of selection of cultivars adapted to intercropping.
5. Maize provides good support for climbing vegetable cowpea in the first season. Planting the cowpea between rows of maize appeared to be more efficient than other spatial arrangements.

Environment – Management interaction

Planting date. Two day-length insensitive cowpea cultivars, VITA-5 and Ife Brown (TVu 3629), were planted at three-week intervals starting from 1 April to 28 October to evaluate the effect of climatic factors on growth and yield of cowpea. Seedling establishment was good in all the plantings so that yield differences could be attributed mainly to climatic factors and diseases. The first two plantings in April gave the highest yields at 2000 kg/ha (Fig. 7). As planting was delayed yield progressively decreased and levelled off at 500 kg/ha. The last planting on 28 October yielded only 160 kg/ha, however. Adequate moisture during crop growth particularly from flowering to harvest was essential for high yields provided plants were not attacked by diseases. Powdery mildew was a serious problem when planting was done during cloudy, cold dry weather from June to August. Seed yield was positively correlated to dry matter yield at flowering ($r = 0.91^{**}$), number of harvests per crop ($r = 0.78^{**}$) and growth duration ($r = 0.70^{**}$) indicating that any factors, climate or disease, which reduced these attributes reduced the yields of Ife Brown and VITA-5.

Weed control level. Weeds are one of the major limiting factors in cowpea production but information is lacking on yield losses by weeds for different cowpea plant types. Four plant types of cowpea were planted at two-row spacings (50 and 100 cm) and subjected to three levels of weed infestation (no weeding, 10-day, and 20-day weed free periods). No weeding resulted in no yields at all spacings and in all the four cultivars. The main weed species was *Euphorbia heterophyla* plus a few grasses.

Weed weight and cowpea seed yield were significantly affected by spacing and duration of the weed free period (Table 34). Semi-erect, broad-leaved VITA-1 was the most competitive, and semi-prostrate VITA-5 the least competitive against weeds. The erect, leafy TVx 1836-19E and strap-leaf TVx 33-1G were intermediate between the two cultivars in their response to weeding. Apparently, the height of the leaf

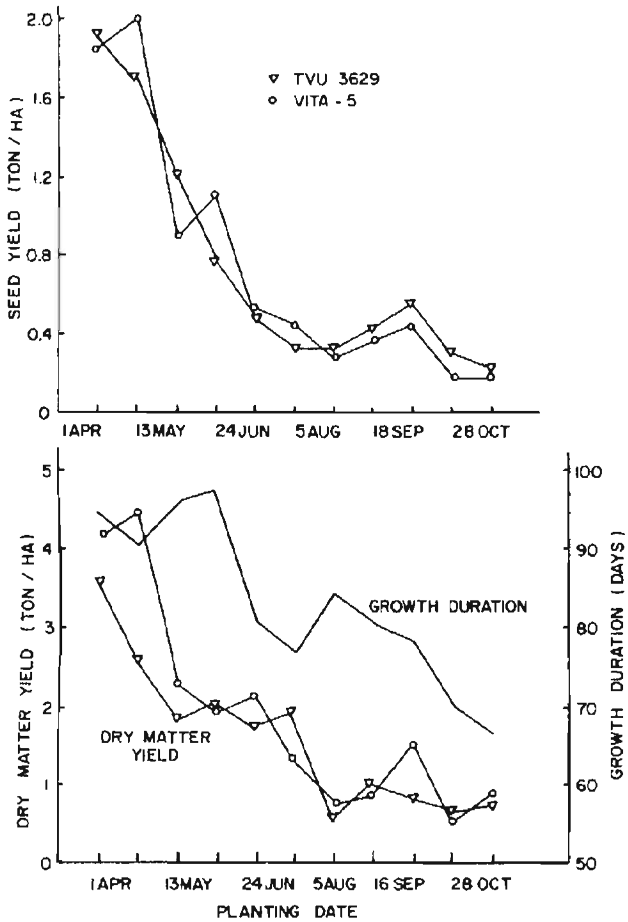

Fig. 7. Effect of planting date on seed yield, dry matter yield at flowering and growth duration of TVu 3629 and VITA-5 cowpea.

Table 34. Effect of spacing and weed free period on weed weight at 64 DAP and seed yield of four cultivars of cowpea planted first season, 1976.

	Weed dry weight (kg/ha)		Cowpea seed yield (kg/ha)	
Cultivar	10 DWP*	20 DWP**	10 DWP	20 DWP
		Spacing: 20×50 cm		
TVx 1836-19E	711	176	978	1216
VITA-1	346	116	443	837
VITA-5	1038	250	319	1357
TVx 33-1G	612	270	1069	1356
		Spacing: 20×100 cm		
TVx 1836-19E	1057	404	890	1231
VITA-1	596	211	487	958
VITA-5	1134	845	449	1307
TVx 33-1G	1057	307	1163	2499
S.E.±	447		117	
C.V.	21		25	

**10 DWP = 10 days weed free period*
***20 DWP = 20 days weed free period*

canopy influenced the ability of cowpea to suppress weed growth, particularly at wide spacings, more strongly than leaf shape and size.

Seed nitrogen content. Seeds from a cowpea management trial of six cultivars grown in four locations (IITA Annual Report 1975) were analyzed for their nitrogen content. The results showed that seed nitrogen content was greatly affected by location and not by fertilization (Table 35). These results suggest that screening cowpea for high protein content should be done in the same environment so that location effects can be minimized. Among the cultivars planted, VITA-1, VITA-3 and TVu 2616-01D consistently showed higher N content than VITA-4, VITA-5 and Ife Brown.

Table 35. Effect of location and fertilization on nitrogen content of cowpea seed. Means of six cultivars planted in second season 1975.

	Location				
Fertilizer level	Fashola	Owerri	Ikenne	Ibadan	Mean
	Seed nitrogen content, (%)				
None	3.77	3.76	4.16	4.47	4.04
20 kg N-20 kg P_2O_5/ha	3.94	3.90	4.40	4.45	4.17
Mean	3.86	3.83	4.28	4.46	

Pest management. The practical approach to pest problems in cowpea should be the use of host plant resistance and minimum number of insecticide applications. In the second season, insect resistant cultivars were compared with five standard cultivars under three insecticide regimes, (0,2) and 4 applications of Nuvacron at 0.5 kg a.i/ha). Without insect control, second season cowpeas produced no seed yield. Increasing the number of insecticide applications increased yield but the differences in yield between two and four applications were variable depending on the susceptibility of cowpea to pests (Fig. 8). The cultivar × insecticide regime interaction was highly significant. Without protection TVx 2869-P_2-2 or ER-1 (a cross between Prima and VITA-4) showed the highest number of flowers and pods per plant compared to the other cultivars. This may indicate the resistance of this cultivar to *Taeniothrips,* an important pest during flowering stage. ER-1 is erect, determinate and showed high resistance to leafhoppers and *Cercospora cruenta.* With two to four insecticide applications it outyielded all the VITA* lines by at least 40 percent. The high yield of ER-1 was partly explained by the short rainy season (about 40 days) which favored erect, determinate cowpeas. VITA-4 performed poorly at all levels of spraying because it was heavily attacked by coreids after the last insecticide was applied at 60 DAP. TVx 2869-P_9-3-2 (ER-7) also performed well but was heavily attacked by *Cercospora* leaf spot just before harvest.

Leaf plucking for vegetable use. In East Africa young leaves of cowpea are often plucked and used as a vegetable. In the second season at IITA, leaves of two cultivars were removed to varying degrees to determine whether plucking leaves for vegetable use had any detrimental effect on seed yield. Results showed that the traditional method of plucking young tender leaves weekly for four weeks from 28 DAP had no effect on yields of both cultivars. Removing up to two-thirds of the leaves did not have any effect on yield of VITA-3 but reduced yield of determinate TVx 1836-19E by 49 percent. This confirms earlier findings that semi-erect cultivars can withstand heavier defoliation than erect determinate cultivars.

Soybean Improvement

Soybean improvement efforts during 1976 laid greater emphasis on developing new recombinants and making early-generation selections between and within crosses to develop

VITA = Vigna lines identified at IITA.*

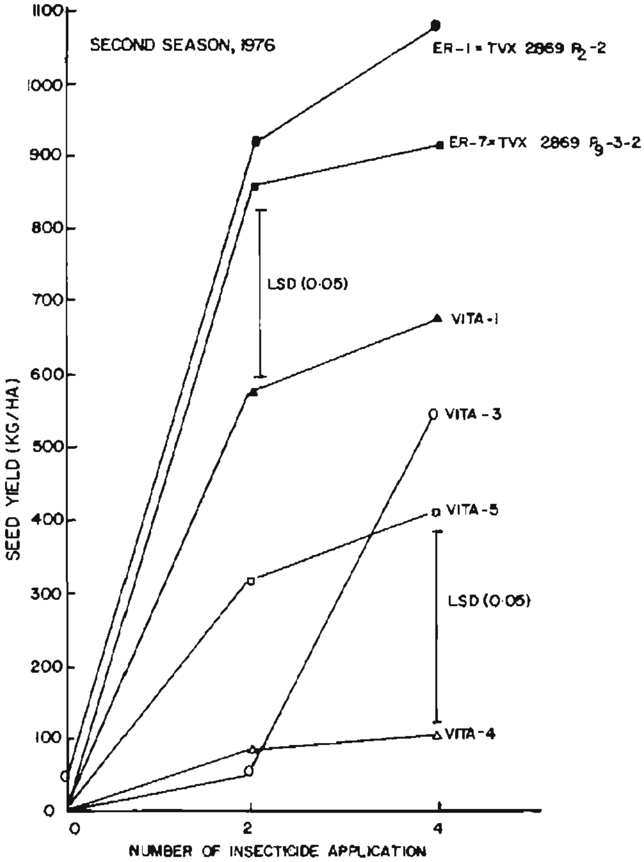

Fig. 8. Effect of number of insecticide application on seed yield of second season cowpea. Two applications at 40 and 50 DAP and four applications at 15, 30, 45 and 60 DAP.

strains with higher yields, good seed quality and viability and resistance to diseases, insects, shattering and lodging. Preliminary screening to identify cultivars with good seed quality and storability was continued. In addition, the elite materials arising from breeding efforts were tested at different stages for ultimate registration as potential cultivars or parent stocks for further improvement.

IITA trial results

Observation plots. During the first season, unreplicated four-row plots of 82 strains bulked last year were grown with standard cultivars. In the second season, strains were divided into early-, medium- and late-maturing groups based on first-season results and were grown in three separate trials. Each trial was replicated twice and had the standard cultivars as checks. Yield levels of the strains ranged from 500 to 3,833 kg/ha in the first season and from 944 to 3,111 kg/ha in the second season. Detailed results of the tests in second season are given in Table 36. Fourteen out of 81 strains tested out-yielded standard cultivars. Two strains, TGx 16-2E and TGx 26-34D, yielded more than 3,000 kg/ha.

Other trials. Results from other trials in the first and second seasons are presented in Tables 37 and 38. In the first season, maximum yields of 3,044 and 3,008 kg/ha were obtained from TGm 249-3 and Bossier respectively. The large variation in yield level of Bossier in trials during first (1,779 kg to 3,008 kg/ha) and second seasons (1,842 kg to 2,736 kg/ha) may reflect the response of a cultivar to soil variability. Three cultivars, TGx 13-3-2644, TGm 220-1-2205 and TGm 210-1-2363 mentioned as high yielders in the 1975 report established their superiority over Bossier.

Shattering resistance. Shattering of seed after maturity was recorded in the second season, as weather became hot and dry. Most of the cultivars in the trials did not shatter badly. Cultivars such as Hampton, TGx 13-4, TGm 210-1-2363 and TGm 273-2 showed 25-50 percent seed shattering. Of the 81 newly developed strains, 19 did not shatter at all even three weeks after maturity. Such cultivars would be suitable for large-scale production. Unfortunately, both the highest-yielding strains mentioned earlier shattered. Sixteen of the 30 strains bulked during 1976 first season also showed resistance to shattering.

International trials. During 1975, 15 sets of Uniform Soybean Trial No. 1 and nine sets of No. 2 consisting of 10 and 15 IITA entries were sent to locations in Africa, Asia and Latin America. Sixty percent of these trials were sent to locations in Africa. Results for eight Uniform 1 and 6 Uniform 2 trials have been received. In Trial 1, Jupiter gave the highest average yield of 2,186 kg/ha followed by TGm 249-2-1-b. Bossier, however, ranked first or second at five to eight locations. In Trinidad and Ethiopia, local cultivars ranked first. In Uniform trial 2, TGx 13-3-2644 gave the highest average yield of 1,475 kg/ha and was followed by TGm 131-1-1-b

Table 36. Performance of some of the newly developed soybean strains during second season of 1976.

	Yield kg/ha	Plant height (cm)	Days to maturity
Early maturity			
Standard check – Hampton	1876	73	88
High yielding lines:			
TGx 68-2C	2306	79	96
TGx 31-1D	2046	73	86
LSD .05	680		
Medium maturity			
Range	944–2375	51-87	88–98
Mean	1718	70	91
Standard check – Bossier	1899	54	92
High yielding lines:			
TGx 32-4D	2375	57	91
TGx 2-23E	2302	60	92
TGx 27-6D	2076	80	92
TGx 43-4C	2034	80	96
TGx 11-39E	2023	80	92
LSD .05	771		
Late maturity			
Range	1354-3111	59-112	87–97
Mean	2206	86	93
Standard check – Jupiter	2477	87	94
High yielding lines:			
TGx 16-2E	3111	93	91
TGx 26-34D	3026	94	93
TGx 57-12C	2849	88	92
TGx 59-3C	2779	59	91
TGx 46-3C	2694	82	96
TGx 26-23D	2688	85	88
TGx 26-48D	2685	90	96
LSD .05	679		

which ranked second at three locations. Detailed results of these trials are to be prepared for a separate report.

During 1976, seed for 52 INSTSOY/IITA trials and 19 Uniform trials of IITA entries were sent out to locations in Africa (90 percent), Asia (5 percent), and Latin America (6 percent). Results from the first of these trials have just been received.

Recombination and selection

About 100 new recombinants were developed, involving parents with high yield, good seed quality, storability and bacterial pustule resistance. Hand crossing, followed by a pedigree system of handling segregating material, was adopted because natural outcrossing on male sterile plants was unsuccessful. Single plant selections were made in the first season from F_2 populations of 93 successful crosses from the previous year. Ten seeds of each of the remaining plants were bulked for further selection in the second season. Selection in early generations (F_2 and F_3) revealed transgressive segregation in some of the crosses. The cross between TGm 220-2205 and TGx 13-3-2644 was the best and showed the highest frequency of agronomically desirable recombinants.

Plant protection

Insect pests. The common pests observed so far at IITA are Barombia beetle, *Taeniothrips*, and *Nazara viridula*. Almost no work has been done to survey insect pests of soybean and the yield losses they cause. However, during the second season a preliminary assessment of leaf feeding by two lepidopterous larvae of *Trichoplusia* sp. and *Plathypena* sp. was made on 144 lines in replicated trial plots. The frequency distribution based on the highest score in any replication is presented in Table 39. Seven lines with 6-10 percent leaf damage included the

Table 37. Grain yield and other agronomic characteristics of selected cultivars from five trials during first season, 1976.

Cultivar	Yield kg/ha	Plants/ m$_2$	Pods/ plant	Plant height (cm)	Days to flower	Days to maturity	Bacterial pustule score	Lodging score
Uniform trial 2.								
TGm 249-4-b	2774	29	39	86.4	31	107	1	2.5
TGm 210-1-2363	2545	41	37	63.7	36	105	1	1.5
TGx 13-3-2644	2288	34	31	95.0	32	110	1	1.5
TGx 66-5100	2264	61	19	98.3	35	94	3	2.5
TGm 249-5-5078	2232	43	28	82.5	33	103	1	2.0
TGm 255-2-4341	2132	49	31	79.0	33	112	1	2.0
Bossier	2003	52	30	65.6	38	111	1	1.5
Mean (16 cultivars)	1899	46	27	77.4	37	107		
LSD .05	739	14	12	17.8	1.52	5.18		
Advanced trial 1.								
Bossier	3008	32	27	61.9	39	109	1	1.0
TGm 242-2-2297	2157	44	37	66.1	37	100	1	2.5
TGm 197-33-4329	2138	45	21	57.2	39	111	1	1.0
TGm 296-1	2090	23	44	49.3	32	107	3	1.0
Amsoy 4192	2056	34	33	105.4	32	99	1	3.0
Mean (10 cultivars)	2006	42	27	78.8	35	102		
LSD .05	461	12	11	7.8	0.23	4.19		
Advanced trial 2.								
Amsoy 5002	2184	34	31	81.9	35	94	2	1.5
TGx 21-2	2024	43	20	87.0	34	98	3	1.0
TGm 240-2-2326	1774	22	38	78.2	35	112	4	1.5
M216	1715	20	50	55.6	43	115	2	1.0
CES 407	1608	40	32	91.9	41	115	4	2.0
Jupiter	955	35	29	101.3	41	115	4	2.0
Mean (10 cultivars)	1553	37	31	79.0	38	109		
LSD .05	613	16	18	7.9	0.9	2.71		
Preliminary trial 1.								
TGm 249-3	3044	34	30	74.7	30	96	1	1.0
TGm 225-3	2336	30	39	65.1	37	96	4	1.5
Bossier	2319	40	29	63.1	36	105	1	1.0
TGm 255-2-2527	2241	35	40	82.7	34	98	3	2.0
Mean (10 cultivars)	2062	43	27	77.4	34	87		
LSD .05	891	12	12	10.7	1.15	5.81		
Preliminary trial 2.								
Hawkeye 41-76	2487	28	59	74.7	31	100	1	1.0
TGm 195-3-4338	2188	52	29	48.0	34	99	1	1.5
Kent 2070	1940	40	32	79.5	35	98	1	1.5
TGm 197-3-3-4321	1806	35	35	59.3	37	99	1	1.0
Bossier	1779	37	21	64.1	37	106	1	1.0
Mean (10 cultivars)	1705	44	28	72.9	36	91		
LSD .05	754	16	28	9.4	0.62	7.92		

cultivar, TVx 13-3-3644 and six new strains — TGx 68-2C, 68-6C, 11-3E, 11-11E, 11-39E and 46-3C.

Additional pod sucking hemipterans recorded this year included *Nazara viridula*, *Acrosternum* sp., *Aspavia armigera*, *Piezodoru* sp., *Cletus* sp. and *Coptosoma* sp. These insects damaged young pods, caused them to shrivel and prevented development of seeds. Cultivars reacted differently to insect damage, and some early- and late-maturing cultivars appearing to escape damage.

Table 39. Frequency distribution of leaf damage score by two insect species, (Trichoplusia sp. and Plathypena sp.)

Score	Leaf damage (%)	Frequency
1	0-5%	0
2	0-10%	7
3	11-25%	45
4	26-50%	49
5	50% and above	43

Table 38. Grain yield and other agronomic characters of selected cultivars from six trials during second season, 1976.

Variety	Yield kg/ha	Plants/ m2	Pods/ plant	Plant height (cm)	Days to flower	Days to maturity	Bacterial pustule score	Lodging score
Uniform Trial 1.								
Forrest	2861	32	–	48	31	92	1.5	–
Bossier	2736	30	–	62	37	92	1	–
TGm 220-1-2205	2347	35	–	57	41	92	1	–
Cobb	2316	11	–	45	31	92	1.5	–
Davis	2285	17	–	38	37	92	1.5	–
TGm 294-4-2371	2263	27	–	72	41	92	1.5	–
TGm 210-1-2363	2228	34	–	55	37	92	1	–
Mean (16 varieties)	2101	23	–	68	37	94		
Uniform Trial 2.								
TGx 13-3-2644	2447	44	20	76	36	95	1	1
TGm 273-2-2340	2419	43	33	72	35	91	1.5	1.5
TGm 260-2-2-4293	2412	54	28	74	36	94	1	2
TGm 220-1-2205	2260	46	23	59	40	99	1	1
TGm 210-1-2317	2024	45	19	66	36	97	1	1
Bossier	2021	41	20	71	34	98	1	1
TGm 187-3-2	2013	52	27	78	42	97	1	3
Mean (16 varieties)	1961	46	21	73	37	95		
LSD .05	377							
Advanced Trial 1.								
TGm 197-3-3-4329	2090	55	24	64	38	98	1	2
TGm 296-1	2043	51	18	57	34	95	3	2
Amsoy 4192	1921	41	21	95	36	93	1	2
Bossier	1842	39	25	57	36	93	1	2
Amsoy 5007	1806	41	20	88	33	92	1.5	2.5
Mean (10 varieties)	1713	50	19	76	36	93		
LSD .05	421							
Advanced Trial 2.								
TGm 197-3-3-4333	2315	53	30	71	40	98	1	2
M216	2126	52	26	67	43	99	2	3
CES 407	2087	48	34	78	42	97	4	1.5
TGm 294-4-4274	1982	48	18	77	42	95	1	1
Jupiter	1869	42	31	76	42	92	4	2
Mean (10 varieties)	1858	50	25	74	38	94		
LSD .05	412							
Preliminary Trial 1.								
Bossier	2420	50	21	66	35	93	1	2
Jupiter	2267	46	39	77	44	95	4	2
TGm 249-3	2157	56	23	66	32	90	1	1
TGm 298-2-21	2071	58	22	85	34	92	3	2
TGm 236-14-1	2058	58	22	87	38	93	3.5	1.5
Mean (10 varieties)	1949	52	24	77	38	92		
LSD .05	513							
Preliminary Trial 2.								
TGm 273-2	2406	54	29	61	37	95	1	2
Kent 2070	2394	55	22	68	34	95	1	2
Bossier	2394	44	22	58	35	97	1	2
Hawkeye 4176	2315	50	28	72	34	96	1	1.5
Mean (10 varieties)	2007	51	26	67	37	94		
LSD .05	537							

Seed infestation by *Cydia* sp. in the field was observed in both first and second seasons, but damage was more serious during the first season. Percent damaged seed among 35 cultivars ranged from 4.8 to 30.5. Five cultivars — TGm 195-3-4338, TGm 242-4-4230, TGm 240-2-2326, TGm 203-1 and TGx 66-5100 — showed damaged seeds less than 10 percent.

Seed quality and viability

Studies were concentrated on the effect of conditions at harvest and during storage, with particular emphasis on varietal differences.

Conditions at harvest. The effect of weeds and lack of insect control on soybean seed quality and yield were investigated in two experiments during the first and second seasons. Weeds reduced leaf area index and yield in both seasons (Table 40), while decreasing both seed quality and germination. In the first season, percentage of purple-stained seed was greatly increased in the presence of weeds, presumably due to the increase in relative humidity in the micro-environment around the pods. In the second season, deterioration due to lack of weed control was less because of reduced weed growth and lower relative humidity at harvest. Insect damage decreased leaf area by 6 percent and 20 percent in the first and second seasons, respectively, but caused no significant yield decline. Lack of insect control had slightly negative but non-significant effects on seed quality and germination.

Table 40. The effect of weed control on leaf area index, seed yield percentage smooth clean seed and germination percentage of two soybean cultivars (averaged) during both seasons, 1976.

	Smooth, clean seed, %	Germination %	Seed yield, kg/ha	Leaf area index
	First season			
Weeding	18.3	88.1	3102	3.15
No weeding	5.1	73.4	1347	1.22
S.E. ±	33.3	3	124	0.12
C.V.%	47	12	7	15
Weeding	94.3	94.9	2260	3.81
No weeding	85.8	89.8	1719	2.97
S.E. ±	18	0.8	142	0.43
C.V.%	4	3	15	26

To determine the effect of foliar sprays of benomyl fungicide during the seed maturation period on soybean seed quality and germinability, an experiment with four cultivars was grown in the first season. Although the incidence of seed purpling was generally low, it was decreased by benomyl application (Table 41). The fungus most frequently isolated from the seeds was the *Phomopsis* state of *Diaporthe phaseolorum* cv. *sojae,* reported to be associated with deterioration of soybean seed quality. There was no evidence that benomyl reduced the contamination of seed by *Diaporthe*. Also, no significant differences were observed between cultivars in the percentage *Diaporthe*-bearing seed (incidence ranged from 20 to 90 percent). Other fungi isolated from seed included the *Nigrospora* state of *Khuskia oryzae, Phoma sorghina* and two species of *Fusarium*. *Cercospora kikuchii* was not isolated from any seed lost although it is known to be associated with seed purpling. *Colletotrichum truncatum* has also been obtained from soybean seed lots in Nigeria, but this species was not obtained in this study. No significant differences were established between fungicide treatments and percent emergence measured at harvest and after storage durations of one to three months.

Table 41. Percentage of clean and purple-stained seed harvested from four soybean cultivars after inoculation with Cercospora kikuchii or application of benomyl fungicide in first season, 1976.

Cultivar	Control Clean %	Control Purple %	Inoculated Clean %	Inoculated Purple %	Benomyl—Sprayed Clean %	Benomyl—Sprayed Purple %
Hardee	61	15	69	11	83	2
Bossier	73	16	78	13	82	10
Imp. Pelican	92	2	93	1	94	0
TGm 627	90	6	90	4	91	2

The need to dry seeds initially to reduce seed moisture was evident from a study with three cultivars. Plants with ripe pods were dried for 24 hours at 40, 50 or 60 C or left undried. After three months of storage, germination of undried seeds of Bossier had declined drastically, presumably because of their high initial moisture content (Table 42). Seeds dried at 40 and 50 C maintained adequate germination whereas drying at 60 C lowered percent germination, particularly in the cultivars with high initial seed moisture content.

Table 42. The effect of drying temperature on percent germination of three soybean cultivars.

Cultivar	Control	Drying Temp. C 40	50	60	Initial moisture, %
	Percent germination				
Bossier	17.0	84.4	85.5	1.4	29
Imp. Pelican	62.2	86.5	84.7	81.9	16
TGm 627	75.8	76.4	85.2	26.4	19

The method of seed threshing used can also influence germination and emergence through its effect on seed breakage. The traditional method of beating the pods in a bag was compared with hand threshing and using a combine. Only combine threshing increased breakage and reduced germination and emergence (Table 43).

Table 43. The effect of threshing method on seed breakage, percent germination and percent emergence of two soybean cultivars (averaged) grown in second season, 1976.

Threshing method*	% Seed breakage	% Germination	% Emergence
Hand threshing (control)	0	90.4	91.4
Beating pods inside a bag	0.08	87.2	90.5
Using a combine	6.02	74.0	72.1
S.E. ±	0.09	4.7	2.2
C.V. (%)	10	12	5

**Moisture content at harvest — 8.9 to 10.4%.*

Combined regression analysis of seed appearance, percent germination and emergence at harvesting using data from a sowing and harvest date experiment with 25 cultivars (IITA Annual Report 1975) indicated that percent infected seed explains 75 percent of the variability in germination at harvest time (Table 44.) Estimation of this character is, however, too slow and laborious to be of use in a screening program. If percent infected seed is excluded from the analysis, percent smooth clean seed and seed size become the next most important factors, explaining 52 percent of the variability. Percent germination can be predicted from the percent smooth, clean seed (a) and 100-seed weight (b) using the following equation:

$$y = 65.3 + 0.60a - 1.56b.$$

Results suggest that selection among lines for high percent smooth, clean seed and small seed size should lead to cultivars with better percent germination prior to storage.

Table 44. Correlation coefficients of some seed characteristics with percent germination and emergence in 25 soybean cultivars. Data are based on three plantings each harvested on two dates.

Factor	% Germination	% Emergence
% Infected seed	-0.869	-0.810
% Smooth, clean seed	0.632	0.639
100 seed weight (g)	-0.562	-0.445
% Cracked seed	-0.546	-0.547
% Purple-stained seed	-0.447	-0.484
% Wrinkled seed	0.102	0.117
% Discolored seed	-0.036	-0.172

Type and duration of storage. Preliminary investigations into the effect of seed appearance on germinability after various storage periods indicated that there was only a slight decrease in emergence for purple versus clean seeds of 27 lines after 60 days of storage under ambient conditions of high temperature and high relative humidity (28-30 C and 75 percent R.H.). By 120 days after harvest, emergence of almost all lines had decreased to 10 and 6 percent for clean and blemished seeds respectively, showing that seed appearance is a poor indicator of seed viability after adverse storage. Three lines: TGm 236-5, TGm 683 and TGm 297-2-4243 gave 40-45 percent emergence after 120 days.

The effect of length of storage and storage temperature on emergence was determined for good-quality seeds of 69 lines harvested in December, 1975 and stored in paper bags under ambient (29 C and 75% R.H.) or cold room (19 C and 70% R.H.) conditions. With increasing length of storage seedling emergence declined more rapidly for seeds stored under ambient conditions than at 19 C (Fig. 9). After 218 days of storage under ambient conditions only four lines gave more than 50 percent emergence, namely Hampton, TGm 249-5-4254, TGm 249-2-4289 and TGm 297-2.

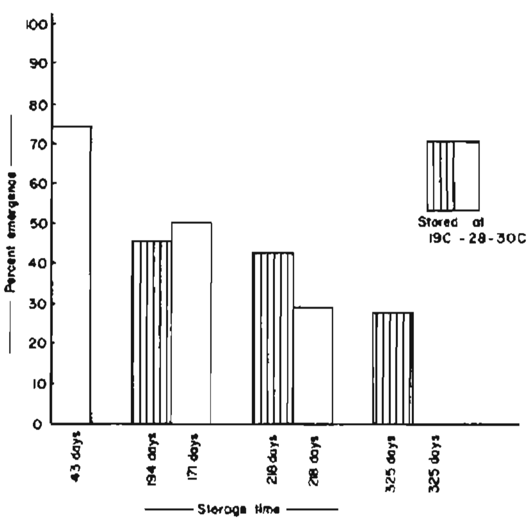

Fig. 9. Mean percent seed emergence of 33 soybean cultivars under various periods storage at 19 C and 28-30 C.

To determine whether the ability to withstand prolonged storage under ambient conditions can be predicted by simple laboratory tests, 50 lines of contrasting seed quality were grown in four successive plantings and harvested promptly or after two weeks delay. The seeds were then stored under ambient conditions for two to nine months. A standard germination test conducted at harvest, and germination tests after accelerated aging of the seed for three days at 40 C and 100 percent R.H. did not correlate well with field emergence after nine months of storage (Table 45). Smaller-seeded lines showed better ability to withstand prolonged storage than large-seeded lines. As expected, storage for short or long periods gave the most reliable indication of storability. In two separate nine-month storage tests, the same lines germinated well (r = 0.64**) (Table 46). More work is needed to determine simple tests to predict seed storability. The lines that possess good seed quality and storability are being used in the breeding program to develop material combining good agronomic characters and the ability to withstand long storage under adverse conditions.

Table 45. The correlation of percent field emergence after prolonged storage with germination and accelerated aging at harvest, emergence after short storage duration and seed size for 50 soybean lines differing in seed quality.

	Germ. test at harvest	Accel. aging at harvest	% Emerg. after s. storage	100 seed weight, (g)
Percent emergence after long storage	0.28	0.40	0.56	-0.56

Table 46. Percent field emergence, germination in standard and accelerated aging tests and seed size of the five best and the five worst (in storability) soybean lines stored for various times under ambient conditions.

		Percent germ. Storage duration		Percent germ.		100 seed
	Rank	9 mo.	2-4 mo.	Acc. aging	Germ. test	wt., g
TGm						
737	1	62.5	84.8	42.5	93.8	8.3
685	2	56.6	91.1	60.0	95.2	9.6
693	3	55.3	86.3	48.8	90.0	8.6
739	4	42.5	81.1	57.2	92.2	10.8
623	5	41.2	88.4	21.2	94.8	8.9
225-3	46	5.0	81.6	45.5	89.2	12.7
236-6-1-b	47	4.6	76.5	4.0	71.2	18.4
245-4	48	3.4	62.2	10.5	64.5	13.0
197-3-3-4321	49	3.1	64.7	37.0	66.5	16.5
667	50	1.7	52.2	28.0	72.0	18.9

Lima bean breeding

Scope of activities

The field plantings covered the three main growing seasons, from December 1975 to mid-November 1976. The unusually dry weather prevailing during the second season seriously affected the results of the experiments and delayed part of the planting of the breeding nursery and the yield trials.

Bush lima beans

Single plant and bulk selections made at IITA have not yet succeeded in improving the disease resistance and plant structure of determinate lima beans. Disease is controlled by low moisture conditions. To assess the yield potential of several cultivars in a more favorable environment, a yield trial was conducted in the dry season 1975/1976 under irrigation. The results are shown in Table 47. The mean dry seed yield for all entries was 230 g/m² after two harvests at 90 and 110 DAP.

Table 47. Dry seed yields and other agronomic attributes of bush lima beans grown at IITA, irrigated dry season 1975.

Pedigree	DFF[a])	DFRP[b])	Thresh. %	Dry seeds yield (g/m²)
Bush Bulk	42	81	70.6	243
Purple bulk	42	85	69.2	241
TP1 191-5	42	81	69.9	225
TP1 191-a	38	81	68.3	224
TP1 176-8	38	80	66.7	223
TP1 170	45	88	68.2	221
TP1 191-8	45	82	72.3	220
Mean (20 entries)	41.6	81.7	68.3	203
S.E. ±	1.0	2.8	1.0	26.9
C.V.(%)	3.5	4.8	2.1	18.7

(a) DFF: days to 50% first flowering. (b) DFRP: days to 50% first ripe pods.

Viny lima beans

Germplasm collection and evaluation. The germplasm collection of lima bean contains a residual heterozygosity which offers the breeder considerable opportunity for selection. Most segregating lines have been evaluated only in the second season and have shown considerable variation every year. Much of this segregating material was planted in the second season 1975 (early July) and harvested up to March 1976. The variation in 15 components of yield, including leaf and fruit characters, flowering time, disease reaction and seed characters, was assessed for 493 lines. The results obtained for some of the attributes are indicated in Table 48.

Table 48. Means, variation and correlation of some agronomic attributes in the viny lima bean nursery (1975/76).

Parameters	Means	S.D.	C.V. (%)	Corr. with yield
DFF	54.6	5.1	9.4	-0.13
Pod N⁰/m²	188.5	83.0	44.1	+0.83
Seed N⁰/pod	2.9	0.4	12.0	+0.07
Seed size (g/100)	40.9	8.5	20.8	-0.16
Pod length	8.7	1.1	12.8	-0.08
Seed yield (g/m²)	154.7	66.5	43.0	

To assess response to long daylength, 150 good-yielding lines representing 60 accessions were planted in the first season on an area previously sown with lima bean. Consequently, disease stress was very high with a large population of root-knot nematodes and a rapid build-up and spread of golden mosaic and Cercospora leaf spot. DFF ranged from 41 to 83 with 21 percent of the material flowering before 45 days. Some lines flowered at the same time as in the second season 1975, a possible indicator of daylength insensitivity. During selection, emphasis was given to lines or plants which podded well in spite of disease.

Of 20 lines showing no nematode galls on the field, only four had a moderate level of resistance in the greenhouse screening by the nematologist.

A germplasm collection comprising 250 accessions was grown in the second season, unreplicated and interplanted with maize, for seed maintenance. Rainfall ceased about one week after sowing and all plantings were exposed to severe drought stress followed by a very short rainy period. Flower and seed production was seriously affected by heavy infestation of post-flowering insects, mainly *Taeniothrips* and *Cydia* enabling selection for drought tolerance and good seed quality. Twelve accessions performed well averaging more than 50 g/m² dry clean seed yield at wide spacing (50×75 cm).

In 1976, 470 new accessions were added to the germplasm: 118 accessions came from Nigeria (southeast of Kaduna State), the remainder from elsewhere, mainly Liberia.

Yield trial. A preliminary viny yield trial, consisting of 16 elite strains selected from previous evaluation of the germplasm, was conducted in both seasons at IITA and in the second season in Onne under very humid conditions. Also, the 10 best lines from the two advanced viny yield trials conducted in 1975 were included in uniform trials, at IITA and elsewhere, using a standard bamboo trellis 2m high with strings for plant supports. Mean yields were lower in the second season and reflect two major factors: drought stress at IITA and waterlogging in Onne.

Preliminary trials. The results obtained from the first season at Ibadan are shown in Table 49. The dry seed yield of 14 entries averaged 175 g/m² in 110 days despite high incidence of golden mosaic, Cercospora leaf spot and root-knot nematode.

Table 49. Yield and other agronomic attributes for the entries in the preliminary viny yield trial (IITA, First season 1976).

Pedigree	DFF [a])	Disease GM [b])	CLS [c])	Seed size g/100	Growth duration	Seed yield (g/m²)	Harvest index (%)
TP1 174	45	4	4.5	31.5	110	247	40
TP1 323A	42	3	5	38.6	110	223	43
C = TP1 60E	43	4	5	36.7	100	209	51
TP1 178-26	48	3.5	5	32.0	110	207	44
TP1 60D	47	4	4.5	38.4	130	138	45
TP1 183-20	42	2.5	6	33.7	110	177	45
TP1 304C	42	3.2	5.5	39.8	100	176	47
TP1 111A	59	1.5	3	97.2	140	158	–
Mean (15 ent)	47.5	3.3	4.6	42.5	110	164	42.9
S.E. ±	1.1	0.9	0.4	1.1	–	22	2.5
C.V. (%)	3.3	36.7	13.3	3.7	–	19.6	8.3

(a) DFF: days to 50% first flowering
(b) GM: Golden mosaic score made visually, on the basis of 1 to 6 (1 is best)
(c) CLS: Cercospora leaf spot score made visually, on the basis of 1 to 6 (1 is best).

Two cultivars, TPI 1974 and 323A, out yielded TPI 60E which was selected as standard of comparison because of previous good performance. Neither showed resistance to the two major diseases, golden mosaic and Cercospora leaf spot. TPI 111A confirmed its high level of resistance to golden mosaic.

In the second season, unusually low dry seed yields were recorded for the two trials, due to climate and soil conditions. At IITA, seed emergence and seedling vigor were reduced by low soil moisture. In addition, a high incidence of green mottling occurred in the early stages of growth. The dry seed yield for the six best entries averaged only 58.8 g/m², with TPI 111A (77.8 g/m²) and TPI 174 (72.0 g/m²) as the best performers.

In Onne, planting was done during the peak of the rainy season on flat beds and stand was severely reduced by waterlogging. In order to assess acid soil tolerance of lima beans, no lime was applied.

The six top entries gave a mean yield of 61.5 g/m². TPI 60D (93.8 g/m²) and TPI 304C (75.2 g/m²) were the two best cultivars. Results of the five best cultivars in the two different environments are summarized in Table 50. The five top-performing lines were the best in the first environment (first season at IITA).

Table 50. Dry seed yield of the best performing entries in the preliminary trial conducted at IITA and Onne (First and second seasons, 1976).

Entries	Location			Cultivar mean
	IITA-F	IITA-S	Onne-S	
	Seed yield (g/m²)			
TPI 174	247	72	23	114
C = TPI 60E	209	55	69	111
TPI 60D	188	20	93	100
TPI 323A	223	59	15	99
TPI 178-26	207	39	44	97
Location mean	164	39	34	79
SE	22.9	12.1	23.3	11.6

Uniform trials. The uniform trial was planted relatively late in the first season (27 April) and symptoms of golden mosaic did not appear until podding. Yield and other attributes are presented in Table 51. All cultivars were susceptible to *Cercospora* leaf spot, the major disease. There was good agreement between 1975 and 1976 results, with TPI 250B and TPI 60E giving the best seed yields, over 300 g/m² in 115 days. Picking was done weekly and the first two harvests produced 68.2 percent of the final yield within 93 days.

The extreme growing conditions affected the yield in the second season, both at IITA and Onne. At IITA, the two best cultivars, TPI 250B and TPI 247, averaged 51 g/m² and 45 g/m² dry seeds respectively. At Onne, the results were better than the results in the preliminary trial. The six best cultivars gave a mean of 109 g/m² dry seed yield. The two top entries were TPI 17 (145 g/m² and TPI 60E (119 g/m²). Table 52 compares the yield of the six best entries under the three different conditions. The four highest performers in the first season (TPI 250B, 60E, 247 and 170-33) showed also the widest adaptation in the three environments.

Table 52. Dry seed yield of the best-performing entries in the uniform trial conducted at IITA and Onne (First and second seasons, 1976).

Entries	Location			Cultivar mean
	IITA-F	IITA-S	Onne-S	
TPI 250B	323	51	81	148
TPI 60E	311	24	119	135
TPI 170-33	285	29	88	124
TPI 247	288	45	24	118
TPI 183-6	237	34	104	111
TPI 17	231	8	145	106
Location	204	25	51	93
S.E. ±	26	7	19	11

Breeding nursery. In 1976, 87 new outcrosses were obtained by alternating bush lima beans between rows of viny types, selected directly from the germplasm. From similar experiments conducted in the dry and first season 1976, using the bush type as seed parent (recessive parent), the percent of viny outcrosses identified in the next generation amounted to 0.7 percent in the dry season and 2.3 percent in the first season, out of a population of 500 bush plants.

Sixty-three crosses involving bush and viny types were made in the greenhouse to recombine genes for high seed yield, resistance to disease (mainly golden mosaic) and other attributes, such as photoinsensitivity, seed size and narrow leaves. The F_1 material was multiplied in the greenhouse and 50 F_2 lines are now being grown in the field.

Other intra-specific crosses were obtained through a cooperative project with the Faculty of Agriculture at Gembloux

Table 51. Yield and other characters of the best entries in the Uniform Viny Yield Trial (IITA, first season 1976).

Pedigree	DFF [a])	Disease		Seed size	Growth	Pod no	Seed yield	Harvest
		GM [b])	CLS [c])	g/100	duration	(per m²)	(g/m²)	index (%)
TPI 250B	39.5	1.5	3.8	40.0	115	355.9	323	44
TPI 60E	43.0	2.0	3.3	46.2	115	319.4	311	45
TPI 247	38.0	2.0	3.5	35.0	115	349.2	288	42
TPI 170-33	38.0	1.5	3.8	54.3	100	254.4	285	46
TPI 187	40.3	2.0	3.5	47.5	125	214.9	246	39
TPI 183-6	40.5	1.8	3.5	39.8	115	241.2	237	37
TPI 17	42.3	1.8	4.8	44.0	115	253.8	231	43
Mean	42.3	1.8	3.8	43.9	115	284.1	204	42
S.E. ±	1.0	0.3	0.3	1.7	–	26.7	26.9	2.7
C.V.(%)	4.9	34.4	17.1	7.6		18.8	26.4	12.8

(a) DFF: days to 50% first flowering
(b) GM: golden mosaic acore made visually, on the basis of 1 to 6 (1 is best)
(c) CLS: cercospora leaf spot score, same as golden mosaic.

Two cultivars, TPl 1974 and 323A, out yielded TPl 60E which was selected as standard of comparison because of previous good performance. Neither showed resistance to the two major diseases, golden mosaic and Cercospora leaf spot. TPl 111A confirmed its high level of resistance to golden mosaic.

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The extreme growing conditions affected the yield in the second season, both at IITA and Onne. At IITA, the two best cultivars, TPl 250B and TPl 247, averaged 51 g/m² and 45 g/m² dry seeds respectively. At Onne, the results were better than the results in the preliminary trial. The six best cultivars gave a mean of 109 g/m² dry seed yield. The two top entries were TPl 17 (145 g/m² and TPl 60E (119 g/m²). Table 52 compares the yield of the six best entries under the three different conditions. The four highest performers in the first season (TPl 250B, 60E, 247 and 170-33) showed also the widest adaptation in the three environments.

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Sixty-three crosses involving bush and viny types were made in the greenhouse to recombine genes for high seed yield, resistance to disease (mainly golden mosaic) and other attributes, such as photoinsensitivity, seed size and narrow leaves. The F_1 material was multiplied in the greenhouse and 50 F_2 lines are now being grown in the field.

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TPl 250B	39.5	1.5	3.8	40.0	115	355.9	323	44
TPl 60E	43.0	2.0	3.3	46.2	115	319.4	311	45
TPl 247	38.0	2.0	3.5	35.0	115	349.2	288	42
TPl 170-33	38.0	1.5	3.8	54.3	100	254.4	285	46
TPl 187	40.3	2.0	3.5	47.5	125	214.9	246	39
TPl 183-6	40.5	1.8	3.5	39.8	115	241.2	237	37
TPl 17	42.3	1.8	4.8	44.0	115	253.8	231	43
Mean	42.3	1.8	3.8	43.9	115	284.1	204	42
S.E. ±	1.0	0.3	0.3	1.7	-	26.7	26.9	2.7
C.V.(%)	4.9	34.4	17.1	7.6		18.8	26.4	12.8

(a) DFF: days to 50% first flowering
(b) GM: golden mosaic acore made visually, on the basis of 1 to 6 (1 is best)
(c) CLS: cercospora leaf spot score, same as golden mosaic.

(Belgium). These involve different combinations of wild and cultivated forms of widely different origin. The wild parental forms are characterized by high photosensitivity, a small leaf size and very low 100-seed weight (averaging 10g compared to the normal size, 40-45g). Eighteen F_2 lines and 20 new F_3 selections were planted just before the drought spell in the second season at IITA. All were susceptible to golden mosaic and green mottling but several combinations, made with the wild types, showed good drought tolerance.

Wide crossing (Gembloux collaboration)

Interspecific hybridization. Interspecific crossing with *P. lunatus* has been realized in the Faculty of Agriculture at Gembloux (Belgium) with two closely related species: *P. polystachyus* and two different ecotypes of *P. ritensis.* These hybrids are aimed at increasing variation by introgressing useful characters, such as drought tolerance and disease resistance. To restore the fertility of this material, several self-pollinations and backcrosses were attempted with little success.

Several combinations, at different stages, (F_2 - BC_1 - BC_2) were introduced to IITA where self and back crosses are being carried out. Two different hybrids: a polyploid, *P. lunatus* × *P. polystachyus* and F_1 F_2 *P. lunatus* × *P. ritensis* were transplanted in the field to test their reactions. The former showed susceptibility to golden mosaic but podded well. The latter *(P. lunatus* × *P. ritensis)* and the wild *(P. ritensis)* were susceptible to *Cercospora* leaf spot and root-knot nematode but neither showed symptoms of golden mosaic, although they were surrounded by spreaders.

Intraspecific hybridization. These crosses involve mainly the wild forms of lima beans and other cultivars, related to three different groups: type *Potato,* (round seeds) type *Sieva* (small seeds) and type *Big* lima (large seeds). Samples of seeds harvested from F_1 plants were sent to IITA. Hybridization of cultivars with a new accession (NI: 543) of wild *P. lunatus* has been achieved in Gembloux. It should be noted that the wild form exhibits high methionine (1.12 percent) and protein contents (27.5 percent).

Protection

Lima bean golden mosaic (LBGM). The effect of planting time on whitefly activity and disease development was investigated at IITA during 1976. Results (Table 53) generally confirm that LBGM develops more rapidly in earlier plantings, though an April planted crop provided an exception. Preliminary results from trapping of whiteflies from May-December suggest that the seasonal effect on disease is related to changes in the vector population. Peak counts were obtained in May; very low counts were obtained during July and August; a similar pattern was obtained for whiteflies and cassava mosaic. Though the cassava whitefly transmits LBGM and breeds on lima beans under controlled conditions, the exact identity and ecology of the vector under field conditions are yet to be established. The aetiology of the disease is under investigation.

During the 1976 first season 340 lines and single plant selections were field screened at IITA for resistance to LBGM, using greenhouse inoculated spreaders (TPl 2B) planted two weeks previously. Thirty-two lines were identified as resistant (scores 1-2 on 1-6 scale), following assessments at 80, 100 and 140 DAP. These lines were subsequently retested under greenhouse conditions, again using TPl 2B as a spreader; six lines (TPl 10, 85, 109A, 110A, and 133A) produced no symptoms and a further four lines (TPl 111A, 133C, 237 and 242) mild symptoms. No attempt was made to distinguish between immunity and tolerance by transmission from the symptomless lines to the susceptible standard. From another trial it was shown that the rate of disease development is slower on a resistant line (TPl 111A) than on a susceptible one.

Table 53. Effect of planting date on development of lima bean golden mosaic (LBGM), IITA 76F + S.

1975			1976		
	DOP	Incidence		DOP	Incidence
April	10	100	April	9	10
May	14	86	May	24	70
June	13	67	July	15	39
July	11	22	Aug.	30	15
Aug.	12	13			

Percent diseased plants/plot at 50 DOP.

Lima green mottle virus. A virus with filamentous particles (c. 800 nm) causes a systemic green mosaic mottle and leaf distortion in lima beans at IITA. The virus is sap transmissible to lima bean, and to certain cultivars of *Phaseolus vulgaris,* cowpea, soybean, winged bean, African yam bean and jack bean to *Nicotiana benthamiana. P. vulgaris,* TPv 114 was found to be a useful local lesion host.

The virus which we propose calling lima green mottle virus (LGrMV) has a thermal inactivation point of 52 C, a dilution end point of 10_{-3} and longevity of three to four days. Its seed and vector transmission, and a search for sources of genetic resistance in lima are under investigation at IITA.

Management

Pest management in lima bean. Insect pests can be a serious problem in lima bean particularly at flowering and podding stages. Leaf damage by leafhoppers and *Ootheca mutabilis* is negligible at IITA and other locations. The effect of spraying regimes on lima bean was evaluated in the second season using cowpea and soybean as comparison. Results showed that insect problems in lima bean are not as serious as in cowpea but more serious than in soybean (Table 54). Without insect control lima bean yielded 52 percent of the sprayed plots but cowpea produced no yield. Soybean yields were generally low due to early-season drought but were not affected by spraying regimes as expected. Three applications of insecticide

Table 54. Effect of spraying regimes on cowpea, soybean and lima bean yields. Second season 1976.

Crop cultivar	Insecticide	Seed yield (kg/ha)	% Seed damaged by pod borers	Seeds damaged by Hemiptera	% Good seeds
Cowpea, VITA 4	None	0	0	0	0
	1	901 b	16.3	21.6	62.7
	2	1302 a	9.9	11.9	79.3
Soybean, Bossier	None	387 a	5.3	8.4	86.3
	3	464 a	3.6	5.0	90.4
	5	596 a	4.1	5.4	90.6
Lima bean, TPl 80	None	588 b	10.6	21.5	68.2
	3	1218 a	3.8	12.9	83.3
	5	1130 a	4.3	10.3	81.5

1 Three applications at 0, 14 and 28 days after first flowers

2 Five applications include above applications plus two pre-flowering applications at 14 and 28 DAP.

Table 55. Effect of seed inoculation and nitrogen application on nodulation and nitrogen uptake of lima bean TP1 80. Greenhouse experiment.

Seed inoculation	Nodule number/plt., 3 wks	Nodule number/plt., 6 wks	Nodule wt (mg/plt.) 3 wks	Nodule wt (mg/plt.) 6 wks	Top dry wt (g/plt.) 3 wks	Top dry wt (g/plt.) 6 wks	N uptake (mg/plt.) 3 wks	N uptake (mg/plt.) 6 wks
None	58	87	33	399	1.8	4.8	35	114
None + 50 ppm N	9	125	10	346	3.6	7.5	99	108
Lima bean inoculant	44	147	84	410	2.0	4.8	45	141
Lima bean inoculant + 50 ppm N	24	110	73	189	3.9	7.9	103	93
S.E. ±	12	31	17	44	0.2	0.9	10	12
C.V. (%)	32	24	8	12	6	14	9	7

endosulfan at 1 kg/ha at flowering and podding stages produced the same yield as five sprays given before and after flowering confirming the previous observation on the importance of post-flowering pests. The important pests of lima bean in the second season were *Taeniothrips sjostedti*, *Cydia ptychora* and several coreids.

Response to seed inoculation and nitrogen. An experiment was conducted to evaluate the response of lima bean TP1 80 to seed inoculation with lima bean inoculant and added nitrogen on Apomu soils series in the greenhouse since field experimentation was not possible due to drought from July to September. Results showed that lima bean nodulated well even without seed inoculation, suggesting that the native bacteria were able to infect the roots of lima bean (Table 55). The presence of added nitrogen reduced the number of nodules per plant at 3WAP but not at six weeks. Nitrogen increased top dry weight at three and six weeks after planting. However, at six weeks the nitrogen fertilized plants (with or without seed inoculation) were yellow and deficient in nitrogen. Plants receiving no nitrogen (with or without seed inoculation) were green and took up more nitrogen from the soil or the nodules than the fertilized plants. Therefore, nitrogen and seed inoculation are not necessary for optimum growth of lima bean provided P and K are not limiting, although this should be confirmed in the field.

Trellis design. In a trellis experiment, lima bean was intercropped with cassava, yam and maize. Lima bean intercropped with yam is common in Nigeria. Sole crop of lima bean growth with or without bamboo trellises was used as a comparison. The results are shown in Table 56. The yields of lima bean under yam, cassava and maize were 61, 30 and 26 percent of the sole crop with bamboo trellises. On the other hand, lima bean reduced the yields of yam, cassava and maize by 20, 51 and 41 percent respectively.

Table 56. Effect of methods of trellis on yield of lima bean and companion crops.

Method of trellises (and spacing)	Yield of lima bean kg/ha	Yield of lima bean % Max	Yield of companion crop kg/ha	Yield of companion crop % Reduction
Bamboo + string (20×100 cm)	1603	100	–	–
Bamboo poles (100×100 cm)	681	43	–	–
With yam on bamboo poles (100×100 cm)	974	61	9360	20
With cassava (100×100 cm)*	480	30	3960	51
With maize (100×100 cm)	412	26	1220	41
Without support	280	17	–	–

**Yam and cassava planted on 1 April and harvested on 10 December 1976. Maize and lima bean planted on 1 June.*

Yam yields were variable because the setts were not uniform. Lima bean greatly increased the percentage of lodging in maize and cassava. The incidence of green mottle virus was high in lima bean intercropped with cassava, and later spread to the rest of the plots.

ROOT AND TUBER IMPROVEMENT PROGRAM

The program aims at genetic improvement in cassava, yams, sweet potato and aroids in that descending order of priority. Major emphasis is laid on a multi-disciplinary approach to varietal improvement and evolution of a package of practices which results in a stable high yield and increased farm income. Concurrent with developing new production technology, the program forges links with various national institutions for a rapid transfer of technology among the peasant farmers of tropical Africa.

Attention is paid to quality characteristics of the tuber crops to ensure wide consumer acceptance of the cultivars and harvest stability so as to minimize losses in storage.

Varietal assessment and cultural practice improvement are dealt with, keeping in view the prevalent practice of intercropping that is extensively practiced by the African farmers. Interacting with the Farming Systems Program of the Institute, the relevance of the research strategy and profitability of the new production technology are continuously reviewed.

Location-specific biological production constraints are identified in close liaison with national programs. The interdisciplinary research team at the IITA and in various cooperative programs then pursue the research leading to alleviation of these problems, for example the development of insect and disease resistant and high-yielding cultivars. Agronomists in the Institute then develop appropriate practices which maximize the farmer income with minimum cash inputs. The resultant package of production technology forms the spearhead for national production campaigns.

Full advantage is taken of the research base of Centro International de Agricultura Tropical (CIAT) for cassava and of the Asian Vegetable Research Development Center (AVRDC) for sweet potato. IITA continues to search for superior germplasm which can make contribution to the current and future breeding programs.

Improved cassava clones developed by IITA such as TMS Nos. 30572, 30017, 30110, 30337 and 30555 are beginning to make an important contribution to cassava production in Nigeria. They retain horizontal resistance to cassava mosaic disease (CMD) and cassava bacterial blight (CBB) in many African countries and in India.

Major studies in the improvement of white yam *(Dioscorea rotundata)* are made utilizing the seed propagation and multilocation screening for plant type, resistance to diseases and nematodes, and for improved tuber characteristics including storability. The improved plant type white yam offers possibility to dispense with staking.

Improved sweet potato clones such as TIS Nos. 2498, 3277, 2532, 1499, 3270 and 3017 established their superiority over the local cultivars for earliness, high yield and resistance to sweet potato weevil *(Cylas puncticollis)*, the most promising clones being TIS Nos. 2544, 2534 and 3039. Storability was found to be noticeably better in the clones TIS Nos. 2532, 3019, 2544 and 2534.

The program with the aroids (*Xanthosoma* and *Colocasia* spp.) is relatively slow due to sparse flowering at Ibadan. Some hand pollinations were made in 10 out of 32 accessions which flowered.

Cassava

Breeding

Selected clones are hybridized for intensification of field resistance to CMD and for breeding clones with low hydrocyanide (HCN) content in the foliage. Additional germplasm introductions as seed were made from CIAT, Zaire and Brazil and 100,000 seedlings originating from 1,474 families were raised therefrom. This material was intensely screened for resistance to CMD, CBB, low HCN content of the leaf and other desirable characteristics. One of the sources, TMI 6027 (IB 35), showed some level of resistance to CMD and CBB.

Varietal testing is pursued in four stages — Preliminary, Intermediate, Advanced and Uniform Yield trials. Intensive screening for field tolerance to insects and diseases, and agronomic and quality characteristics resulted in narrowing down the number of test entries from over 3,000 in preliminary trials to about 50 clones in the uniform trial. For example, the Preliminary Yield trials of 1976 comprised 3,608 clones, 2,500 of which originated from IITA hybridization program. Two hundred and forty-two selections from the 1975 Preliminary trials were advanced to Intermediate trial; 142 selections from the Intermediate trial were promoted to the Advanced trial; and 41 selections from the Advanced trial were nominated to the Uniform trial of 1976.

Severe attack of cassava mosaic disease on cassava plants (left) and a resistant plant (right) to both cassava mosaic disease and cassava bacterial blight.

The Uniform trial comprising over 50 improved clones has been tested at three Nigerian locations over the last three years. Data from 13 of the best clones (Table 1) reflect the level of improvement for yield (2-3 times), and disease resistance (10-50 percent) and a wide variation for *gari* quality in comparison to the Nigerian local check 60444.

Clones with TMS No. 30572 followed by TMS Nos. 30017, 30110, 30337 and 30555 represented distinct overall improvement in most agronomic characters.

Off-site trials in Nigeria were conducted at two heavy-rainfall (about 2,500 mm) locations, Warri and Port Harcourt and one savanna location, Mokwa. The testing at Warri enabled the identification of 32 promising clones (out of 138 tested) which were advanced to the uniform trials. The best of the clones which maintained resistance to CMD and CBB and had satisfactory *gari* quality have yielded 20-25 t/ha as against 4.1 t/ha for the local check, 60444 at Warri. Promising clones which maintained resistance to CMD and CBB and had satisfactory *gari* quality have yielded 20-25 t/ha as against Intermediate trial; and their performance was assessed under semi-dry savanna conditions.

International Cooperation. *In Nigeria,* the National Root Crops Research Institute at Umudike received about 300 promising clones for further testing. This program has selected 18 clones with yield potential of over 40 t/ha and with resistance to CMD and CBB from the set of 427 clones from IITA. Best clones are under further evaluation and multiplication.

In Zaïre, Program National Manioc evaluated many thousands of clones in several locations. Major emphasis was on resistance to CMD, CBB, anthracnose, mealybug and good performance in poor soil conditions.

In Sierra Leone, 40 promising clones were selected from the 94 in the preliminary yield trial, based on resistance to CMD, yield potential and root characteristics. These are being further tested in nine different environments. The IITA clones showed an average CMD score of 2.2 compared with 4.7 for local cultivars and outyielded the latter.

In Liberia, some promising clones were selected and are being further tested under different ecological conditions.

In Cameroon, thousands of seedlings were raised in two different locations and have been screened for resistance to CMD and CBB.

In Tanzania, about 20,000 seedlings were raised from the seeds sent by IITA and they showed a high level of resistance to CMD.

In Burundi, 60 seedlings were selected from the 150 which were raised from 10 IITA families and were planted for further evaluation under highland conditions.

In Uganda, many thousands of IITA seeds were supplied for screening for resistance to green mite.

In Zambia, about 1,000 seedlings were raised from IITA seeds.

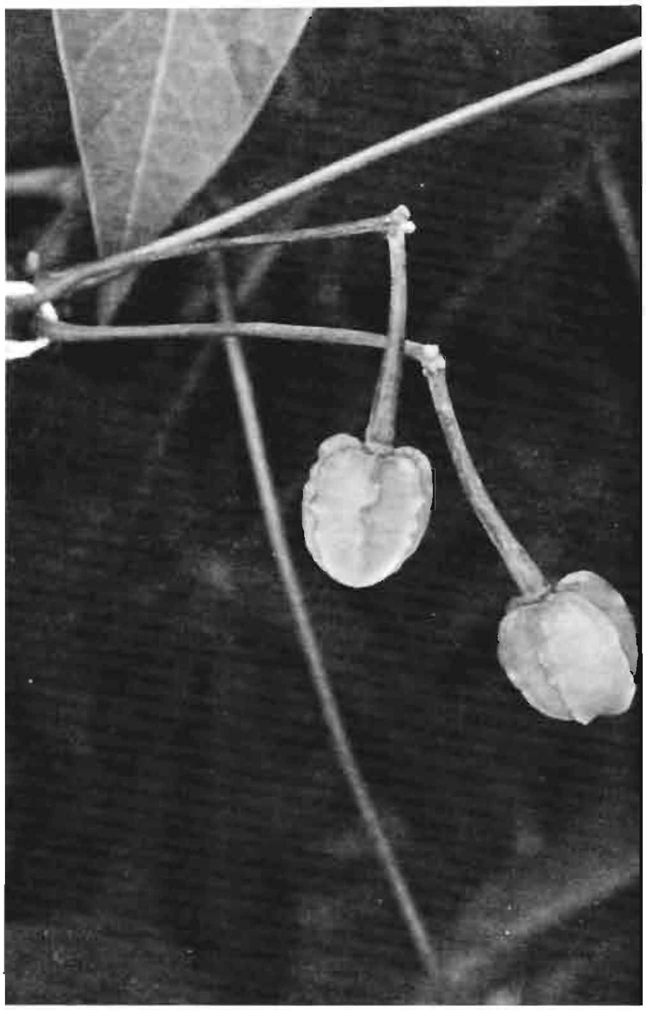
In India, 5,222 seeds from 166 IITA CMD resistant families were tested.

Resistance to CMD and CBB. Earlier reports indicated genetic correlation between resistance to CMD and CBB. A confirmation of this relationship was sought by an intensive study of two crosses involving 60444 (susceptible to both), Isunikankiyan (moderately susceptible to both) and 58308 (resistant to both). Between 60 and 80 seedlings of the two F_1 hybrids 60444×58308 and Isunikankiyan × 58303 were vegetatively propagated by rooting the green tip cuttings. Each plant so grown was subjected to heavy disease pressure of both CBB (stem inoculation) and CMB (exposed to acquisition-fed white flies); and the mean disease scores were used to establish the correlation. The correlation coefficients for the disease scores of the two diseases in both crosses were highly significant ($r = 0.85^{**}$ and $r = 0.51^{**}$)

Table 1. Yield (t/h) of IITA cassava clones compared with local cultivars over years and locations.

		1973-1974	1974-1975				1975-1976		Grand average
		IITA	IITA	Umudike	Mokwa	Warri	IITA	Warri	
1.	TMS 30017	75.6	37.8	30.5	14.0	22.0	31.1	19.8	33.0(248)
2.	TMS 30040	45.7	38.7	17.6	-	21.3	42.8	9.6	29.3(220)
3.	TMS 30054	43.7	69.3	5.0	-	18.0	21.3	21.8	29.9(224)
4.	TMS 30110	94.0	34.0	30.0	-	28.3	42.1	6.6	39.2(294)
5.	TMS 30157	33.3	38.7	16.9	28.3	20.0	35.1	3.2	25.1(188)
6.	TMS 30158	49.0	-	20.6	-	17.5	29.1	16.9	26.6(200)
7.	TMS 30211	32.9	41.3	31.7	46.7	17.5	30.4	7.8	29.8(224)
8.	TMS 30337	60.9	53.6	30.0	19.4	-	38.2	31.0	38.9(292)
9.	TMS 30395	37.1	48.6	23.0	38.7	-	41.5	16.9	34.3(258)
10.	TMS 30555	48.7	58.3	-	-	27.3	31.3	-	41.4(311)
11.	TMS 30572	66.6	54.1	13.7	-	-	35.2	-	42.4(318)
12.	TMS 30786	63.2	39.6	17.9	12.6	-	27.7	15.0	29.3(220)
13.	TMS 30835	38.3	55.2	8.2	-	-	34.4	8.7	29.0(218)
	Average	53.0	47.44	20.47	26.62	21.49	33.86	15.73	32.17(242)
	60444	23.0	24.2	4.0	15.6	1.0	12.1		13.32(100)
	60506			13.3			29.9		21.60
	60447					3.0		5.2	4.10

Figures in parenthesis refer to percent of average yield of the local cultivar 60444.



Fruits of cassava bearing the seeds used for planting.

thereby confirming that the resistance to these two diseases is genetically correlated.

Improvement for quality. The most promising clones are systematically assessed for suitability to make *gari* and other products. Although the *gari* grades of CMD and CBB resistant clones, TMS 30395 and TMS 30211 were far below standard (Table 2) because of high fiber content, farmers' reaction following traditional *gari* making process is satisfactory. The *gari* grades of TMS 30017, 30110 and 30572 were good. Most of the clones of the uniform trial were poor in poundability, and are therefore not as suitable for *foufou* as for *gari*.

The cultivars 60506 and TMS 30964 gave a high leaf protein content of about 35 percent by weight.

Leaf HCN scores were made four times in an eight-month period using the sodium picrate test method on 260 low leaf HCN clones (Fig. 1). The increases observed in HCN may be due to plant age and environmental changes. The low leaf HCN clones, A/40421, A/40705 and 741598-229 showed low root HCN content, high yield potential, some degree of resistance to CMD and CBB, and good *gari* quality. The low leaf HCN plants were significantly shorter in plant height and smaller in stem diameter compared with those of high HCN plants within low leaf HCN families. For reasons not too clear, plants having low leaf HCN in composites A and B have increased by about 10 percent, (Fig. 2).

Seed production for cooperative programs: A vast number of seeds from improved clones and half-sib families were collected and distributed in Africa and some cassava producing countries in Asia. This material contains genes for resistance to CMD and CBB, for higher yield, better root characteristics and plant type.

Multiplication and distribution of planting material: Rapid multiplication units were established at IITA, Umudike and Warri to produce planting material of the most promising clones for the farmers engaged in the Nigerian National Accelerated Food Production Project. Large-scale rapid multiplication of five of the most promising clones to institutions and farmers was undertaken, using both green and mature two-node stem cuttings. Large quantities of mature stems from IITA yield trials were distributed through the federal ministry of agriculture to selected farmers.

Table 2. ***Yield, dry matter percent, resistance to diseases and quality of the IITA clones tested over 4 years and in 4 different locations in Nigeria.***

		Fresh yield (t/h)	Dry matter (%)	Dry yield (t/h)	CMD score	CBB score	Lodging (%)	Gari grade	Leaf protein (%)
1.	TMS 30017	33.0(248)	33.3(126)	11.0(314)	2.8(84)	2.2(58)	0	4.2(120)	30.0
2.	TMS 30040	29.3(220)	32.7(123)	9.6(274)	2.9(88)	2.1(55)	10	2.9(83)	29.3
3.	TMS 30054	29.9(224)	24.5(92)	7.3(209)	2.8(85)	1.9(50)	10	3.1(80)	27.9
4.	TMS 30110	39.2(294)	26.5(100)	(10.4(297)	2.9(88)	2.0(52)	10	4.3(123)	31.9
5.	TMS 30157	25.1(188)	30.0(113)	7.5(214)	2.3(70)	1.8(47)	0	-	27.9
6.	TMS 30156	26.6(200)	28.6(108)	7.6(217)	2.3(70)	1.9(50)	8	3.7(106)	32.0
7.	TMS 30211	29.8(224)	27.1(102)	8.1(231)	1.9(58)	1.8(47)	20	1.8(51)	32.0
8.	TMS 30337	38.9(292)	28.3(107)	11.0(314)	2.7(82)	1.8(47)	15	3.0(66)	31.7
9.	TMS 30395	34.3(258)	26.5(100)	9.1(260)	2.5(76)	2.0(53)	25	1.8(51)	29.2
10.	TMS 30555	41.4(311)	32.8(124)	13.6(389)	2.7(82)	1.8(47)	25	3.2(91)	30.4
11.	TMS 30572	42.4(318)	30.6(115)	13.0(371)	2.2(67)	1.8(47)	20	4.2(120)	30.1
12.	TMS 30786	29.3(200)	35.8(135)	10.5(300)	2.7(82)	2.3(61)	10	2.8(80)	30.1
13.	TMS 30835	29.0(218)	30.2(114)	8.8(251)	2.8(85)	2.1(55)	35	-	30.5
	60444	13.3(100)	26.5(100)	3.5(100)	3.3(100)	3.8(100)		3.5	
	60506	21.6	30.3	6.5	3.5	2.1	42		35.3
	60447	41			3.2	3.5	10		
	YARDSTICK	30.0	30.0	10.0	2.5	2.0	20	3.0	30.0

Figures in parenthesis refer to percent of 60444, a local cultivar.
Yardstick stands for an estimate of the practical optimum attainable.

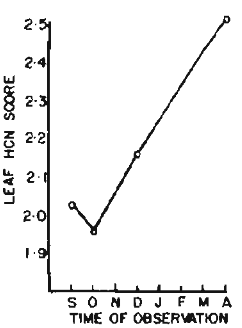


Fig. 1. Changes of leaf HCN scores with time of observation.

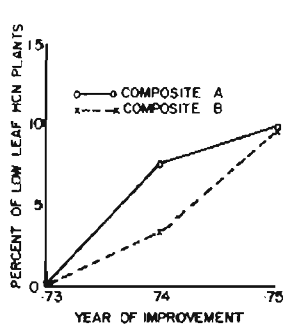


Fig. 2. Increase in percent of low leaf HCN plants of composites A & B with year of improvement.

Agronomy

Leaf harvest and root yield. Data in Table 3. show that in Zaïre cassava leaf harvested as *"pondu"* (fresh vegetable) at regular monthly intervals can give a revenue about eight times that obtained from roots ($5,290 : $636.90).

Since enormous losses are incurred at handling, a low estimate based on 50 percent loss results in four times the revenue from roots. Root yields are depressed after more frequent leaf harvests, but total revenues are increased. Compared with monthly harvests, leaf harvests bi-monthly reduce leaf production by 38 percent but increase root yield by an equivalent ratio.

Limited leaf harvesting may be advantageous for some cultivars such as 02864 where picking once bi-monthly increased the root yield by about 18 percent over the control (Table 4). This observation may have some physiological relationship to light interception and leaf duration, especially since 02864 produces much foliage during rainy seasons.

It seems, therefore, that sufficient *"pondu"* could be produced from fields cultivated for tubers. However, harvesting should be regulated to at most once a month and preferably bi-monthly.

Table 4. ***Effect of frequency of leaf harvest on root yield and revenue from two cassava cultivars.***

	Kangu		02864	
Frequency	T/ha	$/ha	T/ha	$/ha
Irregular (very often)	4.9	172	15.4	540
Once/month	11.0	388	25.2	886
Once/2 months	14.0	493	35.8	1,295
Control	14.5	511	30.2	1,061

Weeding Frequency. Changes in species composition were observed with frequency of weeding at M'Vuazi valley where grasses decreased with increased frequencies and broad-leaved weeds, particularly *Sida rhombifolia* and *Mimosa.*

Table 3. ***Effect of frequency of leaf harvest on yield and revenue from cassava.***

Harvest frequency	Root yield T/ha	Root rev. U.S. $/ha (0.03 k/kg)	Leaf yield T/ha		Revenue + $/ha	Ratio Leaf revenue/ Root revenue
Irregular (Very often)	10.13	355.9	4.86	3.12	1,441.1	4.0
Once/month	18.13	636.9	15.31	13.02	5,290.0	8.3
Once/2 months	24.94	876.0	11.34	8.88	3,739.5	4.3
Control	22.36	785.5	-	-	-	-

+ Based on estimates of 800 g fresh leaf for 10 k during R, rainy season and 500 g for 10 k during D, dry season.

Pathology

Cassava Mosaic Disease: CMD symptom expression. Cuttings of the clone 58308 were established in a randomized complete-block design with four replicates in April, and subjected to cutting back treatments (detopping the growing tips of young shoots) in July, August, July/August combined, and September. An untreated check (no detopping) was included among the treatments.

The rates of symptom inducement on new growth as a result of the detopping and the symptom intensity responses to treatments follow a fairly similar pattern and are summarized in Figure 3.

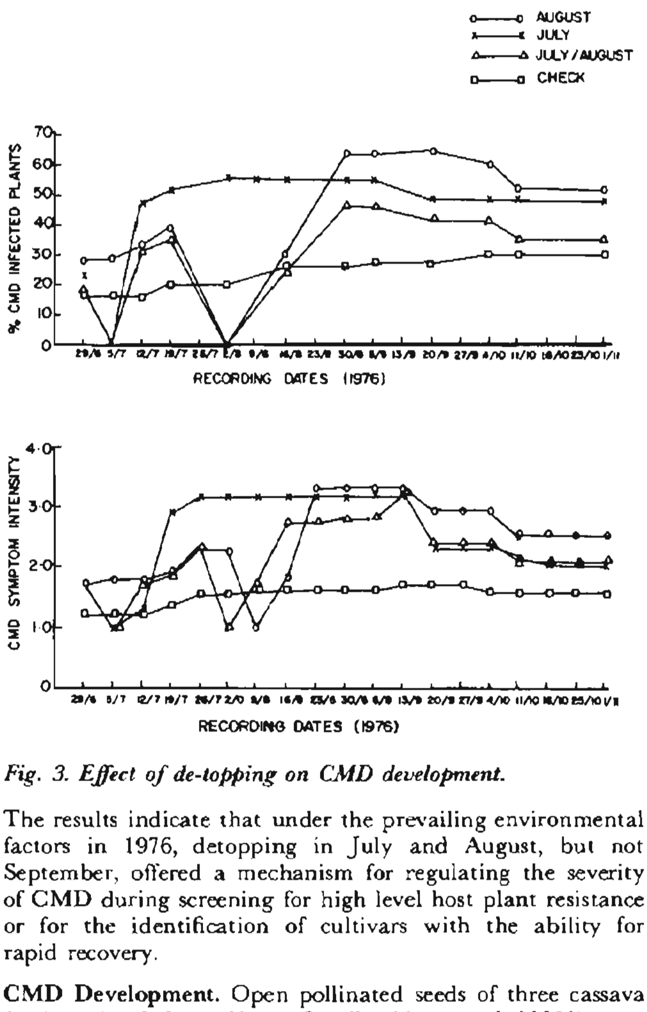


Fig. 3. Effect of de-topping on CMD development.

The results indicate that under the prevailing environmental factors in 1976, detopping in July and August, but not September, offered a mechanism for regulating the severity of CMD during screening for high level host plant resistance or for the identification of cultivars with the ability for rapid recovery.

CMD Development. Open pollinated seeds of three cassava families (seed from 60444, Isunikankiyan and 58308) were germinated in the greenhouse and transplanted at monthly intervals. The incidence of CMD and its rate of development for the first eight weeks of growth during the most active growth period for each month of planting treatment is presented in Figure 4. The rate of mosaic development was highest in April sowings in 60444 and in the May sowings in Isunikankiyan and 58308. Disease incidence and rate of development dropped sharply in July sowings and were lowest in August sowings in all the families. A parallel investigation on the level of *Bemisia tabaci* infestation on the test plants indicates some relationship with disease incidence and development. This method of determining the environmental and biological factors favoring efficient mosaic resistance screening is recommended for adoption in other screening locations.

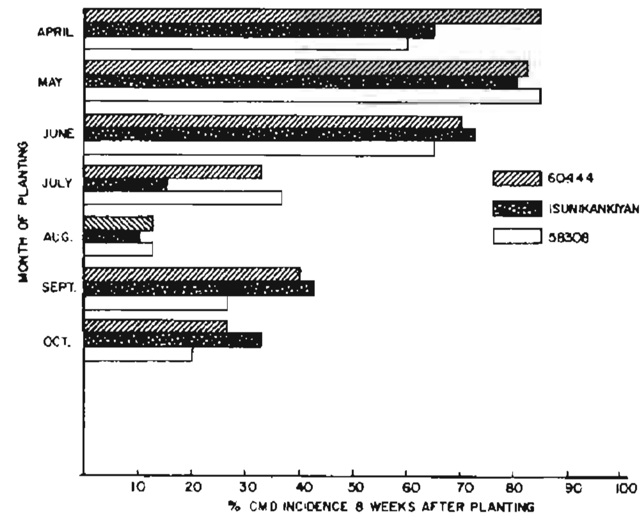


Fig. 4. Effect of month of planting on rate of CMD development.

CMD cultural control. Preliminary evidence indicates that the incidence and severity of CMD may be appreciably reduced by careful selection of planting material. One hundred stem cuttings from field grown plants with extremely severe mosaic disease (severity class 5 + gross reduction leaf size) and 100 from plants with mild mosaic (severity class 2) were grown in pots. The severity and rate of symptom development were monitored in insect proof screenhouses for eight weeks. The results show that by the eighth week at least 42 percent of plants established from severely diseased parent plants developed severe mosaic compared to 9 percent from parent plants with mild mosaic. Careful selection of planting material from plants showing mild mosaic at harvest is therefore recommended.

Cassava Bacterial Blight: Geographical distribution. Incidence of the disease was reported in the Congo Republic and Cameroon. CBB occurs in both forest and savanna regions but was more prevalent on cassava grown as a monocrop in the latter area.

Pathogenic variation. The pathogenicity of nine isolates was compared on three cultivars, 53101, 60444 and Isunikankiyan. The isolates differed in their behavior on 60444 and Isunikankiyan, four being highly virulent, three of moderate virulence and two weakly virulent. There was no evidence of localization of strains of differing virulence on a regional basis.

Biology. Several bacteriophages have been isolated from diseased plant material. Thirty isolates of *X. manihotis* were lysed by five phages while several common white saprophytes which may be confused with *X. manihotis* were not attacked. The phages are being used for rapid identification of *X. manihotis*.

Epidemiology. Preliminary data indicate that six weeks after inoculation, at least twice as many plants were infected in monocropped cassava as in that grown with several other crops.

Resistance screening. Stem puncture, leaf infiltration, leaf spraying and leaf clipping methods were tested for their comparative advantages in resistance screening. Leaf clipping was the most suitable for routine screening under positive disease pressure.

Cassava Anthracnose: Incidence and rate of development. In an observation plot with 1,860 cassava plants (cv.

Isunikankiyan), 377 (20.48 percent) showed one or more of the characteristic symptoms of anthracnose infection. These include stringy superficial stem lesions, leaf blight, and wither-tip.

The rate of development of this disease was monitored on the clone 58308 and the percentage of plants with new anthracnose symptoms for the period July to December was 1.07, 0.4, 5.03, 8.07, 6.63 and 2.23 respectively. The total percentage incidence rose from 1 percent in July to 24 percent in December. The average number of stem lesions per plant ranged from a low of 0.83 in July to 5.53 in October. The incidence and severity of cassava anthracnose are very low in the early season and tend only to increase in the latter part of the season. An efficient technique to produce epiphytotics of anthracnose is yet to be developed.

Brown Leaf Spot: Foliar damage. The fungus *Cercospora henningsii* causes leaf spotting on susceptible cassava cultivars. The magnitude of leaf loss due to this disease was investigated in which Isunikankiyan was subjected to three chemical control treatments: Dithane, Dithane + oil and untreated check. Leaf spotting was observed mainly on older leaves. A summary of the number of percentages of leaves affected on the untreated plants is summarized in Table 5. The data indicate that the prevailing conditions in Ibadan are unsuitable for resistance screening.

Table 5. Magnitude of foliar damage due to brown leaf spot, (IITA, 1976).

Period	Total No. Leaves/Plant	Average No. Leaves/Plant Affected	
June	21	0.63	(3%)
July	37	0.85	(2.3%)
August	39	0.39	
September	39	0.39	(1%)
October	93	1.40	(1.5%)
November	208	14.56	(7%)

Artificial inoculation. *Cercospora* brown leaf spot disease was induced by artificial inoculation of 60-day-old Isunikankiyan plants with a suspension of *C. henningsii* conidia from macerated diseased leaves. Symptoms appeared 21 days after inoculation and a defoliation rate of 46 percent after 14 days was recorded. The disease induced by artificial inoculation was more severe than in the field, resulting in leaf spotting, blight, yellowing and premature defoliation. This indicates that under favorable environmental conditions this disease can cause leaf and tuber yield loss.

The conditions under which this method can be utilized to create brown spot epiphytotics for efficient screening are under investigation.

Entomology

During 1976, cassava was attacked mainly by *Bemisia tabaci* and *Zonocerus variegatus*. Outside Nigeria green mite *Mononychellus tanajoa* and mealybug *Phenacoccus manihoti* Mat-Terr. were the major problems.

Mealybug. The mealybug is the most severe pest problem on cassava in Zaire, Congo Brazzaville, Gabon and in the north of Angola. Together with CMD, CBB and anthracnose, it threatens the future of cassava production.

Initially, the mealybug attacks the terminal shoots of cassava. At a later stage, due to lack of food and space, the insect settles also on the expanded leaves as well. The damage is caused by sap sucking and possibly by introducing in the saliva an unidentified chemical which causes stunting of the shoots. The economic damage to cassava caused by the mealybug is due both to a definite loss of fresh leaves which are eaten as *"pondu"* and tuber yield loss, the extent of the latter being as yet unknown. The latter seems to depend much both on the age of the plant at the time of heavy attack and the soil type.

Little is known about the biology. The mealybug is a typical insect with a hemimetabolic development. The parthenogenetic, wingless female lays several hundred eggs that make the development potential great.

There are two principal ways in which the mealybug is spread: by passive transport on infested planting material and as unsettled first instar nymphs (crawlers). The most important observation was that crawlers, after having hatched from the eggs, easily became airborne in the mornings due to increasing windspread and positive photostatic behavior. The latter makes them move to the upper leaves and tips of the plant. The windspread was established by sticky traps and the first instars were caught 30 m away from the source plants and at a height of four meters. Airborne crawlers seem to be mainly responsible for effective spread over shorter distance (several hundred meters). Only a few parasites and one predator *Spalgis lemolea* Druce (Lycaenid, Lepidoptera) could be found on the mealybug.

An analysis of climatic data of the last 15 years available in M'Vuazi indicates that temperature, humidity and rainfall are the principal factors controlling development of mealybug. The dry season is necessary for building up the mealybug population. Up to July the development is relatively slow, probably because of low temperature, low VPD and the residual moisture in the soil which favor plant growth. Increasing drought stress and temperature seem to favor population build up. The windspread is highest when, due to very high population density, the most crawlers are produced.

Whiteflies. The development of whitefly population in relation to CMD incidence was studied. Three cassava cultivars 60444 (CMD susceptible), Isunikankiyan (moderately susceptible to CMD), and 58308 (CMD resistant). Planting of uninfested open-pollinated cassava seedlings was done every month. Adult whiteflies were caught with sticky yellow traps and counted weekly, while pupae were recorded fortnightly.

In Figure 5, when the numbers of trapped adult whiteflies were plotted against CMD incidence, CMD incidence is highly related to vector density. However, the disease incidence of the April planting was high while the vector density was low, but this effect was caused by different methods of recording. CMD was recorded for each planting over a period of two months, while whiteflies were counted weekly. Therefore the April planting was probably infested with CMD in May.

Pupae counts on the three different cultivars show that 60444 carried one-third less pupae than 58308. This supports the assumption that 58308 is CMD resistant and not whitefly resistant.

Biochemistry

The main objective is the evaluation of quality in terms of physico-chemical, biochemical properties, and nutritional values in accordance with the modes of root and tuber utilization in the tropics; and to pass on any helpful

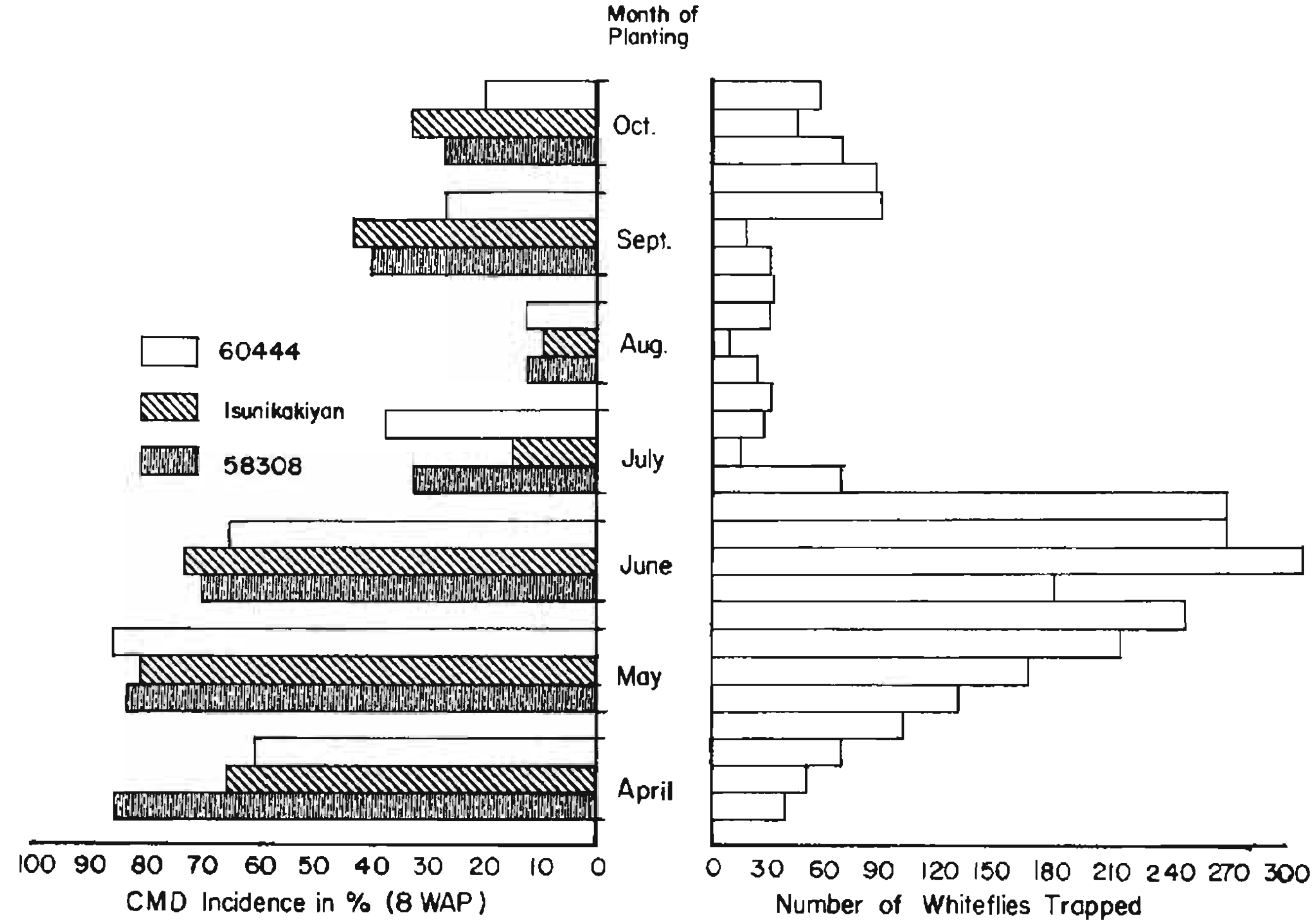


Fig. 5. Effect of monthly planting and vector density on CMD incidence.

information on these matters to breeders for varietal improvement.

Roots and tubers are basically starchy staples that supply most of the energy requirements in human and animal nutrition in the tropics. However, the quality attributes of their starchy tissues go beyond the mere contents of starch and non-structural carbohydrates – sugars. Quality is determined by a complex interplay of many factors.

A scheme was developed to subject each genotype to intensive examination at various product levels from the raw material until it reached the consumer.

Four different trials were examined for quality:

1. Uniform Trial (UT – series), 50 clones
2. Advanced Trial (AT – series), 50 clones
3. Low cyanide selection (LCN – series), 13 clones
4. Local germplasm (LG – series), 11 clones.

Texture Profile. The texture characteristics of a root and tuber determine its suitability for specific food preparation and utilization. The texture of each genotype of a "series" was noted; and where there was no uniformity in tissue texture, a textural profile was annotated. Figures 6 and 7 show the texture profile of UT – and AT – series. The texture of most genotypes is of the "waxy" type. Texture analysis of local germplasm collected for varietal improvement showed that most of the cultivars were waxy. The profiles also show that non-uniformity in texture exists.

Food grades. Each clone was tested against major traditional food types such as: *gari*, *gaplek* (products derived from sun-dried chips, e.g. flour and products), pounded *fufu* (foufou), and for basic eating qualities as a vegetable.

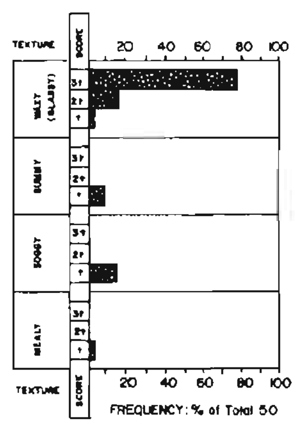


Fig. 6. Texture profile of boiled UT- Cassava series.

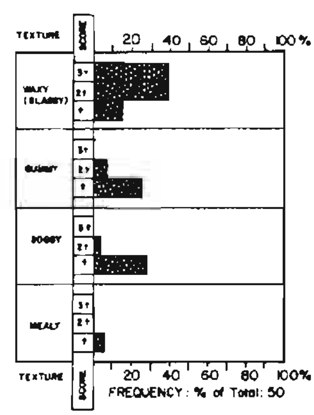


Fig. 7. Texture profile of AT- Cassava series.

About 65 percent of clones from UT – and AT – series passed for *gari* and flour products. On the other hand, only 4 percent and 8 percent of UT – series were acceptable for pounded products and basic vegetable respectively; and for AT – series only 6 percent and 34 percent of cultivars were suitable for pounding and for good vegetable quality respectively. The poor quality performance of both UT – and

Good quality gari in a local market.

AT – series against pounded products is attributable mainly to the texture profile. Waxy textural types are unsuitable for pounding. Most of the clones scored poorly against factors such as taste, flavor and mouth feel when they were rated as vegetables (Figs. 8 and 9).

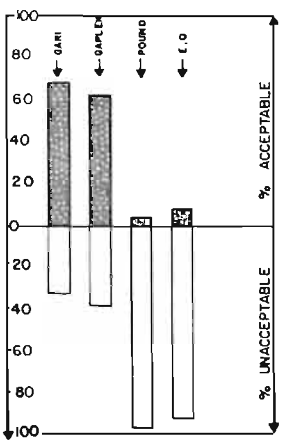


Fig. 8. UT- Cassava quality WRT food grade.

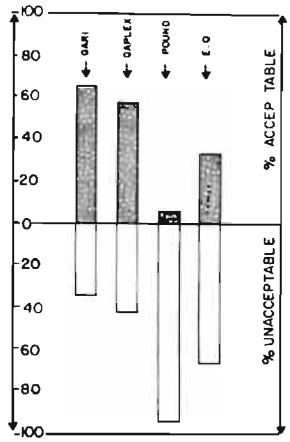


Fig. 9. AT- Cassava quality WRT food grade.

Carbohydrate profile. Starch content of clones of the two series ranged from 15 percent to 31 percent. Clones which showed starch content at the lower end of the range exhibited poor quality characteristics such as: fibrousness, shrinkage of dried tissues, disintegrated pith area and non-enzymic browning.

These characteristics suggest that starch might have undergone partial hydrolysis to produce sugars. Table 6 shows radial distribution of starch and glucose in cooked cassava roots. The last two cultivars showed high levels of glucose in the roots. On the whole the pith areas showed a higher glucose content than cortical and cambial sections.

Functional properties: Hot and cold paste viscosities of flours. Specific functional properties of starch are important for specific food uses. In the case of flour products, hot and cold paste viscosities were used as functional properties for quality evaluation. Starch hydrolysis and the production of sugars reduce the viscosity of the pasting system of starch. There were no significant differences in the amylose content of high and low grade flours tested; however, the lower grades of flour contained higher levels of sugars.

Table 6. Radial distribution of carbohydrates in cooked cassava roots.

Clone	Part of root	% Starch	% Glucose
TMS 4(2)1279	Cambium	59.47	3.00
	Cortex	49.91	3.50
	*Pith area	43.41	4.00
TMS 4(2)0544	Cambium	57.71	4.47
	Cortex	41.14	9.00
	*Pith area	36.84	9.40
TMS 4(2)0460	Cambium	55.97	7.90
	Cortex	52.80	8.00
	*Pith area	49.91	9.40

**Pith area without primary xylem. % on dry weight basis.*

Swelling power of *gari*. Swelling power was used as a quality factor for *gari* as an end product, and as one of the factors for root suitability for *gari* production. Figure 10 illustrates the swelling capacity of *gari* from AT- cassava cultivars. Normally, a swelling capacity of 200 percent, or three times the original volume of dry *gari*, is the average value for most market samples. Figure 8 shows that some cultivars had demonstrated very high *gari* quality.

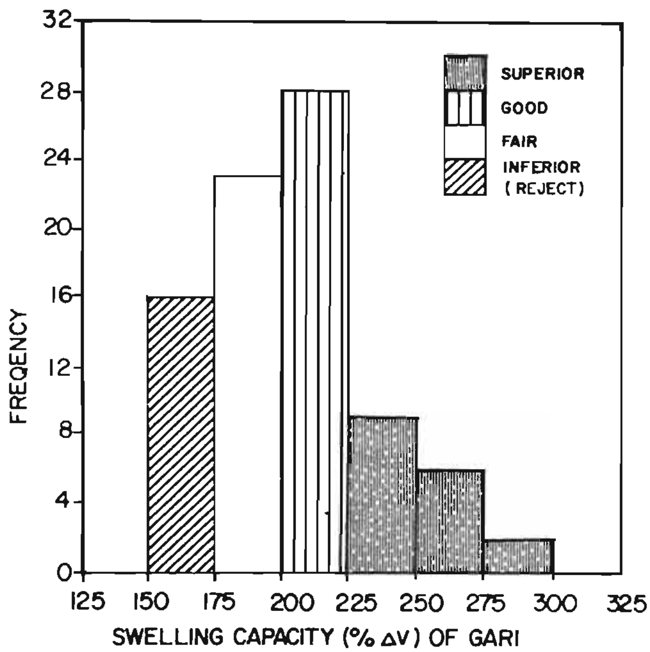


Fig. 10. Histogram of At-series.

HCN in cassava plant. The following investigations were made on the quantitative analysis of HCN in cassava leaves and roots:

- HCN in roots of "low HCN" collection
- HCN in roots of "local germplasm" collection
- Distribution of HCN in cassava roots
- Effect of cooking on cassava leaf detoxication.

HCN in roots of "low HCN" and local cultivars. A study of HCN distribution in cassava roots, as a guide for food preparation, was applied to ordinary clones (Table 6) and LCN-cassava series (Table 7). Levels of HCN in the peel, cambial zone, and the decambiated root were estimated. Tables

3 and 4 show that HCN is highest in the peel, followed by the cambium and lowest in the decambiated root. In traditional food preparations, the cambial layer is often removed. In most of the samples analyzed, the decambiated root showed HCN content below 50 mg/kg, which is said to be a harmless level.

Table 7. Distribution of HCN in roots of ordinary clones.

Clone	Root section		
	Peel	Cambial region	Decambiated root
	mg/HCN/kg fresh wt.		
Isunikankiyan	1190.7	116.1	45.9
TMS 4(2)0336	711.7	175.5	114.4
TMS 42966	335.6	99.9	50.2
TMS 41637	283.5	78.3	44.2
TMS 40852	195.4	63.1	36.1

Table 8. Distribution of HCN in roots of low HCN clones.

Clone	Parts of root		
	Peel	Cambium	Peeled root
	mg/HCN/100g fw		
A/40421	53.05	8.81	2.03
3109-N-47	73.54	8.58	2.97
3109-N-69	11.83	7.09	0.34
B/4219	13.00	12.15	11.20

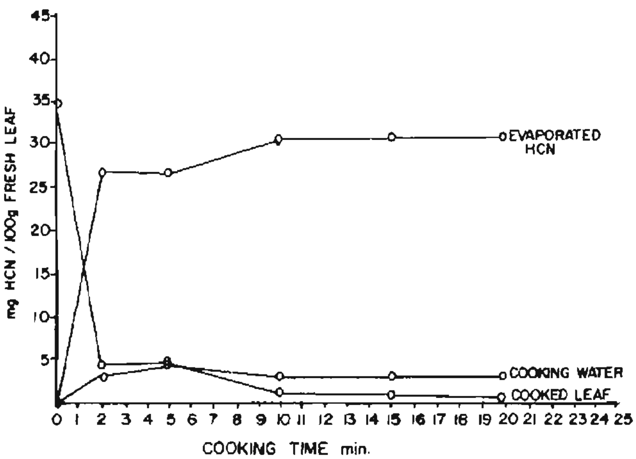


Fig. 11. Effect of cooking time (open-kettle) on HCN detoxication in cassava leaf.

HCN in cassava leaves. Cassava leaves are important as green vegetables in many local parts of the tropics. Special attention was, therefore, given to the study of HCN in the leaves and leaf detoxication by simple cooking methods. Figure 11 and Table 9 show mechanisms of cassava leaf detoxication by blanching and cooking. Blanching of leaves for 10 minutes can effect HCN removal by evaporation to a low level of 0.2 mg/kg. Cooking of leaves for 15 to 20 minutes was found to reduce the level of HCN to 0.07 mg/kg. It appeared that the level of HCN in the cooked leaves was not affected by the HCN content of fresh leaves. Though leaf detoxication is effected to a great extent by evaporation, an appreciable amount of HCN is leached into the cooking water. It is therefore advisable that cassava leaves be pre-cooked (open-kettle), the cooking water discarded, and the cooked leaves washed again before they are used in foods.

Table 9. Cassava leaf preparation for food use and removal of HCN.

Leaf sample	Fresh leaves mgHCN/100g Fresh wt.	Blanching water mgHCN in 250ml./100g fw.	Cooking water mgHCN in 250ml./100g fw.	Cooked leaves mgHCN/100g Wet wt.
Isunikankiyan	49.00	1.16	1.26	0.90
TMS 41301	48.60	0.68	1.01	0.68
TMS 4(2)0489	35.10	1.35	1.01	1.69
60444	30.24	1.08	0.61	0.68

Breeding

Germplasm collection and recombination. More than 100,000 seeds from IITA were added to the breeding program and were grown at five locations in Zaïre. Out-crossed seeds derived from IITA and INERA selections and seeds from hand crosses between preferred local cultivars and IITA resistant clones were produced.

Resistance to CMD, CBB and anthracnose. Many of the selected clones continued to show a high level of resistance to cassava mosaic disease (CMD), cassava bacterial blight (CBB) and anthracnose in Bas Zaïre and Bandundu regions under different ecological locations. Out of 10,520 clones established in Bas Zaïre region and 4,404 in Bandundu region, 401 and 282 respectively showed multiple field resistance to CMD, CBB and anthracnose (Table 10).

Table 10. Selections on the basis of multiple field resistance to CMD, CBB and anthracnose in Zaire.

Region	Test Sites	Number of Clones Tested	Selected
Bas Zaire			
M'Vuazi	4	5,130	202
Kwilu-Ngongo	3	2,540	116
Mbanza-Ngungu	2	1,360	26
Kimpese	2	1,490	57
		10,520	401
Bandundu	6	4,404	282
Total	17	14,924	683

Mealybug. The mealybug, *Phenacoccus manihoti* (*Pseudococcidae*), continued to be a very important dry-season pest in Zaïre, particularly in Bas Zaïre where the soil is poor, sandy and intensely cropped. A simple artificial infestation method which involved attaching infested twigs near the apex of host clones proved effective. Infestation was established within 48 hours and developed rapidly within a week. Observations were taken four times: during the rainy season (March), soon after the dry season commenced (June), late in the dry season (October) and finally about a month after rains had commenced on December 30. (Table 11.) There was hardly any infestation during the rainy season (pre-artificial infestation period). Infestation severity increased by June when a greater proportion of clones rated class 4; and was further escalated by October. The October epidemic receded as the rainy season started in December (rainfall at M'Vuazi = 349 mm in December compared with 86 in November). The effect of the cycle of severe infestation and regrowth on yield needs to be evaluated, especially since severe attacks are associated with the dry season, a lag period in the growth of cassava.

Under M'Vuazi conditions, all clones harvested during November were infested by mealybug and therefore screened.

Table 11. Seasonal variation in mealybug severity in 1976 at Kimpese/Zaïre.

Class +	Time of scoring							
	March		June		October		December	
	Clones	%	Clones	%	Clones	%	Clones	%
1	639	69	86	12	0	0	0	0
2	201	22	135	18	0	0	0	0
3	80	9	128	17	0	0	9‡	1.7
4	0	0	386	53	4	0.6	38	7.3
5	0	0	0	0	701	99.4	473	91.0
Total	920		735		705		520	

Rainfall 1976: March 270.0, June 6.0, October 67.5, December 349 mm
+ Class 1 = no symptom; Class 5 = death
‡Regrowth with symptom rated class 3.

Yield trials. Preliminary yield trials were conducted under different environmental conditions at M'Vuazi, Vanga, Kiyaka, Lowa, Kikwit, and Tonu. The results showed that fresh tuber yields of all clones in poor sandy savanna areas were lower than 1.6 kg per plant although mean annual rainfall was high (Kiyaka 1,600 - Tonu 1,700 mm). At M'Vuazi in the rich valleys with a high water table, some selections yielded higher than 4.0 kg per plant, but better results were obtained from well drained areas with deep top soil.

Preliminary yield trial data from the different test locations (Table 12) indicated the prospects for a major improvement in the year over the local cultivars.

Table 12. Mean tuberous root yields (kg/plant) of the top 5 and 10 percent clones from preliminary yield trials at different sites in Zaïre.

Location	IITA clones tested	Top 5%	Top 10%	Local check
M'vuazi/MK	243	4.53	3.86	1.86
M'vuazi/PV	1,105	6.67	4.92	2.95
Vanga	525	4.15	3.09	2.84
Kiyaka/For	183	4.27	3.23	2.13
Lowa	439	4.38	3.59	2.29
Kikwit	520	5.19	4.90	2.52
Tonu	223	0.82	0.71	0.36
Kiyaka/pl.	1,037	0.41	0.30	0.29

Relationship of tuberous root fresh yield with harvest index. Fresh yield of 243 clones of the preliminary yield trial were plotted in relation to harvest index (Fig. 12). The correlation coefficient between fresh yield and harvest index was 0.57**. The linear regression of fresh yield (Y) on harvest index (X) was obtained as $Y = 41.44X - 1.73$. A selection of high-yielding clones with a high harvest index was attempted.

Nigerian NAFPP Cassava Program

Major activities during 1976 included extension training, distribution of materials, minikit trials, fertilizer trials, production kits and demonstrations of improved technology, all at farmer level. Multiplicaton of planting material was expanded to meet the increased demand.

Investigations on the construction and organization of all trials, demonstrations, and production kits were carried out at zonal substations. These also included commodity research and extension, massive training of all staff and transferring of results to the field for testing by the farmers. Thus farmers acquired new knowledge three to four years sooner than through conventional methods. Project areas and progressive farmers were selected for this purpose and the formation of

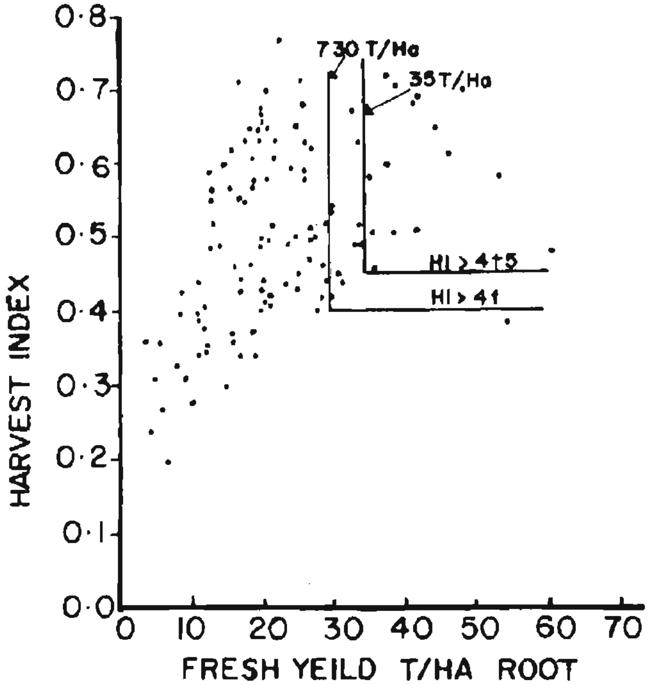


Fig. 12. Relationship of tuberous root fresh yield with harvest index.

cooperatives to cater for marketing, storage and processing was initiated.

Variety/fertilizer trials and demonstrations. Herbicide, minimum tillage and fertilizer trials on cassava, multiplication and comparison of five cowpea cultivars, and screening of improved cassava clones were included in pre-minikit trials. Fifty-nine maize cultivar minikit trials of cassava and cassava/cowpea were planted on 35 m² plots (split into fertilized sub-plots). Eighteen IITA cassava clones were included in the 78 farmer-level minikit trials. In each cultivar minikit trial, 60506 and one best local cultivar were compared with three of the new improved clones.

Results of minikit trials. Cassava cultivar minikit trials with and without fertilizers planted during 1975 were harvested and six of them were selected for further evaluation. The yield data from eight locations are summarized in Table 13. The mean yield of the fertilized cassava was double that of the unfertilized. The 1,147 farmer planted demonstration plots of cassava/maize interplanting were harvested. Plots of improved cultivars and practices out-yielded the traditional plots by 3:1 for cassava and 6:1 for maize (Table 14)

Table 13. Cassava yield of "minikit" trials with and without fertilizers in heavily utilized land.

Location	No. var.	With fertilizers (t/h)	Without fertilizers (t/h)	Difference (t/h)
Owerri	9	24.6	16.8	7.8
Aba	6	21.2	12.2	9.0
Orlu	7	19.7	10.6	6.1
Okigwe	7	12.9	8.0	4.9
Onitsha	8	20.0	10.3	10.6
Enugu	6	19.7	3.8	15.9
Awka	5	19.8	9.8	10.0
Abakaliki	9	15.1	8.2	6.9
Mean		19.3	10.0	9.3

and, overall, the gross proceeds from both crops were four times higher (Table 15).

Table 14. Cassava yield from demonstration plots planted and managed by farmers using improved and local practices.

Location	Improved practice (t/h)	Traditional practice (t/h)
Aba	15.00	8.30
Umuahia	13.77	6.71
Orlu	13.03	3.33
Okigwe	13.83	2.03
Owerri	15.42	4.20
Abakaliki	17.50	5.40
Awka	14.50	5.20
Enugu	18.20	2.80
Nsukka	12.00	5.50
Onitsha	9.00	4.53
Mean	14.23	4.80
Average ratio	3	1

Appropriate use of demonstrations on field days, provision of production kits, good marketing strategies and frequent program promotion all help boost the cassava program in the National Accelerated Food Production Project.

Table 15. Returns from cassava/maize demonstration trials.

Crop	Traditional practices		Improved practices	
	Yield (kg/h)	Price ($)	Yield (kg/h)	Price ($)
Cassava	4,800	319	2,442	944
Maize	362	78	2,442	527
Total	5,162	397	16,672	1,471
Improved/ Traditional	1.00	1.00	3.23	3.71

Demonstrations. Over 100 field days with an average attendance of about 200 farmers were organized. From March to June, 2,203 cassava/maize demonstrations were planted by farmers.

Production kits. Participating farmers were organized to plant cassava/maize on a production basis and loans in kind (cassava cuttings, maize seed, fertilizers and pesticides) were offered to those belonging to a cooperative. Twenty-five cooperative groups were selected and registered by 12 specially trained Cooperative Inspectors. A campaign has been launched, aided by mass media, to encourage further registration of the 244 groups with a membership of about 5,000. Bank loans have been negotiated with the Nigerian Agricultural Bank to help cooperative farmers in Anambra and Imo states for the 1977 season.

A farmer is happy with his high-yielding cassava which originated at IITA.

Yam Breeding

White yam *(Dioscorea rotunda)*. The goals of the white yam breeding program are: (1) to develop cultivars which are high-yielding, resistant to diseases and insect pests, long-storing, with good culinary quality and require a minimum of material and labor inputs; and (2) to generate improved populations with a high frequency of these desirable characteristics. To achieve these goals a breeding scheme has been initiated which includes breeding nurseries for selection of seedlings and field plantings for hill trials, yield testing, and germplasm evaluation. Recombination to create improved base populations for breeding was accomplished through establishing population crossing blocks and controlled hand pollinations.

Selections were made during the growing season for plant type, vigor, resistance to yam virus and leaf spot diseases, and at harvest for resistance to nematodes, for tuber number, tuber size, tuber shape, and tuber smoothness, and finally for storage. Breeding families were evaluated for quality characteristics.

Two breeding populations were evaluated, one grown under traditional conditions of staking, and the other grown without staking for the selection of cultivars adapted to low labor production and mechanical harvesting.

Breeding activities. Breeding nurseries and hill trials were established in two offsite locations (one high-rainfall, one derived savanna) as well as at IITA. A summary of the populations and selection sequences at these sites is presented in Table 16. Hill trials contained individuals selected from 10 families of white yam. The 1976 seedling nurseries comprised 30 families of white yam including outcrossed seed from local cultivars and from IITA breeding populations and seed from controlled hand pollinations. Also included were five families of *D. dumetorum*. Additional 36 open pollinated families of *D. rotundata* and *D. dumetorum* have been

Table 16. Plant populations at each stage of clonal selection and population improvement in white yam (D. rotundata).

	1975-76		1976		1977
	Planted	Selected	Planted	Selected	Plant
Clonal selection					
IITA					
Seedling nurseries	7,000	1,160	13,000	ca.2,000	
Hill trial			700	190	ca.2,000
Preliminary trial					190
Mbiri/Bendel State					
Seedling nursery			600	50	
Hill trial			260	25	50
Preliminary trial					25
Mokwa/Niger State					
Seedling nursery			560	30	
Hill trial			200	25	30
Preliminary trial					25
Population improvement					
IITA – Intercrossing block			400 (190 clones)		

collected from farmers' fields in five states of Nigeria. These introductions plus seed from selected parents in the breeding program will provide seed for next year's seedling nurseries.

Controlled hand pollinations. The technique of hand pollination was further improved with the introduction of several new types of bagging material and the use of modified forceps for transfer of pollen. These forceps were three times as effective as the pin method previously used (23.3 percent fruit set compared to 6.8 percent).

Cross pollinations between selected parents were made for recombinations of desired characteristics. Self pollinations of monoecious individuals and sib pollinations within families were attempted for inbreeding (Table 17). Sib pollinations were reasonably successful, but the percent fruit set from self-pollinations was very low and not sufficiently higher than the controls (female flowers bagged but not pollinated) to conclude that selfing in white yam was achieved.

Table 17. Percent fruit set resulting from artificial self, sib, and cross pollinations in white yam (D. rotundata).

	Bagged and/or Inflorescences	Polli-nated Flowers	Fruit Inflor-escences	Fruit	% Set
Cross pollinations	22	252	5	15	6.0
Sib pollinations	46	719	27	108	15.0
Self-pollinations	54	377	3	10	2.6
Total pollinations	122	1,348	35	133	9.9
Unpollinated controls	39	544	2	8	1.5

Character associations. Associations between vine and tuber characteristics were studied using data from 530 plants of white yam pooled from five families in the IITA, staked hill trial. Results are given in Table 18.

Tuber yield per hill had significant negative correlations with leaf spot score and virus score and a significant positive correlation with a subjective vigor rating. The significant positive association between hill weight and sex expression confirmed past findings relating these two characteristics. The average yield per hill for female plants and monoecious plants was the same: 2.5 kg, compared to 1.6 kg for male plants and 1.3 kg for non-flowering plants. The association between hill weight and number of days from emergence to flowering was non-significant.

Table 18. Character associations in white yam (D. rotundata) based on 530 plants pooled from five families, staked, IITA.

Character	Correlation (r)[1]	Association[2]
Hill wt. vs. leaf spot score[3]	-0.23**	
Hill wt. vs. virus score[4]	-0.30**	
Hill wt. vs. vigor[5]	0.59**	
Hill wt. vs. sex expression[6]		< 0.001
Hill wt. vs. days to flowering[7]		NS
Stem colors vs. thoniness[9]		< 0.001
Stem no. vs. tuber no. at harvest		NS

***1. Significant at 1% level.*
2. Probabilities from independent test of Chi-square.
3. Subjective score (1-4) representing no disease to all leaves showing symptoms.
4. Subjective score (1-4) representing no disease to all leaves showing symptoms.
5. Subjective score (1-5) representing very weak vigorous.
6. Male, female, monoecious and non-flowering.
7. Number of days (10 day intervals) from emergence to flowering.
8. Subjective score (1-4) representing green, green purple, purple green, purple.
9. Subjective score (1-3) representing few, many, very many.

Unstaked hill trial. More than 600 plants from five breeding families were grown without staking and compared with the same families that were staked. The average yield of the unstaked population was markedly lower, 0.8 kg/plant compared to 1.8 kg/plant staked, and the average leaf spot score higher, 3.5 compared to 2.1. Only 14.8 percent of the unstaked plants flowered compared to 48.9 percent of those staked. However, it was possible to select from the unstaked population 68 high-yielding, leaf spot resistant plants for further testing.

Quality evaluation. Tubers from six breeding families were evaluated by a biochemist for those characteristics which determine consumer acceptance and processing quality. The results were used to select those families which are to be continued in the breeding program.

International cooperation. True seed of white yam was distributed to cooperators in Nigeria, Republic of Benin, Sierra Leone, Cameroon, Upper Volta, Ivory Coast, Ghana, New Caledonia, Sudan, Tanzania (Zanzibar), Philippines, Virgin Islands, West Indies, India, Puerto Rico, Jamaica and Brazil.

Water yam germplasm evaluation. Plants of 176 accessions of water yam (*Dioscorea alata*) from the germplasm collection were grown in a replicated trial without staking, in pure stand and with maize. These were evaluated for yield, conformation, resistance to scorch, and flowering. Yields (average of pure and mixed stands) ranged from 2.2 t/ha to 29.2 t/ha with a mean of 13.0 t/ha. High-yielding clones with good conformation were selected for further testing. The highest yields of marketable tubers were obtained from the pure stands at a 1×2-m spacing.

Scorch scores, noted two months before harvest, ranged from 1.5 - 3.5 on a scale of 1 (representing no disease) to 4 (all leaves showing symptoms). No difference was found in the severity of scorch on yams grown in pure stand compared to those intercropped with maize.

One female flowering clone and four male flowering clones were identified. Hand pollinations were made, resulting in one fruit but no seed. However, several new accessions of flowering water yam have been collected.

Pathology

New knowledge on the following major problems of yams (*Dioscorea* spp.) - yam virus disease, yam anthracnose (scorch) and yam leaf spots - was generated during 1976.

Yam virus disease: Disease survey. A yam virus disease survey was made in four states of Nigeria. At the 23 locations sampled, 44 percent of infected *Dioscorea rotundata* plants were showing the characteristic green vein-banding and 42 percent the characteristic shoestring symptoms. The highest percentage of infected plants in farmers' fields (80 percent) was encountered in Ondo State.

Host range studies. Attempts to transmit the *D. rotundata* virus by crude sap inoculation to five other *Dioscorea* spp. (*D. floribunda*, *D. dumetorum*, *D. composita*, *D. alata* and *D. spiculiflora*) were unsuccessful.

Yam virus indicator. A sensitive indicator host (*Nicotiana benthamiana*) has been identified for indexing the yam virus. In laboratory and greenhouse experiments 80 percent of the *N. benthamiana* plants inoculated at the three-leaf stage with purified and crude sap virus preparations respectively, developed diffused mottling, and mild green mosaic 11 days after inoculation.

This indicator was used to determine the virus disease status of 16 symptomless stunted *D. rotundata* plants from a field planting. The characteristic symptom development on *N. benthamiana* after inoculation with crude sap from these symptomless plants indicated that at least eight (50 percent) were virus carriers. Inoculation of *N. benthamiana* with crude sap from *D. alata* plants with suspected virus symptoms did not induce the characteristic symptoms.

Resistance screening. Four thousand, one hundred and twelve *D. rotundata* plants from 14 families were rated for their field reaction to the yam virus disease. On a 0-3 severity rating scale where 0 = no disease reaction and 3 = most severe, none of the 4,112 plants was rated 0, or 1, only 2 plants from the family Boki rated 2, and the rest were rated 3.

Cultural control of yam foliage diseases. Tuber yield loss due to leaf scorch and leaf spots on *D. alata* and *D. rotundata* was investigated in a randomized complete block experiment with four levels of light interception treatments (0, 56, 68 and 74 percent). Each treatment was replicated three times. The severity of the two foliar diseases during the growth cycle is summarized in Figure 13.

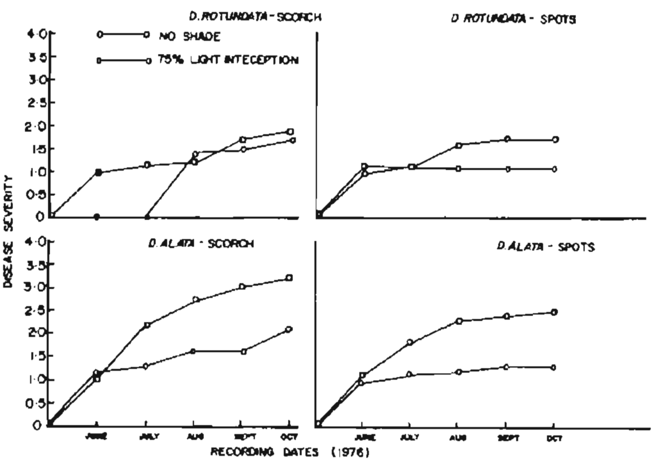


Fig. 13. Effect of shading on yam foliar diseases.

Shading significantly reduced the severity of leaf scorch and leaf spots, but there were no significant differences in yield between the shaded and unshaded check plants (Table 19). It is striking that the unshaded *D. rotundata* plants (0 light interception) showing the highest incidence of both types of foliar diseases produced the highest yields.

Table 19. Effect of shading on the mean yields, (T/ha) of two *Dioscorea spp.*

	Mean yields under 4 shading treatments			
	0%	56%	68%	74%
D. alata	25.80	26.83	17.60	15.13
D. rotundata	22.10	17.57	14.37	10.53

Yam disease report. High incidence of a *D. rotundata* witches' broom disease which was hitherto unimportant in Nigeria has been reported from Imo, Anambra and Kwara States. The disease is characterized by proliferation of lateral shoots (witches' broom), pale yellow leaves, black vines and stunting. The casual agent has not been identified.

Yam entomology.

In 1976 yam was attacked by a Chrysomelidae *Crioceris livida*, Dalm at IITA. The population reached a damaging level and had to be controlled by Gamalin 20. In eastern Nigeria and to a lesser extent at IITA, a gall midge was discovered damaging the leaves of yam. The insect was identified as *Lasioptera* spp. (*Cecidomyidae*). The female lays eggs in the tissue of the leaves, and during egg and larvae development galls are formed. We do not know yet whether economic damage occurs or not.

Biochemistry

Quality evaluation. Special attention was given to enzymic discoloration of flesh tissues as a screening factor. Annotation of texture of cooked tissues was also used to predict varietal suitability for specific food preparation. The presence of bitter taste or aftertaste was evaluated as a negative factor, especially for use as a vegetable. Pleasant flavor scores positively in overall quality evaluation.

Quality performance. Nine "breeding families" were evaluated for quality. About 150 genotypes were tested. Table 20 summarizes quality performance of families of white yam, *D. rotundata*. All individuals of four families (W42, W11, W7 and W3) were acceptable, and showed high percentages of high quality samples. Almost all individuals of one family (W5) were unacceptable. They were highly bitter to taste and demonstrated very intensive enzymic browning and unpleasant flavor.

Table 20. Quality of white yam (D. rotundata).

Family	% unacceptable	% acceptable	% superior	Families tested
W43	13.3	86.7	27	15
W53	14.3	85.7	36	14
W42	0	100.0	40	10
W11	0	100.0	87	15
W7	0	100.0	60	10
W10	14.3	85.7	43	14
W3	0	100.0	53	15
W2	6.3	93.7	25	16
W5	86.7	13.3	0	15

Yam agronomy

An experiment was conducted to assess the yields of cassava, white yam, sweet potato and maize when intercropped. The crops were grown on alternate ridges, spaced 1m apart. Plants were spaced within rows as follows: cassava and yams = 100 cm, maize = 20 cm and sweet potatoes = 30 cm. The four crops were all planted at the same time. Results for yams, sweet potatoes and maize yields are presented in Tables 21, 22, and 23 respectively.

Table 21 shows significantly higher yields of yam when it was grown as a monocrop than when intercropped. This

Table 21. Yield of white yam, D. rotundata, under monocropping and intercropping.

Planting system	Yield (t/ha)
Yam/Yam	15.83 a
Yam/Cassava	7.49 b
Yam/Maize	5.51 c
Yam/Sweet potato	5.77 c

Means followed by the same letter are insignificantly different from each other (5 percent level).

Table 22. Sweet potato yield under monocropping and intercropping systems.

Planting system	Yield (t/ha)
Sweet potato/Sweet potato	14.52 a
Sweet potato/Maize	6.06 c
Sweet potato/Yam	10.80 b
Sweet potato/Cassava	10.05 b

Means followed by the same letter are insignificantly different from each other (5 percent level).

Table 23. Effect of monocropping and intercropping on yield (kernels + cobs) of maize.

Cropping system	kg/ha
Maize/Maize	7,770 a
Maize/Cassava	3,990 b
Maize/Yam	4,120 b
Maize/Sweet potato	4,395 b

Means followed by the same letter are insignificantly different from each other (5 percent level).

may be expected because of the higher number of yam plants per unit area under a monocropping system.

Also, intercropping yams with cassava gave significantly higher yields than intercropping them with maize or sweet potatoes. This is because maize and sweet potatoes, both short-duration crops, have a more rapid growth than cassava. Also, maize would shade the yams while the long creeping vines of potatoes would compete with yams for nutrients. Cassava has a slower growth as do yams, and will not compete with yams because of its short leaves and rooting system. Yields of sweet potato under monocropping were also superior to intercropping (Table 22), although lower than expected. Table 23 shows significantly higher yields of maize when it is grown as a sole crop than when intercropped with yams, cassava or sweet potatoes.

Cocoyam

Breeding

Flowering and artificial pollination. A permanent plot containing 28 accessions of *Colocasia esculenta* and four accessions of *Xanthosoma sagittifolium* was established on site to provide optimum conditions for flowering.

Plants in eight of the *Colocasia* clones and two of the *Xanthosoma* clones flowered. Flowering of several clones began as early as four months after planting.

Table 24. Percent seed set resulting from artificial self, sib, and cross pollinations in cocoyam, Colocasia and Xanthosoma.

	No. Spadices				
	pollinated	with ovary develop.	with seed	% ovary development	% seed set
Colocasia					
Self & sib pollinations	26	11	3	42.3	11.5
Cross pollinations	18	0	0	0.0	0.0
Xanthosoma					
Self & sib pollinations	2	0	0	0.0	0.0
Cross pollinations	1	1	0	100.0	0.0
Total	47	12	3	25.5	6.4
Unpollinated	10	0	0	0.0	0.0

Artificial pollinations were made 1-5 days before, on the same day as, and 1-4 days after pollen shed, and with and without treatment of pistils with Calcium nitrate. Results are given in Table 24. Most of the spadices which displayed partial ovary development and all three spadices which set seed neither promoted nor inhabited ovary development or seed set. Thirteen seeds from three spadices of *Colocasia* developed; however, the viability of these seeds was poor.

Sweet potato

Breeding

Yield trials. The 25 most promising clones from the uniform trial were tested, without fertilizers, at IITA, Warri, Mbiri and Mokwa in both wet and dry seasons and were harvested four months after planting. The results are given in Table 25.

In wet season trials at IITA, TIS 3270 and TIS 3277 gave more than 45 t/ha fresh yield and TIS 2498, TIS 1499, TIS 1145 and TIS 3247 gave about 40 tons. In dry-season trials, TIS 2498 gave the highest fresh yield with 37 tons, followed by TIS 2540, TIS 3030 and TIS 2330 with about 30 tons. At Mokwa (derived savanna), TIS 3247, TIS 2534, TIS 1487 and TIb 8 produced more than 30 tons.

The yield data together with other agronomic characteristics are given in Table 26. TIS 2498 gave the highest fresh yield with 26.2 t/ha which is about 200 percent more than TIb 4, the standard cultivar used.

TIS 3017 showed the highest overall value for all important agronomic traits observed, followed by TIS 2532, TIS 2498, TIS 2534 and TIS 2153.

International cooperation. The most promising clones were supplied to the extension project at the University of Ibadan and Rivers State, both in Nigeria. Harvested tubers were supplied to the Animal Science Department at the University of Ibadan for their experiments on animal feeds.

Many improved seeds were supplied to Ivory Coast, Sierra Leone, Kenya, Tanzania, (Zanzibar), Sudan, Ghana, Guinea, Somalia, Solomon Islands, Sri Lanka, Bangladesh, Brazil, Costa Rica, Philippines, Thailand and Zaïre.

TIb 1 gave the highest yield among their introductions in Liberia and Cameroon, with fresh yield of about 56 tons/ha in the Cameroon.

Quality. The biochemist screened clones of the uniform and advanced yield trials for texture and general eating quality. The general eating quality of TIS 1499, TIS 2498, and TIS 3053 was found to be very good.

Resistance to weevil. TIS 3053, TIS 2544, TIS 2534, TIS 3030, TIS 3290, TIS 3247, and TIS 3017 showed very low tuber damage by weevil.

The 3-10 best clones from each of the clones improved in 1971, 1972, 1973 and 1974 were tested under similar field conditions in four locations and in two seasons for tuber damage by weevil. Field resistance to weevil was remarkably improved in 1973 and 1974 but results indicate that further improvement for this character may be difficult unless new resistant sources are identified, incorporated into breeding populations, and screened for resistance to weevil with improved methods of screening.

Table 25. Fresh yield (t/ha) - 1976 Sweet potato uniform trials.

	IITA		Mokwa	Mbiri		Mean
	Wet season	Dry season	Dry season	Wet season	Dry season	
TIb 4	29.4	15.3	15.1	5.6	2.4	13.6
TIS 1145	40.2	27.7	28.7	21.4	11.2	25.8
TIS 1487	33.6	29.3	30.1	17.7	9.5	24.0
TIS 1499	43.0	27.4	25.8	19.9	6.8	24.6
TIS 2330	42.3	30.5	24.2	6.4	18.8	24.4
TIS 2498	43.1	37.0	25.0	16.0	10.1	26.2
TIS 2532	38.6	24.0	27.3	15.0	18.6	24.7
TIS 2534	25.9	27.8	30.9	17.8	11.2	22.7
TIS 2544	28.3	36.2	29.5	10.4	14.1	23.7
TIS 3017	31.5	28.1	28.5	21.1	13.2	24.5
TIS 3030	36.1	30.9	21.0	8.4	15.0	22.3
TIS 3247	40.6	29.9	31.8	13.5	12.6	25.7
TIS 3270	47.6	24.6	22.5	10.8	17.7	24.6
TIS 3277	46.3	23.9	28.4	12.6	13.0	24.8
TIS 3290	39.7	27.0	27.4	10.0	14.1	23.6
Mean	37.7	28.0	26.4	13.8	12.6	23.7

Table 26. Yield, dry matter percent, resistance to weevil and virus, and storability of IITA clones.

	Fresh yield (t/ha)	Dry matter (%)	Dry yield (t/ha)	Weevil score	Virus score	Storability
TIS 2498	26.2(193)	36.8(111)	8.6(215)	1.0(59)	2.8(127)	Medium
TIS 1145	25.8(190)	31.6(95)	7.0(175)	1.1(65)	3.1(141)	Poor
TIS 3247	25.7(189)	31.5(95)	7.0(175)	0.8(47)	2.3(105)	Poor
TIS 3277	24.8(182)	31.2(94)	6.8(170)	1.3(76)	2.6(118)	Medium
TIS 2532	24.7(182)	32.4(98)	7.1(178)	1.0(59)	1.8(82)	Good
TIS 1499	24.6(181)	30.9(93)	6.6(165)	1.4(82)	3.2(145)	Medium
TIS 3270	24.6(181)	31.7(96)	6.9(173)	1.0(59)	2.1(95)	Medium
TIS 3017	24.5(221)	35.2(106)	7.5(188)	0.9(53)	1.8(82)	Good
TIS 2330	24.4(179)	25.3(76)	5.6(140)	1.2(71)	1.6(73)	Poor
TIS 1487	24.0(176)	36.3(110)	7.7(193)	1.2(71)	2.6(118)	Medium
TIS 2544	23.7(174)	31.2(94)	6.5(163)	0.5(29)	2.7(123)	Good
TIS 3290	23.6(174)	34.6(105)	7.2(180)	0.7(41)	2.7(123)	Medium
TIS 2534	22.7(167)	31.9(96)	6.5(163)	0.7(41)	1.9(86)	Good
TIS 3030	22.3(164)	34.2(103)	6.6(165)	0.7(41)	2.4(109)	Medium
TIb 4	13.6(100)	33.1(100)	4.0(100)	1.7(100)	2.2(100)	Medium

Figures in parenthesis refer to percent of TIb 4. Yields are 4 months data.

An 8×8 diallele cross was made to investigate resistance to weevil under field conditions. TIS 2525 showed the largest general combining ability for tuber damage, followed by two local cultivars TIb 6 and TIb 5. TIS 2525 also showed resistance to weevil in Liberia. The heritability of resistance to weevil was low with respect to tuber damage. High correlation between tuber damage and tuber depth ($r = 0.83$) was obtained, which was due to both additive and non-additive effects. High negative genetic correlation between tuber damage and carotene content ($r = 2.53$) was obtained, which was also due to both additive and non-additive effects.

Resistance to virus. TIS 2330, TIS 2532, TIS 3017, TIS 2534, and TIS 2153 showed field resistance to viruses.

Storability. Storability was tested under ambient temperature conditions using clones from the preliminary, advanced and uniform yield trials. In the uniform trial, TIS 2153, TIS 2532, TIS 2534, TIS 2544 and TIS 3017 proved to have good storability.

Pathology

Mechanical transmission. Crude sap inoculum was prepared from virus infected sweet potato leaves by adding phosphate buffer solution at pH 7.6, activated charcoal, distilled water and carborundum (abrasive). Five plants each from eleven sweet potato (*Ipomoea batatas*) cultivars and 127 plants of the sweet potato virus indicator *I. setosa* were inoculated using a Nitrogen gas cylinder at 15 psi pressure. Eight of the *I. setosa* plants developed characteristic vein-clearing and chlorotic mottling 19-50 days after inoculation. None of the sweet potato plants developed any symptoms. This is the first report of mechanical transmission of the sweet potato virus in Nigeria.

Entomology

The major insect problem observed in sweet potatoes during 1976 was the weevil *Cylas puncticollis* and to a lesser extent *Cylas brunneus*. During October and November a Cerambycidae species *Nupserha deusta* Dalm (*Lamiinae*) was observed tunnelling in the sweet potato stems and this damage can easily be confused with that caused by *Cylas*. The vectors for the sweet potato virus complex, white flies and aphids, were not seen in the field.

Sweet potato weevil. Work in sweet potato entomology was concentrated on *Cylas puncticollis*. Priority was given to field and laboratory evaluation of sources of resistance in the germplasm. Because the weevil attacks the leaves, the stems and the tubers, methods were developed to evaluate each

Table 27. List of 12 sweet potato clones which showed low or no weevil infestation during laboratory and field screening in 1976 compared with Tib 4 (Susceptible) and Tis-2534 (Field resistant).

	Laboratory Screening				Field Screening			
	Eggs/ tuber	Weevils Hatched/ tuber	% Weevils hatched/ tuber	Egg/hour index	Weight/ tuber Kg	Weevil damage score, tuber	Weevil damage score, stem	% Infested tubers
Tis-1491	7	1	14.3	0.07	0.09	0	1	0
Tis-2079	7	1	14.3	0.05	0.15	0	2	0
Tis-2301	9	2	22.2	0.13	0.5	1	1	10
Tis-2373	12	3	24.9	0.09	0.13	1	1	15.25
Tis-2028	6	2	33.3	0.07	0.09	0	1	0
S1-301-25	11	4	36.3	0.06	0.1	1	2	12.9
Tis-3056	8	3	37.5	0.09	0.06	1	2	9.5
Tis-3137	8	3	37.5	0.1	0.14	0	1	0
Norin 20	8	3	37.5	0.09	0.15	2	1	30
Tis-2099	8	5	62.5	0.13	0.06	0	1	0
Tis-3283	8	4	50	0.1	0.22	1	2	13.3
Tis-2108	10	6	60	0.1	0.12	2	2	25.2
Tib-4	8	6	75	0.13	0.06	4	2	51.3
Tis-2534	9	5	55.5	0.13	0.16	2	1	24.5

part of the plant separately. The method of tuber evaluation was described in the IITA Annual Report, 1975. In the laboratory, the number of weevils emerged from the tubers was counted after five weeks and the tubers sliced to check for any that remained. In the field a tuber score ranging from 0-5 was used and in addition a count was made of attacked tubers. For stem damage screening, five cuttings of each clone were put in glass phials filled with water and exposed to weevils for egg-laying for five days. Later they were planted in pots and after 14 days each cutting was sliced to see whether development of larvae had taken place. The test is still in progress.

In a special screening cage the leaves of 45 clones were exposed to about 600 weevils for 12 hours. From each clone seven leaf discs two centimeters in diameter with the petiole still on were cut. The petiole was put in a small glass tube filled with water. No significant differences in the amount of leaf feeding among the clones could be detected.

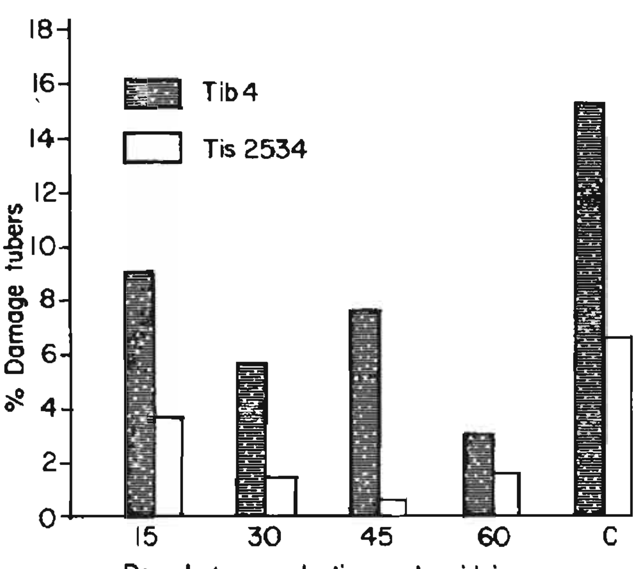


Fig. 14. Wet season tuber depth trial (sweet potato).

Cultural control measures were also carried out in 1976 during the wet and dry seasons. The tuber depth trial in 1975 had shown the important role of tuber depth in avoiding weevil damage. Therefore it was assumed that an additional layer of soil put on the ridge sometime after planting might protect the developing tubers against weevil attack.

The 1976 field tests established the optimal time between re-ridging and planting. Two cultivars Tib-4 (susceptible) and Tis-2534 (field resistant) were used. Re-ridging took place 15, 30, 45 and 60 DAP. The test was randomized and replicated six times. Harvest was done after four months. The results of the wet season tests are shown in Figure 14. The columns indicate the percentage of tubers attacked. The differences indicate that re-ridging was effective in reducing the weevil damage. The best time for re-ridging was 60 days for Tib-4 and 45 days for Tib-2434. In practice, 30 days would be the best because later, vein and foliage development make it rather difficult to put an additional layer of soil on the ridge. This could be done with the first or second weeding. The dry season test showed less encouraging results because of soil cracking which reduced the re-ridging effect.

Biochemistry

Raw material. Fresh tissue was evaluated for color intensity. Four breeding clones examined showed varying degrees of fresh color such as white, creamy, yellow and orange. Quantitative analysis for B-carotene will only be done on the most advanced trials; however, the color intensity of fresh tissues served as a guide for estimating B-carotene which is important as pro-vitamin A. Non-uniform blending of color was detected in some cultivars. Intense enzymic discoloration of tissues is a negative quality factor and was used in the screening exercise.

Texture profile. Texture characteristics in sweet potato examined appeared to be the most complex. Besides the mealy or soggy textures, other textural characteristics were prominent in part or wholly in many cultivars. Non-uniformity in texture was observed in many clones.

The mealy texture is preferred in West Africa, probably because of similarity to yam.

Taste profile. Mouthfeel (texture) and flavor were major factors for consumer preference. Sweetness, on the other hand, was a minor discriminating index. Surveys revealed that less sweetness is preferred, in West Africa, when sweet potato is consumed as a major meal, while very sweet cultivars are popular as a minor meal or snack.

Quality performance. Overall quality performance of "breeding materials" is summarized in Table 28. The small number of very high quality genotypes in TIX-series may be due to over-maturity of tubers. The most recommendable cultivars are: TIB 909, TIX 5091-1, TIX 5013-D, TIS 1499 and TIS 3053.

Table 28. Quality of sweet potato clones.

Varietal group	Clones tested	% unacceptable	% acceptable	% superior
TIX series	24	29.2	70.8	8
TIB series	6	33.3	66.7	33
TIS series	18	38.9	61.1	22

FARMING SYSTEMS PROGRAM

The food situation in the developing tropical countries of the world remains a serious issue because of rapidly increasing populations that cannot be supported by outmoded agricultural systems. The objective of the IITA Farming Systems Program is to develop crop production systems that enable good yields to be produced on a sustained basis in the various ecological zones of the lowland tropics.

With the exception of the intensive rice production systems of south-east Asia, yields of food crops in the lowland humid tropics remained very low. The cropping systems in which they are produced involve intermittent cropping alternating with varying periods of fallow which in some areas have been rendered very short and ineffective by population pressure. Continuous cultivation of tropical soils without fertilizers results in a very rapid loss of soil fertility. Leaving land under fallow for long periods not only ties down a good farm land but also increases the labor cost of periodic bush clearing. Clearing of new land, which remains the most widespread method of increasing production in developing countries, exposes the highly weathered tropical soils of low inherent fertility to intense leaching, further loss of plant nutrients and erosion.

Sustained yields of arable crops can only be attained on a continuing basis with costly inputs of fertilizers and pesticides, scientific land development and soil management. Large-scale mechanization and food production projects in the humid tropics usually fail because of the inability of existing methods to ensure sustained yields of major staples on such farms. The Farming Systems Program seeks to develop suitable methods of land development and scientific soil management to ensure that sustained crop yields are obtained in the humid tropics. Above all, it should develop appropriate and more efficient alternatives to outmoded food production systems of small farmers who constitute 95 percent of farmers of these regions.

Preliminary studies have indicated that increased food production in the humid tropics is possible with intercropping and multiple cropping, minimum tillage, mulches, low inputs of fertilizers and pesticides; improved, high-yielding, pest and disease resistant crop cultivars; improved hand tools, small machines and appropriate technology within the ability of small farmers to obtain and use.

Priorities

In the Program, interdisciplinary teams give high priority to:

1. determining appropriate crop combinations, sequences and management practices for attaining high yields and minimizing the use of inputs (fertilizers, herbicides and other agricultural chemicals) for important cereal, root and tuber and grain legume crops of the humid tropics;
2. finding or generating the most suitable techniques for forest and bush clearing, integrated land development, land preparation, planting and weed control that will ensure good feeding and plant growth conditions and erosion control at a minimal cost;
3. studying and understanding of the plant nutrient status; changes, and availability in highly acid tropical soils as a basis for establishing methods for ensuring optimal nutrient supply with appropriate fertilizer formulations in combination with methods that take full advantage of potential biological nitrogen fixation and enhanced phosphate nutrition by micorrhiza; and
4. designing appropriate tools and machinery and developing techniques for their economic use in crop production and other farm operations ranging from forest clearing and land development to harvesting, postharvest handling and storage of crops in the humid tropics.

Soil chemistry

The assessment of chemical, mineralogical properties and nutrient status of major soils in the lowland tropics of Africa continued for the third year. During 1976, research efforts were focused on soil phosphorus and potassium.

General description of four bench-mark soil groups. The large number of African bench-mark soils studied may be grouped into the following four groups:

1. **Ultisols and Oxisols are derived from intermediate and acidic rocks.** They are the major upland soils in the rain-forest zone of the lowland humid tropics. These soils generally have a good physical condition, but chemically they are very poor. Aluminum is the major exchangeable cation in the soil. Deficiencies of calcium and magnesium are expected if the present "slash-and-burn" practices are to be replaced by more permanent farming systems.
2. **Alfisols and Inceptisols are derived from intermediate and acidic rocks.** They are highly base-saturated, upland soils with wide occurrence in the derived

savanna and in the drier part of the forest zone. They are soils situated in the upper-to-lower-middle slope of a rolling topography. These soils are chemically fairly rich. But most Alfisols formed on basement complex are physically very poor as a result of their sandy top soil and high concentration of quartzite gravels in the upper B horizon. Soil erosion becomes the major limiting factor for large-scale farming. Mulch tillage has been proved a highly effective practice on Alfisols in the drier part of the forest zone where crop residues are not needed for fuel or animal feed as in the savanna zone.

3. **Hydromorphic soils** are found in the valley bottom of a rolling topography. In the derived savanna and drier part of forest zones they are classified as Aquolls (Mollisols), Aquents (Entisols) Aquepts (Inceptisols) and Aqualfs (Alfisols). These soils, though of limited distribution, are fertile because of clay mineralogical content as reflected by the high cation exchange capacity (CEC) and high water holding capacity. Hydromorphic soils in the high-rainfall region are mainly Aquults (Ultisols) and Aquents which are strongly acidic (pH below 5) and less fertile.

   Iron toxicity in flooded rice frequently occurs on newly cleared valleys, particularly when interflow water from upper slopes and drainage conditions are not controlled.

4. **Ultisols, Oxisols, and Inceptisols derived from basic rocks** are a unique group of soils in the tropics, but they are limited in the lowland tropics of western and central Africa. These are fine-textured, porous red soils mostly derived from basalts and volcanic ash. Despite their notoriously high phosphorus fixation, they are among the most productive soils in the tropics with high management input.

The relative distribution of the four soil groups in the lowland tropics of Africa follows the order of I > II > III > IV, whereas their agricultural potential follows the reverse order. The degree of base saturation and particle size distribution of three typical upland soils from the forest zone is shown in Fig. 1.

Potassium status–quantity/intensity relationship. The Q/I relationship is a good measure of the potassium supplying power of the soil because it measures simultaneously the K status in the soil solution phase (intensity factor) and the K buffering capacity of the soil solid phase (capacity factor). The intensity factor is expressed by the equilibrium activity ratio of K in the solution phase with respect to Ca and Mg (ARe). The capacity factor is expressed by the K buffering capacity (PBC) which is calculated from the slope of the Q/I plots. Some representative results are given in Table 1. The commonest feature is that the surface layer has the highest ARe but lowest PBC within each profile. The group I soils (Ultisols and Oxisols derived from acidic parent rocks) are poor K suppliers as indicated by their low ARe and PBC values (Table 1.). This group of soils occupies a large area in the high-rainfall region of the tropics. Heavy basal application of K fertilizers should be avoided to prevent leaching losses. On the other hand, one would not expect a severe leaching loss of K in the other soil groups because of the increasing PBC of the subsoil horizons. The high ARe value in the surface horizons of the Alfisols derived from banded gneiss from the Ibadan area indicates that these soils contain an appreciable amount of weatherable K-bearing minerals in the surface horizons.

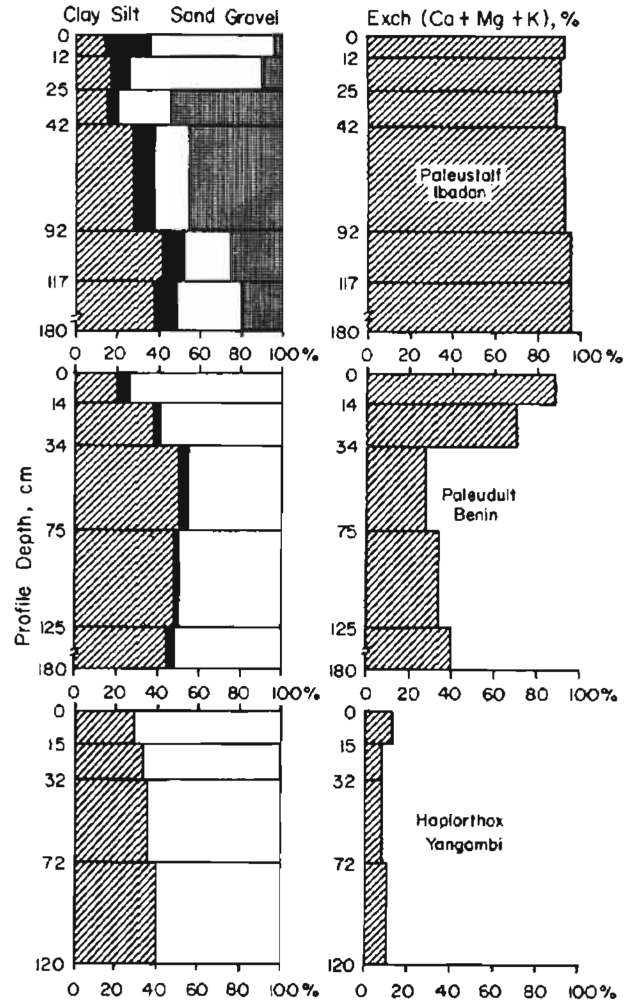


Fig. 1. Percentage of exchangeable base saturation and particle-size distribution of three representative upland profiles.

Table 1. Equilibrium activity ratio (ARe) and potassium buffering capacity (PBC) of some bench-mark soils.

Soils	Horizon	Clay %	ARe $\times 10^2$	PBC
		Group I Soils		
Paleudult, Onne	A_1	18	1.51	2.9
	B_2t	35	0.32	5.1
Paleustult, Nsukka	A_1	26	1.01	3.6
	B_1	29	0.37	5.3
		Group II Soils		
Paleustalf, Ibadan	A_1	15	6.72	11.3
	B_2t	54	1.43	20.3
Paleustalf, Ikenne	A_1	13	1.42	13.7
	$B_{21}t$	45	0.03	17.4
		Group III Soils		
Tropaqualf, Ibadan	A_1	10	1.90	13.8
	B_1	18	0.36	27.3
		Group IV Soils		
Tropohumult, Ikom	A_1	42	0.48	31.6
	$B_{22}t$	79	0.12	20.6

Phosphorus status. For all the soils studied, we found that the external specific surface area of soil measured by the BET-N_2 method is the key factor controlling P fixation. The relationship is particularly convincing when the soils are separated into the various groups as described in a previous section. The highest P fixing soils are those derived from basis parent rocks, particularly from basalts and volcanic ash (Table 2). This is because of the small particle size and high specific surface area of sesguioxides existing in these soils.

Table 2. Correlation coefficients of P sorption capacity of 28 selected profiles with soil properties.

Soil Groups	Clay content	Total free Fe_2O_3	BET-Surface Area
I	0.87	0.79	0.97
II	0.81	0.79	0.98
III	0.40	0.10 (NS)	0.73
IV	0.33 (NS)	0.44	0.88
All Soils	0.73	0.77	0.95

Studies on soil organic P were continued. One major problem is the lack of a reliable method for the determination of organic P in soils. A critical evaluation of the various extraction and ignition methods indicates that the simple ultrasonic-alkali extraction procedure gives the most consistent results for a wide range of soils.

Management of highly weathered acid soils. The highly weathered and strongly leached acid soils (Group I soils) in the high-rainfall region are the most infertile soils in the tropics. Exchangeable Al normally comprises more than 70 percent of the total exchangeable cations. Thus, nutrient deficiencies and soil acidity are the major limiting factors for food crop production on these soils. Traditional cultivation method involves "slash and burn" of 20-to-30-year-old secondary forest. This is still a common practice in the sparsely populated areas such as Gabon and northern and central Zaire. But with increasing population pressure in areas such as southeastern Nigeria, the fallow periods have been shortened to between seven and ten years in Rivers State, and one to three years in Imo, Anambra and Cross River States. Once the forest-nutrient cycle is broken, these strongly leached sandy soils are only able to support crops such as cassava and palms. Crops with higher nutrient requirements and which are sensitive to soil acidity, such as yams, legumes and maize are limited to plots near farm compounds where refuse and ashes could be used as fertilizer and liming materials.

Chemical compositions of plant residue ashes (Table 3) show that potassium is the major component. Ashes from maize stover contain much less Ca, Mg and K than ashes from Guinea grass, Leucaena and natural bush.

Table 3. Chemical composition of plant residue ashes.

Ash*	pH H_2O	Chemical composition, %				
		Ca	Mg	K	P	N
Maize Stover	10.1	0.8	0.6	6.5	1.2	4.7
Guinea Grass	10.8	1.9	1.7	19.5	2.2	1.6
Leucaena	10.5	5.3	1.7	18.0	1.8	5.3
Natural Bush	10.5	6.3	1.2	18.0	2.0	1.6

**Woody parts excluded. Maize sample was taken at silking, and Guinea grass sample was taken at flowering.*

To establish more productive and permanent cropping systems in areas with high population density, chemical fertilizer and commercial liming materials may soon become indispensible. An example is given in Table 4, which shows that the level of exchangeable Ca of limed soil (2t/ha) is comparable with that from a field four months after "slash-and-burn" of a seven-year-old thicket. The farmer's choice is simply between the availability of commercial fertilizers and liming materials, and seven years of waiting. It should be emphasized that when plant nutrients are supplied in the form of fertilizers, these soils normally require less than 1 t/ha of lime to give adequate Ca supply and to correct soil acidity.

Table 4. Exchangeable Ca and pH of limed and burned plots at Onne (Oxic Paleudult).

Soil depth cm	Under 7-yr.-old bush	4 Months after slash & burn	4 Months after liming (2 t/ha)
		Exch. Ca, meg/100g	
0–15	0.35	2.36	2.19
15–30	0.20	0.70	0.61
30–45	0.15	0.60	0.41
		Soil pH (H_2O)	
0–15	4.3	5.5	5.6
15–30	4.4	5.1	4.4
30–45	4.4	4.4	4.4

Liming trials. Long-term liming trials were established at IITA high-rainfall substation at Onne, Nigeria. The main objectives are to study the retention and movement of applied Ca, leaching losses of fertilizer nutrients as affected by liming, and to establish effective cropping and fallow sequences. Results from soils sampled after the first season of maize at Onne (Table 5) showed that taking crop removal into account, a slight downward movement of Ca occurred after the first crop of maize, when the soil (Oxic Paleudult) received nearly half of the 2,400 mm total annual rainfall.

Table 5. Exchangeable Ca (me/100g soil) in unlimed and limed field plots at Onne after first season maize.

Depth cm	Lime rate, t/ha				
	0	0.5	1	2	4
		After 2 weeks			
0–15	0.57	1.37	1.70	2.50	6.43
		After 4 months			
0–15	0.60	0.78	1.22	1.96	4.17
15–30	0.46	0.60	0.50	0.54	0.88

The slow rate of Ca movement is further confirmed by the lysimeter studies in the greenhouse which showed that under an effective crop cover, a relatively small portion of applied Ca (as $CaCO_3$) and K (as KCl) was found in the leachate under intensive leaching. The maximum water applied was equivalent to 1,700-mm rainfall during the two 10-week cropping periods (Table 6).

Table 6. Losses of Ca and K beyond 30-cm depth under intensive leaching condition in the greenhouse.

Lime t/ha	Percent of total added	
	Ca	K
0	–	18.3
1	14.5	2.0
2	8.6	1.7
3	5.4	1.0
5	4.0	1.2

These data indicate that under effective crop cover and efficient fertilizer use, leaching losses of Ca and K could be minimized in these low CEC and coarse-textured Ultisols.

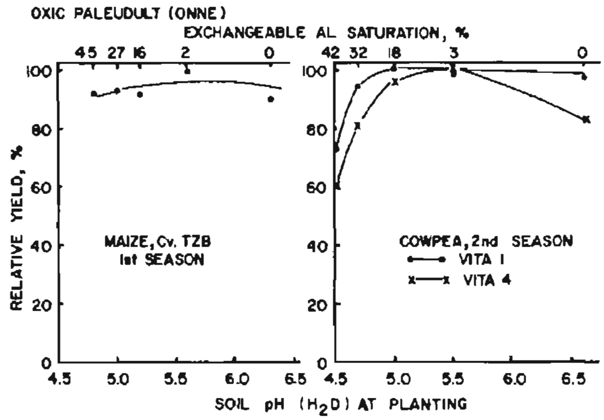


Fig. 2. Effect of liming on grain yield of maize (1st season) and cowpea (2nd season) at IITA high-rainfall substation at Onne, Port Harcourt. Liming rates = 0, 0.5, 1, 2, and 4 t/ha.

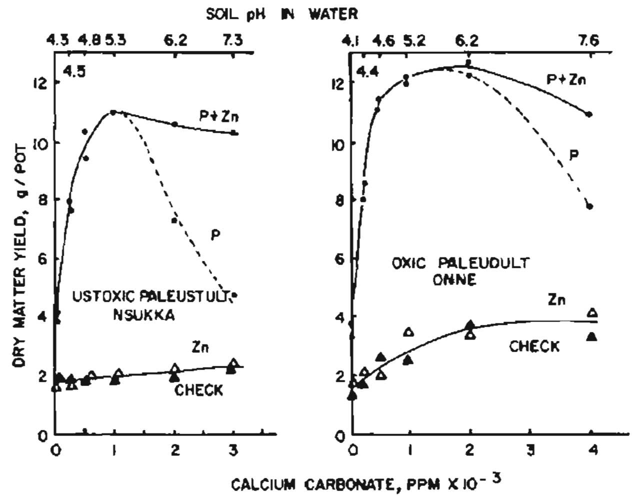


Fig. 3. Lime-P-Zn interaction as shown by maize dry matter yield in two Ultisols (200ppmP and 10ppm Zn).

Yields of maize and cowpea from the Onne field trial in 1976 are given in Figure 2. Maize (cv. TZB) during the first season did not respond to liming when the exchangeable Al saturation of the soil is 45 percent or less. But cowpeas (VITA-1 and VITA-4) grown in the second season showed significant responses to the first two rates of liming (0.5 and 1 t/ha). VITA-1 showed more tolerance to soil acidity than VITA-4. Maximum yield of cowpea occurred when the exchangeable Al saturation is about 20 percent and the soil pH is between 5.0 and 5.5. Maximum yield of maize is about 4.5 t/ha. Maximum yields of cowpeas are 560 and 280 kg/ha for VITA-1 and VITA-4, respectively, harvested during a 10-day period. There was vigorous vegetative growth of cowpea in the limed plots, even though the grain yield was low. Both crops received recommended rates of fertilizer nutrients (N, P, K, Mg, S, Zn) and weekly spraying.

The effect of liming on nodule formation and total N uptake was also investigated in collaboration with the Grain Legume Improvement Program. Liming at a rate of 0.5 t/ha doubled the nodule formation and total N uptake per plant of both cultivars. There was no significant increase in nodule counts at higher rates of liming (Table 7).

Table 7. The effect of liming on nodule formation and N uptake by two cowpea cultivars.

Lime t/ha	Soil pH* H_2O	mg nodule plant VITA-1	mg nodule plant VITA-4	mg nodule plant VITA-1	mg nodule plant VITA-4
0	4.5	78	35	415	370
0.5	4.7	173	80	781	489
1	5.0	168	119	773	416
2	5.5	219	113	740	539
4	6.6	175	153	861	679

**Soil pH was measured at planting time and four months after liming.*

Effect of liming on nutrient interactions and balance. Nutrient imbalance and deficiencies are important problems when the highly weathered acid soils are used for continuous cultivation. The ashes from the traditional "slash-and-burn" practices provide more balanced, though insufficient, mineral nutrients to the crop that follows. Under continuous cultivation, however, the conventional NPK fertilizer applications and liming may induce secondary and micro-nutrient deficiencies. Magnesium deficiency in maize is common in plots at Onne substation where moderate rates of $CaCO_3$ or $Ca(OH)_2$ lime (1 to 2 t/ha) were applied. Zinc deficiency may be induced by higher rates of liming and phosphate applications as illustrated in Figure 3 from a pot experiment. Thus, well-balanced nutrients must be applied in addition to lime. Phosphorus fixation is another limiting factor in these acid soils. Results from collaborative liming and phosphate trials at Amakama in southeastern Nigeria showed that relative maximum yield was obtained when 120 kg/ha of P_2O_5 was applied and the soil was limed to pH between 5.0 and 5.5. Grain yield of maize (cv. TZB) of the second season was low (max. 2.6 t/ha) due to severe stem borer damage in spite of regular spraying.

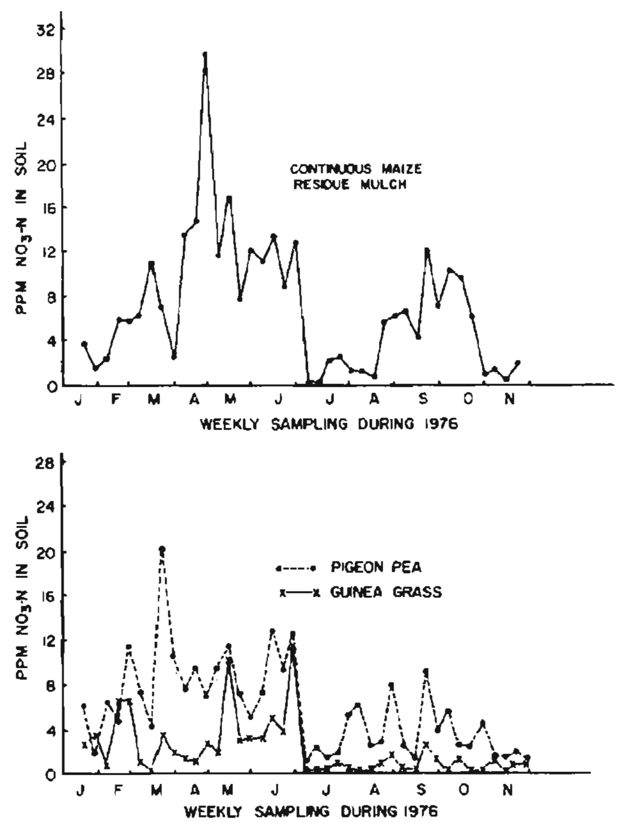


Fig. 4. Weekly nitrate content in surface layer (0-15cm) of an Alfisol (Egbeda Series) under fallow and cropping. Nitrate content expressed on the basis of field moist soil.

Field experiments on lime and potassium interactions were also established on two ultisols in southern Nigeria. Early stage of growth showed that the IITA improved cassava cultivar 30211 is more responsive to liming and K application than the Nigerian cultivar 60506.

Soil properties under fallow and continuous cultivation. This experiment which consists of four cropping treatments and four fallow treatments was continued for the fifth year. Soil organic matter and mineral nutrient status were monitored periodically. During 1976, NO_3-N content in the surface soils under different fallow and cropping treatments were monitored weekly (Figure 4). The date showed both weekly and seasonal fluctuations. Soils under pigeon pea and Leucaena maintained a higher nitrate level than soils under Guinea grass and natural bush during the growing seasons. There were two distinct nitrate peaks in the continuous maize plots. In general, soils maintain a higher nitrate level in the first wet season than in the second wet season.

Adsorption of paraquat by soils. "Paraquat" is a promising herbicide for more permanent and large-scale farming in the tropics. It has been used as a preemergence herbicide in lieu of minimum tillage and for sod destruction in mulching trials. The adsorption of paraquat by selected soils was studied. The maximum adsorption capacity calculated from Langmuir isotherms ranged from 1,200 to 7,500 $\mu g/g$ soil. The iron oxide-rich soils (Ultisols and Alfisols) derived from basalts and amphibolites have the highest adsorption capacity, while the strongly acidic Ultisols derived from sedimentary rocks adsorb the least amount. More than 50 percent of the adsorbed paraquat is held very strongly by the soil.

Soil fertility

Long-term field trials

Maximum yield and cultural trials. Experiments to determine the maximum yields and the long-term effects of fertilizer application and weeding were continued on two of the agricultural benchmark sites – Apomu soil series (Alfic Ustipsamment) at IITA, and Alagba soil series (oxic palenstalf) at Ikenne. A new site was added in 1976 on an Araromi soil series (Rhodustalf) at Isoya in cooperation with the Soil Science department of the University of Ife. The first-season maize grain yields for four years at Ibadan and Ikenne sites are shown in Figure 5. At both locations, the effect of the various treatments on the 1976 maize yields showed a similar trend as it did in previous years. Yields were generally lower on the Alagba soil than on the Apomu soil due to poor weather conditions. With no fertilizer appli-

Trustees Dr. F.F. Hill (left) and Dr. A.H. Bunting (second from right) are briefed on soil fertility experiments in one of the greenhouses.

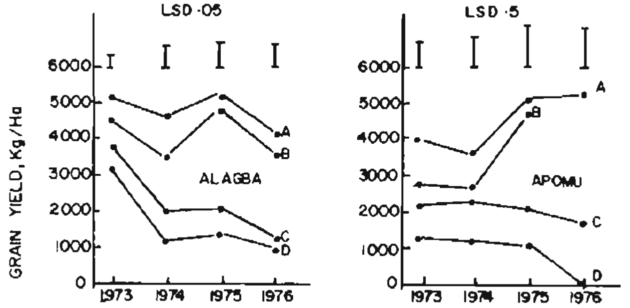


Fig. 5. First season maize grain yield on Alagba and Apomu soils as affected by fertilizer application and weeding (A = + fertilizer and weeding; B = + fertilizer no weeding; C = no fertilizer no weeding; D = no fertilizer no weeding).

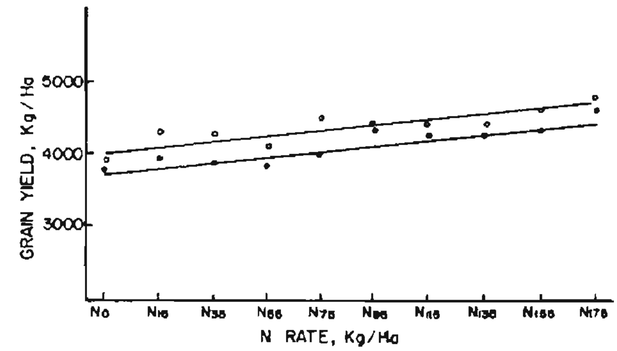


Fig. 6. Grain yield of maize on Egbeda soil as affected by N-rates and tillage methods (● —— ● strip tillage: ○ —— ○ conventional tillage).

cation and weeding, yields continued to decline in 1976 at both locations. Due to heavy weed competition on the Apomu soil and with no fertilizer application and weeding the maize crop gave zero yield in the fourth year of cropping. The maize crop in the fertilized and unweeded treatment on the Apomu soil was damaged by rodents.

Long-term fertilizer trials. The first-season maize grain yield from both locations in the fifth cropping year is shown in Table 5. On the Egbeda soil, significant yield increases were only observed with applications of 40 kg N/ha and 30 kg P/ha. There were some residual effects of the applied N and P on the Egbeda soil. On the Apomu soil, linear significant responses up to 160 kg/ha and a significant response to 40 kg P/ha were observed. A N-rate of 150 kg N/ha was adequate for obtaining maximum yield on the Apomu soil. There were no significant responses to K, S Mg, and Zn application on both soils. Removal of the crop residue for five seasons had an insignificant effect on the maize yield on the Egbeda soil with adequate fertilization. However, on the sandy Apomu soil, there was a substantial yield reduction with annual removal of the crop residue even with adequate fertilization.

Table 5. First season grain yield of IITA maize TZB in 1976 grown on Egbeda and Apomu soils as affected by fertilizer applications and crop residue treatments (5th cropping year).

Soil Type/Treatments	Egbeda soil	Apomu soil
	–kg/ha–	
$N_0P_0K_0S_0$	2086	570
$N_0P_2K_1S_1$	4262	1673
$N_1P_2K_1S_1$	6868	3379
$N_2P_2K_1S_1$	6996	6057
$N_2P_0K_1S_1$	3742	4045
$N_2P_1K_1S_1$	6847	5322
$N_2P_2K_0S_1$	6928	5189
$N_2P_2K_2S_1$	6866	5606
$N_2P_2K_1S_0$	6732	5499
$N_0P_0K_0S_0$ Residue removed	2626	1151
$N_2P_2K_1S_1$ Residue removed	6785	5212
LSD .05	716	1275

**Fertilizer rate:* $N_1 = 60$ *kg/N/ha;* $N_2 = 120$ *kg N/ha for Egbeda soil:* $N_1 = 75$ *kg N/ha;* $N_2 = 150$ *kg N/ha for Apomu soil:* $P_1 = 30$ *kg P/ha;* $P_2 = 60$ *kg P/ha:* $K_1 = 40$ *kg K/ha;* $K_2 = 80$ *kg K/ha:* $S_1 = 15$ *kg S/ha.*

Effect of tillage and N rates. Investigations on the effect of conventional plowing and strip tillage (or minimum tillage) and N rates on maize yield on an Egbeda soil, initiated in 1975, were continued in 1976. Despite the low yield due to drought effect at grain formation stage, similar to the 1975 results, grain yield was consistently lower with minimum tillage over the entire N-range studied (Figure 6). On the average there was a 6 percent yield reduction with minimum tillage.

Fertilizer sources trial

Investigations on the effect of various rock P sources were conducted on a Paleudult at Onne near Port Harcourt. The yield of the maize of first season 1976 was low, partly due to Mg deficiency and late planting. As shown in Table 6, there were no significant effects of P application and P sources.

Table 6. Effect of P rates and sources on first season grain yield maize cultivar TZB on an Ultisol at Onne.

P-Source	P-Rate (kg P/ha)	Grain yield (kg/ha)
Control	0	1,401
Triple supper	40	1,581
	80	1,259
	100	1,824
Morocco rock	80	1,699
Togo Rock	80	1,350

Study on sulfur

The valley bottom land (hydromorphic soils) is becoming increasingly important for rice production in West Africa. Greenhouse tests were conducted to determine the sulfur status of eleven representative hydromorphic soils collected from central and southern Nigeria. S content ranges from 46 to 487 ppm, while the amount of $Ca(H_2PO_4)_2$ extractable A ranges from 41 to less than 1 ppm. The rice plants were grown under flooded and non-flooded conditions. Some of the data on the dry matter yield response and S percentage in the plant are shown in Table 7. Under flooded conditions, 55 percent of the soils studies were S deficient, while under non-flooding, only 22 percent of the soils studied gave a significant response to S application.

Study on potassium

Field investigations with maize in southern Nigeria indicated lower K status of plants grown on soils derived from sedimentary rocks as compared to those grown on soils derived from basement complex rocks. To better characterize the K status of the soils derived from both parent materials, laboratory and greenhouse investigations were carried out. Five soils derived from basement complex rocks and six soils from sedimentary rocks were used in the study. Soils derived from basement complex rocks showed on the average higher K status

Table 7. Effect of sulfur application and water management on dry matter yield and sulfur percentage of rice cultivar IR-20 grown on various Nigerian hydromorphic soils.

Soil Origin		Dry matter yield		Sulfur percentage	
		Flooded	Non-flooded	Flooded	Non-flooded
		g/pot		%	
Ngala	No S	4.91	2.81	0.26	0.29
	+ S	4.88	2.98	0.33	0.31
Shonga(1)	No S	5.72	3.16	0.19	0.34
	+ S	6.23	2.97	0.32	0.42
Shonga(2)	No S	4.57**	2.45	0.12	0.20
	+ S	5.65	3.05	0.32	0.32
Lafiagi	No S	0.62**	1.43**	0.09	0.07
	+ S	2.90	2.63	0.35	0.20
Dekina	No S	1.75	-	0.13	-
	+ S	4.98	-	0.24	-
Ikenne(1)	No S	1.14**	1.14**	0.08	0.19
	+ S	5.34	2.41	0.29	0.41
Ikenne(2)	No S	1.18**	-	0.12	-
	+ S	1.53	-	0.20	-
Ibadan(1)	No S	2.37**	2.52	0.13	0.31
	+ S	4.73	2.60	0.26	0.32
Ibadan(2)	No S	2.08	3.56	0.26	0.29
	+ S	2.55	3.46	0.32	0.38

**Significant at 5% level **Significant at 10% level*

Table 8. Extractable K-content of soils derived from basement complex and sedimentary rocks and dry matter yield response of maize to K-application.

Parent Material	Extractable K (me/100 g)		K-rate ppmK	Dry matter yield g/pot
	1 N NH_4-Acetate	0.25 N H_2SO_4 + 0.05 N HCL		
Basement				
Complex	0.214+0.142	0.156+0.095	0	27.9+6.3
			200	36.2+3.3
Sedimentary	0.103+0.39	0.087+0.031	0	20.2+5.7
			200	33.7+3.1

and less response to K application (Table 8). The amounts of extractable K determined by 1N Am-acetate, 0.25 N H_2SO_4 + 0.05 N HCL and water were significantly correlated with maize dry weight with correlation coefficients of 0.778, 0.721 and 0.718, respectively.

Nitrogen responses in mixed cropping

Studies on the N contribution of grain legumes in mixed cropping and in rotation with cereals were initiated in 1975 on an N deficient Apomu soil series.

Results of the 1976 intercropping trial are given in Table 9. Similar to the 1975 results, there was no apparent direct N contribution of the cowpea crop to the maize. With no N application, there appeared to be competition for N between the cowpea and maize crops. Yield of the cowpea was generally low, in part due to blight damage. There were distinct reductions in nodulation with intercropping and with increasing N rates.

The first year results of the rotation trial are given in Table 10. There appeared to be some N contribution from the preceding grain legume crop to the succeeding grain legume crop, particularly in the No. N treatment.

Table 9. Effect of mixed cropping and N-rates on grain yield of maize cultivar TZB and seed yield of cowpea cultivar Ife Brown and nodulation.

Cropping Treatment	N-rate (kg/ha)	Nodule yield (mg/plant)	Maize yield (kg/ha)	Cowpea yield (kg/ha)
Sole				
cropping	0	773	2,416	636
	30	479	4,482	732
	60	442	4,549	697
	120	522	4,879	647
	Mean	554	4,082	678
Mixed				
cropping	0	706	3,948	81
	30	683	4,930	86
	60	673	5,234	85
	120	488	5,678	67
	Mean	638	4,948	80

Table 10. Effect of preceding grain legume crops and N rates on maize grain yield in 1976 grown on Apomu soil series.

N-Rates (kg N/ha)	Maize-maize*	Maize-cowpea*	Maize-soybean*	Maize-Pigeon pea*
	–grain yield (kg/ha)–			
0	1,920	3,882	3,542	3,170
45	4,087	4,714	4,294	4,539
90	5,942	5,706	5,385	5,531
135	5,674	5,801	5,699	6,008
Average	4,406	5,026	4,730	4,812
Relative yield %	100	114	107	109

**Second season crop.*

Tolerance of tropical grain legumes

The relative tolerance to high soil acidity of the tropical grain legumes (cowpea, soybean, lima bean, pigeon pea, and winged bean) was assessed in the greenhouse using an Ultisol (pH 4.4) from the IITA high rainfall station at Onne, Port Harcourt. Eight lime rates ranging from 0 to 5.0 t/ha were used. All species except winged bean were inoculated with the appropriate *Rhizobium*, and all species were harvested at immediate preflowering.

Table 11. Tolerance of five tropical grain legumes to high soil acidity.

Species	Percent maximum yield obtained at		Percent increase in yield to 0.5 t/ha lime	Mean dry matter yield (g/plant) at		Lime required for 95% of maximum yield t/ha
	Lo	Lo.5		Lo	Lo.5	
Cowpea cv Ife Brown	52.0	89.7	72.4	1.49	2.56	0.75
Winged bean dv TPt 1	51.8	90.1	73.9	1.19	2.06	1.00
Pigeon pea cv 3D 8103G	31.0	70.1	126.4	0.46	1.05	1.05
Soybean cv Bossier	18.9	46.9	148.3	0.36	0.89	1.80
Lima bean cv TPL 170-33	9.5	61.1	542.7	0.24	1.57	2.25

Cowpea and winged bean showed some tolerance while both soybean and lima bean were very sensitive to high soil acidity (Table 11). The percentage yield increase at 0.5 t/ha, the lime rate required for 95 percent of maximum yield, appeared to be useful criteria for assessing tolerance. Nodulation was observed to be more sensitive to high soil acidity than growth of the host plant. Although all species showed substantial growth responses to as little as 0.25 t/ha lime, soybean, lima bean and pigeon pea were all very poorly nodulated at this rate of lime application. The observation of a dry matter yield response in the absence of nodulation suggests that another factor apart from nitrogen may be limiting growth more directly. The symptoms observed and analyses on plant tops suggest this limiting factor was calcium deficiency. However, it would appear that aluminum toxicity, rather than calcium deficiency, was limiting the growth of cowpea and winged bean in the unlimed soil.

The response to lime rates from 0 to 5.0 t/ha of two cassava cultivars grown for three months in the acid Ultisol from Onne is shown in Fig. 7. Top production, using the yield of leaves as the parameter was little affected by lime rates below 3.75 t/ha, while only comparatively small yield benefits in early tuber production were achieved through the application of lime. Higher rates of lime severely restricted tuber development. The success of cassava on highly acid soils is related to its tolerance to high soil acidity; it can produce a crop under conditions that are unfavorable to many other crops including grain legumes and maize.

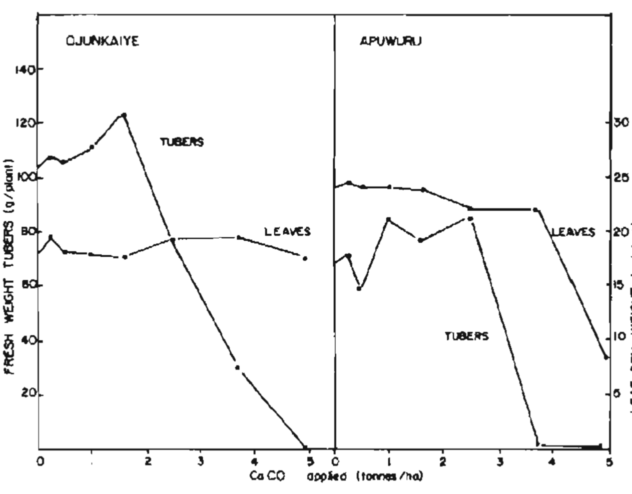


Fig. 7. Tuber and leaf yields of cassava cultivars Ojunkaiye and Apuwuru as affected by lime application.

All plants in this experiment were rated for CMD using the scoring system developed by the Root and Tuber Improvement Program with the modification that half-class units were included to give greater flexibility. A strong reduction in CMD rating was observed in cv. Apuwuru as the lime rate was increased from 1.0 to 2.5 t/ha. No relationship appeared to exist between tuber yield and CMD rating at lime rates from 0 to 2.5 t/h. Some plants with a CMD rating of about 2.0 to 2.2 produced tuber yields (three months old) equivalent to those produced by symptom-free plants. These observations point to the need to re-evaluate whether the major limitation on yield of CMD-affected cassava plants is due to the disease or to the poor nutritional conditions under which cassava is traditionally grown.

Soil microbiology

Carbon-14 decomposition studies indicated that organic matter decomposes very fast under humid tropical field conditions. An examination of the daily pattern of nitrogen fixation in cowpea showed two periods of maximum activity — before noon and during the early evening — although environmental factors likely to influence fixation showed one diurnal peak. All crops examined at IITA except rice were found to be mycorrhizal; the most common endophytes found were *Gigaspora*, *Glomus* and *Acaulospora*.

Biological nitrogen fixation

Diurnal variation in nitrogen fixation. Diurnal changes in nitrogen fixation (estimated as C_2H_2 reduction) over a 30-hour period were compared with changes in soil, canopy and air temperatures, global radiation and vapor pressure deficit. TVu 37 (Pale Green) and VITA-1 cowpeas and TGm 80 (Bossier) and TGm 280-3 soybeans were examined at early flowering (soybeans) or pre-flowering (cowpeas) stage and during pod-fill. Although the environmental factors showed one maximum and one minimum during a diurnal cycle the C_2H_2 reduction rate in nodulated cowpea roots showed two peaks: one between 0600-1200 hrs. and the other between 1800-2400 hrs. and two minima: one between 1200-1600 hrs. and another between 2400-0600 hrs. (Fig. 8). Vapor pressure deficit appeared the most likely factor influencing the decline in nitrogen fixation between 1200-1600 hrs., a period when photosynthesis was expected to be maximum. The rate in C_2H_2 reduction in cowpea was greater at the pre-flowering than the early pod-fill period; the rate in soybeans was similar at both periods. The significance of these findings in relation to carbohydrate metabolism, nitrogen fixation and thus protein content in these species is being investigated.

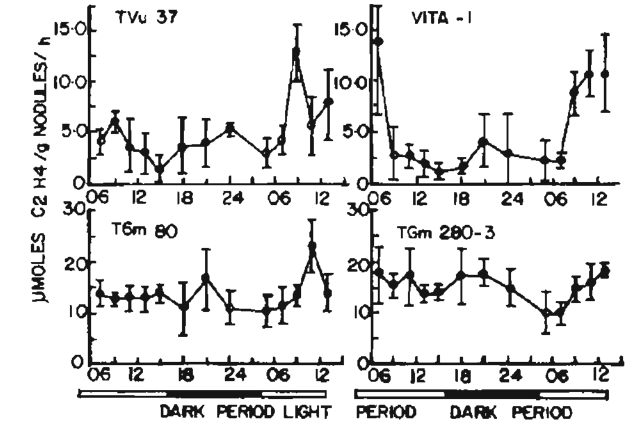


Fig. 8. Reduction changes in C H reduction in nodulated roots of cowpeas (TVu 37 and VITA-1) and soybeans (TGm 80 and TGm 280-3) harvested 55-56 days after planting. Vertical line are standard errors of means of replicates.

Effects of seed inoculation on ***Rhizobium*** **survival and legume performance.** As in the IITA Annual Report 1974, cowpea and soybean were sown in newly cleared Apomu and Egbeda series soils. In 1975 the fields were cropped to maize. In 1976, the surviving rhizobia were counted by the plant infection technique before conducting another seed inoculation experiment at the same locations. Each plot was sub-divided, and planted to inoculated seeds. The results are in Tables 12 and 13. Cowpea rhizoba survived well in both soils. However, *Rhizobium japonicum*, especially that in Nitrogerm inoculant,

Table 12. The effects of seed inoculation in 1974 and in 1976 on survival of rhizobia, nitrogenase activity, yield and nitrogen content of tops and grain yield of Pale Green cowpea and Bossier soybean grown in Apomu soil.

Legume	Inoculum* 1974	Inoculum* 1976	Tops, g/plant	Grain, g/plant	Leaf N %	Oil, %	umol C_2H_4 /g.d.nod/hr	Rhizobia /g.o.d. soil
Pale Green	I_0	I_0	21±4	1.7	3.4	-	97±37	32,000
		I_1	19±6	1.8	3.4	-	126±45	nd
	I_1	I_0	22±4	1.7	3.3	-	198±53	4,700
		I_1	22±4	1.4	3.3	-	197±41	nd
Bossier	I_0	I_0	11±1	9.0	3.2	24.6	80± 2	13,000
		I_2	14±1	11.8	2.9	24.2	86± 8	nd
		I_3	14±1	7.3	3.0	24.9	73±20	nd
	I_2	I_0	12±0	10.3	3.2	24.0	55± 4	3,100
		I_2	16±0	13.1	3.2	24.4	58± 0	nd
	I_3	I_0	12±4	11.0	3.2	24.6	124± 0	1,100
		I_3	13±1	9.7	2.8	24.7	84± 3	nd

**During the year shown, seeds were either uninoculated (I_0) or inoculated with Nitragin cowpea inoculant (I_1) or Nitragin soybean inoculant (I_2) or Nitrogerm soybean inoculant (I_3).*

Table 13. The effects of seed inoculation in 1974 and in 1976 on survival of rhizobia, nitrogenase activity, yield and nitrogen content of tops and grain yield of Pale Green cowpea and Bossier soybean grown in Egbeda soil.

Legume	Inoculum* 1974	Inoculum* 1976	Tops, g/plant	Grain, g/plant	Leaf N, %	Oil %	umol C_2H_4 /g.d.nod./hr	Rhizobia /g.o.d. soil
Pale Green	I_0	I_0	39±5	3.3	3.2	-	82±20	33,000
		I_1	41±2	3.3	2.8	-	157±23	nd
	I_1	I_0	37±4	3.3	2.9	-	144±24	26,000
		I_1	33±5	2.9	2.9	-	152±33	nd
Bossier	I_0	I_0	11±1	12.6	3.0	25.3	68 ± 2	2,700
		I_2	14±2	9.8	2.9	25.1	53 ± 4	nd
		I_3	14±5	14.3	3.1	25.2	58±10	nd
	I_2	I_0	13±0	14.9	3.0	25.0	56± 6	28,000
		I_2	16±0	16.6	3.0	25.2	53± 7	nd
	I_3	I_0	12±0	15.8	3.0	24.9	57±12	13
		I_3	12±0	14.1	3.1	25.3	69±23	nd

**During the year shown, seeds were either uninoculated (I_0) or inoculated with Nitragin cowpea inoculant (I_1), Nitragin soybean inoculant (I_2) or Nitrogerm soybean inoculant (I_3).*

Table 14. Effects of soil moisture on the performance of six grain legumes. Nitrogenase activity at two weeks pre-flowering, flowering and two weeks post-flowering.

Growth period	Legume	umol. C_2H_4 produced/g fr. nod./hr S1	S2	S3	S4	S5	S6	Mean
Pre-flower	Soybean	3.50	5.19	9.17	11.5	13.2	27.2	11.62
	Cowpea	19.4	15.5	16.7	21.0	27.3	36.4	22.71
	Jack bean	3.62	4.62	3.40	14.5	4.24	15.4	7.63
	Lima bean	0.35	0.47	0.16	0.14	0.81	1.82	0.63
	Pigeon pea	2.67	0.91	1.07	11.5	7.33	9.77	5.54
	Winged bean	9.31	13.2	15.9	10.4	11.3	19.0	13.18
Flowering	Soybean	14.9	12.8	10.5	18.7	22.8	19.0	16.45
	Cowpea	14.0	14.0	14.0	22.0	23.1	19.0	17.81
	Jack bean	4.83	4.09	5.92	7.23	13.3	17.6	8.82
	Lima bean	1.42	0.40	0.06	1.35	2.47	6.62	2.05
	Pigeon pea	2.22	1.47	3.88	6.98	7.09	13.2	5.81
	Winged bean	18.3	13.4	15.7	12.8	14.4	9.03	13.93
Post-flower	Soybean	19.1	27.4	13.0	21.8	17.4	19.9	19.76
	Cowpea	7.58	4.91	3.30	4.15	9.85	8.54	6.38
	Jack bean	5.19	5.42	13.2	13.7	14.0	26.5	13.00
	Lima bean	nd	nd	nd	nd	nd	nd	-
	Pigeon pea	5.3	15.8	25.5	5.67	0.06	0.01	8.72
	Winged bean	23.5	12.9	8.97	15.0	15.9	12.7	13.16

Table 16. Common mycorrhizal spore types in Nigerian soils.

Type No.	Genus	Size range, um	Shape	Color	Wall thick-ness, um	Contents*
1.	Gigaspora	346–392	globose — ellipsoidal or irregular	hyaline	5	Reticulate, becoming vacuolate with age
2.	Gigaspora	277	globose	hyaline — very light	5–10	vacuolate with age
3.	Gigaspora	285–304	globose — sub-globose or irregular	yellow	5	reticulate
4.	Gigaspora	449–468	globose — sub-globose	hyaline — v. light brown	15	white opaque becoming vacuolate with age
5.	Gigaspora	521	globose	outer wall: light — dark reddish brown inner wall: golden yellow	11-15	reticulate becoming vacuolate with age
6.	Acaulospora	128	globose (resting spore and mother spore)	hyaline — v. light brown	5–10	reticulate
7.	Glomus	210	globose	light brown	15	vacuolate
–	Other Glomus spp.	Many different *Glomus* spp. of bewildering variety were found (both sporocarpic and not) in nearly all cultivated soils. Compared to above types, however, differences between them are slight and further study will be required to characterize them.				
-	Sclerocystis spp.	In some soil, structures resembling fruit bodies of *Sclerocystis* spp. were frequent. Whether they are mycorrhizal fungi remains in doubt as inoculation tests were unsuccessful. The occurrence of these was noted but no counts were made.				

For descriptions of the terms reticulate and vacuolate see Mosse & Bowen (1968).

indigenous endophytes in soil sievings (250-500 *um*) gave better dry matter yields of yam and cassava in unsterile Egbeda and Alagba series soils than inoculation with *G. fasiculatus*, confirming their superiority over *G. fasiculatus*. Average infection values were 0.50 and 80 percent for control, *G. fasiculatus* and the indigenous endophytes, respectively.

Table 17. Response of cowpea to Glomus fasiculatus inoculation and rock phosphate fertilization in an Alagba soil series under field conditions at Ikenne.

	Days after transplanting			
Treatment	40	80	40	80
	Infection %		Total dry wt.	g/pl ±S.E.
Control (Nil)	60	60	9.8± 0.8	91.5± 8.7
Rock P	70	60	13.2± 1.5	90.1±12.4
Inoculated (M)	85	70	26.7±3.0	117.0±10.7
RP + M	75	65	20.8±4.8	118.5±12.6

Effects of mulches on legume nodule functioning. In the IITA Annual Report 1975, the results of one year of mulching on legume nodule functioning were given. There were no significant differences in specific activity, but in total activity. After the second year of mulch treatments similar effects have again been observed. Mean specific activities varied somewhat more; for cowpea they were in the range 4.0–10.6 and for soybean 10.3–30.3 *umol.* C_2H_4/g fresh nodule/h. Total soybean activity was reduced by the plastics and gravel but increased over the unmulched treatment in all other cases. Cassava stems and sawdust mulches elicited the greatest acetylene reduction rates in cowpea whereas the plastic mulches brought about the lowest rates.

The rates of C_2H_2 reduction were greater in 1976 than in 1975 but not significantly based on two years' results. The conclusion is that the plastic and gravel mulches are likely to reduce total nitrogen fixed by soybean, as compared to unmulched soybean.

Soil physics

Physics of soil erosion

Yield reduction due to erosion. Increasing soil erosion resulted in an exponential decrease in the yield of maize and cowpeas (Eq. 1)

$$Y = ae^{bE} \quad (1)$$

where Y is the yield (t/ha), E is cumulative soil loss in t/ha, and a and b are constants. For maize, the numerical value of a was about 7 and that of b was 0.003. For cowpeas a was 0.5 and b was 0.004. The removal of surface soil and deterioration in soil structure as a result of erosion cannot be compensated for by additional fertilizer input.

Influence of different mulch rates on soil structure. Field experiments conducted with different mulch rates on changes in soil physical properties after land clearing indicated the following effects:

1. Worm activity increased linearly with increasing mulch rates.
2. Saturated hydraulic conductivity (k_s) and infiltration rate increased with high mulch rate and decreased on unmulched plot (Fig. 9).

Comparison of various detachability indices. The suitability of various detachability indices were evaluated for eight tropical soils. Results indicate that perhaps a combination of wet sieving and rain drop impact techniques can predict the field behavior as regards splashability under rain impact.

Comparison of soil properties under mulch and no-tillage with soil conditioning. Field runoff plots on about 10 percent slope have indicated no soil loss under mulch or with no-till. Unmulched plots treated with PAM, Bitumen, Uresol, soil penetrant and asphalt maintained good crop growth. Runoff and erosion losses were observed only under PAM.

Laboratory experiments. Measurement of infiltration rate, contact angle, and diffusivity D (0) showed significant

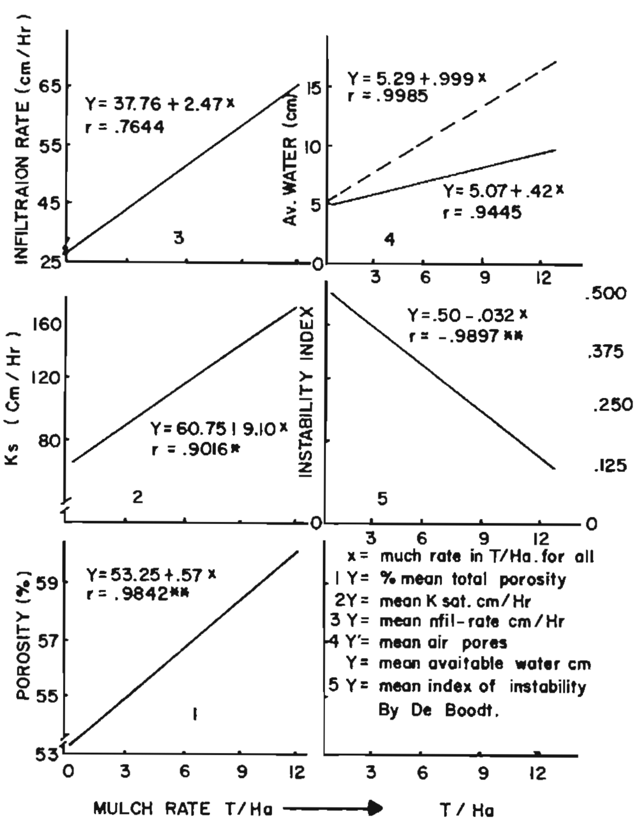


Fig. 9. Effects of various mulch rates on some soil physical characteristics.

differences amongst soils treated with various soil conditioners. Untreated soil from mulched plots exhibited as good as, or better, water transmission characteristics than treated soil from unmulched plots.

Crusting and aggregate stability. Both mulching and aggregate size had significant effects on time to incipient runoff, percent runoff, soil loss, crust conductance, crust strength and time to 50 percent emergence of both maize and cowpeas.

Soil erodibility and crusting with simulated rainfall. Equipment is now available for both field and laboratory investigations on crusting and soil erodibility as affected by simulated rainfall of various intensities and for soil treatments including mulching and various types of conditioners. This is a collaborative experiment with the University of Ghent.

Root growth and development

Effects of soil type and fertilizer use. Both soil type and fertilizer use had a significant influence on the maximum depth, total root number, and root elongation rate of maize.

Maximum rooting potential of maize intercropped with cowpeas. There were no antagonistic effects of intercropping on the root systems of these crops. Roots penetrated to a depth of 2.5 m within 12 weeks.

Influence of cultural practices. There was a significant adverse effect of increased soil temperature under ridges and under clear polythene mulch on root development and rate of root elongation. Straw mulching increased root development of various rice cultivars even under hydromorphic soils, while no-till plots on acidic ultisol at Onne had deeper root systems than with conventional plowing.

Plant-water relationship

Water use efficiency of maize was significantly higher under no-till, as compared with plowed plots. Out of maize, cowpea and soybean, cowpea was more susceptible to transient flooding than maize or soybean. Total consumptive water use, transpiration rate after submergence, leaf color, nutrient content, and plant height were adversely affected (See grain physiology section).

Eight new drainage lysimeters were installed, and studies were initiated on the influence of mulching treatments on potential and actual ET of sweet potatoes and other tropical crops. When the influence of soil type and moisture regime on rice was investigated under field and greenhouse conditions, there were significant differences in diurnal fluctuations in leaf water potential as influenced by soil drought stress (Fig. 10).

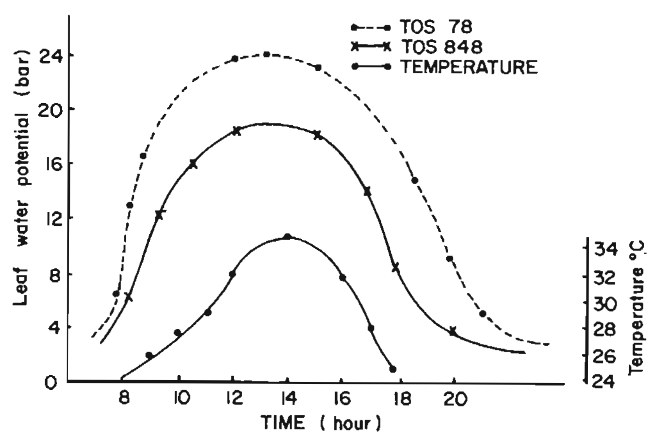


Fig. 10. Influence of soil moisture regime on leaf water potential of rice.

No-tillage and mulching

It was found that plowed, unmulched plots contained more carbon dioxide and less oxygen in the soil when compared with the no-till plots. Also, no-till plots, maintained since 1970, had better response to N and P than plowed plots (Fig. 11).

No-till and plowing treatments did not significantly influence growth of maize, cowpea or pigeon pea on an acidic Ultisol.

Maize yields were higher on this no-till field than on plowed land.

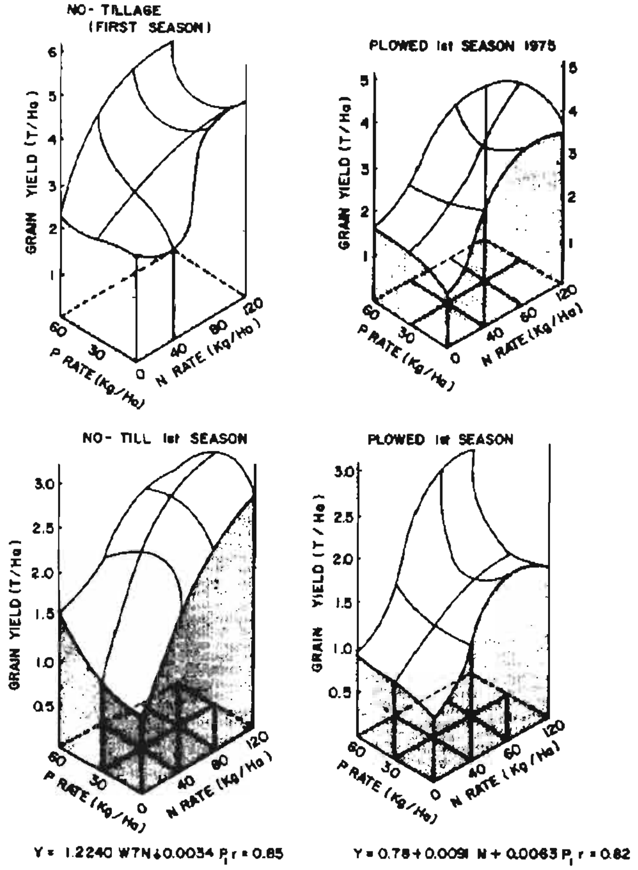


Fig. 11. Fertilizer response of maize under no-tillage and plowing.

The limiting factor in crop production is perhaps water and nutrient availability. In the second season, due to a drought of 5WAP, no-till maize yielded significantly and economically more than plowed maize. Plowed plants showed retarded growth and gave the impression of delayed planting.

Clearing methods and crop response. Mechanical clearing with no fertilizer yielded lower than slash-and-burn without fertilizer. No-till treatments narrowed the difference in the grain yield obtained from mechanically cleared plots and that from manually cleared plots. Perhaps soil and water conservations, as obtained with no-till, is an important factor in deciding on the suitable method of land clearing.

Agroclimatology

Microclimate in maize canopies

Carbon dioxide concentration in air within maize canopies. Analyses of air samples collected at different heights in maize at different stages of growth, using an infrared gas analyzer, indicate moderate to fairly high concentration of CO_2 within these canopies. Therefore the microclimate of maize canopies is potentially conducive to high photosynthetic rates and is favorable for intercrops. But the benefit would be realized only under favorable light conditions – for instance, through proper arrangement of plants to reduce shading (Table 18).

Light profile in maize canopies. In an experiment carried out at three different sites global radiation was measured with line pyranometers at three different heights in maize (above canopy, at mid-plant height, and at ground level), planted at two spacings (100×20 cm, 100×40 cm), and at six fertility levels, (0, 30, 60, 90, 120 and 150 kg-N/ha). The results show: results show:

1. Plant density effect: only 10–20 percent decrease in light received at comparable levels within the canopy by doubling the planting density from 25,000 to 50,000 plants/ha at nitrogen rates of 30 kg/ha or more; the difference is generally small at 0 kg/ha; (Fig. 12).
2. Fertility effect: at the lower plant density (25,000 pl/ha) the amount of light reaching the respective levels remains relatively the same at the various nitrogen rates. At the higher plant density, however, there appears to be an initial decrease (about 10 or less) with increase in nitrogen rates from 0 to 60 kg/ha, but further increase up to 120 kg/ha shows little or no further change.

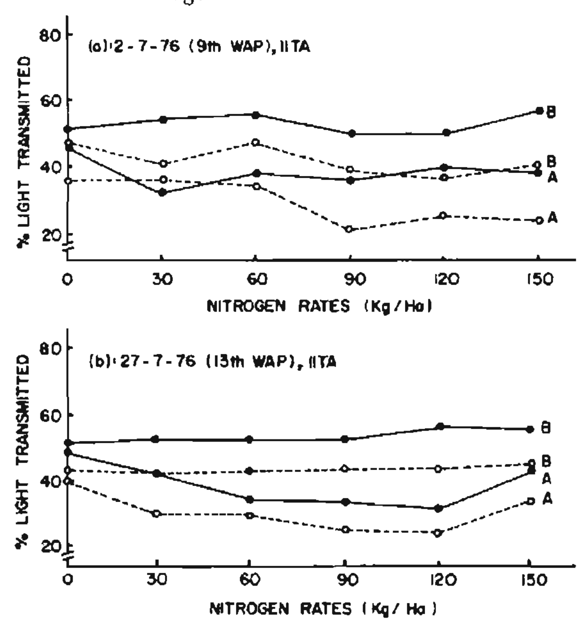


Fig. 12. (a) & (b) Light profile in maize (TZPB) canopy at different stand densities and fertility (Nitrogen) levels.
•—•—•At mid height or cob level;o—o—oat ground level; A ≡ 100 × 20 cm spacing; B ≡ 100 × 40 cm spacing).

Table 18. CO_2 concentration in maize canopies 1976.

Date and stage of growth	Time of day	CO_2 concentration (ppm) at 3.0m	1.50cm	60cm	Calibration standard (ppm) Actual	Specified +
9/3/76: Maturity	1130(LST)	418	342	-	298	302
	1430(LST)	500+	364	-		
	1700(LST)	407	370	-		
13/5/76: Tasselling	0800(LST)	530	485	590	320	302
	1200(LST)	-	370	448	320	302
14/5/76: Tasselling	0800(LST)	495	450	500	326	302

The apparently flat response of light penetration into the crop at medium-to-high rates of fertilizer is noteworthy, because for intercropping it would allow cropping at good levels of fertility without increased shading of an intercrop, such as cowpea. These results were confirmed by measurements taken in a second experiment evaluating the performance of maize and cowpea and maize intercrop at different nitrogen rates, (Tables 19a and 19b).

Table 19a. ***Light profile in Maize (M) at different fertility levels. (1st Season 1976)***

	Percentage of Light Penetration in:*			
	M_0	M_{30}	M_{60}	M_{120}
Top of canopy	100	100	100	100
Mid-plant height	45	45	37	35
Ground level	32	34	33	29

**Subscripts refer to rates of nitrogen applied to plots.*

Table 19b. ***Light profile in maize - cowpea (M + C) intercrop at different levels.***

	Percentage of Light Penetration in:*			
Height	$(M+C)_0$	$(M+C)_{30}$	$(M+C)_{60}$	$(M+C)_{120}$
Top of Maize	100	100	100	100
Mid-plant height (maize)	58	40	40	49
Ground level	(26)	30	28	27

**The increase in light penetration at 150 kg-N/ha is associated with the poorer or negative response of the crops at that rate.*

Crop response to simulated light climates

Studies on the effects of changes in light climate, simulated according to observed seasonal changes within this region, continued in 1976. The results, summarized in Table 20, basically follow previous trends. Observations on plant development showed a delay in flowering with a decrease in isolation, in Maize (TZBc4, Fig. 13) and in cowpea (VITA-1, Fig. 14). About 15 to 20 percent reduction in insolation generally depressed yields by 15-25 percent. This depression in yield increased to between 30 and 45 percent as global radiation decreased by 30-35 percent. VITA-1 cowpea was an exception, being more sensitive to poor light regimes than the other crops. VITA-5 had earlier shown a similar tendency. These results agree with those from the sequential planting experiments reported on below.

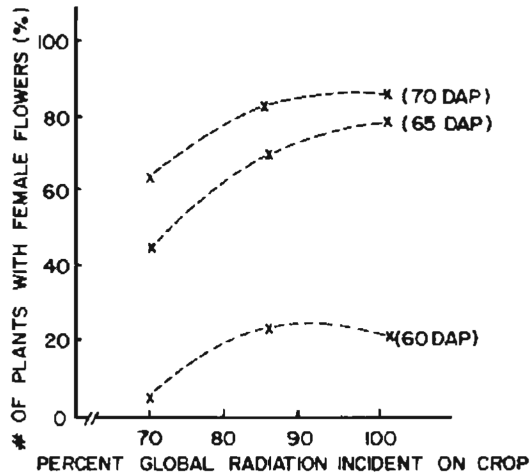


Fig. 13. ***Effect of reduced insolation on flowering in maize, TZBC 4. (Dry season 1975/76).***

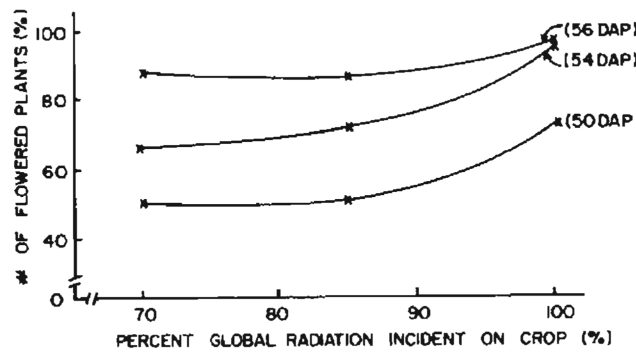


Fig. 14. ***Effect of reduced insolation on flowering in cowpea (VITA-1 dry season 1975/76).***

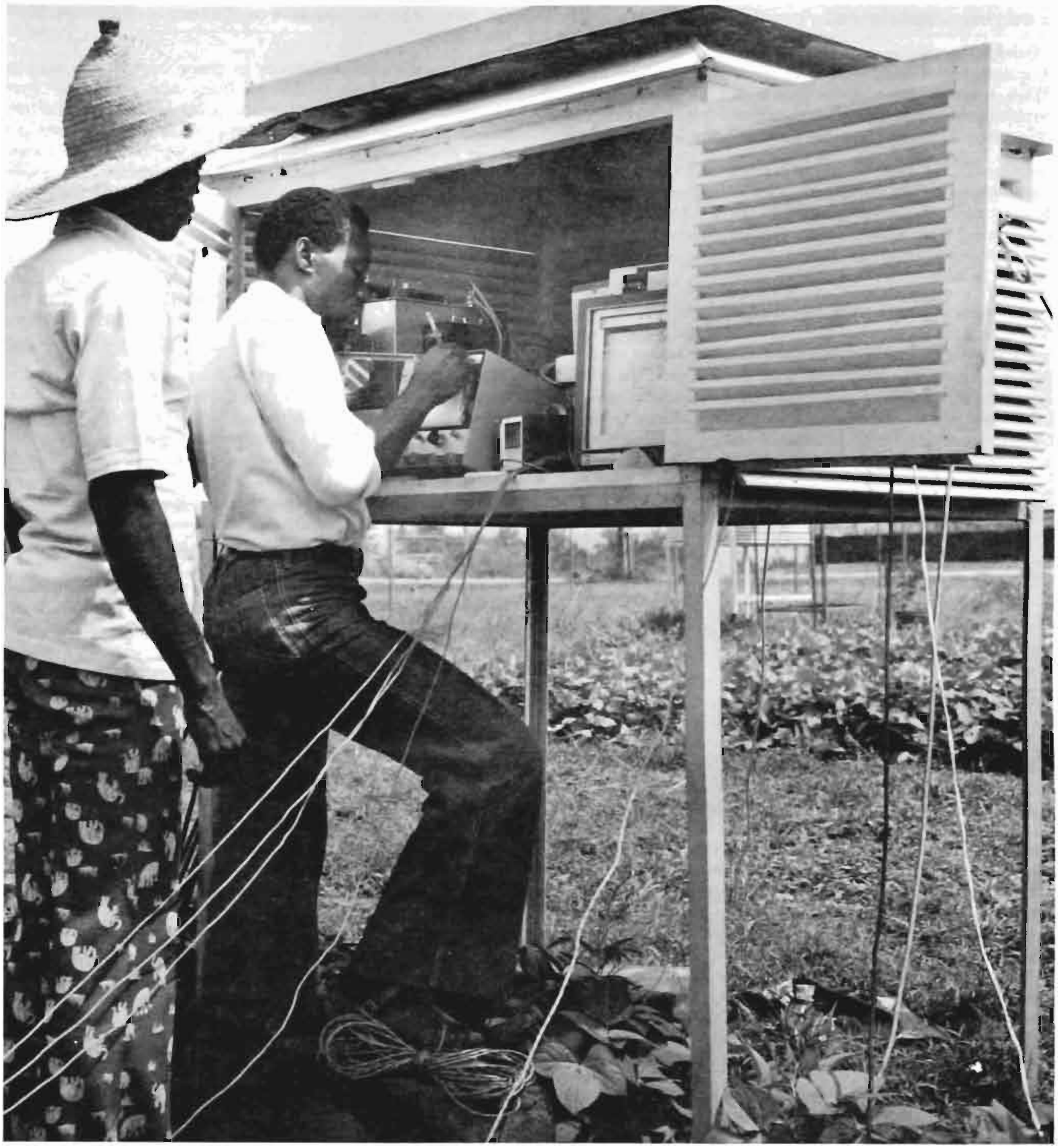
Sequential planting experiment

As before, the objectives of this experiment were to determine the relationship between environmental (agroclimatic) variables and crop yields, hence the potential of producing given

Table 20. ***Crop yields at three different levels of insolation, Rg.***

Season	Crops*	Actual Mean Yield (kg/ha) at 100% Rg	Relative Mean yield/plot (%) 100% Rg	85% Rg	70% Rg	Relative Mean yield/plant (%) 100% Rg	85% Rg	70% Rg
Dry, 1975/76	Maize (1)	4270	100	988	74	100	92	69
Dry	Cowpea	1160	100	54	20	100	54	21
1st, 1976	Maize (1), D1	4030	100	83	59	100	83	60
"	Maize (1), D2	8230	100	68	48	100	77	58
"	Maize (2), D1	4710	100	76	-	100	79	-
"	Maize (2), D2	8120	100	72	-	100	94	-
1st, 1976	Soybean (Bossier)	1690	100	86	69	100	71	55
2nd, 1976	Soybean (Bossier)	2400	100	88	65		76	62

Maize (1) = TZPB, Maize (2) = $TZBc_4$, D1 = Planting at 80×30 cm spacing, D2 = Planting at 80×15 spacing.



Studies continue on the effect of insolation on cowpeas.

crops in given areas during given periods. The weather peculiarities during the year provided sufficient range in the data being accumulated and an opportunity to test the stability of the evolving model.

The analyses of the previous three years' data confirmed the working hypothesis formulated earlier, that moisture conditions in the second six weeks of growth and global radiation during the corresponding antecedent period are two major factors determining the trend in yield, (IITA Annual Report 1973). The results of the analyses are being summarized and will be presented in a subsequent report.

A parallel experiment on cowpea was started during the year in collaboration with the grain legume agronomist. The mean global radiation incident on the respective plantings during the pre-flowering period ranged from 421.4 cal-cm$_2$ day-$_1$ (100%) to 251.1 cal-cm$_2$ day-$_2$ (60%). During the respective growing periods it ranged from 392.3 cal-cm$_2$ day-$_1$ (100%) to 282.4 cal-cm$_2$ day-$_1$ (72%). The mean of the two highest yields within the normal second season was only 23 percent of the corresponding average obtained within the first season. Details on the results of this experiment are presented within the grain legume agronomy report.

Lodging experiment

With the increasing possibility of no-tillage as an alternative to conventional methods of land preparation, at least in some IITA research areas, a "till" and "no till" treatment was superimposed on the previous treatments in this experiment to determine its effect on incidence of lodging in maize.

Because of the lack of severe storms, and therefore of the usual strong winds during the season, lodging was generally low to moderate, averaging 6 to 11 percent of the plant population; the difference in incidence between the tilled and untilled plots was highly significant in favor of the latter (Table 21).

Preliminary analyses of a repeated study in which lodging was simulated by physical displacement of the plants from the vertical position at a specific time during the season confirmed earlier findings that lodging at 8–10 WAP is most detrimental to yield. As the time of peak occurrence of severe storms both in the first and second seasons appears well defined (May and October generally) it is possible to select planting dates to avoid maximum damage, other factors permitting.

Table 21. Incidence of lodging in maize planted with two-row orientation on tilled and untilled plots.

	Mean # of lodged plants (pl/plot)*		
Orientation of row	Tilled plots	Untilled plots	Orientation mean
E - W	46.5	25.3	35.9
N - S	47.0	28.2	37.6
Tillage mean	46.8	26.74	

**For orientation means (between orientation; same tillage) LSD.05 = 8.06; For tillage mean: LSD = 10.33, LSD.01 = 14.69; For tillage mean at same orientation: LSD.05 = 14.61, LSD.01 = 20.78.*

Agronomy systems

Late maize/cassava/melon intercropping

This is a late-season repetition at Ikenne of the 1974 early-season intercropping experiment conducted at Ibadan. Ikenne was chosen for the late-season experiment because of its higher rainfall environment. While the Ibadan experiment involved planting of melon 10 days earlier than maize in April and cassava on different dates at weekly intervals at Ikenne, the first planting was done on 21 June 1975. The maize data have been represented in the IITA Annual Report 1975. The late-season melon crop at Ikenne germinated fairly well but as a result of prolonged drought in August, it did not set many fruits and fruits set failed to mature.

Plant population, lodging, plant height, fresh and dry weights of roots tended to decrease with lateness of planting but varied somewhat in relation to crops in the mixture. The drought in August and the September rains adversely and favorably affected cuttings planted during these periods respectively. Highly significant differences were observed in plant population, and in fresh and dry weights of roots. From the maize/melon/cassava intercropping experiments of 1974 and 1975, the results indicated that relay planting the cassava should not be delayed beyond 4 to 6 WAP.

Yam/maize/melon/cowpeas intercropping

The main objective of this experiment was to study the performance of yams, maize, melon and two plant types of cowpeas in mixtures and patterns some of which resemble traditional practices. In 1976, growth analysis data were collected. The treatments were located in the same plots used in 1975.

Melon: Significant differences in plant population, days to fruit maturity, fresh weight of fruits and seed yield were observed in melon. The highest plant population was observed in melon intercropped with maize at two plants per stand plus yam and climbing cowpea (Sitaopole). There were relatively higher plant populations where melon was grown in alternate rows. Number of days to maturity increased significantly with number of crops in the mixture. Fruit weight was heaviest in sole crop melon as in 1975 (Table 22). It was lowest where melon was intercropped with maize, yam and cowpea. Fruit weight tended to decrease with increasing number of crops in the mixture but varied also with the particular crops in the mixture and pattern of planting. Seed weight followed the same trend.

Maize: During 1976 significant differences were observed in lodging, stover yields and grain yields, but not in plant population as in 1975. Although no overall significant differences were observed in plant population, the tendency was for plant population to follow the trend: maize at one plant per stand > maize at two per stand > maize at four plants per stand (Table 23). Mean plant population in sole crop maize slightly exceeded that in which maize was grown with one crop but was slightly less than where maize was grown with three crops. The highest stover yield was observed where maize at two plants per stand was intercropped with melon which did not differ significantly from the lower yields observed in sole maize at one or two plants per stand and maize at two plants per stand intercropped with erect cowpeas. While the lowest stover yield in 1975 was obtained when maize and yams were intercropped at four maize plants per stand alternating every two rows with either melon or climbing vegetable cowpea (Sitaopole), in 1976 the lowest stover yield was observed when maize at two plants per stand was intercropped with yam, melon and Sitaopole.

Yam. No significant differences were observed in plant population and tuber number in 1976 as in 1975 but in both years significant differences were observed in tuber yields (Table 24). Although tuber yields on sole yam plots were only slightly lower in 1976 than in 1975, those of yams intercropped with maize at two plants per stand irrespective of spatial planting pattern were higher in 1976 than for corresponding treatments in 1975. In general, intercropping resulted in significantly

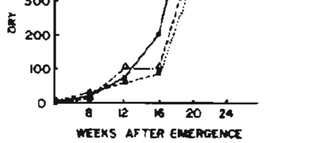


Fig. 15. Changes in tuber dry weight with age in D. rotundata in relation to number of crops intercropped.

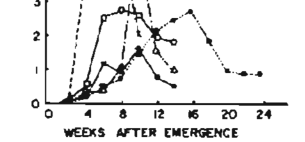


Fig. 16. Leaf area index of various crops intercropped at IITA in 1976.

Table 22. Observations on fruit yield and seed yield (t/ha) in melon grown alone or in various crop mixtures in 1975/76.

Treatments		Weight of fruit t/ha		Weight of seed t/ha	
		1975	1976	1975	1976
1	Melon alone	23.56a	41.76a	1.16a	1.07a
2	Melon + maize 2/stand	7.91bcd	14.56bc	0.20b	0.22b
3	Melon + maize 4/stand	2.16cd	16.06bc	0.03b	0.37b
4	Melon + erect cowpea staggered	3.08bcd	16.40bc	0.05b	0.34b
5	Melon + erect cowpea alt. row	1.80a	20.04b	0.05b	0.35b
6	Melon + sitaopole same rows	10.49b	19.76b	0.25b	0.40b
7	Melon + sitaopole alt. rows	9.66bc	17.04bc	0.55b	0.34b
8	Melon + maize 2/stand + yam	3.51bcd	7.05c	0.06b	0.08b
9	Melon + maize 4/stand erect + cowpea 2 rows alternate	2.92cd	9.20bc	0.08b	0.09b
Summary of Crop Associations					
1	Melon alone	23.56a	41.76a	1.16a	1.07a
2	Melon + maize	5.03bcd	15.31bc	0.12b	0.30b
3	Melon + erect cowpea	2.44cd	16.22b	0.50b	0.35b
4	Melon + climbing cowpea	10.08bc	18.40b	0.40b	0.37b
5	Melon + yam in mixture with maize cowpea	3.14bcd	3.12bc	0.68b	0.09b
	Cropping patterns				
a	Melon alone	23.56a	41.76a	1.16a	1.07a
b	Melon same row with cowpea	5.44bcd	14.77bc	0.12b	0.29b
c	Melon in alt. row with cowpea	4.79bcd	15.42bc	0.22b	0.26b
	Crop combinations				
i	Maize alone	23.56a	41.76a	1.16a	1.07a
ii	Melon + 1 crop	5.85bcd	17.31bc	0.19b	0.34b
iii	Melon + 3 crops	3.22d	8.12c	0.08b	0.08b

Means in the same column opposite the same letter(s) are not significantly different from each other at 5% level.

reduced yam tuber yields but the extent of reduction varied with individual associated crops, number of crops and years. The reduction was greatest when yam was grown with melon, cowpeas and maize. Intercropping of yam with erect cowpea reduced yam yield less than intercropping it with either maize or climbing cowpea.

Growth analysis. Certain interrelationships and differences in development characteristics were observed in yam and other crops. The tuber development of yam was significantly affected by intercropping and number of associated crops (Fig. 15). Growth rate was reduced under intercropping and this was more serious with Sitaopole climbing cowpea than by melon or maize. Earlier senescence and untimely maturity occurred earlier in intercropped yams than in the sole crop. The rate of tuber bulking or development, leaf area (LA), leaf area index (LAI) and relative growth rate (RGR) were in varying degree reduced under intercropping. Tops of intercropped yam turned yellow and died earlier than in sole crop yam. The LA, LAI, and RGR were lowest when yam was intercropped with Sitaopole climbing cowpea. Intercropping, with respect to the different crops in the mixture, affected LA, LAI, NAR, RGR and NAR of the various crops in the mixture.

Fig. 16 shows the leaf area development curves of the various crops in the mixtures. This shows that melon, which is often planted first, reached its maximum leaf area development earliest and the leaves senesced first.

Leaf area development was slower in maize but did not reach the same peak at the same time in yam which was the slow-

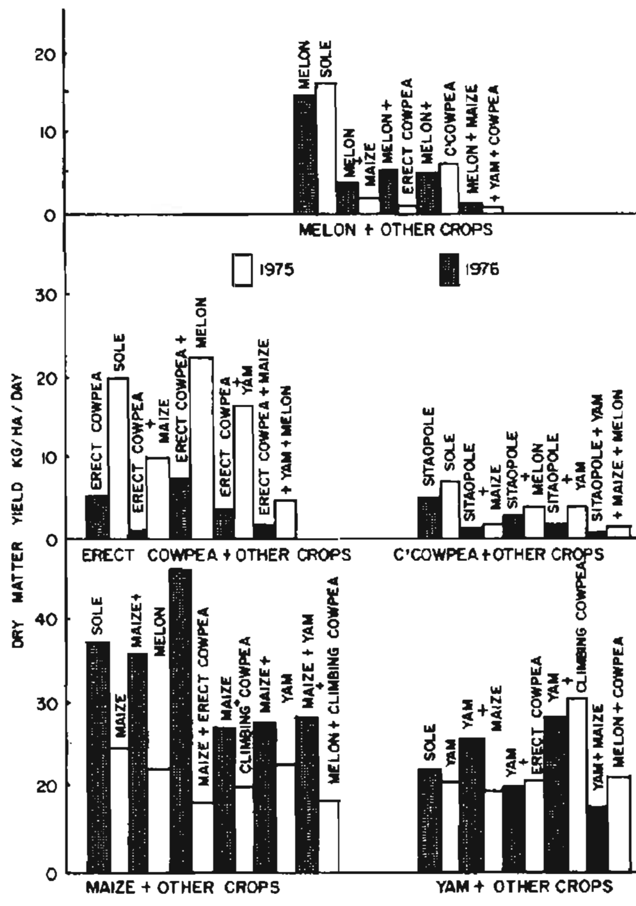


Fig. 17. Dry matter yield in kg/ha/day of different crops grown alone or as intercrops.

Table 23. The effects of intercropping, maize population per stand, crop combinations on stover, cob and grain yield per hectare.

	Treatments	Stover yield kg/ha	Grain yield kg/ha	Stover yield kg/ha	Grain yield kg/ha
1	Maize alone 1 plant/stand	4368abc	2925a	7745a	5825a
2	Maize alone 2 plants/stand	4708ab	2958a	7658a	5118abc
3	Maize 2/stand staggered +Yam	5175a	2868a	5720cd	3555d
4	Maize 2/stand same row with Yam	3793cde	2063bc	6285bc	3428d
5	Maize 2/stand +Melon	4065bcde	2150bc	7815a	4983abc
6	Maize 4/stand +Melon	3218def	2550ab	6283bc	4306bcd
7	Maize 2/stand +Sitaopole	3643cde	2068bc	6728abc	3300d
8	Maize 2/stand +Er. Cowpea	3083af	1168c	7560ab	5178ab
9	Maize 4 stand + Er. Cowpea	2333fg	1500c	5885cd	4265bcd
10	Maize 4 stand +Sitaopole	3353de	1988bc	5818cd	3490d
11	Maize 2/stand +Yam +Melon +Sitaopole	3045ef	1900bc	4774c	3630d
12	Maize 4/stand +Yam + Melon in 2 alternating rows with Er. Cowpea	1958g	1550c	5014cd	3878cd
	Crop associations				
a	Maize alone	4538ab	2941a	7701a	5471a
b	Maize +Yam	4484abc	2465ab	6603bc	3491a
c	Maize +Melon	3641cde	2358ab	7049abc	4644abcd
d	Maize +Sitaopole	3498de	2027bc	6273bc	3395d
e	Maize +Erect Cowpea	2708ef	1584c	6723abc	4721abc
f	Maize +Yam +Melon +Sitaopole	3045ef	1900bc	4774d	3630d
g	Maize +Yam +Melon + Erect Cowpea	1958g	1550c	5014cd	3878cd
	Maize population/stand				
a	Maize 1 plant/stand	4368bc	2925a	7745a	5825a
b	Maize 2 plants/stand	3930bcd	2240abc	6648abc	4170bcd
c	Maize 4 plants/stand	2715efg	1896bc	5750cd	3985cd
	Crop combinations				
a	Maize alone	4538ab	2941a	7701a	5471a
b	Maize +1 crop	3294def	21.7bc	6512abc	4063cd
c	Maize +3 crops	2501fg	1725c	4894d	3754cd

Means opposite the same letter are not significantly different from each other by Duncan Multiple Range Test at 5%.

est. Leaf area development in Ife Brown synchronized with that of Sitaopole. All these affect the degree of competition and the compatibility of various crops in traditional cropping systems. Dry matter accumulation curves follow the same trend as those of leaf area development with melon accumulating dry matter most rapidly before senescence, and other crops in the mixture reached different peaks, with maize, Ife Brown and Sitaopole cowpeas reaching different peaks at almost the same time, while the yam took the longest time to reach its maximum dry matter accumulation peak. Although maize accumulated the highest dry matter per unit area per day followed by erect cowpea, yam, melon and then Sitaopole, the rate and amount accumulated varied with the crop mixture and pattern of planting (Fig. 17). The overall effects of these are jointly expressed in the final yield. This study indicates some of the rationale behind various times, mixtures and patterns of planting in traditional cropping systems, and also explains why when farmers plant many crops simultaneously, the spacings are unusually wide to reduce competition among intercrops.

Calorie equivalents and gross returns. The total calorie equivalents and gross returns of the different crop mixtures are presented in Table 25. In both years, highest calorie equivalents were observed in maize alone followed closely by mixtures containing yam and/or maize. The highest gross returns were observed in yam followed closely by mixture containing yam and maize and yam, maize, cowpea and melon.

Residue management experiment

Two crops per year (early and late) of maize, cowpea and soybeans and one crop of cassava were grown on 22 different kinds of mulch in 1975 and 1976. Results of the early-season crops of 1975 were presented in the 1975 annual report. Results of the 1975/76 cassava crop and the 1975 late and 1976 early maize, cowpea and soybean are discussed.

Cassava 1975. There were significant differences among treatment means in plant height, number of main stems per plant, fresh and dry weight of roots, fresh and dry weight of stems, fresh weight of leaves at harvest, number of tiers of branching and number of roots per plant (Table 26). There were no significant differences among treatment means in plant populations and dry weight of leaves at harvest.

Table 24. Observations on plant population and fresh weight of tubers observed in yams grown alone and in different crop mixtures at IITA in 1975 and 1976.

Treatments	Plant population No./ha 1975	1976	Fresh yield weight of tubers (t/ha) 1975	1976
Yam alone	9375a	9750a	23,088a	21,086a
Yam + maize 2/stand staggered	6938b	9875a	10,008c	12,983bcd
Yam + maize 2/stand same row	7063b	9750a	13,383b	14,594abc
Yam + erect cowpeas*	6438b	9813a	10,925bc	17,738ab
Yam + climbing cowpeas	6813b	9750a	11,900bc	11,269cd
Yam = maize 2/stand + melon + climbing cowpeas	6938b	9375a	11,375bc	8,225d
Yam + maize 4/stand + melon 2 rows alt. with erect cowpeas	6250b	9563a	14,245b	9,244cd
Summary — Crop associations				
Yam alone	9375a	9750a	23,088	21,036a
Yam + maize	7001b	9813a	11,695bc	13,788bcd
Yam + erect cowpeas	6438b	9813a	10,925bc	17,738ab
Yam + climbing cowpeas	6813b	9750a	11,900bc	11,269cd
Yam + maize + melon + cowpeas	6594b	9469a	12,810b	8,734d
Crop combinations				
Yam alone	9375a	9750a	23,088a	21,036a
Yam + 1 crop	6813b	9797a	11,554bc	14,144abc
Yam + 3 crops	6594b	9469a	12,810b	8,734d

Means in the same column opposite the same letter(s) are not significantly different from each other at 5% level.
**VITA-3 in 1975 and Ife Brown in 1976.*

Table 25. Calorie equivalents and gross returns obtained from yam/maize/melon/cowpeas intercropping experiment in 1975/76.

Treatments	Calorie values 1 × 104/ha/day 1975	1976	Gross returns N/ha 1975	1976
Yam alone	6.717	6.123	3001	2734
Maize alone	10.440	20.800	644	1282
Melon alone	8.600	8.600	814	747
Erect cowpeas alone	6.736	1.857	658	116
Climbing cowpeas alone	2.273	1.664	223	162
Maize alone 2/stand	10.560	18.270	651	1126
Yam + maize 2/stand staggered	13.154	16.469	1941	2470
Yam + maize 2/stand same row	11.253	16.486	2193	2651
Maize 2/stand + melon	9.123	19.433	610	1252
Maize 4/stand + melon	9.429	18.127	593	1208
Yam + erect cowpeas	8.762	6.374	1966	2681
Yam + climbing cowpeas	4.727	4.006	1670	1536
Maize 2/stand + climbing cowpeas	7.853	12.135	501	761
Maize 2/stand + erect cowpeas	8.595	18.830	625	1170
Maize 4/stand + erect cowpeas	9.433	15.500	728	962
Maize 4/stand + climbing cowpeas	7.827	12.851	509	806
Melon + erect cowpeas staggered	8.471	4.479	1141	413
Melon + erect cowpeas alt. rows	7.436	3.864	725	358
Melon + climbing cowpeas same row	3.453	4.312	331	412
Melon + climbing cowpeas alt. rows	5.293	3.311	505	316
Yam + maize 2/stand + melon + climbing cowpeas	10.843	16.212	1988	1950
Yam + maize 4/stand + erect cowpeas in 2 alt. rows with melon	11.921	17.701	2410	2157

Table 26. Observations on cassava grown in different mulches in 1975/76.

Treatments	Plant height at harvest (cm)	Roots No/stand	Fresh wt. of roots t/ha	Dry wt. of roots t/ha
Bare — no mulch	254.60g	4.9ghi	16.38def	10.82ef
Maize stover	330.63bcdef	5.6efghi	16.36def	10.80ef
Maize cobs (chipped)	330.27cdef	5.1ghi	17.82edef	11.76def
Oil palm leaves	310.20ef	4.8hi	17.08def	11.28ef
Rice straw	316.03	5.0ghi	17.93cdef	11.83def
Rice husks	352.27abcd	7.3ab	28.32a	18.69a
Pennisetum straw	314.60def	4.6i	14.15ef	9.34f
Elephant grass	303.27f	5.0ghi	16.57def	10.93ef
Panicum straw	309.87ef	5.1ghi	15.50f	10.23f
Andropogon straw	330.77bcdef	5.4fghi	18.47cdef	12.14def
Typha straw	319.37cdef	4.8i	16.72def	11.04ef
Cassava stems (chipped)	335.37bcdef	5.8defgh	20.90cd	13.80cde
Pigeon pea tops	353.47abc	6.4cd	22.92bc	15.13bcd
Pigeon pea stems (chipped)	333.27bcdef	6.3cdef	19.92cde	13.15de
Cowpea lima p'pea husks	356.70ab	7.0bc	26.40ab	17.43abc
Soybean tops	348.37abde	6.3cde	22.90bc	15.12bcd
Eupatorium	338.33bcdef	5.1ghi	18.83cdef	12.43def
Mixed twigs (chipped)	325.03bcdef	5.9defg	18.50cdef	12.21def
Sawdust	343.87abcdef	5.3fghi	20.45cde	13.49de
Black plastic	374.97a	8.0a	30.51a	20.14a
Translucent plastic	337.53bcdef	7.0bc	27.68ab	18.27ab
Fine gravel	343.70abcdef	6.6bcd	22.85bc	15.08bcd

Means opposite the same letter(s) are not significantly different at the 5% level.

Table 27. Maize grain yields (t/ha) as affected by different mulch treatments in 1975/76.

	Treatments	1975 Early	1975 Late	1976 Early	Mean
1	Bare — no mulch	4.0a	2.5bcde	3.0c	3.1
2	Maize stover	4.0a	2.9abcd	3.3cd	3.4
3	Maize cobs (chipped)	3.7a	2.8abcd	3.3cd	3.3
4	Oil palm leaves	4.3a	2.7abcd	3.2cd	3.4
5	Rice straw	4.8a	2.5bcde	3.5bcd	3.6
6	Rice husks	5.0a	3.0abc	3.7abc	3.9
7	*Pennisetum* straw	4.2a	2.8abcd	3.3cd	3.4
8	Elephant grass	4.9a	1.7e	3.3cd	3.3
9	*Panicum* straw	4.3a	2.8abcd	3.6bcd	3.6
10	*Andropogon* straw	4.6a	2.5bcde	3.5bcd	3.5
11	Typha straw	4.5a	2.1de	3.1cd	3.2
12	Cassava stems	3.9a	3.3a	3.8abc	3.7
13	Pigeon pea tops	4.8a	2.9abcd	3.7abc	3.8
14	Pigeon pea stems	4.1a	3.0abc	3.5bcd	3.5
15	Legume husks	4.5a	2.8abcd	4.4a	3.9
16	Soybean tops (chipped)	5.0a	3.0abc	4.2ab	4.1
17	*Eupatorium* tops	4.5a	2.5bcde	3.6abc	3.5
18	Mixed twigs (chipped)	3.9a	2.7abcd	3.4bcd	3.3
19	Sawdust	3.8a	3.1ab	3.7abc	3.5
20	Black plastic	4.8a	2.7abcd	3.0cd	3.5
21	Translucent plastic	4.6a	2.4cde	2.7d	3.2
22	Fine gravel	4.7a	2.9abcd	3.1cd	3.6
	Mulch Groups				
1	Bare	4.0a	2.5bcde	3.0c	3.2
2	Legumes	4.7a	2.9abcd	4.2ab	3.9
3	Non-Legumes	4.2a	2.9abcd	3.6abc	3.6
4	Gravel	4.7a	2.9abcd	3.1cd	3.6
5	Polythene	4.7a	2.6bcd	2.9c	3.4

Plant height was highest in the black polythene mulch (374.97 cm) followed by legume husks (356.7 cm), but lowest on the bare plots (254.6 cm). Fresh and dry weights of roots were highest in the black polythene mulch amounting to 30.5 and 20.1 t/ha respectively, followed by rice husks and translucent polythene mulches. The lowest fresh weight root yields of less than 15 t/ha occurred in *Pennisetum polystachion* straw mulched plots followed by *Panicum maximum* straw mulch. All woody, legume residue and husk mulches gave fresh weight root yields of 19 t/ha or more. Values of other observations were usually highest in the black polythene mulch and lowest in bare and straw mulches. The plants on black polythene grew faster, matured earlier and appeared greener at the early periods of growth than in all the other mulches except legume husks.

Maize 1975/1976. In 1975 late maize crop, significant differences in number of missing stands 2 WAP, lodging, tasselling, times of anthesis and silking, stover and grain yields were observed among mulch treatments (Table 27). The highest stover yields occurred in the soybean tops and mixed twigs followed by legume husks, fine gravel and rice husks. Highest grain yields were recorded in chipped cassava stems and sawdust followed by soybean tops, rice husks, and pigeon pea tops. Tasselling, anthesis and silking occurred earliest in the black polythene, soybean tops, elephant grass straw, translucent polythene and pigeon pea tops but was latest in rice straw, *Pennisetum polystachion* straw, bare and *Panicum maximum* straw. Germination failures and supplies were highest in the *Pennisetum polystachion* straw, fine gravel, rice straw and *Panicum* straw but much lower in the black polythene, soybean tops, cassava stems and elephant grass mulches. This indicated that in some of the treatments a high number of germinations and survivals contributed to the early maturity. It may also be due to temperature and other environmental conditions induced by the mulches.

In the early maize, significant differences among treatments were observed in plant population, tasselling, anthesis and silking times, dry weight of stover and grain yield (Table 27) but not in plant height and lodging. Early-season grain yields in 1976 were lower than those of the early season of 1975 but higher than in the dry season.

Cowpea. In the 1975 late-season cowpea, significant differences were observed in plant population but not in flowering time, and grain yield of Ife Brown cowpea grown on the different mulches (Table 28). The early Ife Brown crop of 1976 resulted in significant differences among mulch means in time to flower and grain yield of Ife Brown. No significant differences were observed in plant population at harvest and pod yield. Apparently the cowpea yielded higher in some of the monocotyledonous organic residue material than in most of the dicotyledonous residues. In general grain yields of soybean and cowpea were higher in the early season of 1976 than during the same season in 1975 when the experiment started.

Soybean. No significant differences were observed among treatment means in plant population, days to flower and grain yield of the Bossier soybean, due to wide difference in yields resulting from poor establishment in some mulches and the associated variation. Grain yields were highest in the maize

Table 28. Cowpea and soybean yields (t/ha) as affected by different mulch treatments in 1975-76.

Treatments	Cowpea		Soybean	
	Late 1975	Early 1976	Late 1975	Early 1976
1 Bare — no mulch	0.67a	0.59a	0.43a	0.58de
2 Maize stover	0.99a	1.11a	0.88a	1.49abc
3 Maize cobs (chipped)	1.03a	1.07a	0.64a	1.35abcd
4 Oil palm leaves	1.03a	1.20a	0.65a	0.91bcde
5 Rice straw	0.98a	1.02a	0.74a	1.50abc
6 Rice husks	0.82a	1.14a	0.48a	0.79de
7 *Pennisetum* straw	1.01a	1.22a	0.81a	1.35abcd
8 Elephant grass	0.92a	0.94a	0.58a	1.29bcd
9 *Panicum* straw	1.08a	2.09b	0.87a	1.53ab
10 Andropogon straw	0.69a	0.98a	0.42a	1.19bcde
11 Typha straw	0.95a	0.97a	0.72	1.08bcde
12 Cassava stems	1.23a	0.77a	0.59a	1.38abcd
13 Pigeon pea tops	0.99a	1.08a	0.66a	0.90cde
14 Pigeon pea stems	1.08a	0.97a	0.63a	1.29bcd
15 Legume husks	1.05a	1.01a	0.82a	1.50abc
16 Soybean tops (chipped)	1.10a	0.97a	0.62a	1.05bcde
17 *Eupatorium* tops	0.90a	1.01a	0.69a	1.23bcde
18 Mixed twigs (chipped)	0.98a	1.02a	0.78a	1.21bcde
19 Sawdust	0.95a	0.93a	0.73a	1.91a
20 Black plastic	0.85a	0.94a	0.60a	1.08bcde
21 Translucent plastic	0.94a	0.96a	0.49a	1.13bcde
22 Fine gravel	0.79a	0.98a	0.70a	1.00bcde
Mulch groups				
1 Bare	0.67a	0.59a	0.43a	0.58de
2 Legumes	1.08a	1.02a	0.73a	1.24bcde
3 Non-legumes	0.99a	1.02a	0.67a	1.37abcd
4 Gravel	0.79a	0.98a	0.70a	1.00bcde
5 Polythene	.90a	0.95a	0.55a	1.11bcde

Means opposite the same letter(s) are not significantly different at the 5% level.

Table 29. Effects of intercropping and cropping patterns on the plant population, pod and grain yields of spreading cowpea (VITA-5) intercropped with cassava.

Treatments	Plant population Per hectare	Dry weight unshelled cowpea pods kg/ha	Dry grain yield kg/ha
1. Cassava on same row as cowpeas	38125.00 bc	1578.13 b	981.25 ab
2. Cassava on one side of ridge cowpeas on the other	37812.50 c	1493.75 b	771.88 bcd
3. Cassava in alternate rows as cowpeas	20468.75 d	1618.75 b	550.00 cd
4. Cassava planted one month later on same row as cowpeas or ridge	38359.38 abc	2250.00 a	1065.63 ab
5. Cassava planted one month later on same row as cowpeas on flat	40078.13 a	2343.75 a	962.50 ab
6. Cassava planted one month later on same row as cowpeas on flat.	39218.75 abc	2462.50 a	1296.88 a
7. Cassava planted two months later on same row as cowpeas on flat	39609.38 ab	2375.00 a	921.88 bc
8. Cassava alternate with cowpea ipw pigeon peas on 1.5m ridges	11328.13 e	1071.88 b	400.00 d
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stover, panicum straw, legume husks and *Pennisetum polystachion* straw as compared to rice husks, maize cobs and black polythene in the early crop.

The early 1976 soybean crop exhibited significant differences in plant population and grain yield (Table 28). In general, all yields of the late crops were lower than in the early crops and response to woody, legume residue, and graminaceous straw and related mulches differed markedly.

Cassava/Cowpea/Pigeon pea intercropping, (Ikenne 1976). This experiment involved study of VITA-5 cowpea performance when grown in combination with cassava on the flat and ridges, on the same and alternating rows with cassava which is planted at the same time, one or two months after cowpea planting. Significant differences were observed in plant population and dry grain yields of the cowpea component (Table 29). Plant population was significantly higher where cowpea was planted.

Diversified cropping

Vegetables

Tomato disease screening. In continuation of our efforts to identify tomato lines with resistance or tolerance to the virus diseases prevalent in West Africa, 2,927 new lines were field screened. The disease incidence was high, and more than 95 percent of the lines showed moderate to severe symptom expression. Screening work on them continues.

Tomato preliminary yield trial. Some of the new cultivars developed for the humid tropics have been sent out for testing in other locations in West Africa. Six new selections were tested against two checks during the first rainy season. Three of the new lines relatively free from the virus-like disease yielded higher than the highest check but only one was significantly higher (Table 30).

Table 30. Performance of six new lines against two standard cultivars.

Lines and cultivars	Yield kg/ha
H9-5-6-4-(7)	32,867
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H33-7-(7)	23,850
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Marzanino*	20,334
H2-2-(6)	19,789
LSD 0.05	6,367

Population density of Egusi melon. Although Eugsi melon *(Citrullus* sp.) is grown and eaten throughout West Africa very little is known about the crop. Reported yields are usually low, but the full potential of the crop may not be determined until the fruit fly (*Daucus* sp.) which destroys the immature fruit is effectively controlled. By using a mixture of Dypterex and Staley's protein bait which give fair control of the fly, the seed yield was determined at various population densities. There were no significant differences in seed yield between population densities but it appeared that the optimum population was somewhere between 2,000 and 3,000 plants/ha. Interplant competition mainly in the form of internal shading appeared to be the limiting factor at high population densities. Wide spacings with two plants per hill appeared to be more advantageous. The yields of over 600 kg/ha are more than five times the yields usually obtained by farmers.

Corchorus olitorius. A germplasm comprising 18 cultivars and two wild relatives *(C. tridens* and *C. aestuans)* was assessed for plant height, number of days to flowering, leaf size, fruit length, leaf appearance, pigmentation of stem and fruit during the early cropping season. On the basis of this assessment two promising types, *"Oniyaya"* and *"Amugbadu"* have been selected for further improvement.

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Okra mosaic virus (OMV). Search continued for resistance to OMV with screening of newly introduced lines along with segregating generations of some crosses between tolerant and susceptible individuals. All plants were susceptible except a short-day lines, Tae 316, which showed tolerance to the disease. When crosses were made to this line, the F_1 plants produced fruits that were mostly seedless. Pollen viability of F_1s ranged from 5 to 15 percent. The pollen grains were of varying sizes and shapes. The viable ones were larger than in either parent. The few seeds collected from the F_1 plants are to be advanced for selection.

Effect of population density on okra performance. The two highest-yielding cultivars in the IITA collection (Tae 38 – of Nigerian origin and Tae 314 – exotic) were established at different plant population densities – 33,000 and 267,000/ha (Table 31). There was no significant difference in the fresh fruit yield of Tae 314 under the two highest densities but both were significantly higher than the next highest population density. However, with the more stout Tae 38 there were no significant differences in fresh fruit yield between the four highest densities showing that increasing plant population density above 67,000/ha does not result in yield increase. Population densities of 133,000 and 67,000/ha could be recommended for Tae 314 and 38 respectively.

Table 31. Performance of okra under different plant population densities.

Cultivar	Plants per hectare	Fresh fruit yield (t/ha)	Yield per plant (g)	Fruits per plant	Mean fruit weight (g)
Tae 314	33,000	9.9	297.1	22.2	13.3
	44,000	10.5	236.5	18.3	12.8
	67,000	12.5	187.6	14.2	13.2
	98,000	11.4	128.7	10.9	11.6
	133,000	16.0	119.0	10.0	11.9
	267,000	16.8	63.0	6.7	9.3
Tae 38	33,000	6.6	199.3	10.1	19.9
	44,000	6.9	155.2	8.2	18.9
	67,000	9.2	138.4	7.5	18.4
	89,000	9.2	104.0	5.7	18.3
	133,000	10.0	75.4	4.7	15.9
	267,000	9.6	36.0	2.8	12.9

Plantain

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Surveys. Three major surveys for banana and plantain cultivars were made during 1976. Fifty-six new entries were introduced at IITA, bringing the total to 139.

Plantain cultivars in West Africa. Preliminary data indicate that the most common plantain type found along the western coast of Africa (Sierra Leone to Nigeria) is the "Horn" plantain. In the eastern part of the Guinean Zone, the "French plantain" types are dominant.

Effect of water table on plantain performance. In an undrained plantation established along a toposequence, bunch weight and number of fruits per bunch were not significantly affected by groundwater level. Nevertheless, the reduction of both was observed where the water table did not fall below 40 cm. Maturity occurred significantly earlier where the mean monthly water table level did not exceed 40 cm in the wet season. Height of the replacing sucker was significantly lower where the water table reached 10 cm in the wet season.

Intercropping

Cassava with vegetables. Intercropping trials have indicated that cassava might be successfully intercropped with tomato, okra and French bean if one of the vegetables was irrigated through the dry season. In those trials planting was carried out in the dry season and irrigation used on the tomato/cassava section. But the yield of tomato planted during the dry season was usually low because at that period the incidence of the virus-like disease affecting tomato is usually high. Because this disease was not observed during the second rainy season it was decided to initiate the sequence with a tomato/cassava combination at that time.

The virus-like disease was not observed in the tomato and yield was higher than observed previously in dry-season crops. The okra crop that was planted during the dry season failed because of poor germination and high incidence of yellow mosaic and stunting virus diseases. The time sequence for the planting of the various crops tomato-cassava-okra-French bean, and the spatial arrangement of the pure stand and the intercrop combinations used were:

1. Pure stand tomato spaced 100 × 60 cm followed by okra spaced 100 × 30 cm, followed by French bean spaced 100 × 30 cm.
2. Pure stand tomato spaced 150 × 50 cm followed by okra and French bean in the same sequence and with similar spacing as in combination (1) above.
3. Cassava spaced 300 cm between rows and 100 cm along the row, interplanted with two rows of tomato spaced 100 × 60 cm. The tomato was followed by okra and French bean as in (1) above.
4. Cassava spaced 2000 cm between rows and 100 cm along the row interplanted with tomato spaced 100 × 60 cm. Tomato was followed by okra and French bean as outlined above.
5. Tomato spaced 150 × 50 cm was followed with cassava spaced 150 × 50 cm, planted after the first picking of tomato.
6. Pure stand cassava spaced 100 × 50 cm.
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In all cases except #8 cassava was planted three weeks after tomato. The performance of the crops and combinations are shown in Table 32. The yields of cassava in combinations #3, #4 and #5 are low because wind damage was high in the plots. Nitrogen fertilizer applied to the other crops apparently caused excessive canopy development in these cassava, making them vulnerable to wind damage. Although the yield of cassava was significantly reduced in the combinations, the returns of the combinations were generally high. Vegetable/cassava combinations may be regarded as cash/staple food combinations which could increase the farmer's income without eliminating the staple.

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Table 32. Yield (t/ha) of tomato, French bean, and Cassava in various intercropping combinations.

Combinations	Tomato	French bean	Cassava	Total
1	33.9a	6.7a	–	40.6
2	29.6a	7.0a	–	36.6
3	32.2a	7.1a	9.4a	48.7
4	35.7a	6.7a	14.7b	57.1
5	34.4a	–	11.8b	46.2
6	–	–	25.9c	25.9
7	–	–	28.2c	28.2
8	–	–	26.0c	26.0

Means followed by the same letter in the column are not significantly different.

Cassava with cowpea. In mixed cropping situations where cassava is planted before or simultaneously with cowpea, the yield of the cowpea is usually reduced. To overcome this, two combinations in which the cassava was planted four weeks after the cowpea were tested.

In combination D (Table 33), both cowpea and cassava were planted on the same ridge while in combination E one ridge with cowpea alone was left between two ridges of cowpea and cassava. The results (Table 33) show that the yield of cowpea was lower in the combinations than in the pure stand, but the differences were not significant. Early growth of cassava expressed as plant height at three months after planting was significantly suppressed by cowpea (Table 34). Although the yield of cassava in the combinations was lower than in the pure stands the differences were not significant. Although cassava in pure stand yielded highest per hectare, the land equivalent ratios (LER) show that the crop combinations were more efficient. The cassava did not affect the quality of the cowpea seeds.

Table 33. Yield of cowpea and cassava in pure stand and intercropping (t/ha).

Treatment	Cowpea	Cassava	Total	LER
A. Cassava pure stand (100×100 cm)	–	22.40	22.40	
B. Cassava pure stand (200×50 cm)	–	18.50	18.50	
C. Cowpea pure stand (100×20 cm)	2.95	–	2.95	
D. Cowpea (100×20 cm) Cassava (100×100 cm)	2.76	18.00	20.76	1.74
E. Cowpea (100×20 cm) Cassava (200×50 cm)	2.61	17.60	20.21	1.83

Marketable cowpea seeds: C = 87.5%, D = 95.8%, E = 91.4%

Table 34. Effect of cowpea on early growth of cassava planted four weeks after cowpea.

Treatment	Height of cassava at 3 months (cm)
A. Pure stand cassava (100×100 cm)	172
B. Pure stand cassava (200×50 cm)	170
C. Pure stand cowpea	–
D. Cassava (100×100 cm)+cowpea (100×30 cm)	87
E. Cassava (200×50)+cowpea (100×30 cm)	87
LSD 0.05	12

Live stakes. In continuation of the experiment on live plant support for yam, a second crop of yam was planted between the *Leucaena leucocephala* plants that served as support. The yam performed poorly, apparently because of nematodes. Measures to suppress the nematode population must be incorporated into the system if the same set of plants are to support more than one crop of yam. It was also observed that shading retarded sprouting and caused etiolated and weak vines.

Horizontal Leucaena branches used as stakes properly support yam growth (foreground). Yams supported by upright stakes are shown in the background.

Horizontally placed branches as support for yam. Untrimmed branches of *Leucaena leucocephala* horizontally placed were found to provide suitable support for vines of water yam (*Dioscorea alata*). There was no significant difference between yields under horizontal branches and conventional upright stakes (Table 35). The cutting and putting in place of the horizontal branches required less time than did staking.

The vines covering the horizontal branches effectively shaded out weeds and weeding was unnecessary after the branches were put in place. Rapid growing strains of *Leucaena leucocephala* that ratoon well have been found to be good sources of the type of branches required.

Table 35. The effect of horizontal branches and upright stake supports on yield of Water yam (Dioscorea alata L.).

Type of support	Tuber/hill #	Tubers/hill kg.	Yield t/ha
Horizontal branches	1.61	1.53	25.5
Upright stakes	1.44	1.55	25.9

Mulch *in-situ*. The high cost of using mulch could be drastically reduced if harvesting, transporting and spreading of the mulch could be eliminated. These factors could be removed by finding a suitable cover crop that would leave sufficient organic residue after it has been killed by a herbicide. *Pueraria phaseoloides*, a legume, has been observed to be the potential crop. This legume grown for 30 months and killed with the herbicide Paraquat, left a uniform mulch of 14.5 t/ha dry weight of organic residue through which tomato was planted by disturbing the mulch and the soil only at the location for the plant. Despite the organic residue when a complete inorganic fertilizer was added, the yield of tomato was significantly increased (Table 36). A single side dressing of nitrogen did not, however, significantly increase yield over the no-fertilizer control. The mulch cover persisted throughout the duration of the tomato and rendered weeding unnecessary. In addition, it protected the fruits from ground rot and produced high-quality marketable fruits.

Table 36. The effect of fertilizer application on yields of tomato grown under mulch from** in-situ **residue of** Pueraria phaseoloides, **killed Paraquat.

Treatment	Average fruit wt.	t/ha	% Marketable
No fertilizer	56.0	20.670	97
N side dressing only	58.0	22.400	95
N.P.K. preplant and N side dressing	63.0	42.570	96

Fresh weight of mulch = 25.0 t/ha. Dry weight of mulch = 14.5 t/ha.

Because it has been shown that the legume can be established by minimum tillage without later cultivation or weeding, the system appears suitable for highly erodible soils that should be maintained under a protective cover of crop or plant residue.

Crop protection

Entomology

Mixed cropping studies. One idea of the farming systems program involves several crop combinations and planting patterns which may possess characteristics with beneficial or adverse implications for insect pest management. It is important that these be identified with a view to minimizing potential pest problems and developing appropriate integrated control procedures. Studies begun in 1976 have been chiefly concerned with the development of methodology and exploration of a simple system of intercropped maize and cowpea.

Leaf feeding insects. Table 37 shows the distribution of leaf feeding insects between treatments assessed by direct counts of occurrence over four rows per plot for each crop type 10 times. Insects such as *Epilachna similis, Nematocerus acerbus, Luperode lineata* and *Lagria villosa* which were present in low numbers are included in the total category.

Table 37. Incidence of leaf feeding pests over the growing season. Mean/100 plants.

Insect	Maize			Cowpea		
	Mixed	Sole^{S}	Sole^{D}	Mixed	Sole^{S}	Sole^{D}
Ootheca mutabilis	2.9	0.4	0.5	10.3	14.0	9.3
Chrysolagria cuprina	12.3	16.5	14.2	8.7	8.2	8.5
Barombia humeralis	13.9	12.5	20.0	4.8	5.6	4.9
Orthoptera	3.6	5.2	5.3	21.0	19.0	11.3
Total leaf feeders	34.6	36.9	41.6	46.9	48.0	35.8

^{S}*single spaced;* ^{D}*double spaced.*

Significantly these insects were recorded more on cowpea than on maize (p 0.05), though overall their infestation level was not affected by spacing or intercropping. Particular insects or groups tend to be associated with either maize or cowpea and the presence of other plant types in a mixture does not make it more liable to attack. However, only *Ootheca mutabilis* occurs at a very low density in the sole maize and significantly (p 0.001) larger numbers are found on maize in the intercrop where the cereal presumably provides a subsidiary food source and a favored resting site. Significant damage to maize does not occur, however, and the phenomenon does not increase population density on the cowpea.

Sap feeding insects. Direct counts are suitable for larger Homoptera such as the Cercopids *Poophilus costalis* and *Locris erythacmela* associated with maize and the Heteroptera *Anoplocnemis curvipes, Acanthomis horrida, Acanthomia tomentosicollis, Mirperus jaculus, Riptortus dentipes, Aspavia armigera, Nezara viridula* and others, primarily associated with cowpea. *Poophilus* shows a preference for maize at the wider spacing (p 0.025) but not at intercrop, where numbers are the same as in the single spaced maize, suggesting a vegetation density effect. The intercrop situation increases the occurrence of Heteroptera on maize (p 0.001), an effect particularly marked for *Anoplocnemis* and the two species of *Acanthomia*. For *A. tomentosicollis* there are indications (0.1 p 0.05) of a reduction in numbers on cowpea in a mixed stand but a consideration of the whole plot situation reveals a redistribution between the two crops rather than a decrease in infestation. Coreid heteropterans both rest and feed on maize and they frequently serve as an oviposition site. Under the conditions of this trial no serious effects were evident as a result of this behavior though in some circumstances the intercrop situation could generate large populations with severe effects on cowpea yield.

Estimates for *Empoasca dolichi* from D-Vac sampling suggested lower numbers from the mixed plots (0.1 p 0.05) with a mean of 8.1 insects/plant from eight sampling times during the growing season in mixed cowpea compared to 10.3 for sole crop at both spacings. *Sericothips occipitalis* populations were also reduced (p 0.01) as were those of *Callosobruchus maculatus* (p 0.01) in mixed plots, an effect likely to be associated with reduced pod production in this treatment.

Cowpea flower sampling. Cowpea flowers were removed and dissected to remove thrips. Results are in Table 38.

Table 38. Mean numbers of** Taeniothrips sjostedti **per flower ±SE.

	Cropping system Maize/cowpea	Sole cowpea^{S}	Sole cowpea^{D}
Adults	10.9±1.4a	25.4±2.9b	23.1±4.3b
Nymphs	16.1±1.8a	29.3±3.8b	19.3±0.5ab
Total	27.0±3.2a	54.7±6.0b	42.5±4.6b

Numbers followed by the same letter are not significantly different (P 0.05).

A significant reduction (p 0.001) in flower infestation in the mixed cropping situation is apparent with a tendency toward lower numbers in the double spaced cowpea than in the single spaced crop. This suggests that increased spacing may present some barrier to dispersal within the crop, which is further reinforced by the presence of the cereal. Caution must be exercised in attributing such effects to mixed cropping, however, since the physiology of the cowpea is profoundly influenced by its situation within the maize canopy and flowering is both delayed and reduced. Lower flower density within the stand could also act as a barrier to effective dispersal and colonization. Larvae of the lepidopterous pod borer *Maruca testulalis* were also recovered from the flowers. No differences were observed between treatments, with a mean of 15.7 percent of flowers infested. Larvae of *Euchrysops* *malathana* were found in 9 percent of flowers from mixed plots. This species was entirely absent from sole plots.

Aerial invasion. An experiment was conducted on the effect of cropping systems on aerial invasion using water traps placed at 0.5- and 2-m height in each of the three treatments such that the 2-m traps were just above the maize canopy and the 0.5-m traps above the cowpea. Results are shown in Table 39.

Table 39. Mean numbers of insects caught in water traps in three days ± SE.

Group	Height of trap (m)	Sole cowpea	Sole maize	Maize/cowpea
Thysanoptera	2.0	30.6 ± 2.3a	12.6 ± 2.2b	18.2 ± 3.1b
	0.5	68.9 ± 5.8a	2.7 ± 0.5b	10.1 ± 1.4c
Parasitic	2.0	5.9 ± 0.8ab	5.8 ± 1.0a	7.9 ± 1.3b
Hymenoptera	0.5	10.0 ± 1.5a	2.3 ± 0.4b	17.0 ± 3.0a
Diptera	2.0	45.0 ± 3.2a	29.0 ± 1.8b	35.9 ± 3.1a
	0.5	36.3 ± 3.2a	10.7 ± 0.9b	20.0 ± 3.5c
Total insects	2.0	96.0 ± 5.3a	64.0 ± 4.0b	84.7 ± 5.2a
	0.5	131.1 ± 8.9a	25.7 ± 2.0b	68.4 ± 5.2c

Means followed by same letter not significantly different (p. 0.05). Compare horizontally.

Results show that the presence of the cereal reduces aerial invasion of cowpea by insects with the numbers of thrips over the intercropped cowpea significantly lower than in sole plots. Because this difference persists at 2-m, the effect may therefore be one of reduced attraction to the mixed crop rather than the maize acting as a physical barrier to invasion. These data support the results of the flower sampling but must be viewed with the same reservations particularly since D-Vac data give values significantly lower for *Taeniothrips* in double spaced cowpea (p 0.05) than in single spaced and mixed. There is evidence that insects are attracted into the mixed crop by the presence of cowpea since consistently more are trapped than in sole maize. Generally, most insects occur at 0.5m in the sole cowpea through parasitic Hymenoptera are an exception with significantly more (p 0.05) over cowpea in the mixed plot. This may be a beneficial effect of intercropping but the data are not supported by D-Vac sampling, where no differences were detected.

Pesticide residue studies. The main objectives of this project have been to establish whether the organochlorine pesticide DDT could, with sustained use for pest control on cowpea, produce long-term deterioration of soil productivity through effects on the soil population and to investigate patterns of distribution and degradation of the pesticide in a tropical crop ecosystem.

Decomposition studies. The major undertaking of the project in 1976 has been a comprehensive experiment carried out during the second growing season on decomposition of cowpea stem and leaf material, incorporating elements of previous studies which have shown significant effects of DDT in reducing decomposition rates. Plant materials were presented in nylon mesh bags with varying mesh sizes to limit access to particular components of the soil population, either on the soil surface or buried. Standard leaf discs and stem sections were used either untreated or pretreated with appropriate amounts of DDT to simulate the spraying effect. Bags were placed at random sites in plots of the three treatments and sampled two times to determine percentage weight remaining.

Buried residues consistently decompose more rapidly than those on the surface, and for both leaf and stem decomposition is slower (p 0.05) in soil containing DDT. The effect is more pronounced (p 0.01) when materials are exposed on the surface, particularly where bags were further contaminated by spraying during the experiment. Effect of substrate treatment with DDT is variable. For buried stems it is significant after six weeks, presumably affecting the later stages of decomposition, whilst no effect is detectable on the surface. Buried leaves respond significantly (p 0.001) with reduced decomposition in the early stages but less so later (p 0.1 p 0.05), whilst the effect on surface leaves (0.01) occurs at the later stage. This may be due to involvement of similar organisms in the earlier stages of leaf decay and the later stages of stem decomposition.

Interesting data were obtained using different mesh sizes to enclose the litter with fine mesh to exclude all but microflora, medium mesh to allow access only to smaller faunal elements, and coarse mesh for maximum access. Significant effects were detected for both materials, leaf and stem, in both positions In nearly all cases, plant tissue in coarse mesh bags decomposed most rapidly, showing the importance of free access of fauna. For stem material the significant difference was between coarse and medium mesh (p 0.01) at three weeks for buried and six weeks for surface bags, whilst for buried leaf the cutoff point was between fine and medium with the leaf in fine mesh disappearing more slowly (p 0.001). Surface leaf material followed the same pattern as stem. These results show the importance of microfauna in decomposition of buried leaf material and macrofauna in buried stem and surface residues.

Population studies. Populations of total microarthropods continued to be significantly reduced in soil containing DDT, (Table 40).

Table 40. Mean numbers of soil microarthropods SE. July 1976. Nos/m$_2$ × 1000.

Depth	Treatment Untreated		Contaminated
0–50 mm	34.49 ± 2.35a	20.65 ± 5.60b	14.91 ± 2.58b
50–100 mm	13.12 ± 9.40a	10.29 ± 1.74a	10.39 ± 2.79a

Means followed by same letter do not differ significantly (0.05).

As in previous years the significant effect (p 0.001) was confined to the 0-50-mm horizon though numbers in the untreated plots were also higher at the lower depth. Mites were the faunal component most affected (p 0.01). Predatory Mesostigmata remained lower (p 0.025) in treated soils but without the increased populations of Collembola observed in 1975.

Quadrat samples showed a very marked treatment effect on total active fauna, principally ants, spiders, Coleoptera and millipedes. Samples were taken three weeks after the final spray of the first growing season, and all groups were reduced in numbers in the treated plots (p 0.001). Earthworm populations were assessed as in previous years by estimates of numbers and dry weight of casts in 0.25m$_2$ quadrats over a three day period and by subsequent handsorting of soil in pits below these quadrats. Casting activity in untreated plots was 81.1/m$_2$ per day in contrast to 4.1 and 1.9 casts/m$_2$ per day in treated and contaminated plots, though earthworm numbers and biomass were the same in all treatments. This suggests either a behavioral effect of the pesticide or selective activity against casting species which could have serious consequences on soil turnover.

Crop Studies. In the second season of 1976 the eighth consecutive crop of cowpea was grown on the experimental plots. Seed yield for the entire period is shown in Table 41.

Table 41. Seed yield from cowpea var. Prima SE. kg/ha.

Season	Treatment Untreated	Contaminated	Treated
73/1	209.0±67.9a	758.5± 23.7b*	401.2±63.4ab
73/2	116.3± 6.6a	164.1± 23.4a	628.8±17.9b*
74/1	108.6±60.0a	488.6± 3.8b	539.2±46.8b*
74/2	80.5±28.8a	94.7± 21.9a	375.2±20.5b*
75/1	290.8±66.1a	480.0±21.9a	386.3±51.8a*
75/2	42.0±16.7a	16.7± 1.6b	280.5±22.1c*
76/1	550.6±95.6a	620.8±110.8a*	613.0±98.7a*
76/2	46.8±15.3a	17.0± 12.6a	198.2±47.7b*

Means followed by the same letter are not significantly different (p 0.05)
**denotes crop sprayed with DDT.*

Yields in 1976 first season were relatively high for the cultivar and continued the trend shown in 1975 for improved performance of the untreated plots relative to treated and contaminated plots. Second season yields from all plots were low. Analysis of the data shows a significantly higher rate of decline (treatment × time interaction p 0.001) in plots with soil containing DDT when all treatments are considered. Where comparison is limited to untreated and contaminated plots in the second growing season of each year, where both treatments are unsprayed, the effect is still significant (p 0.05) and the inclusion of the 1976 data makes the direct treatment effect significant (p 0.05) for the first time with less yield produced from unsprayed crops in contaminated soil than from unsprayed crops in uncontaminated soil.

Nematology

Mulching experiment. Mulch materials held their relative 1975-1976 positions when ranked according to plant parasitic nematode population densities. Elephant grass straw and mixed chopped twigs were two exceptions with each taking the other's position more or less as shown in the IITA Annual Report, 1975.

Mean numbers of nematodes were reduced in relation to the number of nematodes recovered in 1975. Plant parasitic nematodes *(Pratylenchus sefaensi, P. brachyurus, Helicotylenchus pseudorobustus, H. cavenessi, Meloidogyne incognita)* were 50 percent fewer (Table 42) and nonparasitic nematodes 66 percent fewer (Table 43). Maize maintained the mean *Pratylenchus* spp. density at 3,803 and 3,581 nematodes per liter soil respectively for both years. Cassava, soybean, maize and cowpea maintained plant parasitic nematode densities above preplant levels of 808 percent for *Pratylenchus* spp., 162 percent for *Helicotylenchus* spp. and 183 percent *Meloidogyne incognita* juveniles recovered from the soil.

There were four instances of *Pratylenchus* sp. buildup on soybean.

Cassava investigations. In a test to determine the variability in susceptibility or resistance of cassava seedlings to *Meliodogyne incognita* parasitism, 190 11-day-old seedlings were inoculated with 2,000 eggs per pot and grown for 155 days. Forty-six plants died and of the remainder all cassava seedlings proved to be highly susceptible with a mean root-knot index of 4.64 (5.00 = maximum galling).

In a replicated greenhouse trial *M. incognita*, cassava seedling height, tuber weight and root weight were reduced up to 52, 87 and 44 percent respectively after 155 days of growth (Table 44). The lower inoculation rates increased seedling height and root weight over the controls. Tuber weight was reduced at all levels of inoculum.

*Table 44. Cassava seedling attack by the root-knot nematode, Meloidogyne incognita, in a 155 day greenhouse trial.**

Inoculum eggs/plant	Plant height cm	Plant height %	Root tuber g	Root tuber %	Root g	Root %	Root-knot index**
0	785	100	19.6	100	24.3	100	1.00
500	804	102	15.3	78	29.0	119	3.94
1,000	861	110	12.6	65	31.9	131	4.58
2,000***	657	84	8.6	44	31.0	128	4.64
4,000****	481	61	5.8	30	22.4	92	4.56
8,000***	491	63	3.4	17	13.7	56	4.64
16,000****	393	50	2.5	13	14.7	60	4.55
32,000****	331	42	4.6	23	18.3	75	4.28

**Means of 10 replicates of one plant each in a 12 cm pot.*
***Root-knot nematodes index: 1 = no galling, 5 = maximum galling.*
****Two plants dead. ****Four plants dead.*

Nematodes under live mulch. Plant parasitic nematode populations were sampled in live mulch plots after 23 months. Aggregate population means under all mulches were less than preplant means. Root-knot nematode juvenile populations, *Meloidogyne incognita*, were significantly reduced under all treatments except one. Root-lesion nematode *(Pratylenchus*

Table 42. Summary of all plant parasitic nematodes on all crops from mulch treatment trial.

Time of sample	Cassava	Soybean	Maize	Cowpea	Mean all crops	Control	Change in percent*
Preplant	429**	339	257	470	374	313	100
1975	2,612	2,223	6,808	1,165	3,202	3,484	856
1976	574	1,234	4,107	658	1,643	1,682	439

**Preplant = 100%*
***Numbers of nematodes per liter of soil based on 466 samples of 3 observations each. Subsample size was 200 cm_3 soil.*

Table 43. Summary of nonplant parasitic nematodes associated with all crops and treatments in a mulch management trial.

Time of sample	Cassava	Soybean	Maize	Cowpea	Mean all crops	Control	Change in percent*
Preplant	30,407**	24,777	20,949	27,454	25,897	24,175	100
1975	11,044	16,700	12,150	11,906	12,950	11,204	50
1976	2,829	6,728	3,941	3,974	4,368	4,512	17

**Preplant = 100%*
***Numbers of nematodes per liter of soil based on 66 samples of 3 observations each. Subsample size was 200 cm_3 soil.*

sefaensis, P. brachyurus) populations were reduced by all treatments. The spiral nematode *(Helicotylenchus pseudorobustus, H. cavenessi)* populations were significantly reduced by four treatments, maintained by two treatments and increased by three treatments. The data are summarized in Table 45.

Table 45. Mean number of plant parasitic nematodes under selected live mulch treatments 23 months after their establishment.

Mulch treatment	Nematodes/liter of soil*			
	Number of parasites**	Helico	Praty ***	Meloid ****
Stylosanthes gracilis	5	1	4	0
Centrosema pubescens	98	97	0.7	0
Pueraria phaseoloides	122	39	82	1
Paspalum notatum	140	136	4	0.3
Mucuna utilis	153	135	14	4
Brachiaria ruzuziensis	322	318	4	0.3
Cynodon nlemfuensis 'IBA-8'	390	365	24	1
Control (weed cover)	407	352	54	1
Psophocarpus palustris	415	0	54	361
Mean	228	160	27	41
Preplant mean*****	698	168	477	53

**Means based on three replications of 30 samples each. Sample size was 200 cm_3 soil.*
***Helicotylenchus spp.*
****Pratylenchus spp.*
*****Meloidogyne incognita juveniles.*
******Means based on 170 samples.*

Crop rotation investigations. Cultivars selected as rotation crops were grown for six months for plant parasitic nematode control following *Celosia argentea*, a leaf vegetable. In general, plant parasitic nematode population levels were reduced by all rotation crops except *Crotolaria juncea*. The root-knot nematode juvenile soil population levels were significantly reduced by 15 rotation crops. The root-lesion nematodes, at a small preplant population level, significantly increased only on *Crotolaria juncea*. The spiral nematode population levels were significantly reduced by eight rotation crops and to a lesser degree by the other rotation crops. The data are summarized in Table 46.

Weed Science

Cereals

Maize. Two trials were carried out to evaluate and identify suitable herbicides for weed control in maize (cv. TZB (S)C5) and to assess the effectiveness of some herbicides and their combinations in no-tillage maize production. Two weedings, the first of which should be carried out within two weeks of planting were found necessary to prevent yield reduction associated with weed competition (Table 47). Several herbicides among which is EPTC + R (6.0 kg/ha) gave good weed control in maize without crop injury. [R-25788 (N,N-Diallyl-2, 2-dichloroacetamide).] A commercially available mixture of atrazine plus metolachlor at 2.5 kg/ha gave excellent broad-spectrum weed control when applied preemergence. Postemergence application of this mixture was injurious to the crop. Atrazine plus alachlor was effective at 1.5+3.0 kg/ha. There was poor control of annual grasses at lower rates. (All herbicide rates are in kg. a.i./ha).

Glyphosate at 1.3 kg/ha was a better broad-spectrum preplant applied herbicide for no-tillage weed control than paraquat used at the same rate (Table 48). *Paspalum orbiculare* Forst, *Panicum maximum* Jacq, *Talinum triangulare* (Jacq.) Wild and *Commelina* spp. were among the weeds that were either partially controlled by paraquat at 1.0 kg/ha or fully re-

Table 46. Plant parasitic nematode soil populations after cropping and after six-month's growth of selected rotation crops.

Rotation crop	Nematodes per liter of soil							
	Meloidogyne incognita*		Helicotylenchus pseudorobustus		Pratylenchus sefaensis		All parasites	
	Prep	6 mo**	Prep	6 mo	Prep	6 mo	Prep	6 mo
Arachis hypogaea	21***	0	243	28	0	0	264	28
Centrosema pubescens	51***	0	332	127	2	0	385	127
Cynodon nlemfuensis 'IB-8'	533***	0	229	188	11	11	773	199
Desmodium tritolium	220***	0	410	120	5	1	635	121
Digitaria decumbeas	658****	0	344	88	11	5	1,013	93
Indigofera sublatades	82****	0	323	125	50	60	455	185
Pueraria phaseoloides	180***	0	239	24	110	27	520	51
Leucaena leucocephala	549****	0.07	340	118	20	8	909	126
Stylosanthes gracilis	686****	0.4	287	36	2	5	976	41
Clean weeded	538****	0.5	331	173	2	1	871	174
Crotalaria juncea	498****	0.5	259	199	4	412	761	611
Paspalum notatum	359****	0.6	247	164	0	3	606	168
Amaranthus sp.	440****	3	289	76	4	5	733	84
Tagetes patula	413****	4	420	130	4	7	937	141
Vigna unguiculata VITA-1	96***	10	242	42	9	32	347	84
Arachis prostrata	310***	132	425	26	10	6	736	164
Psophocarpus palustris	345***	199	263	12	0	38	608	249
Celosia argentea	263***	198	375	215	60	34	698	447
Celosia argentea	593****	442	358	312	2	2	953	756
Mean	359	52	306	116	16	35	688	203

**Juveniles only.*
***Pre — preplant samples for rotation crops, 6 mo = six months growth of rotation crop.*
****Based on four replications of six observations each. Sample size 200 cm_3 soil.*
*****Based on nine replications of six observations each. Sample size 200 cm_3 soil.*

covered in about four weeks after treatment. Glyphosate killed all weeds when applied sequentially with atrazine plus metolachlor (2.5 kg/ha) or as a tank mixed preplant treatment. Although glyphosate does not mix well with atrazine plus metolachlor, there was no loss of preemergence activity as a result of tank mixing these herbicides.

Rice. Several herbicides applied singly and in combination were evaluated for weed control and for their effects on crop yield in direct seeded lowland rice (cv. TOS 42) under poor water management conditions characteristic of the conditions in which lowland rice is grown locally. The best weed control was obtained in plots in which bifenox was applied preemergence at 2.0 kg/ha (Table 49). Other herbicide treatments that gave superior weed control are postemergence

Table 47. Weed control in maize (IITA, first season, 1976).

Treatment	Rate (kg/ha)	Timing[1]	Weed control[2] G 1st	G 2nd	BL 1st	BL 2nd	Grain yield (kg/ha)
1. Atrazine	2.5	PE	90	59	90	87	5383
2. Primextra[3]	2.0	PE	91	49	99	78	5813
3. Primextra	2.5	PE	97	71	100	83	5348
4. Primextra fb paraquat	1.5+0.5	PE fb Post	87	95	99	94	5612
5. Atrazine + alachlor	1.0+1.5	PE	93	54	98	93	4116
6. Atrazine + alachlor	1.5+3.0	PE	98	74	100	87	5191
7. Gramuron[4]	2.8	Post	100	95	100	97	5040
8. EPTC + R	6.0	PPI	98	78	98	83	5414
9. Butylate + R	4.0	PPI	96	68	98	73	5222
10. Butylate + R	6.0	PPI	98	84	100	77	5066
11. Terbutryn	3.0	PPI	90	49	99	78	5193
12. Hoe weeding	–	7+28 DAE	100	89	100	89	6393
13. Hoe weeding	–	7+35 DAE	100	86	100	87	6217
14. Hoe weeding	–	14+35 DAE	100	92	100	87	5184
15. Weed free check	–	–	100	100	100	100	6240
16. Weedy check	–	–	0	0	0	0	3884
LSD 0.05	–	–	0	0	0	0	543

[1] PE = Preemergence PPI = Preplant incorporation, DAE = Days after emergence DAP = Days after planting, fb = followed by
[2] Weed rating scale: 0 = No control, 100 = Excellent weed control. Plots rated at 21 and 53 DAP, G = Grasses. BL = Broadleaves.
[3] Trade name for formulation containing atrazine + metolachlor.
[4] Trade name for formulation containing paraquat + diuron.

Table 48. Herbicide evaluation in no-tillage maize (IITA, first season 1976).

Treatment	(kg/ha)	Timing[1]	Control rating[2] Sod	Weeds G 1st	G 2nd	BL 1st	BL 2nd	Grain yield (kg/ha)
1. Glyphosate + Primextra[1]	0.72+2.5	PP	70	86	35	89	59	3238
2. "	1.3+2.5	PP	98	86	47	90	35	3833
3. Glyphosate + atrazine + alachlor	1.5	PP	89	83	55	99	80	3225
4. Glyphosate + Primextra	2.0+2.5	PP	96	91	55	100	74	3622
5. Glyphosate fb Primextra	2.0 fb 2.5	PP fb PE	100	98	73	100	76	3131
6. Glyphosate fb atrazine + alachlor	1.3 fb 1.0+1.5	PP fb PE	93	96	52	100	77	3570
7. Paraquat + atrazine + alachlor	1.0+1.0+1.0	PP	45	78	33	95	85	3074
8. Paraquat + Primextra	1.0+2.5	PP	50	77	38	93	59	3507
9. Paraquat fb atrazine + alachlor	1.0 fb 1.0+1.5	PP fb PE	60	96	55	96	70	3243
10. Paraquat fb Primextra	1.0 fb 2.5	PP fb PE	50	97	60	99	77	3501
11. Paraquat + Hand weeding	1.0	Weekly	–	100	100	100	100	3914

[1] PP = Preplant, for other abbreviations and rating scale see previous table.
[2] Sod kill rated at 28 days after treatment weed rating at 28 & 60 DAP.

applications of fluorodifen plus propanil (1.5 + 2.0 kg/ha) and bentazon at 2.0 kg/ha. Highest crop yield was obtained with postemergence application of fluorodifen plus propanil. Delayed application of a formulated mixture of propanil plus thiobencarb reduced weed control by this formulation. Formulated mixture of propanil plus silvex and granular 2,4-D were very effective against sedges. Yield was significantly reduced when only one manual weeding was carried out under the poor water management conditions of this study. Prevalent weeds in the weedy check were *Heteranthera* spp, *Sphenochloa zeylanica* Gaertn, *Alternanthera sessilis* (L.) R. Br. ex Roth, *Pentodon pentandrus* (Sehum & Thonn.) Vatke, *Leptochloa caerulescens* Steud, *Pycreus* spp, *Cyperus difformis* L and *Fimbrystylis* spp.

Herbicide evaluation in hydromorphic rice was carried out at IITA using TOS 2583 rice cultivar. Herbicides that gave good weed control under lowland conditions performed poorly in hydromorphic rice. An early post-emergence application of fluorodifen plus propanil (2.0 + 2.0 kg/ha) however gave acceptable weed control (Table 50). Paddy yield from weed-free plots was superior to yields from herbicide treated and hand weeded plots. Yield reductions caused by weeds in weedy plots and in plots that were weeded twice were 92 percent and 50 percent respectively, relative to the weed-free plots.

In order to reduce weed competition in hydromorphic rice, it may be necessary to increase the crop's inherent ability to compete with weeds. Row width was uniformly altered using Nelder's systematic design in a drilled hydromorphic rice trial. Weed control treatments included no weeding, weeding once, weeding twice and weed-free. Row width varied from 6 cm near the center of the circle to 60 cm at the circumference.

At crop maturity, weeds and crops were harvested from each of 60 acres of concentric circles. At a row spacing of 24 cm or less, yield reduction associated with each of the weeding frequencies was less than 20 percent of the weed free check. Yield reduetions due to weed competition increased in all weeding treatments with increase in row spacing (Fig. 18). Weed growth was greatly reduced as row width decreased below 30 cm (Fig. 19). Better weed control in hydromorphic rice should be possible at eloser row spacing than the 30 cm used in hydromorphic rice herbicide evaluation.

Grain legume

Susceptibility of cowpea to early weed competition and its

Table 49. Weed control in direct-seeded rice (cv. TOS 42) 1976.

Treatment	Rate (kg/ha)	Time	Dry wt weeds kg/ha BL	G	S	Crop[1] injury	Paddy yield kg/ha
1. Fluorodifen + propanil	1.5 + 2.0	14 DAP	3.9	0	100.7	0	5918
2. Bifenox	2.0	PE	0.7	7.4	39.6	23	5089
3. Bentazon	2.0	14 DAP	1.1	0	51.6	8	5061
4. Propanil + thiobencarb	2.2 + 2.0	7 DAP	2.8	0	86.0	0	4877
5. Propanil + thiobencarb	2.2 + 2.0	21DAP	0	0	126.3	0	4104
6. Propanil + silvex	2.9 + 0.9	14 DAP	14.7	0	33.3	3	4781
7. 2,4-D (granular)	0.75	28 DAP	21.1	0	21.1	0	4724
8. Thiobencarb	3.0	14 DAP	293.7	0	42.5	0	2863
9. Hand weeding	–	21 DAP	115.1	2.1	126.7	0	4389
10. Hand weeding	–	14 + 42 DAP	8.1	0	7.7	0	4764
11. Weed free check	–	Weekly	138.9	0	413.3	0	2373
LSD 0.05							543

[1]Injury rating at 3 WAP: 0 = no injury, 100 = complete kill; Mean of 3 replications.

Table 50. Weed Control in hydromorphic rice (IITA 1975).

Treatment	Rate (kg/ha)	Timing[1]	Weed control rating G 1st	G 2nd	BL 1st	BL 2nd	Paddy yield (kg/ha)
1. Fluorodifen + propanil	2.0 + 2.0	14 DAP	79	58	80	52	1725
2. Bifenox fb propanil	2.0 fb 2.0	PE fb 14 DAP	84	67	91	72	1462
3. Rilof H3	2.0	14 DAP	72	48	74	26	1124
4. Propanil + silvex	2.9 + 0.9	14 DAP	62	33	70	42	733
5. Benthiocarb + propanil	2.0 + 2.2	14 DAP	83	62	76	46	676
6. Bifenox	2.0	PE	57	39	63	45	649
7. Hand weeding	–	14 + 42 DAP	53	60	71	57	1171
8. Weed free check	–	–	100	100	100	100	2360
9. Weedy check	–	–	0	0	0	0	197
LSD 0.05							596

[1]For key to abbreviations and weed rating scale see previous Table.
[2]Plots rated at 39 and 90 DAP.

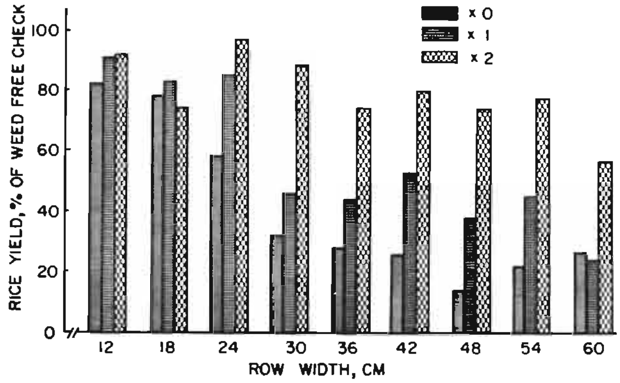


Fig. 18. Effect of row width and weed competition on rice yield.

marked sensitivity to commonly available grain legume herbicides constitute a major constraint in developing satisfactory weed control practices for this crop. During the early rains, a semi-erect cowpea cultivar (VITA-5) was planted and sprayed weekly with Gammalin 20EC insecticide (3 ml product in one litre of water). Metolachlor at 2 or 3 kg/ha applied preemergence to both the crop and weeds gave good control of annual weeds. Grain yield in treated plots was as good as in the weed free check (Table 51).

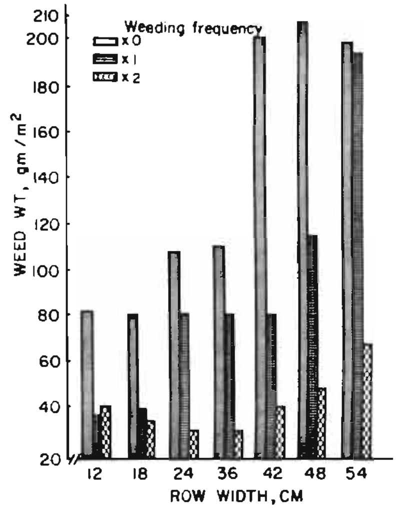


Fig. 19. Effect of row width on weed growth.

Euphorbia heterophylla L is a serious weed in cowpea and none of the herbicides tested controlled it effectively. Alachlor at 2.0 kg/ha is tolerated by cowpea, but injury has been observed where applications are made on wet soils.

Methods of controlling weeds in cropping patterns receive increased attention from scientists.

Root and tuber

Yam. Several methods of weed control were evaluated in white yam (*Dioscorea rotundata* L. var Nwaipoko). When weeds were not controlled they caused above 50 percent reduction in yam yield (Table 52). At least three hoe weedings were observed to be necessary in order to minimize yield reduction caused by weeds. All the herbicides tested significantly reduced tuber yield relative to the weed free check. All the herbicides with the exception of diuron (4.0 kg/ha) failed to control weeds for the first three months after planting the yam.

Cassava. There was good weed control in cassava without noticeable crop injury in preemergence treatments involving fluometuron (2-3 kg/ha), formulated mixture of atrazine plus metolachlor (2.5 kg/ha), and diuron (2.0 kg/ha). These treatments gave cassava yields that were comparable to yields from the weed-free treatment (Table 53).

Table 51. Weed control in cowpea (IITA, first season 1976).

Treatment	Rate (kg/ha)	Timing*	D.W. weeds (kg/ha)	Grain yield (kg/ha)
1. Alachlor	2.0	PE	258	842
2. Butralin	4.0	PE	4632	574
3. Chlorbromuron + metolachlor	1.5 + 1.5	PE	449	510
4. Metolachlor	2.0	PE	166	986
5. Metolachlor	3.0	PE	12	977
6. Oryzalin	3.0	PE	2516	492
7. Paraquat	0.25	14 DAE	1181	748
8. Hoe weeding	–	14 DAE	855	554
9. Weed free check	–	–	0	942
10. Weedy check	–	–	3310	216

For key to abbreviations, see previous table.

Agricultural economics

Cropping systems

Analysis of long-term fertility trials. Trials conducted on Egbeda and Apomu soil series by the soil fertility scientist during 1972-75 were analyzed to assess whether artificial fertilizers could economically substitute for the bush-fallow phase in shifting cultivation.

Data on maize yields, applied nitrogen and phosphorus, pan evaporation, rainfall and a soil test for phosphorus were submitted to a series of regression analyses (Table 54). Points to emerge during model development were:

1. The Bray No. 1 extractable P values did not provide a useful contribution to the explanation of yield variability;

Table 52. Weed control in Yam (D. rotundata) IITA, 1976.

Treatment	Rate kg a.i./ha	Time	Weed Control[2] Broadleaves 1st	2nd	3rd	F.W. Grasses 1st	2nd	3rd	F.W. Tuber t/ha
1. Simazine	5.0	PE	95	89	46	98	74	58	13.3bcd[3]
2. Primextra[1]	3.0	PE	96	82	40	97	85	64	14.2bcd
3. Diuron	3.0	PE	93	76	33	95	84	59	15.4bcd
4. Diuron	4.0	PE	97	99	75	95	86	74	14.6bcd
5. Ametryn	3.0	PE	93	74	14	91	73	40	9.2d
7. Gesaten[1]	3.0	PE	89	47	21	90	74	56	13.0bcd
7. Simazine + metolachlor	1.5 + 2.0	PE	95	80	18	98	87	68	15.9bc
8. Gramuron[1]	2.8	PE	97	97	78	78	63	13	15.1bcd
9. Hoe weeding	–	14 + 42 + 84 DAP	72	81	84	71	78	86	18.6ab
10. Hoe weeding	–	21 + 56 DAP	64	93	54	62	93	61	14.8bcd
11. Weed free check	–	–	100	100	100	100	100	100	22.4a
12. Weedy check	–	–	0	0	0	0	0	0	10.3cd

[1] *Trade names.*
[2] *Weeds rate 35, 65 and 91 DAP*
[3] *Means followed by the same letter are not significantly different at the 5% level using Duncan's multiple range test.*

Table 53. Weed control in cassava (cv Isunikankiyan) IITA, 1976.

Treatment	Rate kg/ha	Time	Weed control Broadleaves 1st	2nd	3rd	Grasses 1st	2nd	3rd	F.W. roots (t/ha)
1. Fluometuron	2.0	PE	99	84	68	98	81	73	12.4
2. Fluometuron	3.0	PE	100	79	67	99	83	77	10.3
3. Primextra[1]	2.5	PE	100	80	56	97	70	56	10.4
4. Gramuron[1]	2.8	21 DAP	100	87	82	100	78	59	10.3
5. Diuron	2.0	PE	96	64	70	95	59	34	11.3
6. Terbutryn	3.0	PE	100	80	63	98	68	45	8.7
7. Hoe weeding	–	21 + 56 DAP	87	92	88	83	94	93	14.6
8. Hoe weeding	–	14 + 42 + 70 DAP	75	83	89	75	73	83	12.0
9. Weed free check	–	Weekly	100	100	100	100	100	100	12.8
10. Weedy check	–	–	0	0	0	0	0	0	4.6
LSD 0.05									3.9

[1] *Trade names*
Plots rated at 39, 67 and 90 DAP.

2. Average daily pan evaporation readings during the first 6 WAP did not vary greatly between years so it could not be treated as a variable;
3. Both soil series exhibited declining crop productivity over time irrespective of fertilizer treatments;
4. Fertilizer responses were not intrinsically related to the number of years that had passed since the bush-fallow period. That is given the same weather, optimal N and P applications would be the same in each of the four years.

The estimated response functions were used to calculate profit maximizing N and P levels for subsidized and unsubsidized fertilizer prices and for low and 'average' rainfall conditions (Table 55). Because the Egbeda site showed linear returns to nitrogen application, it was more profitable to apply either nitrogen, or the minimum rate for the trials, depending on relative prices.

Table 55 shows that:

1. In terms of maize yields, the Apomu soils series was

Table 54. Maize yield – fertilizer response functions for Egbeda and Apomu soils series.

Independent variables	Mean value	Range Min	Range Max	Egbeda bi	Egbeda t value	Apomu bi	Apomu t value
Constant	–	–	–	1901	6.10	957.9	3.01
N_2 (kg/ha)	60.00	0	120	-9.084	-2.93	15.63	3.02
N	5538	0	14400	not included		-0.05885	-1.63
P_2 (kg/ha)	30.00	0	60	27.93	2.74	15.52	1.50
P	1385	0	3600	-0.5685	-4.23	-0.2533	1.76
N.P.	1800	0	7200	-0.1884	3.67	not included	
Rain* (mm/day)	4.475	0.9	6.8	1132	8.97	1134	8.25
$Rain_2$	25.01	0.81	46.24	-79.36	-5.22	-70.34	-4.18
N. Rain	268.5	0	816	1.604	2.98	2.147	3.75
P. Rain	134.3	0	408	4.435	4.12	3.416	2.98
Year	2.5	1	4	-599.3	-7.30	-1123	-13.20
R_2				0.78		0.77	
Durbin Watson statistic				1.89		1.93	
Residual root mean square				762.8		802.4	
N				208		208	

Rain is the average rain per day in the second six-week period after planting.*

Table 55. Optimal fertilizer applications.

Base yield (no fert.)	Unsubsidized fertilizer prices N	Unsubsidized P	Unsubsidized Yield**	Unsubsidized Additional net revenue	Subsidized (75%) fertilizer prices N	Subsidized P	Subsidized Yield**	Subsidized Additional net revenue
(t/ha)	(kg/ha)	(kg/ha)	(t/ha)	($/ha)	(kg/ha)	(kg/ha)	(t/ha)	($/ha)
A. Egbeda soils series								
				Low rainfall (3 mm/day)				
4.0	0	25	4.7	64	0	34	4.7	99
	120*	45	5.2	-66	120*	53	5.3	126
	( )				( )			
				Average rainfall (6 mm/day)**				
5.2	0	37	6.5	130	0	45	6.5	179
	120	57	7.9	127	120*	60*	7.9	330
B. Apomu soils series								
				Low rainfall (3 mm/day)				
2.6	81	26	4.5	125	120*	45	5.1	305
					(161)			
				Average rainfall (6 mm/day)***				
4.1	120	46	7.8	3.05	120*	60*	7.9	506
	(136)				(216)	(65)		

**Limited to trial maxima (actual 'optima' in brackets)*
***First crop after bush-fallow. Yields in subsequent years decline by 0.6 t/h/yr for Egbeda and 1.1 t/ha/yr for Apomu.*
****Average of 10 years' data, 1965-74, University of Ibadan, 2nd six-week period after planting for crops planted mid-April.*

Prices assumed: *US$0.15/kg maize*
$1.50/kg P applied ($0.375 subsidized)
$1.50/kg N applied ($0.375 subsidized)

Opportunity interest rate 25%

i.e. unsubsidized price ratio $\frac{N,P}{Maize} = \frac{12.5}{1}$

subsidized price ratio $\frac{N,P}{Maize} = \frac{3.125}{1}$

more responsive to fertilizer applications than the Egbeda series.

2. In future trials on these soils, higher levels of N, in particular, and P should be included as treatments.
3. It was economic to apply P at least 25 kg/ha irrespective of soil type, amount of rain or whether fertilizer prices were subsidized or not.
4. Nitrogen application was economic on the Apomu series generally.
5. Nitrogen application was not economic for the Egbeda series unless N prices were subsidized.
6. Despite the underlying yield decline, maize yields can reach economically viable levels after four years of cultivation, providing fertilizers are used.

Economic analysis of maize tillage systems. A preliminary economic analysis was made of the minimum versus traditional tillage experiment conducted at IITA. Field data on construction and maintenance of soil conservation works, crop operations and maize yields were analyzed for first- and second-crop seasons, 1975. Experimental blocks were about five hectares each in area; however, to simplify presentation of results, budgets were based on 25-hectare farms owning and operating the appropriate machinery. Economics of size were not investigated. Initial assumptions were:

1. For the traditional tillage system, 20 percent of land (7 percent slope) was occupied by soil conservation terraces and was therefore not available for crop production.
2. Soil erosion was controlled under both systems.
3. Long-run maize yields per cultivated hectare were the same, and constant, for both systems — 4.5 t/ha for first-season maize and 3.5 t/ha for second-season maize.
4. Fertilizer requirements were the same for both systems with fertilizer prices subsidized 75 percent.

Table 56 compares annual net revenues for the two systems for plans based on both the initial set of assumptions and modifications of the initial assumptions.

Table 56. Annual net revenues for traditional versus minimum tillage systems.

Plan		Net revenue per year* Traditional tillage	Minimum tillage
		($/ha)	($/ha)
(1)	Initial assumptions	510	720
(2)	Fertilizer unsubsidized	380	550
(3)	All land cultivated	720	720
(4)	50% additional fertilizer to minimum tillage system	510	700
(5)	Plan (4) + 85% land cultivated under traditional tillage system	560	700

**Gross revenue less fixed costs (of machinery and soil conservation works) variable costs, for two maize crops per year on 25 hectare farms.*

For all plans, net revenue for minimum tillage was equal to or greater than for traditional tillage. For plan (3) net revenues were the same for both systems indicating that the added costs due to mechanical weed control under traditional tillage were about equal to the added costs due to chemical weed control under minimum tillage.

To further relax the initial assumptions, particularly those relating to yield levels, parametric revenue equations were developed for each system:

$$NR_T = 156Y.P-137P-0.56P\,(1-S)\,R-334 \text{ and}$$

$$NR_M = 156Y-0.56\,(1-S)\,R-470$$

where

Y	= total yield (t/cultivated ha) from 1st and 2nd season crops
P	= proportion of land cultivated
R	= fertilizer application rate (kg/ha of 15-15-15)
S	= proportion of fertilizer price subsidized
NR	= net revenue (US$/ha/year)
T	= traditional tillage
M	= minimum tillage

The equations were used to construct Figure 20 — corresponding to plan (5) in Table 56, but showing continuous relationships between yield levels and net revenues, for subsidized and unsubsidized fertilizer prices.

The break-even yield levels for the two systems, as shown by the x-axis intercepts in Figure 20, are not greatly different. Also, these yield levels may not be easily exceeded on commercial farms given currently available management and technology. Forces tending to encourage the development of large-scale mechanized maize production systems employing minimum tillage rather than traditional tillage techniques would include:

1. Continuation of fertilizer subsidies.
2. Maintenance of lower rates of runoff and soil loss for minimum tillage compared with traditional tillage.
3. Achievement of higher long-term yield levels for minimum tillage compared with traditional tillage.
4. Demonstration that minimum tillage systems do not require additional fertilizer, for given yield levels, compared with traditional tillage systems.

Future prospects for either system will be affected by movements in maize and labor prices relative to prices for machinery, chemicals and fuel.

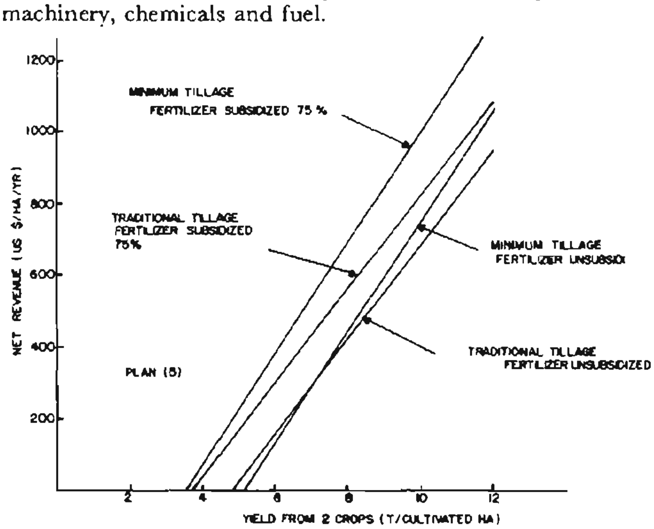


Fig. 20. Relationships between net revenues and yields for minimum versus traditional tillage systems.

On farm maize production, high rainfall. Sixty-nine farmers from three villages in southeastern Nigeria collaborated with IITA and grew sole crop maize using improved production practices during 1976. The three villages differ in population density, number of years of fallow and as a result, in soil fertility (Table 57). As mentioned in the IITA Annual Report 1975, model yields declined from 3 to 3.5 t/ha in the low-density village to below 1 t/ha on the most depleted soils of the high-density village.

Table 57. Soil analysis of maize plots in the three survey villages, 1975.

	Village/population density		
	High	Medium	Low
Years of cultivation	1-2	1-2	1-2
Years of fallow	1-2	3-4	5-6
pH	4.8	5.1	5.2
Organic Carbon %	2.77	3.15	2.74
Base Saturation %	50.38	74.40	71.28
P (Bray P1) ppm	9.60	22.12	29.75
Exchangeable K me/100 g	0.12	0.11	0.13
Effective CEC me/100 g	2.86	3.91	4.10

To quantify the factors influencing maize yields and the relative importance of these factors, a regression model was estimated using soil parameter and management factors as the independent variables (Table 58). (The partial requirement coefficients indicate the sensitivity of maize yields to changes in the levels of each explanatory variable and quantify the percentage change in yield due to one-percent change in the level of that variable).

Given the technology which included 100:50:50 NPK the model demonstrates the importance of these factors in achieving high maize yields in the area:

1. Increasing the organic carbon level.
2. Increasing the base saturation of soils.
3. The management practices of planting early, thinning the crop early, weeding the crop twice and maintaining stand density.

The largest single cost component of the recommended practice was fertilizer (63 percent of cash costs; $30/ha) which is heavily subsidized by the Government.

The percentages of farmers who would be financially worse off by using the technology than by following their traditional practices for various levels of fertilizer subsidy are shown in Table 59. If the farmers had to pay for all the cash inputs, the technology might be too risky and not sufficiently superior to present practices – particularly on the least fertile soils – (even at subsidized fertilizer prices) to be generally attractive to the typical small farmer in the region.

In summary, unless the allied problems of low-base saturation and low pH can be overcome economically, it appears that many farmers in the region are likely to be better off by not specializing in crops like maize which are more vulnerable to these soil conditions than other crops like cassava.

Table 59. Percentage of farmers who were worse off by using the "improved" technology than had they followed traditional practices.

Village	Population density	n	Level of fertilizer subsidy "Current"	50%	Nil
			%		
Okwe	Low	21	19	43	52
Umuokile	Medium	24	17	38	67
Owerri Ebeiri	High	23	74	83	91

Maize production in the derived savanna

To provide a farm-based test of the weather and fertilizer models, data were collected from 69 farmers growing maize in the derived savanna zone of Oyo State. Average yields of shelled maize recorded were 1.86 and 1.59 t/ha in the first and second seasons of 1976 respectively.

Factors influencing yields. Table 60 identifies several factors influencing on-farm maize yields in 1976. (Soil fertility indicators were not included in the analysis). The best model is consistent with the time-of-planting and long-term fertility trials. Average number of hours of sunlight was used as a proxy for evaporation/radiation as usable records for these factors were not available. Average input levels used to grow the maize crops in the first and second seasons are listed in Table 61. Except for weeding, labor and other inputs used to grow the crops were not significantly different in the two seasons up to harvest. Labor used for harvest was significantly correlated with yield (r = .056), as were labor or tractor days used to haul the cobs to the farmer's store. Most farmers used tractor hire services (government and private) and employed contract and hired labor for manual operations.

The returns to land and management from producing maize appears attractive, partly due to the high price of maize in Nigeria (when compared to world prices) and the subsidized price of fertilizer to farmers. At world prices for these commodities (including freight) the returns to land and management for the first- and second-season maize would have been $45 and $35/ha respectively.

Table 58. Factors significantly influencing maize yields on farmers' fields.

Variable		Mean Value	Min	Max	Regr. Coeff.	t value
X_0 Constant					$0.9636 X 10^{-5}$	7.83
X_1 Planting date**		25	5	48	-0.0135	0.45
X_2 Days to first weeding, DAP		23	7	65	0.3469	3.25
X_3 Days to thinning, DAP		17	7	53	-0.4368	2.12
X_4 Dummy for second weeding		-	1	2	0.4450	2.80
X_5 Density at harvest	('00)	184	106	346	0.7152	4.23
X_6 Organic carbon	%	2.90	2.00	3.71	1.2353	2.88
X_7 Phosphorus	ppm	20.73	1.36	49.95	0.1761	2.58
X_8 Base saturation	%	66.00	18.08	98.44	0.8300	7.44
X_9 pH		5.07	4.2	6.1	not included	
R^{-2}(adjusted for degrees of)					0.729	
F ratio $n_1=8$, $n_2=56$					23.513	
Durbin Watson Statistic					1.894	
s_{yx} (tons/ha)					0.375	

$Y = b_0$ X_i b_i where Y is estimated yield in tons/ha.

***Number of days after March 15, 1975 crop was sown.*

Table 60. Factors influencing maize yields, Oyo area, 1976.

Variable	Mean Value	Reqr. Coeff.	t Value
Constant, t/ha		.9074	2.69
Av. sunlight, hrs/day, 1st 6 weeks	5.08	.1014	2.93
Av. rainfall, mm = day, 2nd 6 weeks	4.64	.0469	1.56
Fertilizer, kg N/ha	59.07	.0056	1.33
No. weedings	1.65	.2577	2.27
No. years of crop since last fallow	4.49	-.1059	4.52
$\bar{R}^2$ (adjusted for degrees of freedom)		.39	
Durbin Watson		2.14	
Residual root mean square		.4528	

Table 61. Average inputs used for maize production, Oyo area, 1976.

		First Season No.	First Season $	Second Season No.	Second Season $
Average yield	kd/ha[1]	1.67	467.60	1.43	400.40
Seed	kg/ha	21	8.40	21	8.40
Fertilizer	kgN/ha	59	19.00	59	19.00
Tractor	dais/ha				
land preparation[2]		1.08	40.00	1.08	40.00
hauling[3]		.90	21.00	.75	18.18
Labor	man days/ha[4]				
planting		2.64	8.49	2.64	8.49
weeding		17.62	56.38	10.39	33.25
harvest		10.80	34.57	9.10	29.38
hauling		1.80	5.76	1.50	4.80
shell/bag[5]		13.33	16.00	11.73	14.08
Total labor		46.19	121.20	35.36	90.00
Baskets/hoes (est.)			10.00		10.00
Bags		19	15.78	16	12.88
Cash costs $/ha			235.38		198.46
Returns over cash costs			232.22		201.94
Other expenses					
Interest on annual capital			5.88		4.96
Repairs and depreciation (est.)			10.00		10.00
Returns to land and management $/ha			216.34		186.98

1. *Assumed farm-gate price for maize in large lots, $280 per ton; 10% loss between harvest and sale.*
2. *Two cultivations at $20 per hectare each. Typically took 5 days to plow one hectare (including travel, breaks etc.).*
3. *$6 per load, averaging .75 tons of cobs/load.*
4. *Labor charged at $3.20 per man day*
5. *Average $.80 per 90 kg bag (2 women thresh 2 to 4 bags a day by beating cobs in sacks).*

Root crop/oil palm farming systems

An intensive farm level survey, whose field work was completed in 1975, was conducted in southeastern Nigeria to quantify changes in farming systems, resource use and production; the productivity of land and labor; and soil properties and plant climaxes in response to increasing intensity of use of agricultural land and to assess possibilities for increasing the profitability of farming under such circumstances.

Labor allocation. Labor allocation for the three survey villages over the farming year is shown in Figure 21. The main cultivation period is the first four months of the year (wet season). The latter half of the year was a relatively slack period with respect to field work; weeding and harvesting are the major operations. The distribution of the use of hired labor follows the same general pattern as total labor with the major use of hired labor being for clearing and weeding – 30 percent each and planting 22 percent.

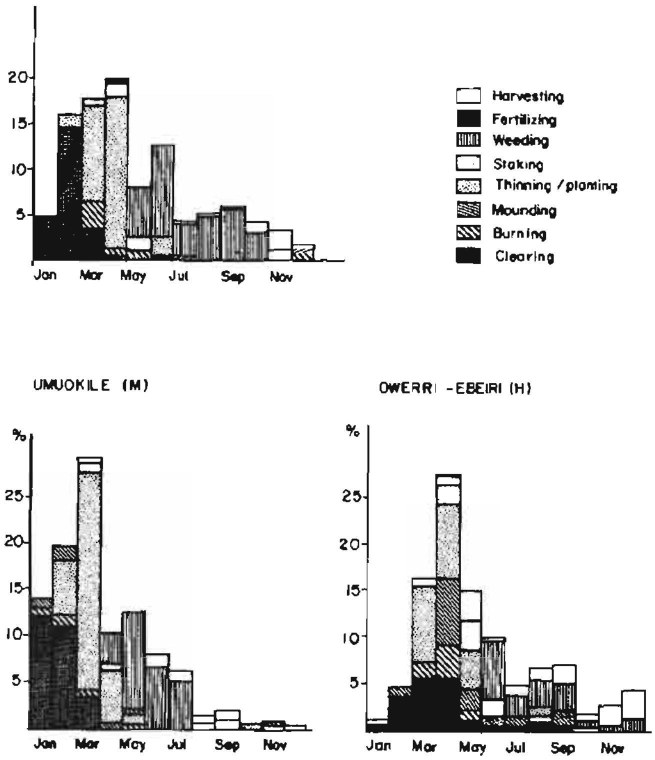


Fig. 21. Seasonal distribution of field work in three villages in eastern Nigeria, 1974/75.

Factors influencing farm production. The two most important resource factors found to influence farm income within villages were farm size and the size of the family labor force (Table 62). The marginal productivity of extra land was found to be higher the greater the population pressure, while the marginal productivity of additional labor was higher in areas where there was no land shortage or where population pressure was low. Of the fertility indicators measured, only levels of organic carbon and soil test phosphate were found to be significantly related to crop productivity.

Table 62. Relationships between farm family income, farm size and man equivalents available for farm work, three survey villages, eastern Nigeria, 1974/1975.

Man/Land Ratio		Const.	Regr. coeff.	r	n
a) Farm family income and farm size.					
Okwe	Low	323.81**	189.58**	.70**	24
Umuokile	Medium	159.85**	552.62**	.63**	25
Owerri-Ebeiri	High	33.57	832.87**	.78**	25
b) Farm family income and farm labor force.					
Okwe	Low	176.37	67.37**	.53**	24
Umuokile	Medium	161.00	60.85*	.47*	25
Owerri Ebeiri	High	87.07	54.51*	.44*	25

Farm production and sales. The farm family consumes much of what it produces. As the pressure on land use increases, the proportion of the food crops produced that are also sold diminishes, and the sale of products derived from tree crops becomes the principal source of cash income (Table 63).

General conclusions from study. The results of the survey demonstrate the impact of increasing population pressure on farm organization, management and productivity. The increasing pressure on land had the following consequences in the farming systems studied:

Table 63. Average values of total farm production and sales, E.C.S. 1974-75.

Village/population density		High	Medium	Low
Total farm production	$	391	514	768
of which food crops	%	48	45	56
tree crops	%	40	43	35
livestock	%	12	21	9
Cash income (sales)	$*	122	277	491
Sales as % of production	%	31	53	64
of which food crops	%	10	21	47
tree crops	%	77	71	49
livestock	%	13	8	4
MPC home produced crops		.46	.79	.66

1. Fallow periods were reduced, resulting in lower soil fertility, and as a result diminishing land and labor productivity.
2. Internal farm differentiation gained in importance. Farmers were found to intensify their compound farming, which involved the import of mulch from outer fields and fallows, and the use of household refuse.
3. The density of trees and arable crops increased, as did the number and range of crops grown in mixtures.
4. Livestock and tree crops increase in importance as a proportion of total farm production and cash income.

An important result derived from the survey was the somewhat neglected appreciation of the value and role of various shrubs and tree species in the farming systems. Several indigenous species provided food during food deficit periods of the year, inputs for farming and for the household, in addition to being a major source of income. But while the farmers recognized the importance of tree crops as a source of cash income, their priorities result in labor being allocated first to food crops and second to the cash (tree) crops during periods of labor scarcity.

Two points emerge from the study of food crop/tree crop associations in the forest zone. First, it seems that research aimed at developing food crop technology for these zones should be carried out in a more realistic environment than in an open field, i.e., within a food crop/tree crop complex. Second, if the output of tree crops (e.g. oil palm, cocoa) is to be increased by small farmers (which is an objective of many governments) then it will probably be necessary to increase labor productivity during periods of labor scarcity on food crops first.

National Accelerated Food Production Project

The National Accelerated Food Production Project (NAFPP) was launched to develop a "master plan" that would make Nigeria self-sufficient in the production of maize, rice, millet, sorghum, wheat and cassava.

The key components and accelerating features of the NAFPP system are research, extension and an agro-service center system.

Research. Research is brought together for greater emphasis and specialized treatment for each of the NAFPP crops through three national crop centers:

1. Wheat, sorghum and millet – Institute of Agricultural Research, Samaru
2. Maize and rice – National Cereals Research Institute, Ibadan
3. Cassava – National Root/crops Research Institute, Umudike.

The site-specific concept is employed with problem identification in the field and quick feedback to the crop centers for timely solutions. Research is designed to develop high-yielding cultivars responsive to management in two to three years instead of the normal seven to nine years, using research tools such as mini kits, production kits and risk transfer of cultivar selection to farmers.

Extension. The primary mission of the extension component of the NAFPP system is to bring research information to the mass of small-scale farmers as rapidly and as completely as possible. Feedback of problems encountered in the field are referred to State subject matter specialists, and to the research workers for solution.

Agro-Service Center System. The agro-service center system implies an integrated institutionalized delivery system for making agricultural inputs available to farmers when needed and provides a market for their produce. It makes all inputs required for agricultural production and a market conveniently available to farmers in one location.

Required inputs are agricultural technology, credit, chemicals, seeds and equipment hire. The responsibility for dissemination of inputs and providing information on product-use rests with the agro-service center management. Agro-service centers with primary and limited processing and storage have connections with national marketing systems. The method of ownership may be cooperative, private, government, or quasi-government arrangements.

Each Center will have a profit and loss responsibility. When the NAFPP is fully implemented, it is planned that farmers in major agricultural producing areas will be within 16 km. of a source of inputs and a market place.

Engineering

A major constraint to increased land and labor productivity is the peak demand for labor at various stages in the crop cycle, when the time available for a particular operation is limited either by the environment or by the characteristics of the crop. For many crops a bottleneck occurs at the field preparation and planting stages when it is vital to make the best use of the period of available rainfall for crop growth rather than in preparation for planting, thus enabling the growing of more crops within a limited time.

Field preparation, planting (seeding) and weed control should be considered together, as one invariably affects the potential of the other. Efficient manual methods of weed control require planting with constant inter-row tillage. The design of a planter needs to take into account both the pre-planting practice and the weed control system. Flexibility in design is essential to provide for various tropical crops and the physical environment and socioeconomic conditions under which crops are grown. Simplicity in design is essential. Invariably, a compromise in design is required among simplicity, cost and multiple crop use.

Figure 22 illustrates typical soil-slope zones of the humid tropics and the range of crops generally suited to each by virtue of its erodibility and soil moisture capacity. The development of energy reducing systems for crop production and the appropriate tool technology require (a) a range of crops be grown within each of these zones (b) cultural practices most appropriate to a sustained agriculture, (c) a water-regime is likely to be available, and (d) methods of weed control which may be applied appropriately.

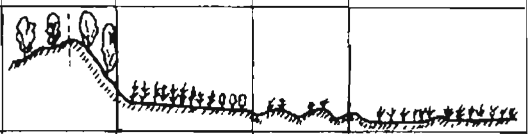
SOIL-SLOPE ZONES	UPPER/STEEP SLOPES	MIDDLE SLOPES	TOE SLOPES	BOTTOM SLOPES
				
CROP RANGE	Perennials e.g. Oil-Palm, Cacao Coconut, Rubber, Kola Fruit-trees, Timber and kindling	Cereals Maize, Rice (upland) Sorghum, Millet Grain-Legumes; Soya, Cowpea Mung, Pigeon pea. Roots: Cassava Sw-Potato. Vegetables: Melon, Okra.	Cereals Rice, Maize Roots; Yams Coco-yam Cassava Vegetables; Peppers, Tomato.	Cereals Rice (flood-irrigated) Vegetables; (raised bed)
PRE-PLANTING OPERATIONS	Contour-platforms Cover-crops	'Zero'-or-minimum-(strip) tillage (and/or herbicide)	Ridges; Raised-beds.	Tilled and levelled (bunded); Herbicides Ridges/raised beds
IRRIGATION	Rain	Rain; Sprinkler	Rain; Sprinkler; Trickle	Rain; Flood; Furrow.
PLANTING/ SEEDING	Manual	Seed: 'Jab' or 'Propelled' Planter; average spacing: Rice - 25 x 25 (150,000/ha.) Legumes - 25 x 50 (100,000/ha.) Maize - 25 x 75 (50,000/ha.) Roots: Manual - 100 x 100 Mechanised- 150 x 65		
CONTROL	Herbicide	Herbicide: Pre-planting .... Contact " Pre-emergent) " Post-emergent) .... Selective " Inter-row .... Contact Manual Inter-row .... Mechanical		

Fig. 22. Illustration of typical soil-slope zones in the humid tropics and the range of crops generally suited, with the corresponding tillage-planting-weeding practices appropriate to each.

In general, there are three levels of human energy associated with various farm operations: high (digging, ridging etc.), medium (transplanting, weeding etc.) and low ("jab" planting, "propelled" planting). The objectives in the designing of the tools being developed at IITA, therefore, are to reduce the energy and drudgery involved, increase productivity and achieve several functions per improved operation.

Hand held planters (seeders) for mulched/tilled soils. The conventional American 'jab' planter deserves further recognition. A new design of this tool for use by African small farmers was developed. The new operational techniques developed involves walking backwards (along a laid line) and simultaneously jabbing one 'hill' while compacting the preceding one, thus achieving a constant in-row spacing (25 cm). Consistent seeding rates of 20 to 30 'hills' per minute with uniform spacing have been achieved during local tests. As with the hand-fed 'jab' planter, initial training and practice are necessary to achieve a high rate of work with a minimized tendency to clog or malfunction. Seed plates are provided each for maize, cowpea, soybean, rice, sorghum, millet and also for fertilizer. So far, pelleted/granular fertilizers perform better than ground or powdered fertilizers. In terms of the present development, drawings and operational instructions are being compiled into a manual.

a. **Two-wheeled-tractor-propelled design.** The two-row 'No-Till' planter at IITA for operation with the two-wheeled (5–7 h.p.) tractor was found to suffer under heavy trash conditions like other big tractors. Development and testing will continue with the hope of achieving trouble free operation under adverse conditions occasionally encountered in tropical fields.

Development during 1976 included simplification of the transmission to the seed-feed mechanism and conversion to disc, rather than shoe-type, furrow openers.

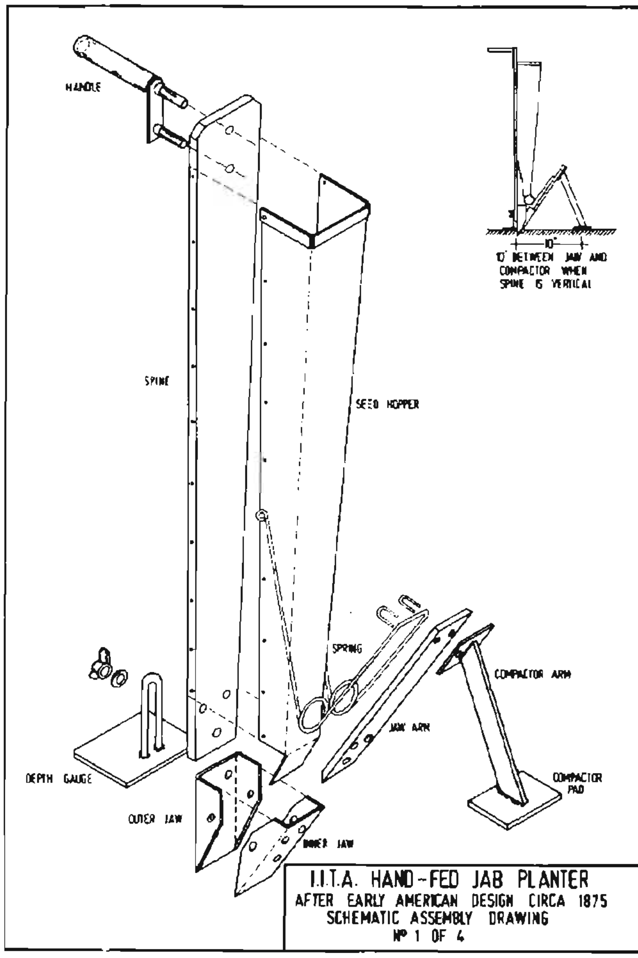


Fig. 23. Drawing illustrating instructions for constructing a hand-fed jab planter. Plans for the auto-feed jab planter can be obtained from IITA.

b. **Hand propelled design.** Trials with various hand propelled (pushed) planters have shown a rate of operation about two to three times greater than for the 'jab' planter. The hand propelled planter, however, can only be used in well tilled soils, and is therefore unsuited to 'zero-tillage'. During 1976 a feasible tool for strip-tillage has been developed and tested. A simple design of hand propelled planter is therefore being developed.

CDA Agrochemical applicator (Herbicide). The CDA (Controlled Droplet Application) or ULV (Ultra Low Volume) system of herbicide application warrants further research. At present one advantage of the CDA system is requirement of only 10 to 15 litres of water per hectare as against 500 litres using the conventional knapsack sprayer.

Inconsistencies in results from use of the CDA technique of herbicide application in the field have been investigated:

a. Uneven coverage across the swath width which is apparent at very low rates of application.
b. Tendency for strips to be left unsprayed despite careful

preparatory marking of the intended spray swath.

c. The electric motor used to spin the disc not being sufficiently rugged, resulting in inconsistent speed during operation and frequent electrical faults.

Test rigs have been built to gain a better understanding of the pattern of droplets and the corresponding swath coverage at various angles of the axis of the spinning disc. These results have led to the development and testing of units with twin spinners for broader swaths of up to 2m. per "run". Preliminary trials demonstrate that with twin spinners a more even coverage and a 50 percent increase in the ground speed over the earlier CDA method of application is possible. So far the twin spinner with 160 cm swath width appears to provide the best coverage.

The widespread adoption of the CDA sprayer is at present deterred by the limitations of the delicate small DC motor.

Table 64. Maize and cowpea: Labor requirements for conventional and an innovative system of crop establishment.

Operation	Man-Hours per hectare "Innovative"	"Conventional"
A. **Field Preparation**		
a. Mechanically slashing high growth of *Imperata*	15	
b. CDA spraying of regrowth with contact herbicide	3	
c. Slash, burn and till manually		180
B. **Seeding**		
a. Jab planting using IITA auto-jab-planter. Alternate rows maize and cow-pea 75cm × 25cm	20	
b. Manual planting of maize using a machete		20
C. **Weeding**		
a. CDA application of pre-emergent selective herbicide	3	
b. Manual weeding, twice		280
D. **Fertilizer Application**		
a. Using a hand propelled band applicator along rows of crop (30 kg N/ha)-(twice)	30	
b. Banding fertilizer by hand along rows		40
E. **Plant Protection**		
a. CDA application of insecticide, twice	5	
b. No insecticide applied		Nil
Total man-hours spent/ha to establish the crop	76	520
Comparison of yields (actual at Fashola) (1) with NAFPP average (2)	(1) 2400 kg/ha	(2) 1255 kg/ha

Note: In system (1) omission of the pre-emergent herbicide reduced yields by half!

A simpler motor suitable for local manufacture is being designed so the CDA sprayer would be as easy to operate as a torch.

Project on the design of a simple maize sheller. A popular traditional U.S. design for a hand cranked maize sheller (costing $40) was studied for possible simplification in design. A simple hand sheller costing about $1.00 to fabricate has been developed. A leaflet containing drawings for fabrication of the "Tube-sheller" and simple instructions for use is in preparation.

Preliminary field trials with the planting systems and complementary tools developed. Certain trials were conducted to evaluate the scale of improvement which might reasonably be expected if a farmer were to adopt the simplified systems and tools developed here so far.

Manual methods for preparing land for upland rice production are both laborious and time consuming. This is true even when assisted by 'contract' or hired tractor tillage for the primary operation; so is seeding. However, weeding is the most time consuming as the high moisture levels of the rice field invariably result in a profusion of weeds. While tillage with a two-wheel tractor provides an adequate seed bed for broadcast sowing, chemical weed control is necessary as an alternative to manual weeding.

The "innovative system" under test using the CDA sprayer and "Jab" planter suggests a significant reduction in drudgery and labor requirements. A relatively small cash investment in this system would enable small farmers to cope with a larger land area than the conventional methods permit.

As a means of reducing still further the 60 man hours per hectare required for jab planting an alternative of strip-tillage and propelled-seeding is potentially feasible and research in this area will be conducted in 1977. The main constraint of the approach is the high number of hills per hectare (150,000).

The potential of the 'CDA spray plant' system for establishing a crop on land heavily infested with spear grass (*Imperata cylindrica*) is illustrated in Table 64. The low manual effort and simple equipment used in the trial are noteworthy. The trial will continue.

FAO/DANIDA African Rural Storage Centre

The year 1976 was the final year of the first phase of the project. Therefore, the main aim for the year was rounding off experimental work and documenting the material collected during the first three years. In addition, the planning of an extension of the project was initiated, culminating in DANIDA approving a second phase for the period 1977 to 1978, to be entitled the "Post Harvest Engineering Centre (West Africa)."

Drying and storage of maize in the humid tropics

The effectiveness of the crib for safety drying first-season cob maize, over a three-to-four-month period (August-December) to 15 percent moisture content or below, was conclusively demonstrated, notably through the availability of some 120 tons of cob maize from IITA experiments, necessitating the use of 225 cu m crib.

The use of the crib by some farmers has been recorded in Ghana, the Republic of Benin and the south-east of Nigeria. Acceptance of the system is largely linked to situations where an effort in general extension in agriculture is being undertaken and where crib drying forms part of a package in maize production.

The control of insects in crib stored maize appears to present a major worry to farmers, partly due to the non-availability of insecticides and partly due to the unimpressive performance of many commonly available insecticides. Some encouraging possibilities have, nevertheless, been revealed through experiments conducted in 1975/76 and again in 1976/77.

Insect control in cribs

The relative effectiveness of the light stable pyrethroid Permethrin (NRDC 143) and Pirimiphos methyl was revealed in the 1975/76 experiments as is shown below in Table 65.

Table 65. Grain damage by insects 1975/76.

	% Damaged grains caused by insects						
Treatment	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.
Control	4	6	12	19	28	39	55
1% Pirimiphos methyl (15 ppm)	2	5	11	13	15	19	26
Permethrin 5, 10 & 15 ppm	2	7	5.5	5.5	5.5	5.5	5.5

The Permethrin applied at 5 ppm, 10 ppm and 15 ppm proved to contain damage below 10 percent up until the end of March, April and May respectively. The relative insensitivity of maize cobs to superficial wetting whilst in cribs was previously established by the project, suggesting scope for the use of liquid insecticides, and thus possibilities for better insecticidal coverage of cobs.

For the 1976/77 trials the main emphasis was placed on evaluating liquid insecticides, the only exception being "Perma Gaurd" a diatomaceous dust (basically silicon dioxide) applied at a rate of 3.5 kg/ton.

The monthly live insects/200 gm of grain observed in each of the treatments are shown in Table 66, together with the percentage damaged grain observed at the end of December.

Table 66. Insect control in cribs, 1976/77.

	Live insects/200 gm grain				% damage end Dec. 1976
Treatment	Sept.	Oct.	Nov.	Dec.	
A Control–nil	5	10	80	48	23.6
B Decis W.P. 5 ppm	2	7	24	31	14.3
C Perma Gaurd 3.5 kg/tonne	0	6	18	27	11.3
D Actellic–15 ppm initially only	0	10	14	22	15.5
E Actellic–nil initially, then outside sprayed monthly	0	16	6	6	7.4
F Permethrin 5 ppm	0	1	3	8	5.6

The Permethrin (NRDC 143) at 5 ppm as an E.C. is clearly the best performer (see 'F' in Table), confirming the 1975/76 findings. Two series of experiments were conducted using Actellic 50 E.C. (Pirimiphos-methyl). In one case the insecticide was sprayed at 15 ppm a.c. on to successive layers of cobs at the time of initial loading to the cribs (see 'D' in Table). In the other case no Actellic was applied initially, but after 30 days, the cribs were sprayed monthly on the outside with a 2 percent a.i. solution of Actellic. This insecticide has a fumigant effect and its effectiveness applied in this way is shown in the Table.

The Perma Gaurd performed reasonably well, although the presence of considerable quantities of dust at the time of shelling necessitates its removal.

Decis, a further synthesis of the light stable pyrethroids, performed somewhat indifferently, and may well need to be applied at a higher dosage rate.

In the case of the Control, the insect population exploded after October. In early December therefore, the outside of these cribs were sprayed with a 2 percent a.i. Actellic solution, resulting in a 3/8 reduction in insect activity by the end of December, but which naturally had no effect on insect damage sustained earlier on.

The Actellic applied initially only performed as the 1 percent dust did in the previous year, with damaged grain reaching the 15 percent level by the end of December.

Although Permethrin seems to offer the greatest hope for the future, it is not yet being produced commercially. Meanwhile, Actellic sprayed monthly to the outside of cribs in a 2 percent solution would seem to be well worth using in the control of *sitophilus* and *tribolium*.

In Ghana, a reasonably successful technique proved to be fumigation of cobs prior to loading to the cribs and then to admix the material with 2 percent Malathion at the rate of 120 g/200kg dehusked cobs. Damaged grain reached the level of about 15 percent after five months. However, the technique is cumbersome and presents many practical problems.

Maize shelling

The outputs achievable through the use of various small and intermediate-level techniques for the shelling of maize were determined and are presented in Table 67.

Table 67. Grain output achievable through various techniques.

Group	Method	Output Kg/hr	Output per day Kg/day	Persons required to carry out operation.
1	Pure hand shelling	7-12	50	1
2	Beating cobs in sacks	30-40	200-500	1 or 2
3	Tubes with internal ribs.			
	–Cast aluminum (6 ribs)	20-29	150	1
	–Mild steel (4 ribs)	20-29	150	1
	–PVC split (4 ribs)	20-30	150	1
	–Hardwood (4 projections)	15-20	-	1
4	Rotating disc–single intake	30-50	200	1 or 2
5	Rotating disc–twin intake			
	–hand operated	180-190	1000	2
	–pedal operated	190-203	1000	2
	–engine driven	270-300	2500	2

An analysis of the cost/ton and labour requirements for the alternative shelling methods, in relation to various annual tonnages to be shelled suggests the following:

1. The cost/ton using the power or hand operated twin intake sheller would be less than that using labor with the internally ribbed tubes, if some 10-11 tons or more were to be shelled per annum.
2. The power operated sheller would become more economical that its hand or pedal version if at least 20 tons would be shelled per annum.
3. The cost of the labor intensive system (with internally ribbed tube) is likely to be $13/tons or 6.5 percent of the value of maize selling at $200/ton. The cost of machine shelled maize at optimal level of employment (30 or more ton/annum) is likely to be some $5/ton, or, 2.5 percent of the value of the maize.

The beating of cobs in sacks is popular because of its relatively high output, but is somewhat limited by the heavy wear and tear of sacks (some 10 "beatings" being the expected "life" of a sack).

There is clearly scope for more efficient and economical shelling machines and techniques for operation by individual farmers with a production of up to some 10 to 15 tons of maize per annum. The machines and hand appliances evaluated thus far depend on handling of individual cobs, and it is unlikely that any dramatic improvements in the rate of shelling for these techniques is likely to result from further design refinements, because the handling of individual cobs is an inherent limiting factor.

Major Soils of West Africa

Iron toxicity in rice

The dynamics of iron toxicity in rice fields, outside of recent marine alluvial plains, were investigated. It was found that iron toxicity is, in nearly all cases, related to a source of Fe_{2+} present at a higher level in the landscape than the affected rice fields. Ferrous iron and eventually manganese in solution also is transported to the root zone by interflow. The process is schematically represented in Figure 24.

Ferrous iron is produced in a harmful concentration by weathering primary minerals under conditions of waterlogging in areas with crystalline rock, but it may also be related to plinthite formations in sedimentary parent materials. Conditions for interflow iron toxicity are most favorable in small hydromorphic valleys in areas where dominant soils are Ultisols.

Iron toxicity of this type can be alleviated by interception of the interflow water, by improving the overall drainage of the affected areas and the cultural measures, mainly by introducing a system of alternate flooding and drying of the land during the growing season. Present studies of hydromorphic soils at IITA, subject to interflow iron toxicity are providing additional data on optimized water management and land use of such soils.

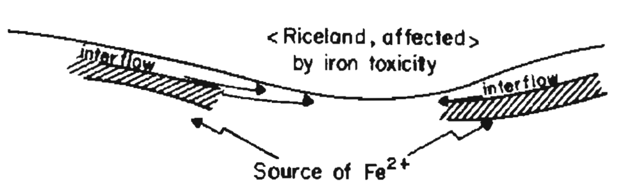


Fig. 24. Schematic representation of interflow iron toxicity in rice lands.

Studies on hydromorphic landtypes

Comparison of two management levels of rice cultivation. On newly cleared valley bottom land at IITA, rice was grown in hydromorphic soils at two levels of soil and water management:

1. According to the predominant farmers' system in most of West Africa, i.e. without irrigation on non-levelled, non-bunded land. The cultivar was OS6; 25 kg N/ha was applied at 4 WAP.
2. With slightly improved management, on bunded and partially levelled paddy fields, applying intermittent irrigation by simple diversion from an existing small stream. The cultivar was IR20; 200 kg/ha of 15:15:15 was applied, with a subsequent 40 kg N/ha as a top dressing, 6 WAP. Yields obtained for the two systems were respectively 760 and 2,370 kg/ha of unhulled rice. The difference reflects partly the higher yield potential of IR20 and partly the effect of the management type.

   An analysis of the labor input is given in Table 68, the land preparation labor in the intensified system includes the largely non-recurrent bund construction and levelling. Time for bird scaring was not included.

Table 68. First year labor requirement for rice growing under two management levels on newly cleared land.

Level	Labor in H/ha	Land preparation %	Planting %	Weeding %
Non-improved	1,900	31	22	26
Improved	6,200	54	13	14

Residual labor requirements are for such activities as water management, fertilizer application, harvesting and threshing. Bird scaring, which is critical in Africa, cannot be expressed in labor per hectare; for one crop, approximately 600 hrs of bird scaring are required. Based for unhulled rice, net returns were US $0.10¢/hr. for the low and US $0.09¢/hr. for the intermediate management level. It should be noted however, that net returns for the improved system will increase in subsequent years due to diminished labor requirement for land preparation and for weeding under proper water management. Hence, the improved soil and water management of hydromorphic soils is essential for sustained rice cultivation with increased productivity.

Effect of high groundwater on the performance of maize. Maize, grown on land with high groundwater, rapidly diminished in growth and productivity. From data gathered on the study of maize performance on a toposequence, the negative effect of high groundwater during the first six weeks after planting could be determined. Cultivars used are the current improved IITA lines. Results are represented in Figure 25.

It can be inferred that the negative effect of yield of high groundwater is both determined by the actual depth of the groundwater and by the duration of waterlogging throughout or at shallow depth in the profile. Maize planted at the beginning of the rainy season (Fig. 28b) reacted less to high groundwater than that planted during the minor dry period before the second rainy season. In the latter case, soils were more humid throughout, leading to a poorer plant development at groundwater depth, comparable to those of the first season. Implications are that on moderate hydromorphic soils early maize can be included in the cropping pattern, while maize is not suitable for such conditions in the period of higher rainfall.

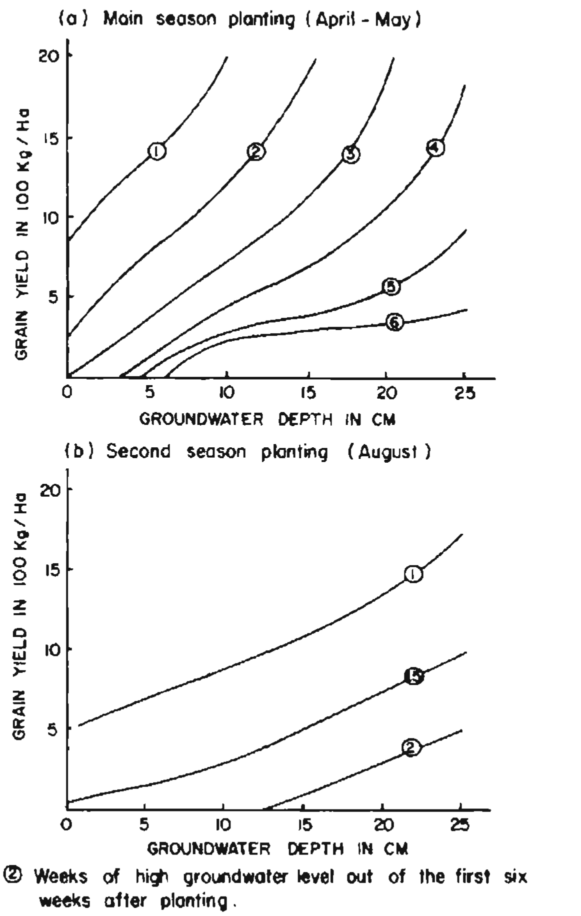


Fig. 25. Relation between yield of maize and the effect of various durations of damaging high groundwater during the first six weeks after planting.

Groundwater classes. Studies on the hydromorphic portion of a toposequence at IITA revealed that determination of the highest and lowest groundwater levels during the growing cycle of crops is a good measure for the suitability of such land for these crops. Based on several years of experimentation, groundwater classes valid for the general agro-ecological area of IITA were determined; these are schematically represented in Figure 26. Class 1 is closest to dry land conditions, and groundwater has no or little influence during the growth cycle of the crop. Class 11 is submerged during the whole growth cycle, while other classes are intermediate. These classes can be used to characterize conditions for when any given crop is to be grown; classes vary through the year according to climatic and related hydrologic conditions in the hydromorphic land.

In Table 69, a summary is given of the suitability of the 11 classes of maize, rice and cassava grown during various seasons at an intermediate level of surface drainage and fertility

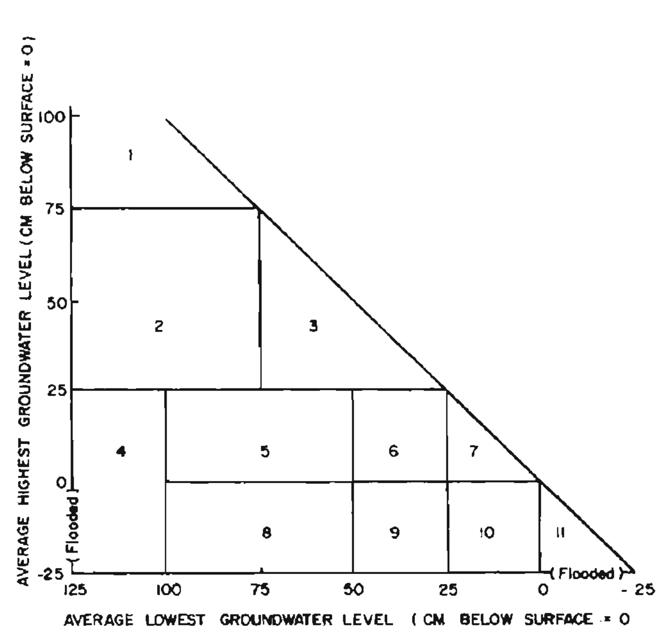


Fig. 26. Groundwater classes in function of average highest and lowest groundwater — and surface water levels during the growth cycle of annual food crops.

management. For maize, the early season starts in March after the first rains. For the first, second and dry seasons, planting of maize and rice is done respectively in April, September and December. For maize, only the first 8 WAP are used for determining crop performance of groundwater class; for rice and cassava the whole growth period was used. Six performance classes are distinguished in this study, which have been simplified in Table 69 to three groups, i.e.

A: no or little crop damage from high groundwater and/or drought.
B: moderate to severe damage.
C: marginal crop performance, or failure.

Table 69. Suitability of 11 classes of maize, rice, and cassava grown.

Gr. W.	Rice		Maize			Cassava	
Class	*First	Second	Early	First	Second	Dry	Yearly
1	B	C	C	A	B	C	A
2	B	C	C	A	B	C	A
3	B	C	C	A	B	B	A
4	B	C	C	B	B	B	A
5	A	B	B	A	B	A	B
6	A	A	B	B	B	B	B
7	A	A	B	B	C	B	C
8	A	A	B	B	B	B	B
9	A	A	B	B	C	B	C
10	A	A	B	C	C	C	C
11	A	A	C	C	C	C	C

*Season

GERMPLASM COLLECTION

During the Unit's plant collecting expeditions a total of 828 germplasm samples were added to the Institute's collections.

In Ghana, the National Crops Research Institute assisted the team in collecting 248 food legume accessions (Table 1), 116 of roots and tubers (Table 2) and 82 of rice. The rice collected included *Oryza* sativa, *Oryza* glaberrima and *(Oryza longistaminata)*.

From the northern parts of Nigeria, 212 food legumes, 160 rice and 10 root and tuber samples were added to our collections.

Seed production and distribution

The Germplasm Collection Unit has taken responsibility for the Institute's seed storage, seed production and distribution. Planned developments in these activities are not complete, but some progress has been made.

Seed production. The Kaduna State Ministry of Agriculture in northern Nigeria gave IITA 25 ha of irrigable land for seed multiplication by IITA. The land is suitable for wet- and dry-season cropping, and it has an assured supply of irrigation water. The objective in taking IITA seed multiplication to the northern Guinea Savanna zone is to obtain quality seed from disease-free crops which mature in a dry environment. In the 1976/77 dry season about 10 ha. of legumes were multiplied at IITA for Grain Legume Improvement Program.

Seed distribution. Food legume seeds were distributed in response to 226 requests from 54 countries. The numbers of requests for each food legume species were: Cowpea-95, Soybean-17, Pigeon pea-28, Lima bean-14, Winged bean-53 and Others-19.

Table 1. Legume samples collected in Ghana during 1976.

Legumes:	No. collected
Vigna unguiculata (cultivated)	111
Vigna spp. (wild)	32*
Phaseolus lunatus	56
Phaseolus adenanthus (wild)	1
Phaseolus spp. (wild)	2
Voandzeia subterranea	1**
Cajanus cajan	4**
Sphenostylis stenocarpa	9
Sphenostylis holosericea (wild)	2
Mucuna pruriens var. *utilis*	4
Mucuna spp. (wild)	2
Centrosema spp. (naturalized)	14
Calopogonum mucunoides (naturalized)	3
Canavalia spp. (cultivated)	6
Canavalia rosea (?) (wild)	1

**Wild Vigna species include V. unguiculata, V. reticulata, V. racemosa, V. pubigera and V. paludosa.*

***Crops of Voandzeia in the Sudan Savanna and of Cajanus everywhere were encountered often, but without mature seed. Arrangements have been made with the CRI to gather additional samples of these and some other legume species for IITA in 1977.*

Table 2. Roots and Tubers collected in Ghana during 1976.

True seed:	No. collected
Manihot esculenta	33
Manihot glaziovii	2
Dioscorea rotundata (cayenensis?)	50
Dioscorea alata	2
Dioscorea dumentorum	2
Dioscorea spp.	8
Aerial tubers (bulbils):	
Dioscorea alata	
Dioscorea alata	7*
Dioscorea bulbifera	4
Dioscorea spp. (cultivated)	6
Dioscorea spp. (wild, probably *togoensis*)	2

**These aerial tubers of D. alata are of special interest. They were gathered from male and female flowering plants in the collection maintained by the CRI at Kwadaso (Kumasi).*

Exploration in Ghana

Full details of exploration in Ghana will be published in a special IITA report (so will the details of all other exploration missions in future, using standard format). Very briefly, some interesting points arising from Ghana are:

1. We had expected to gather many more than 452 samples. There are at least two reasons why we did not. In our attempt to cover all ecological zones and to gather a wide range of species our itinerary was arranged so that we spent at most four nights in any one base. Much travel restricted the time available for collection; it was difficult to dry, sort, package and document seed collected; and much time was spent either in "barren" parts of the Guinea Savanna zone, or in the Forest zone where many of the food crops in our mandate are rare. In trying to cover a large area in limited time we often found crops of interest bearing no fruit, or immature fruits. Severe drought during August and September, followed by flooding in October/November, especially in the north, resulted in poor crops and so restricted our collecting activity.
2. Compared with cowpeas in Nigeria those in Ghana have little diversity. Spreading, photosensitive types of few kinds are interplanted with pearl millet in the north (surprisingly rarely with sorghum). Only a non-photosensitive type with red seed was found in the moist forest and rain forest regions. It is most commonly sown in April/May for harvest July/August. An interesting cowpea interplanted with Guinea yams is widespread around latitude 7°-8° N. It climbs to 5 m or more on trees and by late November bore no reproductive organs. Its phenology deserves attention. Wild *V. unguiculata* is abundant and diverse in the northern moist semi-deciduous forest, but not elsewhere.
3. Lima beans are common in the moist deciduous forest

zone. None that we saw showed golden mosaic virus symptoms.

4. Miscellaneous "minor" food legumes were encountered unexpectedly rarely.
5. The diversity of dry upland and swamp rice in the Sudan savanna deserves more attention than we had time to give.
6. All the cocoyams we found were *Xanthosoma*. They are everywhere in the south where farmers say the cocoyams flower one year after planting in April/May. There were no reports of seed.
7. A high frequency of defoliated cassava (without *Zonocerus*) occurred where crops had suffered serious drought, perhaps aggravated by pathogens.
8. In general, apparently sterile plants of *D. rotundata* were rare. A large proportion of females bore fruit. In some areas we found *only* fruiting females and wondered where the pollen had come from.

Nigerian collection

In the Sokoto State of Nigeria, the deep-water and floating types of *Oryza glaberrima* are grown in the valley of river Sokoto which is a tributary of River Niger and flows through the northwestern part. In recent years, lesser rainfall, damage due to plant-hoppers and introduction of *sativa* cultivars is fast changing the varietal picture of the area. In coming years embankment of the rivers and the development of dams and irrigation schemes will further alter the varietal spectrum of the area. The collection of local cultivars of rice from this area was therefore considered an important and deserving priority. Collection of cowpea, Bambarra groundnut, cocoyam and yam was also undertaken during this trip with little additional cost.

Altogether 262 samples of germplasm were collected from the whole area. Their area-wise and species-wise distribution is provided in the Table 3. In so far as rice is concerned, the farmers do not rogue their fields and often a number of cultivars grow in the same field. The two species, *Oryza glaberrima* and *O. sativa* are not differentiated by the farmers. The varietal diversity seems to be poor when compared with an area of equal size in southeast Asia.

The farmers prefer cowpea to Bambarra groundnut for palatability and cultivate the former more often. Only two cultivars of cocoyam seem to be prevalent in the area.

Table 3. ***Area-wise and crop-wise distribution of germplasm collection from Sokoto State in 1976.***

	Yelwa	B. Kebbi	Argungu	Sokoto	Zuru	Total
Rice	49	45	27	27	12	160
Cowpea	13	13	5	8	6	45
Bambarra	23	7	6	2	9	47
Cocoyam	6	2	1	–	–	9
Yam	1	–	–	–	–	1
Total	92	67	39	37	27	262

TRAINING PROGRAM

The Training Program has administrative and organizational responsibilities for the following Institute activities:

1. Research training
2. Training courses
3. Postdoctoral fellowships
4. Training associated with cooperative programs
5. Seminars.

The three categories of research training are: degree-related, non degree-related and vacation student research scholarship.

To the end of 1976, IITA had received 33 Research Scholars (M.S. candidates) and 23 Research Fellows (Ph.D. candidates) from 22 universities and schools of agriculture of Africa, Australia, Europe and North America.

Potential candidates are identified by scientists, cooperative program personnel, governments, experiment stations, university deans and professors and through letters of inquiry from those who are interested in conducting their degree-related research at IITA.

Non degree-related research and training are arranged for employees of departments of agriculture, universities, research institutes, international organizations and private agencies. To the end of 1976, 47 participants (Research Training Associates) had been received from 16 countries of Africa, Asia and North America.

A participant in the research training program examines rice for disease symptoms.

Under the vacation student research scholarship program, scholarships are awarded to penultimate year students in faculties and university level schools of agriculture throughout West and Central Africa during the long vacation. Potential awardees are nominated by the deans and directors of the schools invited to participate. Those who are selected are assigned research projects in their field of interest. To the end of 1976, the Institute had awarded 94 vacation student research scholarships.

Organized training courses offered during 1976 included the following:

1. Course for WARDA rice field technicians
2. Cassava production technology and extension
3. Maize production technology and extension
4. Soil and water conservation and management research
5. Course for research workers assigned to grain legume production in the tropics
6. Crop production and seed multiplication technology and extension.

The total number served by these courses was 149 people representing 29 countries of Africa, Asia and South America. In addition, representatives of the NAFPP conducted a course at IITA for 28 Nigerian rice field assistants which emphasized rice minikits and production kits.

Postdoctoral fellowships are offered to selected, qualified applicants who have newly acquired Ph.D. degrees. Through this program the Institute helps to increase and strengthen the body of trained agricultural scientists working on problems of food crop production in the tropics. Young scientists work with experienced research scientists on relevant problems of crop production. Postdoctoral fellows, in return, help the Institute achieve its research goals by designing and carrying out research studies on priority problems.

To the end of 1976, the Institute has awarded 26 postdoctoral fellowships. In addition, there have been two Rockefeller Foundation Fellows, one IDRC Fellow and four Belgian AGCD/FAO Associate Experts assigned to IITA.

Training associated with cooperative programs. Included in IITA's cooperative agreements with national programs are clauses outlining the Institute's responsibility to provide or arrange for training related to the intent of the program. The Training Program assists in this area by determining where the required training may be obtained and by arranging for this training. To date, training for those associated with cooperative programs has been arranged at IITA, IRRI, ICRISAT, CIMMYT, Oklahoma State University, Kansas State University, the University of Wisconsin, and the National College of Agricultural Engineering at Silsoe, Bedford, England.

LIBRARY ACTIVITIES

About 1,000 volumes of books and 2,000 volumes of periodicals (back and current volumes) were acquired during 1976, bringing the collection to 10,000 books and 15,000 volumes of periodicals. We also have 2,500 pamphlets and reprints plus microfiche, microfilm and slide-set collections. Our collection of French language agricultural publications is also growing and with the increased number of French-speaking training participants and visiting scientists, it is being heavily used.

During 1976, a bibliography on yams was completed and distributed. The bibliography brings together the scattered literature on the genus *Dioscorea* beginning from the 19th century to the year 1975. We intend to publish supplements to this bibliography from time to time.

The bulk of the work was completed on a bibliography on farming systems research in Africa. A bibliography of plantains was also finished bringing together the world literature on the subject.

The International Grain Legume Information Center is a special project of the Library and Documentation Center supported by an IDRC grant. Its objective is to collect, organize, and distribute information on selected tropical grain legumes worldwide. The Center publishes the "Tropical Grain Legume Bulletin," a publication designed as an informal communication channel to keep grain legume workers around the world informed of developments in their field. Each issue contains abstracts of current grain legume literature written by staff of the project in addition to contributions from scientists. Five issues of the "Tropical Grain Legume Bulletin" have been published and two issues are now in press.

The Bulletin is currently distributed to 917 individuals and libraries in 92 countries.

IITA library collaborated with the libraries of the other international agricultural research institutes in the compilation of a union catalogue of theses and dissertations, and a union catalogue of periodicals available in the Centers' libraries. The union catalogue of theses and dissertations has been printed at ICRISAT and distributed. The catalogue of periodicals is being printed at CIAT.

COMMUNICATIONS AND INFORMATION

Communications and Information provides editorial, translation, print, photographic, and graphic art support for IITA research and training programs and also for administration and special projects.

New efforts begun during 1976 that will be continued or expanded include design and development of exhibits and displays for use both on- and off-site, at field days and agricultural exhibitions, and initial planning and production of synchronized slide/tape presentations to orient visitors to the Institute. In the future, it is anticipated that such presentations will be developed to help individual scientists explain specific aspects of their work to interested visitors.

A French-English translator joined the staff in November 1976 and a major thrust now is to publish in both languages.

Preliminary screening of the mailing list for IITA publications now including more than 5,000 addresses was completed during 1976, and the lists will be programmed for computer printing of mailing labels. This will make it possible to readily identify specific audience groups and to channel relevant information to them. Existing publication categories are being reviewed and new ones will be developed to meet identified information needs.

PERSONNEL

Administration

W.K. Gamble, *Ph.D., director general*
M.A. Akintomide, *B.S., director for administration*
D.L.C. Pritchard, *assistant director and treasurer*
C.E. Barringer, *B.A., planning and budget officer*
D.C. Goodman, Jr., *M.B.A., assistant to the director general (Special Projects)*
R. Jacob, *assistant to the director general*
A.R. Rinde, *assistant to the director general*
K.A. Aderogba, *principal administrative officer*
S.J. Udoh, *accountant*
C.A. Enahoro, *assistant to the director for administration*
J.E. Brinkworth, *manager, data processing*
D.J. Sewell, *dormitory and food service manager*
R.O. Shoyinka, *B.S., personnel manager*
O. Adebiyi, *personnel officer*
C.I. Onah, *B.A., conference coordinator and head, visitors' services**
J.D. Abidogun, *B.S., supplies & purchasing officer*
E.A. Onifade, *security superintendent*
J.T. Okediran, *purchasing superintendent*
M.G. Etuk, *administrative assistant, Ikeja*
D.A. Kasumu, *assistant accountant*
CA.O. Nylander, *nursing sister*
S.B. Okiti, *assistant accountant*
Oye Olatawura, *housing superintendent*

Research

D.J. Greenland, *Ph.D., director of research**
J.C. Flinn, *Ph.D., acting director of research*

Genetic Resources Unit

W.M. Steele, *Ph.D., coordinator*
S.D. Sharma, *Ph.D., plant explorer*
Postdoctoral Fellow
R.B. Eastwood, *Ph.D., plant explorer*

Farming Systems Program

B.N. Okigbo, *Ph.D., assistant director and agronomist*

Soil and Environment Management

T.L. Lawson, *Ph.D., agroclimatologist*
F.R. Moormann, *Ph.D., pedologist*
B.T. Kang, *Ph.D., soil fertility specialist*
A.S.R. Juo, *Ph.D., soil chemist*
R. Lal, *Ph.D., soil physicist*
A.A. Ayanaba, *Ph.D., soil microbiologist*

Cropping Systems

G.F. Wilson, *Ph.D., agronomist (vegetable and conservation)*
I.O. Akobundu, *Ph.D., weed scientist*
T.J. Perfect, *M.S., entomologist*
A.G. Cook, *B.S., insect physiologist*
R. Yeadon, *B.S., pesticide analyst*
R.F. Chapman, *Ph.D., entomologist**
B.R. Critchley, *Ph.D., entomologist*
F.E. Caveness, *Ph.D., nematologist*

Agricultural Engineering

P.R. Wijewardene, *M.S. agricultural engineer*
E.U. Nwa, *Ph.D., agricultural engineer (soil and water)**
W.H. Boshoff, *Ph.D., agricultural engineer — FAO, (post harvest)*
J.M. Beck, *B.S., storage engineer FAO**

Agricultural Economics

J.C. Flinn, *Ph.D., agricultural economist (production)*
L.B. Williams, *M.S., planning economist, NAFPPE, Nigeria*
F.E. Winch, *Ph.D., agricultural economist*
C. Kivunja, *M.S., research associate*

Visiting Scientists

D.K. Acquaye, *Ph.D., soil chemist*
R.G. Dumsday, *Ph.D., agricultural economist**
D.G. Edwards, *Ph.D., plant nutritionist**
F.E. Sanders, *Ph.D., microbiologist**
D. DeVleeshauwer, *Ir., associate expert, FAO, soil physics*
J.M. Hoyoux, *Ir., associate expert, FAO, agricultural economics*

Research Associates and Assistants

M.O. Adeniran, *B.S., research assistant, vegetable crops*
O. Falayi, *M.S., research associate, soil physics*
A.I. Fagbamiye, *B.S., research assistant, agronomy systems*
A.C. Okeke, *B.S., research assistant, soil & water engineering*
S.N. Anekwe, *B.S., research assistant, agricultural engineering*
S.E. Ekweronu, *B.S., research assistant, agroclimatology*
E.O. Okafor, *B.S., research assistant, soil microbiology*
O.O. Ibitayo, *B.S., research assistant, agronomy*

S.D. Akindotun, *B.S., research assistant, soil physics.*

Grain Legume Improvement Program

P.R. Goldsworthy, *Ph.D., assistant director and physiologist*
F.E. Brockman, *Ph.D., agronomist, Tanzania Program*
R.A. Luse, *Ph.D., biochemist**
D. Nangju, *Ph.D., agronomist*
P.N. Patel, *Ph.D., breeder/pathologist, Tanzania Program*
S.R. Singh, *Ph.D., entomologist*
J.B. Smithson, *Ph.D., plant breeder*
H.C. Wien, *Ph.D., physiologist*
P.C. Duffield, *Ph.D., coordinator, Tanzania Program*

Visiting Scientists

E.J. Littleton, *Ph.D., physiologist*
G. Nsowah, *Ph.D., physiologist*

Post-Doctoral Fellows & Associate Experts

V.D. Aggarwal, *Ph.D., cowpea breeding*
D.J. Allen, *Ph.D., pathology*
J.P. Baudoin, *Ir., Associate Expert FAO, lima bean breeding*
K.V. Nwanze, *Ph.D., entomology*
E.L. Pulver, *Ph.D., physiology*
Z. Russom, *Ph.D., soybean breeding*
E.E. Watt, *Ph.D., cowpea breeding*
T.P. Singh, *Ph.D., soybean breeding*
W. Horst, *Ph.D., plant nutrition*
P.E. Okwuraiwe, *Ph.D., biochemistry**

Research Associates and Assistants

J.R. Knight, *visiting research associate, physiology**
F.M. Falade, *research assistant, biochemistry*
S.O. Oluwaleye, *research assistant, agronomy*
M.A. Akinpelu, *B.S., research assistant, breeding**

Cereal Improvement Program

I.W. Buddenhagen, *Ph.D. assistant director and pathologist*
P.J. Soto, *Ph.D., entomologist*
K.J. Treharne, *Ph.D., physiologist*
J.C. Ballaux, *Ph.D. Agronomist*
M.N. Harrison, *B. Sc. maize breeder*
V.L. Asnani, *Ph.D., maize breeder***
LG Rothney, *M.S., maize co-ordinator NAFPP, Nigeria*
A.O. Abifarin, *Ph.D. rice breeder*
S.S. Virmani, *Ph.D., rice breeder, Liberian Program*
J. ter Vrugt, *B.S. rice agronomist*
I.C. Mahapatra, *Ph.D., rice agronomist, Sierra Leone Program*
S.A. Raymundo, *Ph.D., pathologist, Sierra Leone Program*
A. Perez, *Ph.D., rice specialist, NAFPP, Nigeria*
S.J. Pandey, *Ph.D., sorghum/millet co-ordinator NAFPP, Nigeria*
R.B. Thakare, *Ph.D., sorghum/millet specialist, NAFPP, Nigeria*
R.J. Redden, *Ph.D., wheat specialist, NAFPP, Nigeria*

Visiting Scientist

F.M. Quin, *Ph.D., maize physiologist*

Post-Doctoral Fellows

R.A. Coker, *Ph.D., entomology*
K.A. Alluri, *Ph.D., agronomy/physiology*
Z. Siddiqi, *Ph.D., entomology*

Root and Tuber Improvement Program

S.K. Hahn, *Ph.D., assistant director and breeder*
W.N.O. Ezeilo, *B.S., coordinator, cassava center, NAFPP, Nigeria*
H.C. Ezumah, *Ph.D., cassava breeder, PRONAM, Zaïre*
P.H. Haynes, *M.S., project leader and agronomist, PRONAM, Zaïre*
G. Heys, *B.S., agronomist*
K. Leuschner, *Ph.D., pathologist, PRONAM, Zaïre*
Sidki Sadik, *Ph.D., physiologist*
E.R. Terry, *Ph.D., pathologist*
J.E. Wilson, *Ph.D., yam breeder*

Visiting Scientist

O.U. Okereke, *M.S., physiologist**

Post-Doctoral Fellows

G.S. Ayernor, *Ph.D., biochemistry and food technology*
W. Claussen, *Ph.D., physiology*
R.B. Kagbo, *Ph.D., agronomy*

Research Associates and Assistants

A.K. Howland, *B.S., research associate, breeding*
R. Aroki, *research assistant, breeding**
S.F. Oderinde, *B.S., research assistant, physiology**
J.O. Kalabare, *research assistant, breeding*

Training

W.H. Reeves, *Ph.D., assistant director and head of training*
D.W. Sirinayake, *production training officer (anglophone)*
L. Babadoudou, *Ing. Tech., production training officer (francophone)*
G. Cambier, *Lic., translator/interpreter*

Research and Training Support Units

Communications and Information

R.A. Woodis, *M.S., head*
J.O. Oyekan, *B.S., communications officer editorial*
C. Achode, *Ph.D., translator*

Visiting Scientists

E. Bortei-Doku, *M.S.*
W.B. Ward, *M.S.*

Farm Management

D.C. Couper, *B.S., farm manager*
S.L. Claasen, *M.S., assistant farm manager*
E. Bamidele, *farm superintendent*

Library and Documentation Center

S.M. Lawani, *M.S., head*
G.O. Ibekwe, *B.A., principal librarian*
E.N.O. Adimorah, *B.S., documentalist*
E.F. Nwajei, *B.A., acquisitions librarian*
Lynette Yip-Young, *documentalist, IDRC*
B.O. Adenaike, *B.S., bibliographer, IDRC*

Biometrics/Statistics

B. Gilliver, *M.S., biometrician*
M.J. Garber, *Ph.D., biometrician**
M.A. Jaiyeola, *computer programmer*

Analytical Services

B.O. Nana, *B.S., research assistant*
O. Fapojuwo, *B.S., research assistant*

Physical Plant Services

J.G.H. Craig, *assistant director*
A.C. Butler, *buildings and site services officer*
Donald Cockburn, *refrigeration services officer*
J.M. Ferguson, *fabrication services officer*
C.W. Robertson, *electrical services officer*
N. Georgallis, *scientific and electronic services officer*
O.O. Fawole, *automotive services officer*
H.C. Kinnersly, *heavy equipment services officer*
S.O. Odetayo, *electronics superintendent*

*Left IITA during 1976.
**Part year only, part year maize specialist National Accelerated Food Production Project (NAFPP), Nigeria.
***National Accelerated Food Production Project.

COLLABORATION AND TRAINING

Farming Systems Program

Collaborators

Dr. E. De Langhe, *University of Ghent, Belgium*
Dr. M.J. Swift, *University of London*
Mr. R.M. Moore, *University of London*
Dr. R.F. Chapman, *Centre for Overseas Pest Research, London*
Prof. A. Cottenie, *State University of Ghent, Belgium*
Dr. F.O. Uzu, *National Cereal Research Institute, Ibadan*
Prof. A.J. Herbillon, *University of Louvain-le-Neuve, Belgium*
Prof. M.H. Miller, *University of Guelph, Canada*
Dr. E.J. Udo, *University of Ibadan*
Dr. G. Brown, *Rothamsted Experiment Station, England*
Dr. J. Hughes, *Rothamsted Experiment Station, England*
Dr. H. Grimme, *Buntehof, Agricultural Research Station, West Germany*
Prof. T. Ajibola Taylor, *Institute of Agricultural Research & Training, Ibadan*
Prof. H. Caswell, *Ahmadu Bello University, Zaria*
Mr. L.Z. Reeves, *Central Agricultural Station, Suakoko, Liberia*
Mr. J.K. Famulo, *Central Agricultural Station, Suakoko, Liberia*
Prof. M.N. Makumbi, *University of Zaïre*
Dr. D.S. Jenkinson, *Rothamsted Experiment Station, England*
Dr. B. Mosse, *Rothamsted Experiment Station, England*
Dr. J.N. Sasser, *North Carolina State University, Raleigh, N.C.*
Dr. Ir. J.J. Smith, *Institute of Agricultural Research, Samaru, Zaria*
Mr. C.A. Igeleke, *Nigerian Meteorological Service, Lagos*
Dr. I.C. Mahapatra, *IITA/UNDP Sierra Leone Project*
Dr. O.A. Osiname, *IAR&T, Moor Plantation, Ibadan*

Research Fellows and Research Scholars

W.J. Veldkamp, *Ir., research fellow, pedology*
E. Bachmann, *Dip. Ing. Agri., research fellow, agricultural economics*
D.K. Friesen, *M.Sc., research fellow, soil chemistry*
L.E.A. Diehl, *Dip. Ing. Agr., research fellow, agricultural economics*
S.O. Afolami, *B.S., research scholar, nematology*
G.A. Agbahungba, *D.A.G., research scholar, soil microbiology*
J. Lagemann, *Dip. Ing. Agr., research fellow, agricultural economics**
K. Alli, *M.S., research fellow, agricultural economics**
D. Cummings, *B.S., research scholar, soil physics**
E.L. Dinking, *M.S., research fellow, soil microbiology*
P.O. Aina, *M.S., research fellow, soil physics**
M. Adomou, *D.A.G., research fellow, soil physics**
H.J. Pfeiffer, *research scholar, soil chemistry*
A.H. Azontonde, *D.A.G., research scholar, soil physics*

Research Training Associates and Vacation Research Scholars

R. Malafa, *Cameroon, research training associate, soil physics*
S. Adeleke, *Nigeria, vacation student research scholar, agric. engineering*
T.A. Aduragba, *Nigeria, vacation student research scholar, agric. engineering (storage)*
A. Adejumo, *Nigeria, vacation student research scholar, agric. engineering (mech.)*
A. Olufayo, *Nigeria, vacation student research scholar, agric. engineering (storage)*
J.B. Fatoyinbo, *Nigeria, vacation student research scholar, agric. engineering (mech.)*
S. Lawson, *England, vacation student research scholar, agric. engineering (mech.)*
M. Ogunjimi, *Nigeria, vacation student research scholar, soil physics*
Etina Ndoita, *Zaïre, research training associate, soil chemistry*
J. Nwachukwu, *Nigeria, vacation student research scholar, soil physics*
E.Y. Koroma, *Sierra Leone, research training associate, agric. engineering (mech.)*
R.B. Njwe, *Cameroon, research training associate, intercropping*
G. Ugwueze, *Nigeria, vacation student research scholar, soil physics*
A.O. Giwa, *Nigeria, vacation student research scholar, soil microbiology*
I.L. Turay, *Sierra Leone, research training associate, agric. engineering (mech.)*
A. Karp, *England, vacation student research scholar, entomology*
A.B. Conteh, *Guinea, research training associate, soil chemistry*
R. Butler, *Cameroon, research training associate, agric. engineering (storage)*
T. Bouare, *Mali, research training associate, vegetable production*

Grain Legume Improvement Program

Collaborators

D. Boulter, *Department of Botany, University of Durham, England*
E. Evans, *Department of Botany, University of Durham, England*
A. Eaglesham, *Soil Microbiology department, Rothamsted Experiment Station*
J. Elston, *Nottingham/Reading/IITA Photosynthesis Project*
J.L. Monteith, *Nottingham/Reading/IITA Photosynthesis Project*
R.J. Summerfield, *Plant Environment Laboratory, Reading University*
F. Minchin, *Plant Environment Laboratory, Reading University*
H.F. van Emden, *Department of Horticulture and Agriculture, Reading University*
K.A. Skipp, *Plant Growth Substances and Systematic Fungicides Unit, Wye College, University of London*
H. Marschner, *Institute of Crop Science, Technical University of Berlin*
R. Marechal, *Faculte des Sciences Agronomiques de l'Etat, Gembloux, Belgium*
C. le Marchand, *Faculte des Sciences Agronomiques de l'Etat, Gembloux, Belgium*

Research Fellows and Research Scholars

J. Detongnon, *D.A.G., research scholar, cowpea breeding*
B.M. Khaemba, *M.Sc., research fellow, entomology*
W.M. Lush, *M.Sc., research fellow, physiology**
Moffi Ta'ama, *Ing. Agr. d'Execution, research scholar, entomology*

R.S. Ochieng, *M.Sc., research fellow, entomology*
V.K. Raman, *M.Sc., research fellow, entomology**
A.J.M. vander Reijden, *research scholar cowpea breeding*
P.C. Swain, *B.S., research scholar, physiology/intercropping*
J.A. Oyefeso, *M.S., research fellow, biochemistry**

Research Training Associates and Vacation Student Research Scholars

O. Agarah, *Nigeria, research training associate, biochemistry*
Ekpe Onedo, *Nigeria, research training associate, biochemistry*
F.E. Anno-Nyako, *Ghana, vacation student research scholar, virology*
M.P. Akyeampong, *Ghana, vacation student research scholar, agronomy*
J.J. Afuakwa, *Ghana, vacation student research scholar, physiology*
J. Okonkwo, *Nigeria, vacation student research scholar, breeding*
T. Chester, *U.S.A. research training associate, entomology*

Cereal Improvement Program

Collaborators

W.D. Guthrie, *Entomology Department, Iowa State University, Ames, Iowa*
V. Gracen, *Cornell University, Ithaca, N.Y.*
E.F.I. Baker, *Institute of Agricultural Research, Samaru, Kaduna State*
J. Brewbaker, *Horticulture Department, University of Hawaii*
M. Akposoe, *Crops Research Institute, Kumasi, Ghana*
D. Sperling, *USAID/CIMMYT Tanzania Project, Ilonga, Tanzania*
D. Adedzwa, *Institute of Agricultural Research, Samaru, Kaduna State*
R.K. Raghunathan, *Institute of Agricultural Research, Samaru, Kaduna State*
N. Khayltash, *Ministry of Agriculture and Natural Resources, Plateau State*
J. Ayuk-Takem, *Bamenda Research Station, Cameroon*
K.A. Ayotade, *National Cereals Research Institute Badeggi, Niger State*
I. Amagon, *Gangnum Farm Centre, Shendam, Plateau State*
S. Matsushima, *Adarice Production Company Limited, Adani, Anambra State*
A.N. Aryeetey, *Agricultural Research Station, University of Ghana, Kpong, Ghana*
B. Lyschik, *German-Ghanaian Agricultural Development Project, Tamale, Ghana*
A.G. Carson, *Agricultural Research Institute, Nyankpala, Ghana*
J. Olufowote, *NCRI, Ibadan*
G. Heys and Chief P.U. Ohunyon, *Shell-BP, Warri, Bendel State*
Awoniyi and Abubakar, *Kwara Agricultural Development Corporation, Shonga*
P. Abraham, *Ministry of Agriculture & Natural Resources, Kwara State*
A.U. Salami, *Ministry of Agriculture & Natural Resources, Bendel State*
A.J. Chacko, *Ministry of Agriculture & Natural Resources, Rivers State*
J. Deeming, *Entomology Department, Institute of Agricultural Research, Samaru*
J-M. Bidaux, *IRAT, Bouake, Ivory Coast*

Research Fellows and Research Scholars

I.N. Timti, *M.S., research fellow, maize pathology*
H. Rudat, *Ing. Agri. Trop., research fellow, maize agronomy**
S.R. Voudouhe, *D.A.G., research scholar, rice breeding/physiology*
N. Djegui, *D.A.G., research scholar, rice agronomy**
D. Kossou, *D.A.G. research scholar, maize agronomy**

Research Training Associates & Vacation Student Research Scholars

I. Camara, *Senegal, research training associate, soil chemistry*
M. Goita, *Mali, research training associate, rice breeding*
A.I. Toure, *Mali, research training associate, rice agronomy*
P. Dolo, *Mali, research training associate, rice production*
T.A. Mtuy, *Tanzania, research training associate, maize breeding*
R. Tuni, *Tanzania, research training associate, maize breeding*
R.T. Awuah, *Ghana, vacation student research scholar, maize pathology*
G.O. Obayi, *Nigeria, vacation student research scholar, physiology*
S.A. Adepoju, *Nigeria, vacation student research scholar, rice breeding*

Root and Tuber Improvement Program

Collaborators

D. Boulter, *Department of Botany, University of Durham, England*
J.F. Bradbury, *Commonwealth Mycological Institute, London*
O.F. Esuruoso, *Department of Agricultural Biology, University of Ibadan*
A.C. Hayward, *Department of Microbiology, University of Queensland, Australia*
T.P. Hernandez, *Department of Horticulture, Louisiana State University, Baton Rouge, Louisiana*
Tunde Ikotun, *Department of Agricultural Biology, University of Ibadan*
Nizar Mohammed, *Department of Scientific and Industrial Research, Plant Disease Division, Auckland, New Zealand*
J. Meyer, *Laboratoire de Phytopathologie, Université Catholique de Louvain, Belgium*
J.F. Peterson, *Mcdonald College, McGill University, Montreal, Canada*

Research Fellows and Research Scholars

G.J. Persley, *M.S., IDRC research fellow, pathology*
V. Lawin, *B.S., research scholar, breeding*
M.O. Akoroda, *B.S., research scholar, breeding*
D.J.R. Perreaux, *research scholar, pathology*
M.T. Dahnia, *M.S., research fellow, physiology*
R. Soenarjo, *research scholar, breeding**

Research Training Associates and Vacation Student Research Scholars

N. Kilumba, *Zaire, research training associate, cassava production*
M. Msabaha, *Tanzania, research training associate, cassava breeding*
T. Azike, *Nigeria, vacation student research scholar, virology*
K. Maliki, *Nigeria, vacation student research scholar, biochemistry*
J.B.K. Kasirivu, *Uganda, research training associate, breeding*
J.F. Fumbug, *Cameroon, research training associate, cassava breeding*

Research Training Associates and Vacation Student Research Scholars

K.D. Kpegio, *Benin, vacation student research scholar, physiology/pathology*
S. Kamara, *Sierra Leone, research training associate, production*
Library and Documentation Center
H. Matip, *Cameroon, research training associate, library science*
A.B. Sesay, *Sierra Leone, research training associate, library science*

CONFERENCE AND SEMINAR PAPERS

Papers presented by IITA staff members at conferences, seminars, and workshops during 1976:

AGRONOMY

Buddenhagen, I.W. & K.J. Treharne. *The rice program of IITA — a five-year overview, 1976-1980.* Presented at the International Rice Conference. IRRI, April 1976.

Buddenhagen, I.W. *Ecosystems, pathosystems and rice improvement.* Presented at the Second Varietal Improvement Seminar, WARDA, Monrovia, Liberia.

Haynes, P.H., H.C. Ezumah and R.P. Pacumbaba. *PRONAM Review Paper* ((Mimeo). Presented at the First PRONAM Review, Kinshasa, Zaire, November, 1976.

Mahapatra, I.C. *Enhancing rice yields through improved fertilizer efficiency.* Presented at the International Rice Conference, IRRI, April 1976.

Mahapatra, I.C. & B.A.K. Kamara. *Cropping systems in uplands.* Presented at the Sixth Annual Conference of the Agricultural Society of Sierra Leone.

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Mahapatra, I.C. & S.G. Kamara. *Enhancing fertilizer use efficiency through improved cultural practices.* Presented at the FAO/NORAD Fertilizer Conference, Njala, Sierra Leone, September 1976.

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BREEDING

Ezumah, H.C. *Breeding activities of PRONAM* (Mimeo). Presented at the First PRONAM Review, Kinshasa, Zaire, November 1976.

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Vimani, S.S. and F. Sumo. *Highlights of rice varietal improvement program in Liberia.* Presented at the Second Varietal Improvement Seminar, WARDA, Monrovia, Liberia.

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COMMUNICATIONS AND INFORMATION

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Oyekan, J.O. *We Need Better Publications.* Presented at the Annual General Meeting of the Nigerian Association for Agricultural Information, Enugu, November 3-5, 1976.

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Ochieng, R.S. *The bionomics of Ootheca mutabilis, a major pest of cowpea in Africa.* Presented at the International Symposium on Pests of Grain Legumes, IITA, November 1976.

Perfect, T.J. and M.J. Swift. *The effects of DDT on biological processes in tropical soils.* Presented at the International Soil Zoology Colloquium, Uppsala, Sweden, June 1976.

Singh, S.R. *Host plant resistance: Research and development in resistance and economic usefulness of released crops in Africa.* Presented at the 15th International Congress of Entomology, Washington.

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Lawani, S.M. *Indexing and indexes.* Special lecture presented to the Lagos Division of the Nigerian Library Association, November 12, 1976.

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Akobundu, I.O. *Primextra – A new pre-emergence herbicide for weed control in tropical crops.* Presented at the Sixth Annual Conference of the Nigerian Society of Plant Protection.

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Devos, P. *Proposed standard procedure for photographing plantain for classification purposes.* Presented at the Plantain Workshop, IITA, January 27-29, 1976.

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Uzo, F.O. and A.S.R. Juo. *Response of maize to phosphate and liming in three Ultisols from southern Nigeria.* Presented at the 68th Annual Meeting, American Society of Agronomy, Houston, Texas, December 1976.

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