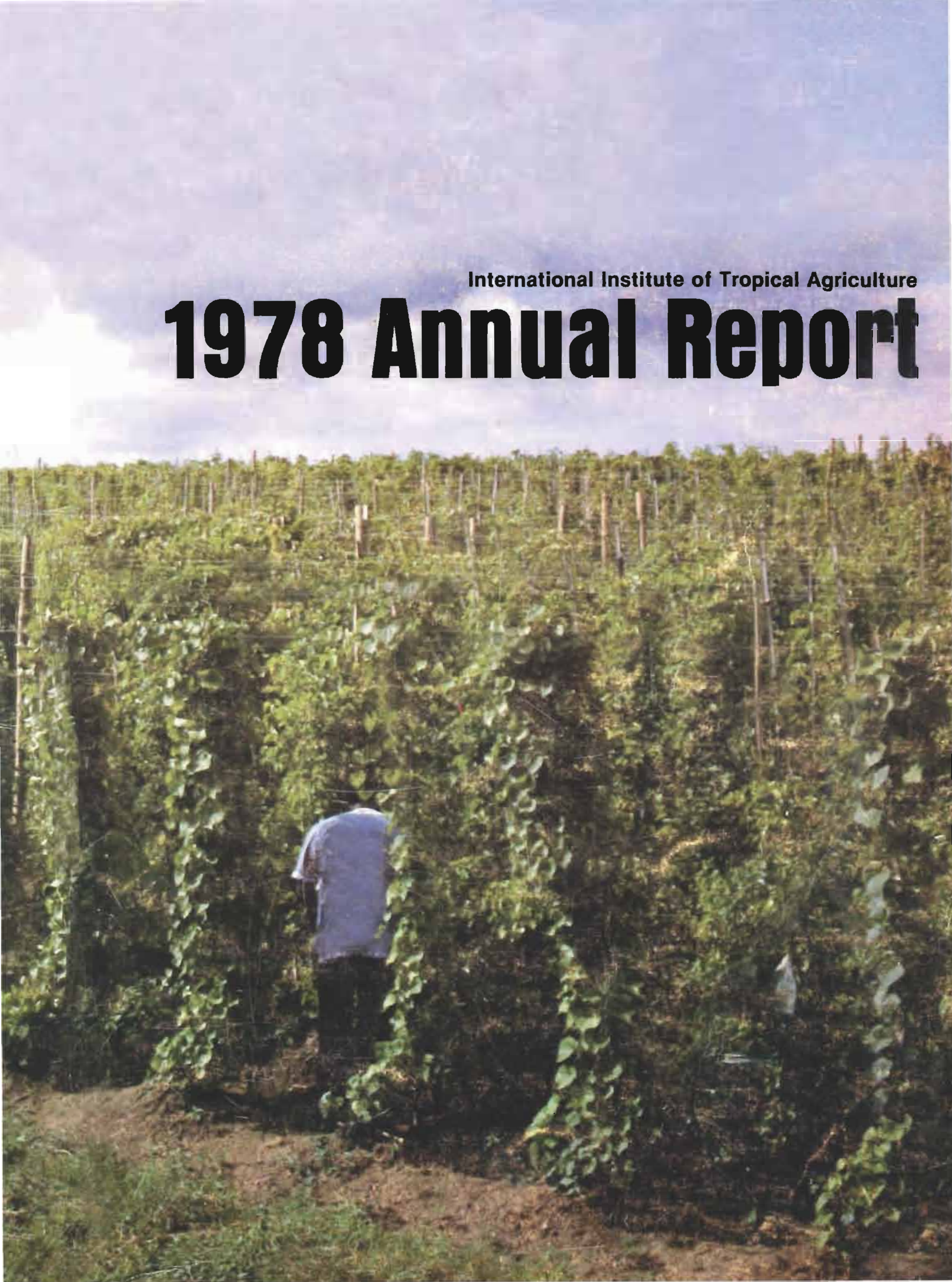
International Institute of Tropical Agriculture

1978 Annual Report



Cover Photo

White yam research plots at IITA, Ibadan, Nigeria.

1978

Annual Report

International Institute
of Tropical Agriculture

On July 27, 1967, the International Institute of Tropical Agriculture (IITA) was established as an autonomous, non-profit corporation by a decree of the Federal Military Government of Nigeria and was formally organized at the first meeting of its board of trustees in Ibadan during July, 1968.

The Federal Republic of Nigeria provided 1,000 hectares of land for the IITA site and the Ford Foundation the capital for buildings and development. Support for research and day-to-day operations in 1978 came from the Ford Foundation, the Canadian International Development Agency (CIDA), the Overseas Development Ministry of the United Kingdom, the U.S. Agency for International Development (USAID), the World Bank, the United Nations Environment Program (UNEP), and the Governments of Australia, Belgium, Iran, Japan, Netherlands, Nigeria, Norway and the Federal Republic of Germany. The Institute is governed by an international board of trustees.

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Contents

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Foreword

Located near Ibadan, Nigeria, in a transition zone between the humid and sub-humid tropics, the International Institute of Tropical Agriculture is responsible for conducting research on food crops and farming systems and for improving national research capabilities by a series of training programs.

The Institute's research for the humid tropics throughout the world is organized into three crop improvement programs — cereals, roots and tubers, and grain legumes plus a fourth program, farming systems, which brings research from the crop improvement programs together into improved farming systems for the African tropics. The Institute's research extends to several African countries through formal cooperative programs, scientific meetings, workshops and informal scientist-to-scientist contacts.

During 1978, the Institute made good progress in developing insect and disease resistant germplasm of maize, cassava, sweet potato and cowpea. Also the soybean breeding research was given greater support than in previous years to combine the good attributes of U.S. and Asiatic germplasm. A research unit on plant virus diseases and a laboratory for tissue culture were put into operation. Collection of African germplasm of selected food crops was intensified during 1978.

Results of research on tillage systems appropriate to the tropics and the design and development of low-cost machinery and tools appropriate to African farming systems are gaining wide acceptance in Nigeria and other tropical African countries.

As this report has been edited for conciseness and clarity, details that some readers require may have been eliminated. Additional information may be obtained by addressing a request to the appropriate program leader or scientist involved.

W. K. Gamble
Director General

Weather in 1978

A rather erratic rainfall pattern, with wet months alternating with dry ones, marked the weather in 1978. The distribution of the rains was also uneven on the shorter time scale, particularly during the first rainy season; this further limited rainfall effectiveness. Late rains in early November, however, effectively prolonged the second rainy season which proved to be rather productive despite a late start. Warmer temperatures generally prevailed at night during much of the year, while daytime hours were, on the whole, cooler. Insolation was comparatively better in the first and last quarters but below average during the rest of the period. The prevailing airmasses were more humid and the observed winds faster. Table 1 summarizes the observed values of the main variables.

Rainfall and evaporation

The first rains of the year came in mid-January in association with two disturbances. The total amount of water received, 17.1mm, was as usual ineffectual in view of the high moisture demand — 155.2mm. There was no improvement in February which also saw the passage of two major disturbances but little precipitation. The first of these disturbances was remarkable for its intensity, judging from the destructive effects of the associated winds. The exact strength of wind gusts could not be monitored because of instrument breakdown. Cumulative rainfall increased by only 10.4 mm. by the end of the month. (Table 1, Fig. 1.)

The first rainy season started in March (Fig. 1) and broke the six-year (1972-1977) run of below-normal rainfall for the month. Water balance in the first three weeks proved conducive to early planting (Fig. 2). A deficit, however, occurred during the fourth week and continued through much of the first week of April, subjecting crops to moisture stress ranging from mild to moderate. There was a quick recovery with the regularity of the rains following the first incidence of the month on April 6.

Dew and light precipitation

Dew and fog contributed 9.7 mm of water to the total precipitation during the period May-December. Accurate data for the balance of the year are lacking due to instrument breakdown. Assuming that the mean deposition per month during this earlier period is not substantially different from that obtained in the latter months, an estimate of 14.6 mm may be deduced for the year as a whole. This is just over 1 percent of the observed total precipitation and is comparable to the value for 1977.

A notable downpour on April 20 yielded nearly 150 mm (about six inches) of water in a little less than 7 hours,

Table 1. Summary of climatic data for 1978. (IITA Central station.)

Months	Total rainfall (mm)	Total evaporation (mm)	Solar radiation Gm-cal/ cm^2/day	Temperature °C Min	Temperature °C Max	Rel-Hum % Min	Rel-Hum % Max	Mean temp °C	Mean rel-hum %
January	17.1	155.20	427.59	19.7	33.1	31	94	26.5	63
February	10.4	161.00	465.07	24.3	35.0	35	94	29.7	65
March	123.1	153.41*	478.14	23.2	32.7	48	95	28.0	77
April	268.4	129.90*	448.76	23.1	31.0	59	96	27.1	78
May	132.1	145.60*	424.48	22.9	30.5	60	96	26.7	78
June	113.1	112.95*	388.85	22.8	29.1	64	96	26.0	80
July	204.7	94.24*	302.16	21.6	26.7	72	99	24.1	85
August	61.5	89.28*	301.60	21.7	27.3	68	97	24.5	83
September	161.9	91.92*	336.10	21.5	27.6	68	98	24.6	83
October	179.0	121.44*	411.40	22.5	29.3	64	99	25.9	82
November	86.2	118.07	463.10	21.3	30.9	49	98	26.1	74
December	0	118.60	410.41	22.6	31.4	46	98	27.0	72

Values adjusted for days with missing data.

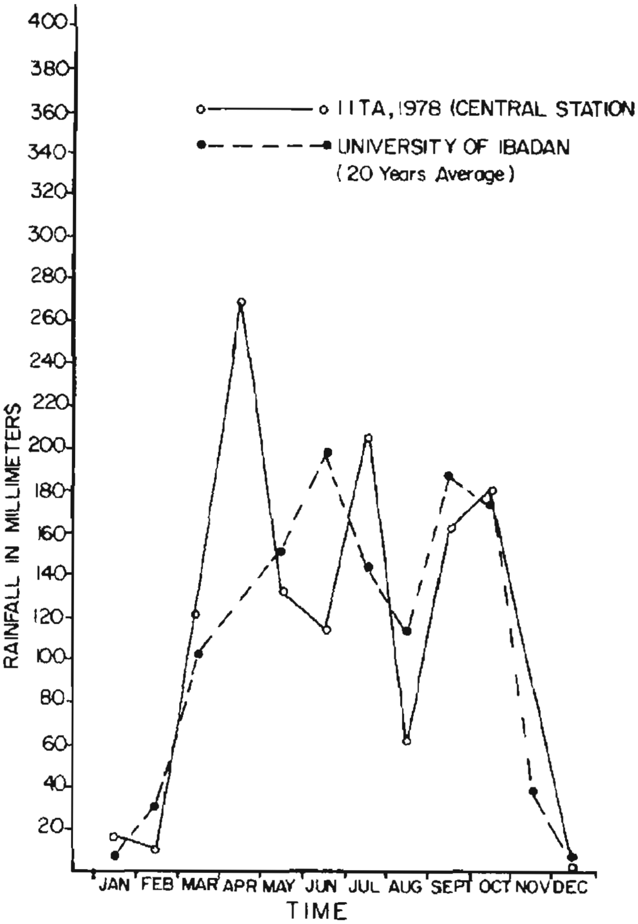


Fig. 1. Mean monthly rainfall.

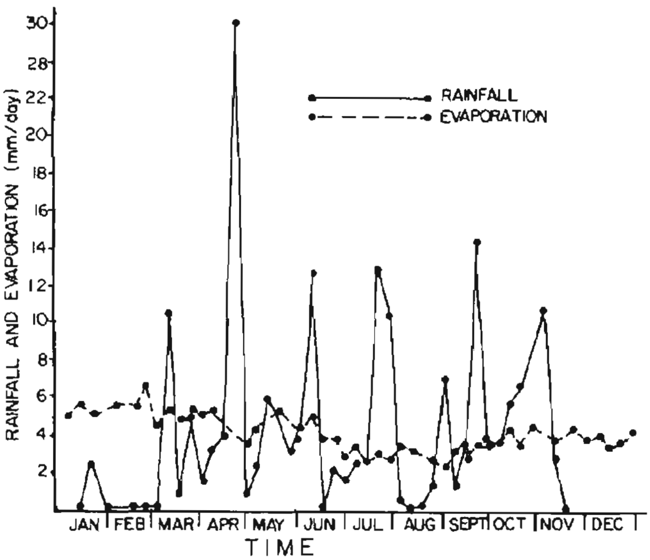


Fig. 2. Weekly mean rainfall and evaporation. (IITA, 1978.)

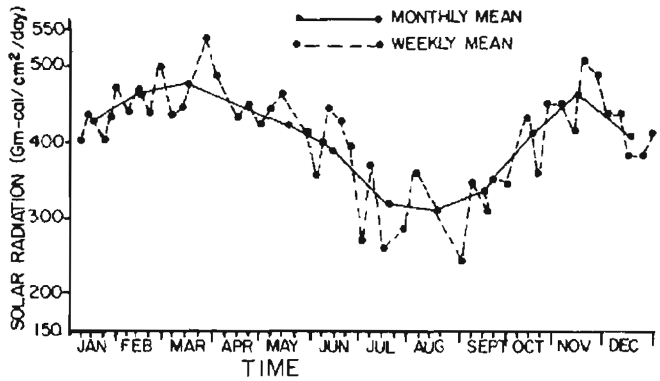


Fig. 3. Weekly and monthly mean solar radiation. (IITA, 1978.)

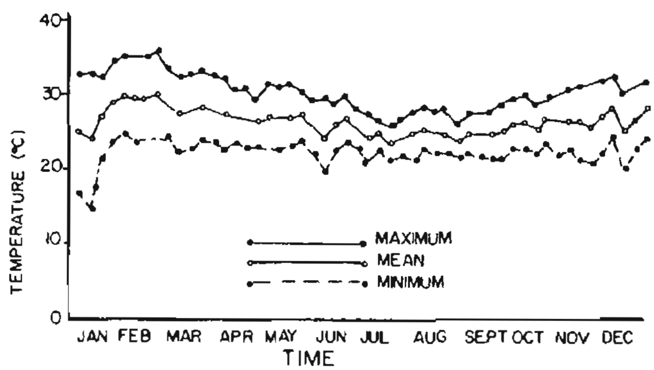


Fig. 4. Weekly mean maximum, minimum, and mean temperatures. (IITA, 1978.)

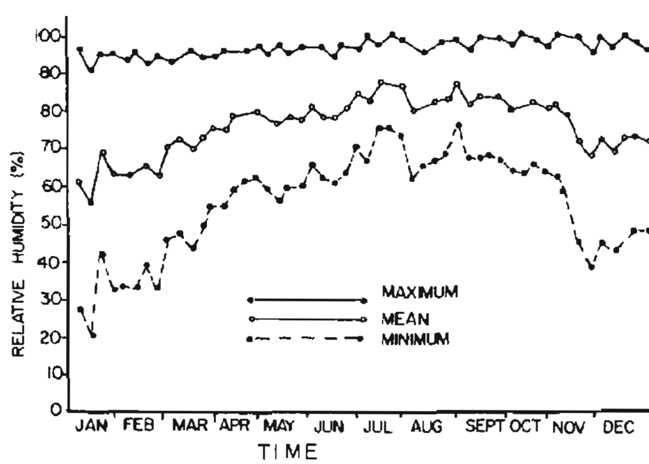


Fig. 5. Weekly mean maximum, minimum, and mean relative humidity. (IITA, 1978.)

with peak intensity of 147.5 mm/hr. over a five-minute period during the first 15 minutes. Fully 83 percent of the total amount fell in the first three hours. Soil erosion was widespread and severe in the recently tilled fields and very limited on minimum tillage plots. The total rainfall for the month, 268.4 mm, was more than double the corresponding 20-year (1953-72) mean and a record amount for the period.

A second incidence of moisture deficit occurred in early May following the rather limited rainfall in the last week of April (Fig. 2). Favorable water balance was again restored in the second and third weeks only to be followed by yet another spell of insufficient moisture in the fourth week. The total rainfall by month end showed a 13 percent deficit compared to 'normal.'

June was unusually dry (Fig. 1) with a 40 percent departure in precipitation. The strongly negative water balance experienced in the second half of the month considerably lowered the prospect for the first-season crops. July on the other hand received above average rainfall (+41%) thus maintaining the apparent continual reversal in the moisture regime. Field drying conditions remained throughout the period.

The continued dominance of south-westerly winds in February without any pronounced cloudiness meant a lesser attenuation of solar radiation than is normal for this time of year when haze prevails. Insolation was therefore above average and remained so through March. The largest departure (+15%) took place, however, in January.

A high frequency of persistent stratiform clouds during April-September resulted in a poorer light climate in the first growing season and a good part of the second. Monthly values of global radiation ranged from 448.8gm-cal/cm^2/day (4% below average) in April to 301.6gm-cal/cm^2/day (9% below average) in August. (Table 1, Fig. 3.) The largest decrease, in this case, was in July with a departure of −15 percent.

The trend in the last three months of the year reverted to that of the first three months. The higher values observed in October (4% above average) were particularly beneficial to crops under the non-limiting moisture conditions. November and December values (Table 1) both average 10 percent above their respective five-year (1972-76) mean.

Temperature/relative humidity

Above-average relative humidity (Fig. 5) prevailed throughout the year; the largest difference, +7 percent, was observed in March and December. The brief period of harmattan in early January saw a drastic drop in daytime values to an absolute minimum of 12 percent on the 4th.

The generally higher moisture content of the air from month to month meant comparatively lower radiative cooling while persistent clouds during the day prevented pronounced increases in daytime temperatures. The maxima (Table 1, Fig. 4) were thus generally lower and the minima higher in comparison to their corresponding multi-annual averages.

These departures reached extremes of +2.6°C for the average minimum temperature in February and −1.4°C for the average maximum in April. It was on the whole a warmer year.

Cereal Improvement Program

This program pursued research on genetic improvement, crop management and analysis of insect and disease problems in maize and rice.

Of particular interest in the genetic improvement of maize is the development of early-maturing and streak virus resistant populations which are in various stages of development and propagation. The performance of prolific populations remains to be determined. An intensive research on the physiology of tropical maize is reported. The studies include the selection for plant efficiency, prolificacy, and the design of tropical maize with morpho-physiological attributes of U.S. germplasm. Research data are reported on artificial rearing of maize borers, the etiology of stalk and cob rots and on field techniques for screening for maize streak virus resistance.

Genetic improvement in rice, appropriate to different systems of rice culture, each with a different set of production problems, is pursued. The main constraints under upland rice cultivation are blast disease and drought — a combination which can be devastating. Recognizing the ephemerality of "vertical" resistance to blast disease, techniques for identification of horizontal resistance have been developed. It is observed that the semi-dwarf plant-type is not incompatible with upland rice culture, but that blast or drought susceptibility is the major adaptational deficiency in many presently available semi-dwarf varieties which were primarily developed for irrigated rice.

Fe-toxicity is a major production problem in swamp rice. Varietal resistance to this stress is recognized and elite materials have been released for cultivation. Among the disease stresses in swamp rice are rice yellow mottle virus against which the land varieties of Africa have a high degree of tolerance.

Maize

Genetic improvement

Ninety-five maize introductions were evaluated for adaptation to various ecological zones of Africa. Materials introduced were inbred lines and synthetics from Zambia, populations and hybrids from India, Kenya, Ivory Coast, Mexico and the United States. Materials found to be promising were incorporated in the appropriate populations in the on-going program.

Multi-location testing

The major emphasis during 1978 was to extensively test the promising early-maturing populations which were selected and put together in 1977. The grain yield and other agronomic characters of the composites tested in these trials are given in Table 1.

Two populations, TZE 3 (Indonesia White Early — U.V. — F.S.C_2; origin — 993 × 994) and TZE 4 (Tropical Early Yellow Flint — U.V. — F.S. C_2; origin — 995 × 996), were identified to be the most promising at various locations. They yielded about 4 t/ha and matured in about 90 days.

Seeds of TZE 4 (yellow) and TZE 3 (white) are available for extensive testing and demonstration plots.

A regional maize variety trial consisting of 15 early-maturing composites developed at IITA with two local checks was organized and sent to the Republic of Benin,

Table 1. Grain yield t/ha of early-maturing composites.

Exp. cultivar	Ibadan First season	Ibadan Second season	Ikenne	Mokwa	Zaria	Kano	Average
TZE 15	2.4	2.9	5.9	4.4	5.5	2.3	4.4
TZE 4	2.7	3.8	5.6	4.2	4.6	2.1	3.8
TZE 17	2.2	3.0	4.9	3.8	5.2	2.3	3.6
TZE 3	2.0	2.5	4.8	3.1	4.5	1.5	3.1
Upper Volta (check)	0.9	1.3	2.3	2.5	3.1	1.4	1.9
TZB (check)	3.1	5.0	6.0	4.8	6.6	-	-

Togo, Upper Volta, Mali, Nigeria and the Central African Empire. Although complete data from most countries are still awaited, the general observations and the comments from these countries indicate TZE 4 to be the most promising composite in most of the locations.

Seeds of four early-maturing populations, including TZE 3, TZE 4, TZE 15 and TZE 17, were also given to the Nigerian Federal Department of Agriculture for on-farm testing and for seed multiplication by the National Accelerated Food Production Project (NAFPP). These populations have been included in pre-minikit trials to be conducted in all the states of Nigeria during the 1979 season.

Population improvement

The recurrent selection through S_1 line testing was continued in three populations: (TZB, TZPB and TZO_2) for overall improvement in three composites.

TZB: The eight cycle of selection of TZB was initiated this year. A total of 305 recombined ears were planted ear-to-row in the first season to generate a new set of S_1 lines. On the basis of yield and other agronomic characters at two locations (Ibadan and Ikenne), 34 lines were selected. The remnant seed of these lines have been planted in the third season for recombination.

TZPB: Two hundred and fifty-three recombined ears were planted ear-to-row in the second season 1978 to initiate the next cycle of selection. Altogether. 305 S_1 ears were finally selected; these will be tested in a replicated trial during 1979. Both TZB and TZPB are white populations maturing in 115-120 days.

TZO_2: One hundred and thirty-nine ears in TZO_2 population were planted in the second season to develop S_1 lines. Selected S_1 ears will be used for testing in the 1979 early season.

Plant type selection

Selection for efficient plant type in TZPB. Selection for efficient plant type under low plant population level was initiated with TZPB as a base population. A set of 280 full-sib families generated in 1977 were tested in a replicated trial at Ibadan and Ikenne in Nigeria. Grain yield of some top families selected for recombination was noted. The TZPB full sib gave the highest yield of 7 t/ha (av. of two locations) which is 68 percent higher than the TZPB check population. The mean of 22 selected families is 6.2 t/ha (av. of two locations) which is 48 percent higher than the TZPB composite. These full-sib families were recombined during the 1978 second season by chain crossing. This population. TZPB (E.P.S.) C2, will be tested against the base population in 1979 to find out the effect of efficient plant selection on the average grain yield of the population.

Selection for prolificacy in TZPB. Another approach being followed to achieve physiological efficiency and higher yield is to select plants with two good ears in the TZPB populations. (IITA Annual Report 1976.) One hundred and eighty S_2 ears and 61 full-sib families were finally selected and were planted in the breeding nursery during the 1978 second season. Several S_2 lines and full-sib families had almost all the plants showing a high tendency for prolificacy. Such families will be closely observed during the next season.

A total of 138 new full-sibs generated in the 1978 second season are now available for replicated yield trials during 1979. The best 10 families showing high frequency of prolificacy and grain yield will be recombined to produce a prolific experimental composite.

Selection in tropical × U.S. germplasm population. The objective in this study is to combine the plant architecture and high efficiency of U.S. germplasm with the adaptation and resistance to tropical diseases from the tropical materials.

Based on yield trial data and observations in the breeding nursery, 51 full-sib families were selected. One hundred and four full-sibs have been generated in the population for testing in 1979.

This population in general looks notably promising due to its plant architecture — medium height, low placed ears, fairly uniform and having reasonable resistance to tropical rust and blight. This population is also early-maturing: thus it is appropriately included in IITA's project on the development of early-maturing composites.

Maize streak resistance

Population development. Two high-yielding composites, TZSR (white) and TZSR (yellow), were synthesized based on yield performances of the best 10 full-sib families tested in the field and their reaction to maize streak virus (MSV) in the screenhouse. (Table 2.) In addition 80 full sibs of TZSR (w) and TZSR (y) and 330 S_1 lines of TZSR (w) were sent to Tanzania and Zaire. These lines and families will be evaluated and utilized in developing high-yielding streak resistant composites for the two countries. This effort represents a cooperative effort between CIMMYT and IITA on breeding for streak resistance.

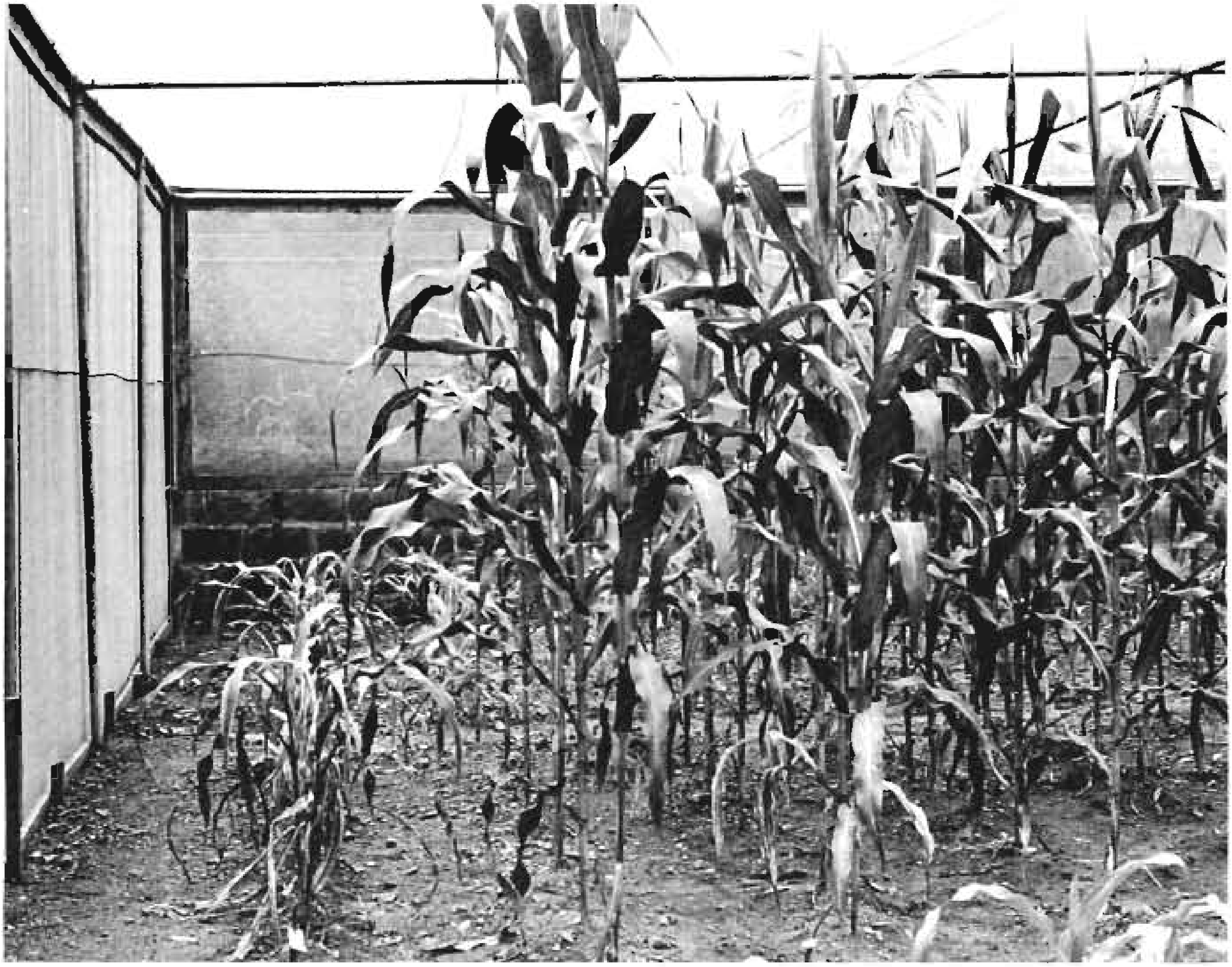
Table 2. Performance of selected full-sib progenies of TZSR composite tested at Ibadan, 1977 third season.

Pedigree (TZSR full-sib No. 5)	Grain yield kg/ha	Score for streak in the screenhouse*
236	4425	2
254	4300	1
267	4300	1
280	4300	3
31	4280	2
150	4280	2
45	4250	2.5
250	4250	3
251	4250	2
TZPB (check)	4520	4

**1 = Resistant; 4 = Susceptible*

Combining earliness and streak resistance. High-yielding and streak resistant TZSR (w) composite was used as donor parent to cross TZE populations. In 1977, the F_1 generation of streak resistant sources × early materials was grown. The plants with mild symptoms and superior agronomic characters were selected and selfed. Segregants for earliness and resistance will be recombined during 1979.

Conversion program. A number of promising populations including two mid-altitude ones were "converted"



In breeding for resistance to maize streak virus, the initial screening procedure was done under screenhouse conditions. Now, large amounts of material are infested under field conditions.

into streak resistance by crossing with IB-32, a resistant line developed at IITA. For the first time, artificial infestation by releasing viruliferious leaf hoppers in the field was tried with some success. Agronomically superior plants with a high level of field resistance under these conditions were selected and crossed to generate full-sib families in each population.

Attempts to back-cross resistant segregants to the recurrent parent failed because the recurrent parents were found to be very susceptible under the streak pressure and most of the plants were dead before pollination.

In the third season 1978, a field trial of five composites which were included in the conversion program were compared under artificial infestation conditions and under disease free conditions. The two versions which are being compared are (1) the normal variety and (2) bulk of 4-5 full-sibs having resistance to MSV from the conversion program. Disease rating of an individual plant was based on 0-5 (0 = no infection and 5 = severe infection followed with premature death of the plant) severity scale. Results from this trial showed that the level of sensitive plants was 2-8 percent in the resistant populations and more than 50 percent in the sensitive populations. The converted material yielded 200 percent more than the original counterpart in a streak situation, whereas in the disease free situation, the yield was equal to the original populations. Results of this experiment indicate an improvement level of yield in these converted populations.

An inbred parent of the East African hybrid SR 52 from Zambia is also being converted into streak resistance from an IITA resistance source. The S_1 lines and full sibs developed in five CIMMYT experimental varieties which are included in the conversion program have been sent to CIMMYT for evaluation, recombination and utilization in their program.

Modified infestation technique for MSV. After the initial screening procedure under screenhouse conditions was completed, there was need for the breeder to infest large amounts of material under field conditions to continue the improvement of streak resistance. For this purpose a field infestation method has been developed.

After acquisition feeding, 300-500 leaf hoppers were collected in a plastic vial by a modified dust cleaner. The number of vials needed depends on the size of the trial. Before release in the field, the lids of the vials were replaced by ones with a 5-mm hole. Then the leaf hoppers were anaesthesized by CO_2. By holding the vial horizontally and tapping it gently it was possible to drop 5-10 leaf hoppers into the whorl of the young maize plant. A trial infested by this method showed an overall streak incidence of 50 percent of the total plant population. However, improvement needs to be made on the distribution of the number of leaf hoppers per plant.

Major fungal diseases

Cob and stalk rots occur frequently in tropical maize and are caused by several different fungi. The ecology of the pathogens and the biology of the diseases are hardly investigated in tropical Africa. Studies were begun to determine the major cob rot pathogens; the major stalk rot pathogens, and what is termed as "pokka long." The source of inoculum for the pathogens, and their incidence as influenced by tillage (conventional vs. zero tillage) systems are being investigated.

Preliminary results indicate:

(1) *Fusarium moniliforme* occurs at high frequency in diseased kernels, as well as in symptomless kernels. From freshly harvested kernels incidence was as high as 66 percent. Kernels stored for varying periods of time maintained high frequencies of infestation . . . over 50 percent after 10-15 months.
(2) Seedlings grown from symptomless kernels contain *Fusarium moniliforme* internally at least up to 40 days, both in root and in mesocotyl tissues.
(3) Seedlings and young plants can contain this fungus without exhibiting symptoms.
(4) This same organism occurs as a major stalk rot pathogen in late stages of growth.
(5) No organism was isolated from pokka long (malformed) symptoms even though many attempts were made.

Other fungal diseases

(1) A large leaf spot hitherto undetected at IITA occurred in TZE composite, sometimes at high incidence. This leaf spot was caused by *Diplodia macrocorpa*.
(2) A leaf disease known as "physiological spot" or "genetic spot" by many maize breeders and pathologists in the tropics, and as "leopard spot" in Zambia by maize specialists there, was shown to be due to a *Chytrid*, *Physoderma* sp.

CIMMYT international testing

Three experimental variety trials, EVT 14A, EVT 14B and EVT 16, were conducted during 1978; OMVT 11 and IPTT 33 were also conducted. EVT 14A was conducted at Ibadan in the first season and OMVT 11 and EVT 16 in the second season. EVT 14B and IPTT 33 were conducted at Ikenne in the second season. Promising experimental varieties and the full sibs from IPTT 33 are listed in Table 3.

Table 3. Grain yield (kg/ha) of promising experimental varieties selected from CIMMYT international trials conducted at IITA during 1978.

(1) *OMPT 11, Ibadan 1978 Second Season*	
Pedigree	*Yield*
Eto Blanco H.E. O_2	6943
La Posta H.E. O_2	6477
Blanco Cristalino 1 H.E. O_2	6361
Yellow Flint H.E. O_2	6361
Mezcla Tropical Banca H.E. O_2	6338
TZPB (check)	6804
TZB (check)	5942
TZO_2 (check)	4404
(2) *EVT 16, Ibadan 1978 Second Season*	
Tlaltizapan 7633	4645
Obregon 7633	3898
Tlaltizapan 7642	3898
Cali (2) 7642	3871
Palmira 7434	3871
TZB (check)	4032
TZPB (check)	3578
(3) *EVT 14A, Ibadan 1978 First Season*	
Across 7526	4707
Delhi 7535	4613
Santa Rosa (1) 7624	4054
Santa Rosa (2) 7624	4054
Ludhiana 7526	3914
TZPB (check)	4753
096 EP6 (check)	3635
(4) *EVT 14B, Ikenne 1978 Second Season*	
San Andres (2) 7530	6058
Poza Rica 7523	5802
Cotaxtla (2) 7530	5732
Nyankpala 7623	5569
Ilonga 7530	5545
Across 7623	5475
TZB (check)	5429
TZPB (check)	5406
(5) *IPTT 33, Ikenne 1978 Second Season*	
Selected ten full-sib families are: AM. Sub tropical F.S. Nos. 214, 122, 208, 196, 45, 89, 70, 24, 238 and 22.	

SAFGRAD project

This was the first year for the maize work under the Semi-Arid Food Grains Research and Development project (SAFGRAD). Planning of all the maize work including the testing of breeding material at Kamboinse and Saria (Upper Volta), as well as the regional testing in cooperative countries, was coordinated with Ibadan.

Out of 146 experimental lines planted in an observation nursery at Saria, 45 populations were identified as promising and were sib-pollinated to maintain the populations. The selected entries are listed in Table 4.

Maize physiology

The maize physiology research program covered three areas during 1978:

(1) TZE, growth and yield studies.
(2) Growth and yield of U.S. Hybrids in the humid tropics.
(3) Selection criteria for plant type improvement in TZPB, with particular reference to prolificacy and plant efficiency.

By late 1977 the TZE breeding program had about 12-15 selections that were available for yield testing. These lines matured in 90 days, produced favorable yields (about 4-5 t/ha), had a plant type that was shorter, and had fewer, smaller leaves than intermediate-duration cultivars. Growth, partitioning and yield component studies were made at the same time as the yield evaluation of the selected lines to provide base line data in more depth than that of a straight yield evaluation.

Data were collected from the maize breeding 14 entry TZE yield trial (5 locations, 2 population densities). In addition, first and second seasons' plantings of some of the better selections (TZE 3, TZE 4 and TZE 15) were made at IITA. Growth was compared with check cultivars of Upper Volta for short duration and TZB for intermediate duration.

The main feature of difference in TZE lines compared with TZB is their earlier date after emergence for tassel initiation (18 days compared with 28 days) and consequently their earlier flowering, and lower leaf number. (Table 5.) Duration of grain fill is also shortened by about 10 days. An interesting feature of early-maturing lines is the formation of 18 leaves in 18 days compared with 21 leaves in 28 days in late-maturing cultivars.

Table 4. Populations selected after testing 146 experimental lines at Saria, Upper Volta 1978.

No.	Pedigree
1.	H634
2.	H763
3.	La Posta
4.	Composite 4
5.	(MIX 1 x COL GPO 1) ETO BLANCO PB
6.	Poza Rica 7428
7.	Antigua GPL x Rep. Dominicana
8.	Poza Rica 72A, Mez, Amarillo P.B.
9.	ATC 4388
10.	South African white, resistant to H. Turcium
11.	Golden Crystal
12.	Zaire/Tuxpeno x Eto
13.	Biu Yellow
14.	Mexico 18
15.	NCA RB
16.	Zaire/PN M 1
17.	Zaire/Shofa Safi x Eto Tuxpeno
18	PHIL DMR COMP #2
19.	DMR 1
20.	PHIL DMR COMP. #1
21.	DMR 2
22.	Blanco Cristauno—1
23.	Compoesto hungria
24.	Local maize Cuban Yellow
25.	Antigua G.P 2 x Rep. Dominicana
26.	Ant. GPO 2 Sel. Blanca
27.	GRH
28.	Antigua x Rep. Dominicana
29.	Indian white mixed
30.	TZB Bulk
31.	TZPB Bulk
32.	TZY Bulk
33.	Pionneer x 304 A
34.	Ant. GPO 2 x Tuxp. Sel. Blanca
35.	IDRN
36.	TZPB (Prolific) H. Sibs Bulk
37.	(IPA E2 x UV) E 5
38.	(BTB. F x UV) E 1
39.	(IPA E x UV) E 1
40.	(PBI x UV) F.S. 2
41.	(PBI x UV) F.S. 11
42.	(ATPF x PHIL DMR E 3 x UV) E2
43.	TZSR White Bulk
44.	(PBI x UV) F.S. 10 x (PBI x UV) F.S. 11
45.	(ATP.F x UV) F.S. 7 x (ATP.F x UV) F.S. 20

Yield data (Table 6) show that when leaf diseases are controlled, TZE yields are approximately what would be predicted for their duration by comparison with that of TZB. Upper Volta shows a greater shortfall because disease control was not complete for this entry.

Table 5. Phenology and plant type comparison in Upper Volta, TZE improved lines and TZB.

	UV	TZE (best) lines	TZB
Days to tassel initiation	16	18	28
Days to 50% tasseling	40	40-45	55-60
Days to maturity	80	85-90	110-115
Duration of grain fill, days	40	45	55
Total no. of leaves formed			
Modal value	17	18	21
Range	16-18	17-19	20-22
No. of nodes to first earnode			
Modal value	6	7	9-10
Range	5-7	6-8	8-11
No. of nodes above first ear		5 or 6 in all cases	

Table 6. Comparison of yields of Upper Volta, TZE 3, 4 and 15 with TZB maize. (2nd season, IITA, 1978, plant population 53,700 pl/ha.)

Cultivar	Duration days	Grain wt g/ear	Yield t/ha	Predicted yield, t/ha*
Upper Volta	81	66.0	3.54	4.81
TZE 3	87	86.6	4.65	5.16
TZE 4	90	86.2	4.63	5.34
TZE 15	90	97.6	5.24	5.34
TZB	110	121.6	6.53	
S.e.±		4.1	0.219	

**Calculated from yield of TZB x (duration of var.)/110.*

Yield components (Table 7) show that both size and number of grains per cob are responsible for greater yields of TZB. TZE lines have fewer rows per cob, fewer grains per row and fill to a smaller size. The rate of grain fill (Fig. 1) is similar. The difference in final grain weight comes from the longer grain fill period but not from greater rate of grain fill. Harvest index did not differ significantly between TZB, TZE lines and Upper Volta.

Table 7. Yield components for TZE 3, 4 and 15 compared with Upper Volta and TZB maize. (Data from IITA and Ikenne, 2nd season, 1978, at 2 plant populations, 67,000 and 44,500 pl/ha.)

	Cultivars				
	TZB	TZE 3	TZE 4	TZE 15	Upper Volta
200 Grain wt. g*					
	65.2	51.1	49.2 S.e. ± 1.37	46.8	31.9
No. rows/ear*					
	14.3	14.0	13.4 S.e. ± 0.24	13.1	12.7
No. grains/row					
67,000 pl/ha.	35.1	27.9	30.1	29.5	29.9
44,500 pl/ha.	39.1	30.7	33.5 S.e. ± 1.11	30.1	31.1

**No significant difference between spacings for these characters.*

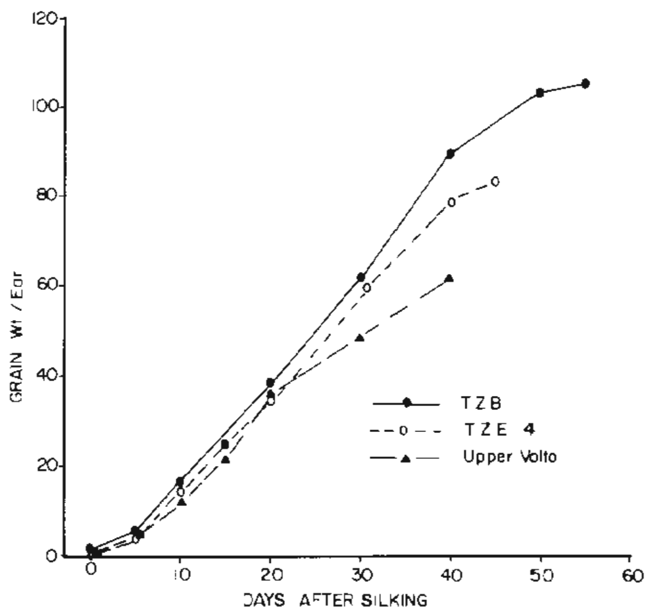


Fig. 1. Changes in grain wt. with time in TZB, TZE4, and Upper Volta.

Temperate germplasm

The purpose of this study was to answer two questions:

(1) Is the greater efficiency of dry matter partitioning into grain that is recorded for temperate germplasm a feature of the germplasm *per se*, or a feature that displays itself only when the crop is grown in a temperate environment?

(2) Is the efficiency only expressed when the crop is grown at high plant densities, when crop competition and individual plant characters influence yield and plant performance?

The reason for needing this information was to assess the rationale for using temperate germplasm for yield improvement of tropical maize.

During 1978, growth and yield of three U.S. Hybrids (H610, H638 and H652) were compared with two tropical varieties, TZPB and Pioneer Double Cross Hybrid X306B. Of necessity, the crops were regularly sprayed with fungicide for control of rust and blight.

Spacings of 1m and 40cm between plants on 75-cm rows (equivalent to 13,400 and 33,500 pl/ha respectively) were used to evaluate individual plant performance and to look at "in crop" performance at a spacing where growth and development of tropical maize was not seriously disadvantaged by closed canopy conditions.

Striking differences were noted between U.S. and tropical varieties in leaf number and size. (Table 8.) Heights of plants were similar, but ear placement was lower in U.S. varieties, so that the canopy above the ear for the same number of leaves was more open. This was more marked in the close-spaced crop.

Date of tassel initiation was slightly earlier in U.S. cultivars, at 23 compared with 28 days. Similarly, tassel emergence was about five days earlier. Maturity of the U.S. cultivars was one week earlier than in tropical cultivars.

Tropical varieties were leafier, grosser plants than their U.S. counterparts (Figs. 2, 3a. and 3b.) and consequently from the time that plants reached full height and leaf area (around time of silking to silking plus 5 days), significant differences existed in leaf, stem and husk dry weights. Of greater interest were the subsequent changes in dry weight that took place in these plant parts as grain development proceeded.

In U.S. varieties stem and leaf dry weights were about constant from silking through the period of rapid grain fill. Husk weight declined very slighly. Thus it appeared that assimilates produced by the leaves during this period moved to the grain, with no surplus storage in leaves, stem or husks. The slight decline in husk dry weight (at about 12 days after silking) could be that they provided a small supply of assimilate to the grains. In tropical varieties, during grain fill, an increase in stem and leaf dry weight accompanied grain development. Some assimilates were retained by leaves, and some were stored in stem as well as grain. The decline in husk dry weight came later than in U.S. cultivars.

The consequence of this difference in partitioning of assimilates was that tropical varieties achieved only the same grain yield as U.S. varieties and had significantly lower harvest index (Fig. 4) because the plants partitioned assimilates into three sinks rather than one.

Table 8. Plant type characteristics of U.S. and tropical maize cultivars. (Wide-spaced planting, IITA, first season, 1978.)

Cultivar	Total no. of leaves formed	No. of nodes to first ear node	No. of nodes above first ear*	Ht., cm. to first ear node*	Ht., cm. above first ear node	Relative ear position†	Leaf area dm²
U.S.							
H638	19.6	7.2	6.2	83	119	0.41	61.9
H610	18.5	7.1	5.9	88	105	0.46	66.0
H652	18.7	6.9	5.7	80	104	0.44	73.4
Tropical							
Pioneer X 306B	21.6	8.5	6.3	107	101	0.52	76.9
TZPB	21.8	8.8	5.9	103	99	0.52	85.7
Mean U.S.	18.9	7.0	5.9	84	109	0.44	67.1
Mean Tropical	21.7	8.7	6.1	105	100	0.52	81.3
S.e.±	0.23	0.21	0.17	3.3	3.7		4.47

**Node counts and leaf area measurements apply to mature plants, c.7 days after silking (60 DAE).*
†Relative ear position, ht. to first ear node/total ht.

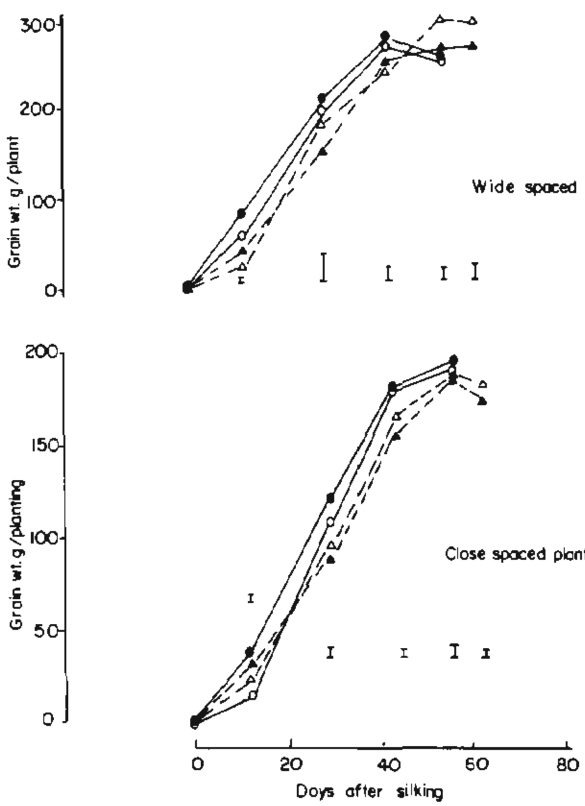


Fig. 2. Comparison of grain fill and final yield, (g/plant) of U.S. and tropical varieties.

——●—— Hb10, ——○—— H638, - - ▲ - - Pioneer x 306B, - - △ - - TZPB.

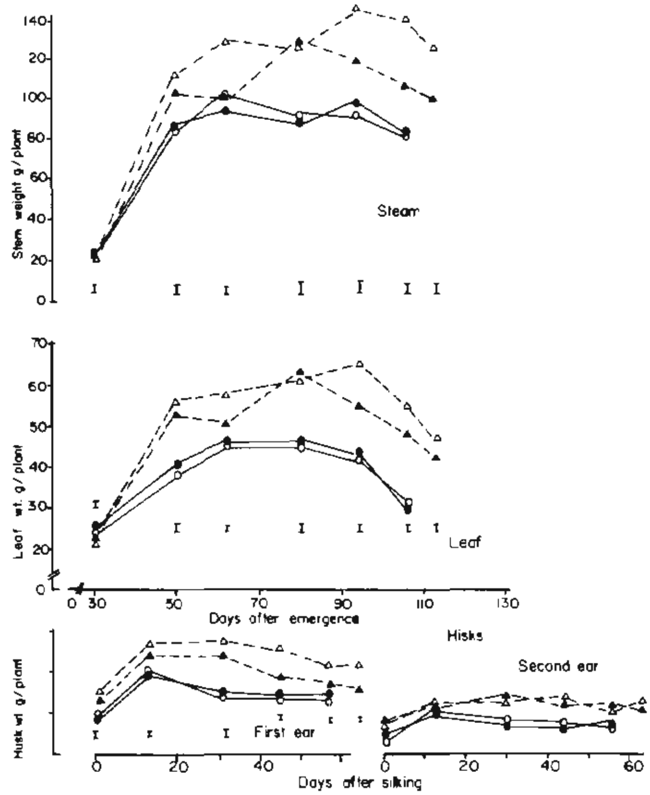


Fig. 3a. Changes in stem, leaf and husk weight with time in U.S. and tropical maize varieties at wide spacing. (Symbols as in Fig. 2.)

At close spacing the advantage of the less leafy U.S. varieties was even more evident. Harvest index in tropical varieties declined from 49.6 to 43.8% from wide to close spacing, but in U.S. varieties from 55.3 to only 53.0%.

Although U.S. variety yields were not significantly greater, the grain weight data (Fig. 4) suggest that had plant population been higher, the U.S. varieties would have shown a greater yield per plant than the tropical ones.

There were two differences between U.S. and tropical maize in yield components. The U.S. maize had more rows of grains per ear and smaller grain size. (Table 9 and Fig. 4.) These features were common to both first and second ears of wide-spaced plants and to the single ears at close spacing. The greater number of rows produced significant differences in total grain numbers per ear. The reason for similar yields between U.S. and tropical cultivars was because the smaller final grain size of

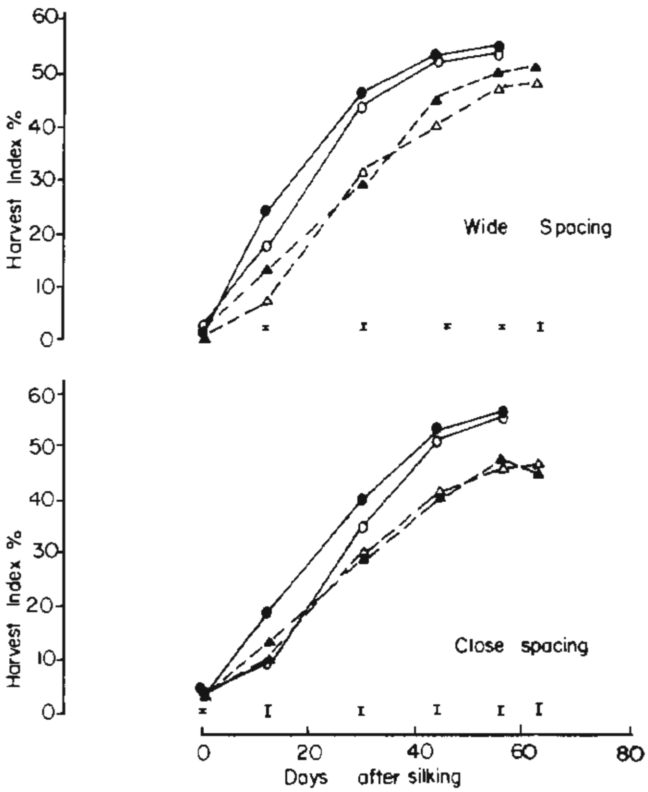


Fig. 3b. Changes with time in percent of total plant dry weight that was located in grain, (harvest index), in U.S. and tropical varieties. (Symbols as in Fig. 2.)

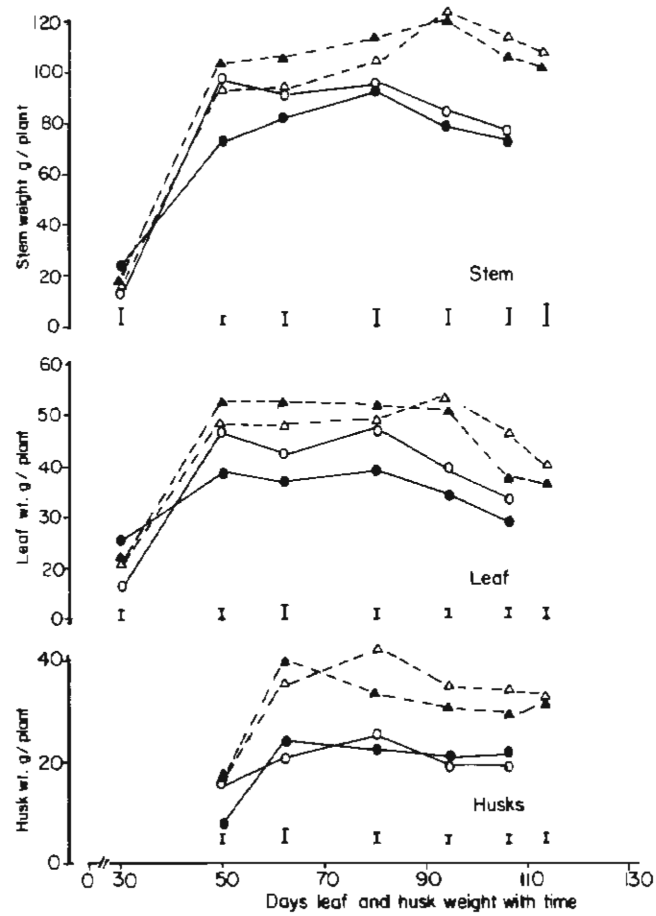


Fig. 4. Changes in stem, leaf and husk weight with time in U.S. and tropical maize varieties at close spacing. (Symbols as in Fig. 2.)

U.S. offset their greater number of grains per ear. The difference in grain numbers (ca. 80 grains for first ear, both spacings and 40 grains for second ear, wide spacing only) is the only evidence of increased "sink strength" in U.S. compared with the tropical varieties.

U.S. × tropical crosses

The germplasm differences mentioned above must be related to the rationale of the U.S. × Tropical breeding program. In making the crosses, can one select for part (morphological) or all (morphological and physiological) of the attributes of U.S. germplasm?

Table 10 gives plant character data for F3 and F5 selections of U.S. × tropical crosses. Important points in the table are:

(1) In the F3 generation the U.S. plant type, morphologically had been successfully selected.
(2) Yield and grain size have not altered from the F3 to F5 generation.

Table 9. Yield components of U.S. and tropical maize varieties. (Wide-spaced planting, first season, IITA, 1978.)

	First ear					Second ear				
Cultivar	Rows/ ear	Grains/ row	Potential grains/ row	Total no. grains	200 grain wt., g	Rows/ ear	Grains/ row	Potential grains/ row	Total no. grains	200 grain wt., g
U.S.										
H638	15.1	43.4	48.2	652	56.4	15.2	25.8	44.4	383	53.6
H610	14.4	44.1	50.7	633	59.9	14.4	26.0	45.4	376	59.6
H652	16.0	43.7	49.6	697	57.2	15.3	15.2	41.9	236	36.5
Tropical										
Pioneer x 306B	13.7	40.1	50.9	550	73.1	14.2	19.9	45.3	279	70.2
TZPB	14.1	43.3	46.9	610	70.5	14.1	22.2	42.5	313	60.4
Mean U.S.	15.2	43.7	49.5	661	57.8	15.0	22.3	43.9	332	49.9
Mean tropical	13.9	41.7	48.9	580	71.8	14.1	21.1	43.9	296	65.3
S.e.±	0.42	1.27	1.47	24.3	1.97	0.49	2.63	1.45	39.5	33.98

Table 10. U.S. x tropical crosses: plant type, dry weight partitioning, yield and yield components compared with U.S. germplasm.

Character	U.S.	U.S. x tropical crosses Dec. '77 (F3)	Dec. '78 (F5)	Standard deviations 1977	1978
(No. plants harvested)		(133)	(297)	-	-
No. nodes to first ear node	7.0	6.5	6.8	0.93	0.87
No. nodes above first ear	5.9	6.0	5.9	0.60	0.68
Ht. to first ear node, cm	84	-	94	-	14.7
Ht. above first ear node, cm	110	-	130	-	16.2
Relative ear position	0.44	-	0.42	-	-
Wt. at maturity per plant, g					
Leaf	31.0	44.7	36.7	10.2	8.2
Stem	77.2	135.4	119.2	33.3	30.5
Husk	39.3	62.0	46.7	19.0	13.3
Cob + Shank	45.8	50.6	44.8	12.5	8.3
Grain	244.6	219.9	219.8	55.4	42.1
First ear, rows/ear	15.2	-	14.8	-	1.8
grains/row	43.7	-	42.7	-	5.8
200 grain wt, g	57.8	66.2	66.6	8.6	9.0
Harvest Index, %	55.3	42.8	47.2	6.5	5.4

(Data from 1st season IITA trial, 1978.)

(3) Harvest index has increased, apparently by selection of less leafy plants of less gross ear structure.
(4) The main physiological contribution to improved harvest index is the lower level of storage of assimilates in the stem.

The next question is: what advance can the next cycle of selection hope to achieve? With respect to plant morphological type, little more is required. Future selections could improve on leaf size per leaf position, but not on leaf numbers. The main requirement is yield improvement with no biomass change. Lower husk weights and stem weights are needed. Selection for these traits would produce harvest index improvement, and with it yield improvement. The problem is that although yield is easily selected for, no visual characters remain for selection that can link yield to efficiency.

The only remaining visual selection criteria that might produce improvement in harvest index is selection of ears with smaller grains and more rows per cob (200 grain weight of less than 60g and 16 rather than 14 rows of grain per ear).

At the present stage of selection, the plant type, as it is, should have a yield advantage at high plant populations over straight tropical materials. If the materials are also to have real possibilities as individual plants, more selection is required.

Selection criteria

The 1977 physio-breeding program established that in tropical maize populations yield and harvest index are positively correlated. The breeders' method of selecting high-yielding lines automatically carried with it selection for improved population harvest index (HI). However, the selection pressure for improving HI was low because high-yielding lines, whilst automatically carrying restricted variability for yield, had a wider variability in HI. Within high-yielding lines, individual plants were identified that combined high yield with higher efficiency (HY/HE). The identification was based on grain and stover dry weight analysis at maturity. The objective of the 1978 physio-breeding program was to determine what HY/HE plants looked like, whether their characteristics could be distinctly recognized in the field at the time of anthesis and silking and whether these characteristics provided selection criteria for making more rapid progress in improvement of HI.

Materials for 1978 population studies were from plants in the category HY/HE taken as half-sib selections out of full-sib entries in TZPB (EPS) and TZPB (prolific) trials of 1977. During first season, 64 half-sib entries were planted out, ear to row, at wide spacing, (4 rows/plot, 75 cm between rows, 1 m between plants).

At the time of anthesis, individual plants were marked if plant type was subjectively acceptable (plant not too tall or leafy). Date of silking of first and second ears, and length of silks produced were noted. Seven days after silking, marked plants were reselected on basis of ear numbers and size. Plant data that described morphological attributes were recorded on all selected plants — number of nodes to and above first ear node, height below and above first ear node, leaf angle (measured on first leaf above first ear node), circumference of first and second ears, where present, at widest point of the ear. All selected plants were harvested for grain and stover dry weight analysis.

At the time of harvest, field observations suggested that half-sib entries that had come from full sibs where HY/HE had higher frequency were still providing good materials with respect to ear size and number and plant type. A total of 61 individual plant half-sib selections out of these entries were planted in second season. Plant type correlation data, and grain and stover dry weight were recorded on selected plants in these entries. A full-sib crossing program within the half-sib entries on the basis of subjective assessment of plant type and ear number was also carried out.

Figure 5 shows that there were no visible plant characteristics that indicated in the field, at the time of anthesis, that a plant had the potential for HY/HE. Features that might be thought to indicate efficiency, such as lower

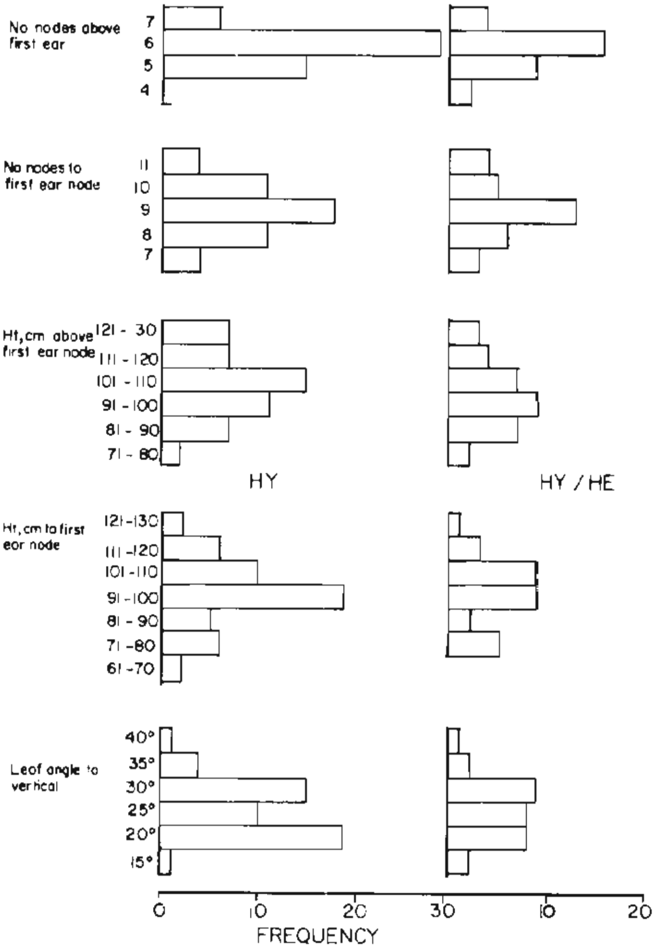


Fig. 5. Frequency distribution of plant characteristics in HY plants compared with HY/HE plants. (From 1st season, 1975, TZPB EPS + PROLIFIC HS selections.)

node number to the first ear or low ear placement and open canopy above the ear, occurred with similar frequency in both HY and HY/HE plants. The feature that characterized HY/HE and HY plants at wide spacing was that of prolificacy. No special feature of ear development was associated with HY/HE. HY/HE plants could only be selected retrospectively when dry weight data showed greater efficiency of dry weight distribution into grain rather than stem compared with HY plants.

Since HY/HE plants could not be selected at time of pollination, full sibs between plants that were subsequently found to be HY/HE relied on chance. In the second season pollinations, full sibs of this type amounted to no more than five out of about 800 pollinations. Part of the problem for successful chance pairing was the low frequency of HY/HE in the overall population. In the original source populations of TZPB (EPS) and TZPB (prolific), HY/HE accounted for ca 9 percent of the selected population. In the first and second seasons' half-sib populations, 13 percent of the plants finally selected were in category HY/HE.

If a breeding strategy was designed that accommodated the need for retrospective analysis for selection of HY/HE plants, the fact remains that HY/HE plants are *not* a particular plant type as far as visible morphological characters are concerned. Selection for HY/HE or HY does nothing to improve plant type for specific cropping situations. If morphological plant type is seen as a requirement in tropical maize populations, it must be selected for objectively. It may not lead to yield improvement per plant but yield improvement would be achieved per unit area of land, if the plant type allowed for higher plant densities than are currently used.

Maize stem borers

In the maize stem borer resistance program, high priority has been given to developing artificial rearing methods for *Sesamia calamistis* and *Eldana saccharina*. The methods of rearing *Sesamia* and *Eldana* on artificial diet are virtually the same. Vials are filled up to half with artificial diet. In each vial, 30-40 eggs are placed on tiltered paper to avoid direct contact with the wet diet.

After hatching, the larvae penetrate the diet and are kept there for about 10-15 days. Then they are transferred to a bigger container for further development. One hundred and fifty larvae are kept in one container. After pupation the pupae are sexed and transferred to cages until hatching. The adults are fed on sugar solution. Eggs are laid on rolled paper towels.

Egg masses of *S. calamistis* collected from the maize field and "seeded" in the artificial diet had a hatching rate of 66.66-93.33 percent after 6-8 days of incubation under a temperature regime of 30°C.

Larval stages lasted 12-32 days and pupae 10-11 days. These gave an average development period of 45 days. The maximum number of pupae formed from larvae fed on the diet was 73.33 percent; the minimum recorded was 46.66 percent. The highest level of emergence from the pupae was 60 percent while the lowest was 26.6 percent. The preoviposition period for females lasted one day.

From 10 females + 10 males tested out of the emerging population, the average number of eggs laid per female was 326. Most of the egg batches contained 20-40 eggs. At the end of the seventh day all females were dead.

Data for only one generation are available. Adult mortality increases after one generation, but *Sesamia* has been reared for two more generations on artificial diet. The last adult population showed clear signs of low vitality. Out of 400 pupae, only about 100 hatched without signs of damage. These adults were able to produce only about 4,000 eggs, a number considered low.

Six cultivars obtained from the National Cereals Research Institute, Ibadan, Nigeria, have been screened for resistance against *Sesamia*.

In two trials (one in the first season and the other in the second season), each plant was infested with 30-40 eggs placed behind the leaf sheath. Forty plants were infested in each trial. Observations were made on leaf injury, stalk breakage, dead hearts and extent of tunneling. The results in percent damage for the different damage criteria are presented in Table 11.

Except for tunneling no significant differences could be observed. Significant differences were, however, obtained when all the criteria used for assessment were combined in the analysis. The least susceptible cultivar was Bende local.

*Table 11. **Overall damage of maize cultivars by* S. *calamistis.***

Maize cultivar	Dead hearts	Broken stalks	Tunneling	Total %
Umonichi (39)*	25.64	30.76	12.82	69.23
Bende Local (40)*	12.5	17.5	15.00	45.00
Egbena (40)*	32.5	37.5	20.00	90.00
Ikeja (40)*	15.00	10.00	37.00	62.50
Ugep White (40)*	30.00	42.50	17.50	90.00
Obior Local (39)*	25.64	20.51	33.33	79.48

**Total number of plants infested by* S. calamistis *per cultivar.*

No data on the performance of *Eldana saccharina* in the artificial diet are available. The incubation time for eggs is about 5-6 days. From larvae to pupae it takes about 30 days and the pupa stage lasts 5-6 days. Visual observations on the population development show that after about six generations in the laboratory the vitality of the insect has not declined.

IITA-NAFPP Maize Program

IITA supports the National Maize/Rice Center in implementing the Nigerian National Accelerated Food Production Project (NAFPP) throughout the country. This is done through providing seed of improved cultivars, putting together recommendations for minikit and production kit trials and training.

Improved maize cultivars distributed to cooperating farmers are 50-75 percent higher in yield than local cultivars. Proper fertilization can also contribute additional 50-75 percent increase in grain yield and close spacing is expected to improve yield at a similar rate if fertilizer is not short. Chemical weed control, which is of major interest to many farmers, is now being tested in the minikit stage, using Atrazine and Primextra in comparison to hand weeding.

Pre-minikit trials. A preliminary testing trial was grown in government farms in 13 states during 1978 to observe the performance of four maize composites that mature in 90-95 days instead of 110-120 days required for the cultivars grown in the minikits. Three of these, TZE2, TZE3 and TZE4, were developed at IITA and Kewesoke at the Institute of Agricultural Research and Training (IAR&T), University of Ife. Average grain yields shown in Table 12 indicated that all the four early-maturing populations were similar and they compared favorably well with TZB.

Variety minikits. In each variety minikit, there are four cultivars grown in comparison with the local cultivar of that particular area. The four cultivars in each area are chosen according to their adaptability to the corresponding ecological zone, i.e. all four recommended cultivars are not necessarily the same from one ecological zone to another. This procedure would enable the farmers to see for themselves the minikits grown by their fellow farmers and would also allow them to participate in selecting the cultivar they prefer to grow in their area. This system will speed up the mass adoption of the research recommendation. The results of the states that have the same cultivars included in their minikits are reported in Table 13. In general, averaged over eight states, TZPB gave 3.2 t/ha, which is 75 percent higher than the local yield.

The three other cultivars included gave about 50 percent higher grain yield than the local. FARZ 27 (TZPB) and FARZ 34 (TZB) both have white dent kernels and are accepted for dry grain consumption. On the other hand, FARZ 7 (WY1) and FARZ 23 (096 EP 6) have yellow kernels and are preferred in some areas as feed for livestock.

Production kits. Once a cultivar is chosen by farmers from among the four cultivars of the minikits grown in the area, this selected cultivar is grown the following

Table 12. Grain yield (kg/ha) of early-maturing maize cultivars grown in pre-minikit trials, 1978.

State	TZE2	TZE3	TZE4	Kewesoke	TZB
Benue	1834	3301	1669	3311	2476
Kwara	2750	1742	2200	2017	1650
Oyo	1807	1318	1304	1422	1916
Ondo	-	2201	2558	1834	2934
Mean	2130	2141	1933	2148	2244

Table 13. Grain yield (kg/ha) from NAFPP state maize cultivar minikit trials, 1978.

State	No. of Trials	FARZ 7 (WY1)	FARZ 23 (096EP6)	FARZ 27 (TZPB)	FARZ 34 (TZB)	Local
Bendel	20	3138	3290	3385	3568	2285
Benue	20	3280	3648	4050	3953	2087
C/River	78	3300	3100	4453	3001	2300
Imo	11	1418	1132	1312	1010	600
Lagos	43	2181	2163	2512	2479	1282
Ogun	2	2391	2604	2433	2454	1731
Ondo	4	2682	2508	2942	2727	1770
Oyo	19	3467	3690	2617	4330	2671
Mean over states		2732	2767	3213	2814	1841
% of local		148	150	175	153	100

season in a production kit to evaluate its yield potential under improved practices (close spacing and fertilization) when grown in a larger plot of 1/10 ha (1000 m²). These production plots, if grown under isolation, could also provide the improved seeds to other neighboring farmers for planting their maize fields for the mass adoption phase. A summary of grain yields from maize production kits grown in four states is given in Table 14. These yields are expected to be at least 50 percent better than yields of local cultivars grown under similar improved practices.

Table 14. Grain yield (t/ha) of NAFPP maize production kits in four states, 1978.

State	No. of kits	Grain yield
Kwara	30	2.5
Oyo	74	2.4
Ogun	17	2.9
Ondo	48	2.6
Mean		2.6

Rice

Genetic improvement

Five criteria for the improvement of irrigated, hydromorphic and dryland rices are to:

(1) Obtain stable and high grain yields.
(2) Identify resistance to the prevailing disease and insect pests.
(3) Identify resistance to moisture and nutritional stresses.
(4) Develop cultivars with moderate grain dormancy and non-shattering characters.
(5) Improve grain quality.

Irrigated and hydromorphic rice

Desirable plant type for rice under irrigation with good water control, and for hydromorphic rice is dwarf or semi-dwarf statures that ensure productivity and adaptability under varying cultural and ecological conditions. In addition to being dwarf to intermediate in stature, these improved cultivars should have early plant vigor with high-tillering ability and good ground cover.

Tox 514-16-101-B (Moroberekan/SE 363G, Ikong Pao) was initially selected in upland up to the F3 stage and then selected under low nutrient status in irrigated paddies where it was superior to all the 120 other lines tested. In the 1978 rainy season (April-August) at IITA, it was among the top three ranking cultivars in three situations, (1) irrigated paddies with good management (7.7 t/ha), (2) rainfed dryland with severe drought, blast compound stress at IITA (1.2 t/ha), and (3) rainfed dryland with marginal drought during the reproductive stage and neck blast, brown spot disease pressures at Ikenne (4.6 t/ha). This line is picked for multilocational testing.

Dwarf lines, Tox 490-6-103-1 and Tox 490-6-104-1 yielded 8.2 and 7.2 t/ha in a hydromorphic valley bottom as against the highest yield of 3.8 t/ha for the standard OS6 check. Further testing in paddy is in progress.

For irrigated/hydromorphic rice, high yield and blast resistance is being combined by crossing the high-yield potential dwarfs — BG 90-2, IR 2035-120-3, RP4-14, ADNY 2 and Tox 514-16-101-B with:

(1) Blast resistant dwarfs: IR 34, IR 2071-586-5-6-3, IR 1416-131-5.
(2) Blast resistant, intermediate stature types: AUS 8, FARO 15 and MRC 172-9.

Upland rice

The major objective in upland rice is to incorporate lodging resistance and higher yield potential to the African farmers' cultivars adapted to upland conditions. The visual characteristics used as selection criteria are: large panicle size and medium-to-high tillering ability; upper leaves erect for good light interception and lower leaves droopy to compete with weeds; thick and deep root system to explore large soil volume for water and nutrients.

Methods to reach this goal include:

(1) **Hybridization.** Crossing adapted upland cultivars IAC 25, Dourado Precose, OS6, 63-83, LAC 23 and Moroberekan with high-yield-potential dwarfs, selected in Africa for general performance with (a) the introductions from IRRI, Philippines; AICRIP, India; CIAT, Colombia; (b) dwarf segregants of earlier similar crosses and (c) short cultivars derived from mutation breeding.
(2) **Induced mutations.** Irradiating the African upland cultivars and selecting the short culm mutants which otherwise resemble the parent.

For upland rice, an important attribute is the selection for appropriate growth duration of cultivars based on the rainfall pattern of the region. Selection for early-maturing (90-110 days) cultivars has been done in most countries where upland rice is grown. The probability of consecutive drought days increases with lengthening rainfed crop season. Thus short-duration cultivars should have an advantage when the rainfall distribution is monomodal, as in parts of West Africa. Several breeding lines of varying growth duration have been developed at IITA to suit the rainfall pattern of different regions in Africa. Some of the promising lines are listed in Table 15.

A large number of advanced breeding lines were evaluated in upland conditions at IITA, Ibadan, Ikenne and Onne. The performance of the selected superior cultivars and the standard upland rice cultivers is presented in Tables 16, 17 and 18.

Tox 475-B1-1-B1-B yielded 4.4 t/ha as against 3.4 t/ha for OS 6 among 148 advanced Tox lines tested in two locations. The same line yielded 1.9 t/ha (the top yielder) in high rainfall at Onne, under highly leached acid soils. Drought stress occurred 100 days after sowing because of late planting.

Tox 504-21-128-B-B gave consistently good performance in the multilocational tests conducted by IAR&T. Although this particular line was not identified in other trials, several lines from this cross performed well in other locations.

Swamp rice

For swamps with probable iron toxicity stress superior cultivars are being developed by crossing cultivars with good tolerance to iron toxicity — Gissi 27, Suakoko 8 — with those that have high yield potential in normal swamps such as IET 3257, IR 4625-132-1-2, Improved Mahsuri and IR 5.

Plant type and adaptability

Upland rice in Africa is essentially planted to traditional, tall cultivars characterized by low tillering, long and droopy leaves and large panicles. Generally, upland rice is grown the first year after bush clearing with little or no application of fertilizers at low seed rate. Under such conditions, the farmers' cultivars with droopy leaves and low leaf area index utilize the solar energy efficiently and their thick and deep root system helps to withstand drought and utilize the soil nitrogen efficiently. However, the yields of these cultivars continue to remain low.

Table 15. Pedigree, plant height and growth duration of some promising IITA rice cultivars.

Pedigree	Cross	Plant height cm	Growth duration (days)
Tox 86-B-B3-B	63-83/IR 773A1-36-2-1	129	122
Tox 95-8-1-1-LS3	63-83/ Moroberekan	121	123
Tox 475-B1-1-B	Tox 7-4-2-5-1-B-8/63-83	125	116
Tox 502-25-126-B	63-83/ROK 1, Dourado Precose, SE 363G	125	116
Tox 502-46-ML-B_1	63-83/ROK 1, Dourado Precose, SE 363G	118	109
Tox 504-14-14-1	Lac 23 (red)/IR 528-1-32, Tox 7-3-2-3-B, Tox 7-3-2-B_1-B_1 1-B-2	130	116
Tox 504-21-128-B-B	Lac 23 (red)/IR 528-1-32, Tox 7-3-2-3-B, Tox 7-3-2-B_1-B_1 1-B-2	130	122
Tox 515-22-107-B	Moroberekan/IR 1416-131-5, IR 30	81	119
Tox 515-38-101-B	Moroberekan/IR 1416-131-5, IR 30	119	122
Tox 516-28-103-8-B	Moroberekan/ Juma 1, SE 363G, Tox 7-3-2-3-B2	127	120
Tox 737-12-B	OS6/63-83	125	120

The characteristics and the high-yield potential of semi-dwarf (IR8) plant types under relatively high management and good water control has been consistently demonstrated. However, growth and yield performance of upland rice cultivars are often limited by water and nutrient supply and disease pressures in upland.

Screening techniques have been well established for selection of high-yielding lowland cultivars since the development of the semi-dwarf plant type. The success is mainly the result of the close association between certain morphological characters of rice cultivars and yielding ability in response to nitrogen application. Unlike the "plant type" for lowland rice, the desirable characteristics of a high-yielding upland rice cultivar are not clear.

As regards the "ideal" plant type for upland rice, the following questions arise:

(1) Are the dwarf plant type cultivars with generally high-yield potential under well managed paddies unsuitable for dryland?
(2) What plant type characteristics are desirable for dryland?
(3) What cultivars are better than IR8, IR5, BG 90-2 and OS6?
(4) Is there a need to practice selection under different ecosystems?

Research efforts were directed to the agronomic evaluation and growth analysis of a high yield potential semi-dwarf, BG 90-2, tall, traditional farmers' cultivar, OS6 and an intermediate-statured cultivar, TOs 2583, developed by crossing OS6 with a high-yielding semi-dwarf. Three spacings were used to realize the potential growth: 20 × 20 cm recommended for paddy, 30 × 30 cm recommended for OS6 in Nigeria and in isolation at 60 × 60 cm. The study was conducted under paddy, hydromorphic valley bottom and upland conditions to identify varietal characteristics and growth features that are associated with the complex stress problems that occur under moisture stress.

The growth and yield performance of the three cultivars under three spacings and three water regimes (Table 19) indicates the superiority of a high-yield potential dwarf, BG 90-2, in the absence of moisture stress, both under flooded paddy and near saturated hydromorphic conditions. In upland, the results were the opposite. The

Table 16. Grain quality characteristics of some promising IITA advanced breeding lines and checks.

Pedigree	Milling recovery (%)	Head rice recovery (%)	Length (mm)	Breadth (mm)	Length: breadth ratio	1,000 Grain weight (g)
Tox 475-B1-1-B1-B	64	58	107	28	3.8	36.0
Tox 502-29-ML-B1-B	57	45	110	30	3.7	38.8
Tox 502-46-ML-B1	60	30	98	28	3.5	36.4
Tox 504-14-14-1	58	52	95	29	3.3	32.6
Tox 514-16-101-B1	72	52	84	27	3.1	28.4
BG 90-2 (check)	70	30	91	26	3.5	30.6
IAC 25 (check)	66	64	94	28	3.4	32.6
OS6 (check)	69	65	96	27	3.6	35.6

Table 17. Yield and other agronomic characteristics of promising upland rice cultivars evaluated at IITA, Ibadan, 1978.

Pedigree	Grain yield (t/ha)	Growth duration (days)	Plant height (cm)	Panicles per hill	Harvest index (%)
Tox 515-22-107-B	2.38	119	81	10	36
Tox 516-8-10-B	2.38	118	86	12	41
IRAT 13	3.38	125	102	13	47
Tox 4688	2.58	121	106	14	45
Tox 95-8-1-LS5	2.02	162	116	10	21
Line 13d x Moro #2057	2.39	120	116	7	41
Tox C1-47-1-3 LS1	2.21	179	118	8	28
Moroberekan	0.70	130	123	5	14
IAC 25	2.52	112	126	7	49
OS6	0.82	124	128	10	22
Lac 23	1.22	145	129	6	21
S.E.±	0.25				
C.V. percent	39.9				

Note: The period from 30 July (90 days after sowing) to 30 August was droughty with a total rainfall of 21 mm.

Table 18. Grain yield, plant height and growth duration of high-yielding upland rice cultivars.

Pedigree	Grain yield (t/ha)	Plant height (cm)	Growth duration (days)
Advanced IITA breeding lines			
Tox 502-10-101-5	2.89	81	105
Tox 502-46-101-B	2.28	106	95
Tox 503-7-101-B	2.58	110	103
Tox 504-13-102-B	2.40	110	109
Tox 504-14-103-B	2.99	99	114
Tox 507-8-1-B	2.94	100	114
Tox 515-39-104-B	2.66	98	112
Tox 516-7-104-B	2.74	83	109
Tox 16-20-102-B	2.60	95	112
IURYN, 1977			
B9C-md-3-3	2.62	80	112
IRAT 13	2.33	103	112
Standard cultivars			
IRAT 13 x Dourado #852	2.07	99	107
Lac 23	0.92	121	145
Moroberekan	1.78	122	136
OS6	1.13	123	124
S.E.±	0.62		
C.V. percent	15.5		

Note: Major stress: drought.
Minor stresses: brown spot, leaf scald and leaf blast.

semi-dwarf, BG 90-2, failed to yield while both the tall OS6 and the intermediate TOs 2583 yielded moderately. Blast alone reduced grain yields of BG 90-2 in the hydromorphic location while a combination of severe drought and blast stress ruined the productivity in dryland. (Fig. 6.)

The dry matter production (DMP) in isolation at 60 × 60 cm (Figs. 7 and 8) corresponds to the yield performance of the three cultivars in paddy and hydromorphic conditions. But under dryland (Fig. 9) up to flowering stage, there was little difference in DMP between cultivars, indicating that growth, *per se*, is not the limiting factor for

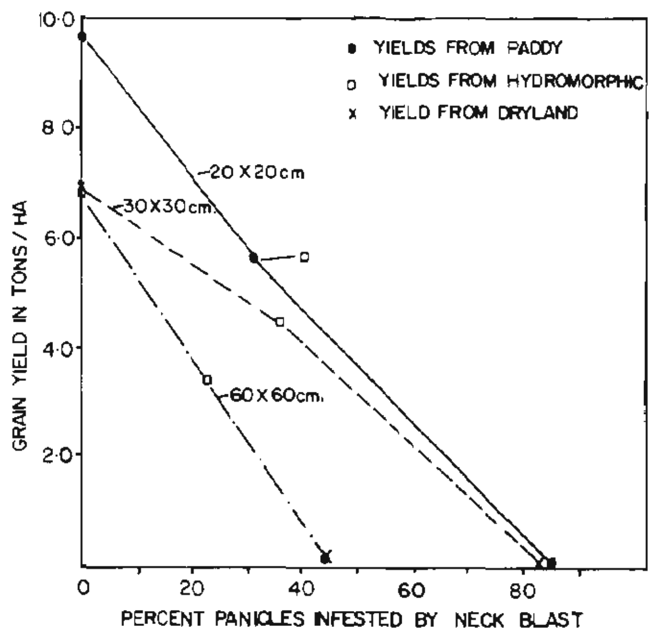


Fig. 6. Effects of drought: blast stress on grain yield of BG 90-2.

a semi-dwarf in dryland. The collapse of BG 90-2 after flowering was caused by its high susceptibility to drought and neck blast.

Although the data suggest that high-tillering character and short plant height are undesirable for dryland, the drought stress was compounded with severe blast incidence in BG 90-2.

Agronomic traits of dwarf-tall sib F_5 generation selections obtained from F_4 single plants were studied in an upland field at IITA. (Table 20.) The indications are that even under dryland conditions higher grain yield could probably be obtained by reduction of the plant height, which favors tillering and harvest index.

In tests on the efficiency of applied N for rice as affected by varing soil types and moisture regimes, semi-dwarf

Table 19. Growth and yield performance of semi-dwarf, intermediate and tall rice cultivars under different water regimes.

	Grain yield (t/ha)			Plant height (cm)			Tillers per m²			LAI at flowering			Harvest index (%)		
Treatments	P*	H**	D***	P	H	D	P	H	D	P	H	D	P	H	D
20 x 20 cm															
BG 90-2	9.67	5.63	0.02	115	104	77	265	218	333	6.1	3.3	4.9	54	48	19
TOs 2583	5.39	4.33	1.87	150	144	124	243	168	332	3.4	1.6	3.8	47	46	27
OS6	6.62	3.46	2.17	178	182	130	151	156	228	4.2	2.0	4.6	47	40	35
30 x 30 cm															
BG 90-2	6.84	7.10	0.04	111	108	73	182	170	321	3.0	1.9	3.6	56	51	22
TOs 2583	4.27	4.06	2.11	148	141	130	158	125	223	2.6	1.5	3.0	50	47	32
OS6	4.19	4.41	2.11	172	184	142	112	110	166	3.2	2.8	3.3	46	44	34
60 x 60 cm															
BG 90-2	6.72	4.29	0.07	115	104	78	126	119	165	3.0	3.9	2.6	56	42	33
TOs 2583	2.10	2.93	1.63	128	147	127	76	83	105	1.4	1.2	1.7	46	50	40
OS6	2.34	2.81	1.82	164	170	148	49	55	100	1.8	1.9	2.5	49	49	40
S.E. ± 0.64	*0.45*	*0.29*										*1.39*	*1.24*		*2.45*
C.V. % 36.0	*31.0*	*42.6*										*8.3*	*8.1*		*23.7*

P : paddy.*
*H** : hydromorphic.*
*D*** :dryland.*

Table 20. Difference in agronomic traits between dwarf-tall sib F_5 generation selections.

Agronomic trait	Dwarf sib	Tall sib
Plant height (cm)	81	111
Tillers/m²	166	110
Panicle length (cm)	22	24
Panicle exertion (cm)	2	6
Weight per panicle (g)	2.7	3.1
Grain weight/hill (g)	36	30
Harvest index (%)	51	46
200 grain weight (g)	6.0	6.2

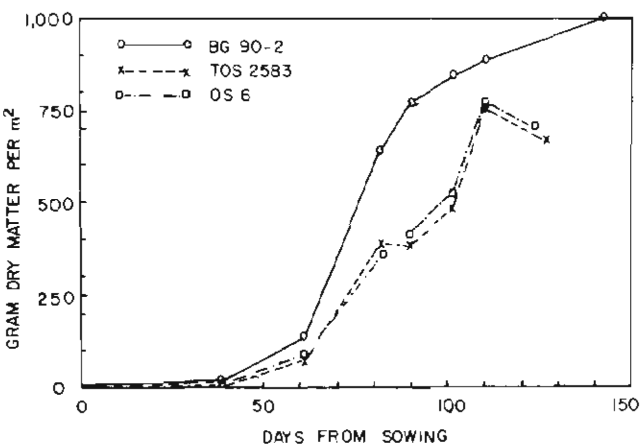


Fig. 8. Dry matter production per day in BG 90-2, TOS 2583, and OS6 at 60 x 60 cm spacing in hydromorphic conditions.

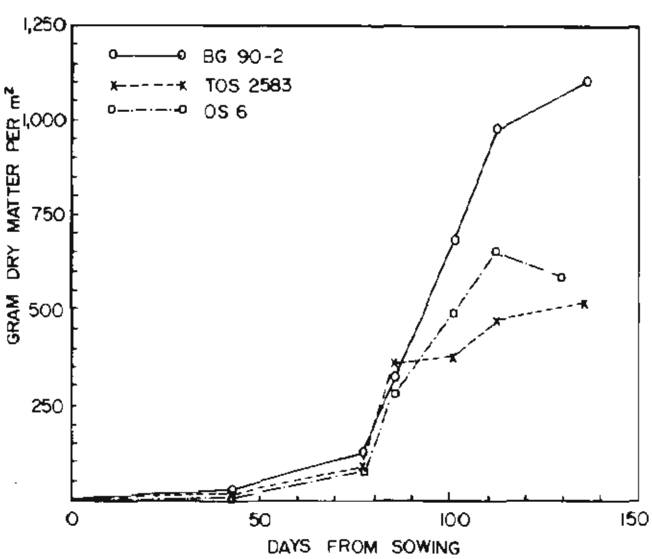


Fig. 7. Dry matter production per day in BG 90-2, TOS 2583, and OS6 at 60 × 60 cm spacing in paddy.

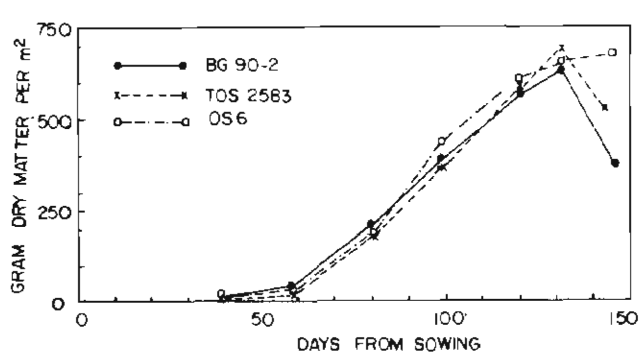


Fig. 9. Dry matter production per day in BG 90-2, TOS 2583, and OS6 at 60 × 60 cm spacing in dryland.

cultivar BG 90-2 was grown at two levels of N-40 and 80 kg N/ha in 10 plots along a toposequence in IITA. The plots 1 to 4 suffered from drought stress throughout the growth period. A sharp decline in yield was observed between the adjacent plots, 4 and 5, along the toposequence due to drought. In the wetter plots of the toposequence, as expected, higher grain yields were obtained with 80 kg N/ha. The lower yields in plot 10 were due to iron toxicity. The results indicate that there is a critical moisture level beyond which it is detrimental to push crop growth by applying N. At near critical level with low management, traditional upland cultivars with limited number of large panicles may be better suited.

The reason for lower yields in the 5-7 plots with low N is probably the loss of N in particular due to frequent fluctuations in moisture regimes.

A total of 68 cultivars, including 10 tall check cultivars and 58 cultivars whose selection was based on their high yield performance in Africa, were evaluated for their general growth yield performance in dry land (IITA, Ikenne and Onne) and paddy (IITA). Moisture and blast stress occurred severely 90 days after sowing at IITA dryland. At Ikenne drought stress and neck blast did not occur until 100 days after sowing. But at Onne no blast was prevalent and drought occurred only 95-100 days after sowing.

The grain yields of most of the dwarfs at IITA dryland were extremely low and some produced no grain because of their susceptibility to blast. The performance of the 15 top yielders in paddy together with the check cultivars BG 90-2 (semi-dwarf), OS6 (tall, upland type) is presented in Table 21. Many dwarfs failed to yield due to drought and blast complex.

The data suggest that most cultivars selected in paddies with good water control and management do not have the tolerance to drought and blast complex that is likely to be encountered in uplands. As such, for upland rice where a complexity of stress problems occur, selection should be made under such stresses rather than in their absence under irrigated paddy conditions. However, the data clearly indicate that no physiological barrier is expected to limit the possibility of obtaining semi-dwarf types for dryland. The semi-dwarf plant type, *per se*, is no limitation for upland rice. The performance in upland is cultivar-specific and not plant-type-general characteristic.

Considering the present status of upland rice farming in Africa and the magnitude of the shift needed in management practices to promote semi-dwarfs, selection of cultivars should be simultaneously made — semi-dwarf types for high level management and intermediate-statured types for low to moderate levels of management.

Tolerance to RYMV

Rice Yellow Mottle Virus (RYMV), first described from Kenya in the early 1970's, was later also found to occur in Sierra Leone and Ivory Coast. The virus is probably endemic to tropical Africa and has become a problem in irrigated rice in these countries. Resistance screening to this virus had previously been done in Sierra Leone by the plant pathologist in IITA's cooperative program and resistance has been identified mostly among farmers' upland cultivars.

The virus was recently identified positively from rice in Nigeria enabling screening for resistance to begin at IITA and it has been determined that cultivars BG 90-2, IR 1416, Suakoko and IR5 being popularized for paddy and swamp culture are highly susceptible to RYMV.

Cultivars IRAT 78 and IR 2071-586-5 were found to be highly and moderately resistant to RYMV respectively,

Table 21. Performance of cultivars with high-yield potential in different locations in Nigeria, 1978.

Cultivars	Grain yield (t/ha) Paddy (IITA)	Dryland Onne	Dryland Ikenne	Dryland IITA	Growth* duration (days)	Plant* height (cm)	Panicles* per m^2	Leaf blast score (DAS)** 60	Leaf blast score (DAS)** 75
BG 66-1	6.74	0.85	3.10	0.0	135	110	248	2	2
C4-63	7.23	N.T.	0.81	0.30	157	127	306	2	3
IET 1996	6.88	0.69	2.61	0.20	147	92	376	2	2
IR 8	6.73	0.97	3.56	0.0	130	91	207	2	3
IR 1416-131-5	6.60	0.60	N.T.	1.24	140	98	331	0	0
IR 1529-430-3	6.92	1.23	3.24	0.0	124	85	237	3	2
IR 2035-120-3	8.23	1.66	4.43	0.42	138	107	305	2	2
IR 2035-244-3-2-2	7.19	0.73	3.34	0.27	153	96	374	1	0
IR 2061-228-3-9	6.87	0.88	1.73	0.33	125	131	288	3	4
IR 2071-586-5-6-3	5.75	N.T.	2.44	0.83	132	108	330	0	0
IR 2071-588-3	6.04	0.81	2.32	1.36	154	108	418	0	0
PMI 6624-257-1	7.00	1.54	2.53	0.0	138	118	199	2	2
RP4-14	7.21	1.23	2.41	0.0	146	110	254	2	3
RPW6-17	6.87	N.T.	3.15	0.0	139	104	285	3	3
Tox 514-16-101-B-B	7.67	N.T.	4.58	1.15	114	113	350	0	0
BG 90-2 (Check)	7.90	1.21	2.40	0.0	129	106	258	5	4
OS6 (Check)	N.T.	1.08	2.38	0.92	120	180	-	0	0
S.E. ±	*0.22*	*0.09*	*0.21*						
C.V. %	*12.6*	*31.2*	*29.7*						

* = *Paddy, IITA.*
** = *Dryland, IITA.*
N.T. = *Not Tested.*

the latter combining this resistance with blast resistance and general adaptability. Many IITA lines derived from resistant African land cultivars are resistant to RYMV and possess high levels of horizontal resistance to blast. Among these are TOX 490-3, TOX 494-5, TOX 502-11, TOX 503-5 and TOX 737-6. IITA was found to be a good location for resistance screening under field conditions with artificial inoculation to determine potential yield reduction due to early infection with this virus, because virtually no natural spread was observed, probably as a result of extremely low vector population densities.

A screening design can therefore be used that enables evaluation of resistance levels in terms of potential yield reduction rather than subjective judgement of symptom severity. (Table 22.)

Table 22. Yield reduction of RYMV on susceptible and tolerant cultivars. Effect of RYMV on grain yield.*

Tolerant Group	Grams per plant Healthy	Infected
TOX494-1110	47	45
2628	38	37
BL629	38	38
13d x R75	34	34
BL680	32	37
IR8084	28	29
IRAT 13	21	23
Intolerant Group		
BG90-2	80	26
Suakoko 8	70	18
IR2071-586	68	18
BG66-1	66	21
IR4422	65	35
IR5	60	15
IR1416-135	56	11
Adny 2	55	26
IR8	47	7
TOX514	37	17
4445 (Colombia)	33	13
IR1746-226	22	11
RPW6-17	19	13

**Paired rows of 10 plants per treatment at 30 x 30 cm spacing with 60 cm between entries. Inoculated 21 days after being transplanted in irrigated paddy conditions.*

Bacterial leaf blight (BLB)

In 1973, bacterial blight of rice was reported for the first time outside Asia, being found in northern tropical Australia. Two years later it was discovered on and around some rice experiment stations in Colombia and Panama in South America. There have been no confirmed reports of the disease from Africa or Malagasy. But there have been private unconfirmed reports of the presence of symptoms resembling those of BLB in connection with earlier Taiwanese rice projects in several West African countries, on cultivar TN 1 which was introduced in the 1960's.

Symptoms resembling BLB were noted at a rice experiment station located at Kogoni in Mali during the 1978 growing season. IITA researchers visited this station along with a Malian national and an IRAT scientist at the end of the growing season and found BLB symptoms in one block of a local cultivar, Gambiaka kokum. It and other cultivars were being raised at the station in large blocks for seed for distribution. Other local cultivars being raised for seed, and Asian dwarfs in variety trials in other blocks nearby, were not visibly affected, indicating a very localized source in the one block.

The location is in an arid area with less than 600 mm rainfall, about 15°N latitude, 400 km southwest of Timbuktu. It is about 100 km west of the natural rice area of the inland delta of the Niger River and it has been developed recently as an irrigated rice area through large canal construction by the Office du Niger. Rice was examined at several locations a few miles away from the experiment station and also at an irrigated rice scheme at San, 200 km to the southeast on the Bani river, without detection of BLB. Rice was also examined at a project area 50 km from Bamako at Bancoumana, without detection of BLB. Bacterial streaming was abundant from vessels of affected leaves and typical colonies of *Xanthomonas oryzae* were obtained on isolation. Further studies and survey will clarify the distribution of this disease.

Rice Diseases

Horizontal resistance (non-specific) to rice blast disease. Blast disease of rice is the major problem in many rice growing countries. In the past, breeding for resistance to blast has relied upon "vertical" genes from different sources. Resistance so incorporated has often been ephemeral, cultivars previously considered resistant becoming susceptible. This "breakdown" of resistant cultivars is due to the propagation of a strain of blast pathogen which was undetected in the development of the cultivar. This occurs because so-called vertical resistant host genes operate against the existing common strains, but they are strain specific and therefore are ineffective against non-matching but currently rare strains.

Many upland rice cultivars have a good level of background or "horizontal" resistance which is not strain specific and so does not break down quickly. The problem then is how the old land cultivars can be improved in yield potential without losing their high background resistance to blast. IITA has developed effective methods of screening for horizontal resistance to blast in breeding lines as they undergo general selection under normal conditions.

The methods depend on the following three elements:

(1) Parents must have some susceptibility to a major local blast race. This ensures that the progenies are not resistant due to "vertical" genes.
(2) Environment must provide conditions, or be manipulated to provide conditions, such that blast will occur at a certain level that is low enough to ensure identification of small differences in severity under essentially normal rice growing conditions.
(3) Field design must enable the rate of development and/or spread of the pathogen within the genotype to be judged in terms of time from epidemic onset and/or distance from an inoculum source.

The design used for fixed or almost fixed lines is shown in Fig. 10. (A modified design is required for the earlier generations.) The design enables the breeding row plots to be challenged at one end from a perpendicular

Severe natural occurrence of leaf blast disease of rice at IITA's high-rainfall substation. (Onne, Nigeria.) This incidence helps in identifying and developing blast resistant varieties.

spreader band of many different susceptible cultivars from which infection begins. The level of horizontal resistance is then determined by measuring the amount of blast occurring at different distances from the spreader band at different times, and calculating the rate of disease increase in terms of either time or distance. (Figs. 11 and 12.)

Using this method, 186 lines in screenhouse, and more than 600 lines including IURON 77 from IRRI and international and Japanese differentials in upland were tested. (Table 23.) The most promising lines have been selected from the crosses of TOX 494, TOX 502, TOX 503, TOX 504, TOX 515, TOX 516 and TOX 737. On the other hand, high levels of horizontal resistance have been obtained in improved types from crosses involving African land cultivars, Moroberekan, Lac 23, 63-83 and OS 6. In addition to other characteristics of these African land cultivars, F_2, F_3, F_4 crosses of Japanese upland, Indica and many lines from Latin and South America are presently under intensive screening.

Maximum progress can be made in breeding for horizontal resistance by constantly recombining the most horizontally resistant genotypes.

Table 23. Blast epidemic rate coefficients of major lines and varieties of rice under screenhouse conditions.

Lines and varieties	Epidemic rate coefficients
TOX 494	0.030
TOX 502	0.069
TOX 503	0.023
TOX 504	0.092
TOX 515	0.091
TOX 516	0.060
TOX 737	0.069
IAC 25	Slight lesion
Moroberekan	Slight lesion
OS 6	0.153
Norin 5 (upland)	0.080
Hideri Shirazu	0.107
R 50	0.110
Sokoni	0.179
CAES x (0)-15-7	0.208
Khao Maleuh	0.208
BG 90-2	0.226
ADNY-11	0.214
IR 2734	0.248
ADNY 2	0.482

IITA's work on varietal screening for tolerance to iron toxicity was recognized internationally when Suakoko was selected as one of four sites in the world where co-operative work on varietal tolerance to this nutritional disorder would be done. The three sites are located in Bangladesh, Malaysia and Sri Lanka.

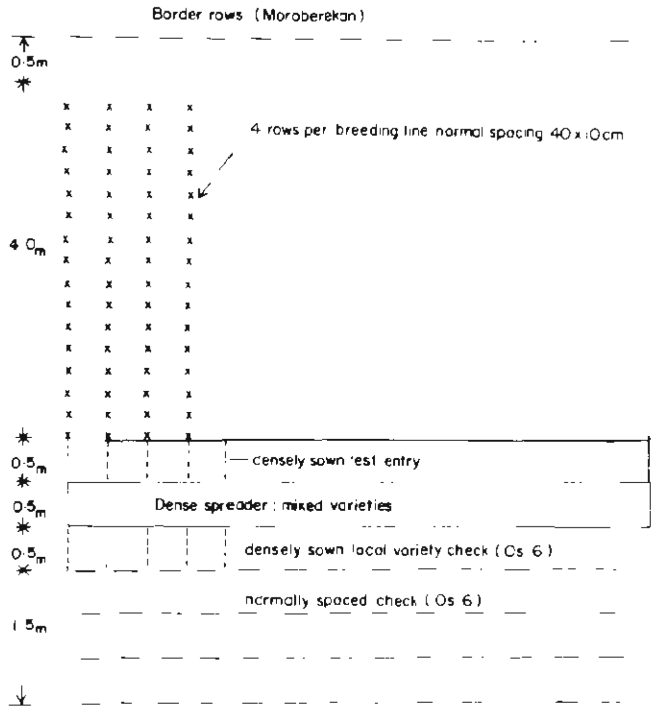


Fig. 10. Field design layout for horizontal blast screening in breeding lines under upland conditions.

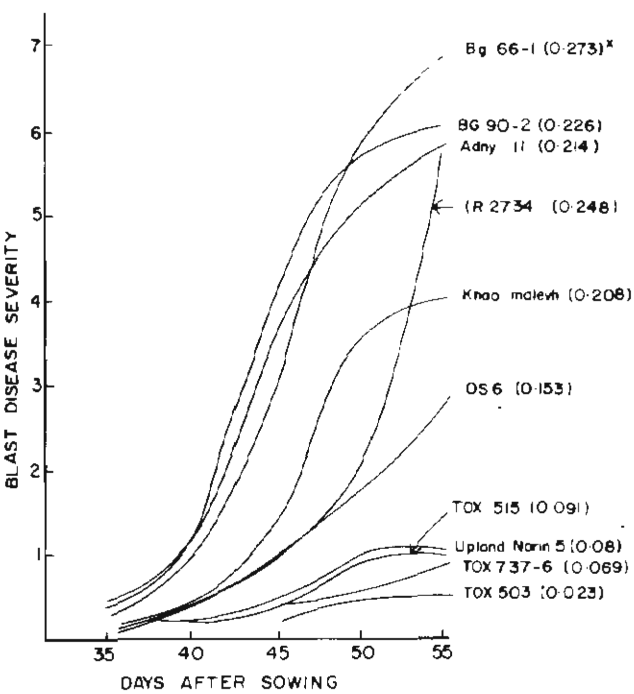


Fig. 11. Increase in severity of blast with time and epidemic rate coefficients.

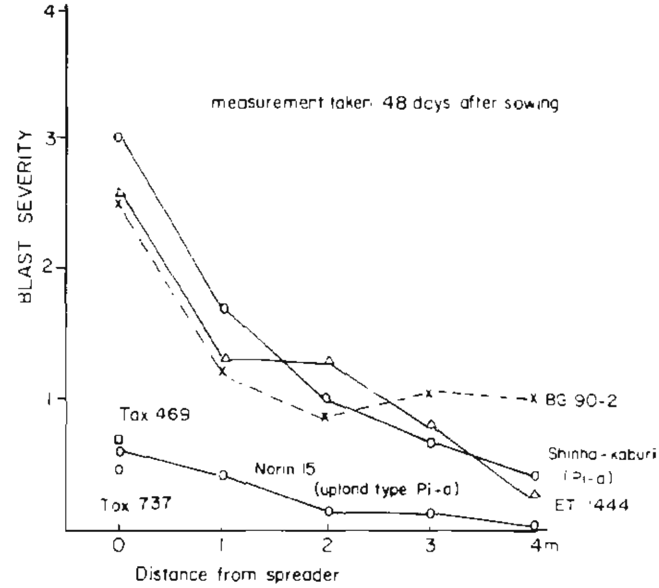


Fig. 12. The relationship between distance from inoculum source and epidemic development in different genotypes.

"Udbatta" disease, caused by *Ephelis pallida* fungus was observed for the first time in Liberia in 1978: it had been reported earlier from Sierra Leone. Also incidence of false smut disease was found more severe during the year.

Improved cultivars for lowland

Two cultivars, Improved Mahsuri (from Malaysia) and IR1416-131-5 (from IRRI, Philippines) have performed better than the recommended cultivars under lowland conditions. Improved Mahsuri yielded higher in the wet season whereas IR1416 yielded higher in the dry season. Improved Mahsuri performed better than IR5 under low as well as moderate-to-moderately-high fertility levels. This may be named Suakoko 10.

Yield trials on upland

Yield trials at Suakoko and Songai Farm showed that among the medium-duration cultivars LS(1)-31-2, LS(25)-4-1 and TOX 95-8-1-1-LS3 (bred locally) IR2035-108-2, IR2053-243-1 (from IRRI) and 4418 (from Colombia) were found to out-yield LAC 23 and white-grained LAC 23. Among short-duration cultivars, IR1154-243-1, IRAT13, and M18 out-yielded LAC 23. These cultivars will be evaluated in on-farm trials.

In the National Rice Observation Nursery, 207 cultivars were screened at Suakoko during dry and wet seasons under three fertility levels ($N_0P_0K_0$, $N_{40}P_{40}K_{40}$, and $N_{80}P_{40}K_0$) to identify cultivars superior to IR5 and Suakoko 8 for inland valley swamp. Cultivars performing better under low fertility and showing better response to fertilizer application in comparison to the recommended cultivars are promoted for evaluation in coordinated yield trials. Cultivars showing better performance than IR5 in these trials are: IR2797-105-2-3-3; IR 4422-164-3-6; IR 2588-19-1-1-2; IR 1416-131-5, BW 78; Imp. Mahsuri; BR 95-75-2; ROK 7; 4421; BR 51-118-2; IR 83/Carrean; IET 1785; C46-15/IR247; BRJ 51-74-6.

Under upland conditions, out of 136 cultivars evaluated in comparison to white-grained LAC23, only five cultivars, B 29C-Mr-31-3, B2149 b-Pn-26, B 130-4 (all from Bogor, Indonesia) and 2607-3, 2660-5 (from IRAT, Ivory Coast) appeared superior to the check cultivar; therefore these will be evaluated further.

Under inland valley swamp conditions, 180 cultivars were evaluated in comparison to IR5 and Suakoko 8 and Improved Mahsuri. These stresses observed were: iron toxicity, neck blast, sheath rot, sheath blight and glume discoloration. Seven cultivars — BR168-28-2-4, B 1665b-Mr-Si-5, B 2931-19-2-2-1, S32-C-46-1, S39F-254, BW248-1 and IR5631-46-1 — were found superior and shall be evaluated further.

During the year, 193 cultivars selected for the rice observation nursery under lowland conditions, were screened for tolerance to iron toxicity in iron toxic swamps at Suakoko and Bong Mines. (Table 24.) Iron toxicity was found to be more serious at the screening site of Suakoko than that of Bong Mines Project.

Table 24. Cultivars identified to be tolerant of iron toxicity in Liberia, 1978.

Cultivar	Iron tox. score (1-9 scale)* Suakoko	Bong Mines
IR2902-50-1-4	8	3
BW78	6	1
IR32	3	5
IR4816-70-1	5	3
BR95-75-2	7	3
4320	1	4
BRN6323	5	3
BKN6986-278	3	4
Brri sail	7	4
IR2668-65-5	9	2
4348	9	2
IR2063-87-1-2	9	3
BR51-118-2	8	2
BR51-67-1/1/c	6	2
4269	3	4
IR2793-k5-2	7	2
IR2793-k5-2	7	1
Suweon	8	3
4456	7	2
IR20	4	2
Maullaga	2	4
BRT52-52-5	4	2
4336	8	2
BR51-199-1	8	2
B189b-29-3-1	5	4
BW196	-	1
IR1416-131-5 (Suakoko 12)	4	1
IR2070-85-1-1-1	7	3
Imp. Mahsuri (Suakoko 10)	6	3
Suakoko 8	5	3
IR5	7	5
Mean	6	3

1 = tolerant; 9 = susceptible

Rice Cooperative Programs

Rice project in Sierra Leone

The project conducts research in agronomy and pathology. During the year, 44 research trials have been conducted on various aspects of agronomy — soil fertility management, cultivation practices, water management and cropping systems.

Upland rice. In flat lands (below 5% slope) the yields of upland rice could be maintained at a good level over four years by mulching, fertilizer application and deep plowing in comparison to bare fields which received no fertilizer or mulch. Weed control and fertilizer application are the key elements to obtain high yields in upland rice. An evaluation of nitrogen response in promising breeding material reveals big differences among the tested varieties. For example, PN 623-3 continues to respond up to 80 kgN/ha, PN 872-1 only up to 40 kgN/ha, LAC 23 up to 80 kgN/ha but with a poor magnitude of response while ROK 3 hardly responds to N fertilizer. (Fig. 13.)

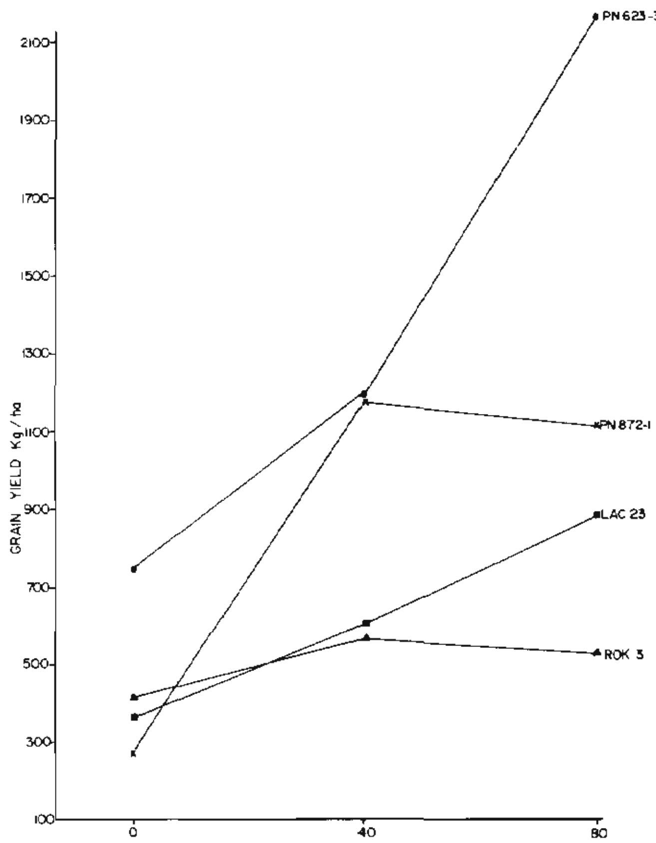


Fig. 13. Pattern of response to added nitrogen by six cultivars tested along with 19 others during the wet season 1978. (Makassa, Sierra Leone.)

Swamp rice. Among 25 varieties tested for adaptation to shallow and deep flooding, GD-28 performs well under both the regimes (3.8-4.5 t/ha) while Gissi 27, BD-2, Mahsuri and Mange 2 perform well (3.4-4.1 t/ha) only under shallow flooding.

In the inland valley swamps, the biggest gains in yield are obtained by drainage, followed by fertilizer application and soil amendments. With an intermediate technology package, yields of 4.1-5.7 t/ha were obtained with ADNY 11.

In a pot experiment with two varieties (Gissi 27 and BD 2), Fe-toxic and non-toxic soils, under water-logged and well-drained water management regimes and with four levels of NPK fertilizer, yield and yield components have been investigated. Gissi 27 had higher dry weight, length and volume of roots compared to BD 2; and these differences perhaps account for higher tolerance of Gissi 27 to Fe-toxicity.

Liberia Rice Project

The IITA-IDA-Liberia Rice Project completed five years during 1978. Cultivar Suakoko 8, released in 1977 through the efforts of this project, has been accepted by the farmers for cultivation in inland valley swamps in various parts of the country. Both IR5 and Suakoko 8 are being promoted for lowland rice cultivation in the country.

Two new improved rice cultivars, Improved Mahsuri and IR 1416-131-5, were found to be superior to IR5 and Suakoko 8 and are proposed to be released as Suakoko 10 and Suakoko 12 respectively. (Table 25.) IR 1416-131-5 was nominated to WARDA coordinated trials from Suakoko in 1976. Reports from these trials during the past three years have also confirmed its high yield potential and blast resistance in several other West African countries. This cultivar also may be named Suakoko 12.

For upland conditions LAC 23 continued to be promoted to farmers. White-grained LAC 23 was found to be equally good or better than LAC 23. Therefore it is proposed to be released as Suakoko 9 for the farmers who prefer white-grained rice. (Table 26.) Suakoko 9 is similar to LAC 23 except that it is about five days earlier in maturity and has shown slight leaf tip "bronzing" (suspected to be zinc deficiency) under certain conditions.

Several new lowland rice cultivars: 4336, 4445, IR 2058-435-2-1 (medium-duration), ADNY 2, IR 2071-621, IR 2053-94-1-2, IR 2588-19-1-2-2 and IR 2053-375-1-1-5 (short-duration) and upland rice cultivars, LS(1)-31-2, IR 2053-243-1, IRAT 13, and M 18 were found superior to the recommended cultivars. These are recommended for evaluation in on-farm trials.

Varietal screening trials indicated that cultivars from Indonesia, Bangladesh, Sri Lanka and Ivory Coast showed better adaptability to upland and lowland rice growing conditions in Liberia.

Table 26. Performance of white-grained LAC 23 (Suakoko 9) compared with LAC 23 in yield trials.

Trial Site	Yield (t/ha) White-grained LAC 23	LAC 23
Suakoko	1.93	1.92
Suakoko	1.48	1.58
Suakoko	1.90	1.70
Sangai Farm	2.32	1.19

Nine promising rice varieties were compared for N-responsiveness under irrigated conditions in the dry season with N rates of 0, 40, 80 and 120 kgN/ha. The varieties ADNY 11, DJ 684D, ADNY 16 and IR 1520-680-3 yielded well (1900-2200 kg/ha) even when not fertilized, followed by a good N response at higher rates of N with yields of 4100-4700 kg/ha at the highest N level. In contrast, ADNY 202, S × S 55-296 and IR 2070-464-1-3 were low yielding (1300-1400 kg/ha) when not fertilized and were also poor in N- response, their highest yields being 1800-2300 kg/ha.

Pathology. Under shallow irrigated swamp conditions, a total of 33 cultivars which were promising during the previous year were tested along with three appropriate checks. Assessment of varietal performance was based on total adaptation with desirable traits. Performance of the best 12 cultivars is as follows:

IR 1529-680-3-2: 139 days total duration, heavy panicle, good tillering, erect flag leaf, good growth but low incidence of sheath rot and neck blast.
ADNY 2 (IITA Sel): 140 days with long grains, heavy panicle, erect flag leaf but low neck blast (15%) and low brown spot disease.
4414: 121 days — long panicle, high tillering, erect leaves, good growth, with low incidence of "dirty" panicles.
4435: 143 days — long grain, heavy panicle, erect leaves and good growth but grassy type, low incidence of sheath rot.
BG90-2: 127 days — long heavy panicle, good tillering, erect leaves, good growth. Brown spot and low incidence of neck blast.
IR9660-0095-F_9: 126 days — heavy long panicles, clean grains erect good growth, low incidence of both sheath rot and neck blast.

Table 25. Performance of improved Mahsuri (Suakoko 10) and IR1416-131-5 (Suakoko 12) in yield trials under inland valley swamp condition, Liberia, 1976-1978.

Season	Year	Location	Yield (t/ha) Improved Mahsuri	IR1416	Suakoko 8	IR5
Dry	1976-77	Suakoko	3.89	3.95	4.25	3.44
	1977-78	Suakoko	3.17	3.50	3.38	3.52
	1977-78	Foya	5.15	5.80	-	4.56
	1977-78	Voinjama	4.28	6.20	6.39	5.13
		Mean	4.12	4.86	4.67	4.16
Wet	1977	Suakoko	5.99	3.35	4.93	5.08
	1977	Voinjama	-	5.90	5.77	5.85
	1977	Kolahun	-	3.90	4.05	5.21
	1977	Zleh Town	4.68	3.81	3.35	4.37
	1978	Suakoko	4.68	-	3.63	3.36
	1978	Bong Mines	3.68	5.44	-	3.67
		Mean	4.76	4.48	4.54	4.59

RPW 6-17: 140 days — heavy panicles, good tillering, erect flag leaves — low incidence of brown spot and neck blast.
Tres Manias: 140 days — heavy panicles, good tillering, erect flag leaves having dirty grains and 10 percent neck blast.
IR 2058-78-3-2-3: 125 days — long grains, heavy panicles — erect growth having exposed panicles, dirty grains; neck blast 10 percent.
C 168-184: 150 days — good grains, heavy panicles, erect plants and flag leaves, Brown spot (low), neck blast 10% and dry upper leaves.
TH 008 ADNY 101: 140 days — good, long heavy panicles having weak stem, lodging, brown spot, dirty panicles.
RP 4-14: 140 days — Long panicles, good grain, good tillering and erect leaves, sheath rot and brown spot (low), neck blast (15%).

The first seven varieties performed well during both seasons.

Evaluation of promising lines. Out of 118 lines tested, 41 lines were promising with good disease resistance. Out of 1048 cultivars tested at four different locations in different ecosystems, 132 entries were selected based on their good performance. Out of these, 34 showed "horizontal resistance" to blast, 17 were tolerant to iron toxicity and 20 were resistant to pale yellow mottle virus.

Nematology. Investigations were made to identify the cause for decline in plant growth and vigor in area continuously cropped to rice by analyzing soil and root tissue samples for parasitic nematodes. Results of analysis showed presence of three species (*Pratylenchus*, *Helicotylenchus* and *Criconemoides*) of nematodes both in soil and root.

Grain Legume Improvement Program

Research resources are shared among cowpea. soybean and lima bean improvement. with cowpea and soybean taking about 95 percent of the total.

Pests and diseases are major problems to increased production of cowpea. As from the outset of the program in 1971, therefore, priority was given to the development of methods for their control. As a result, many sources of host plant resistance to major diseases have been identified and incorporated through breeding and selection into elite lines which have been widely distributed. During 1978, new sources of resistance were further identified and evidence of the stability or instability of existing sources has been gathered.

Work on host plant resistance to insect pests has been very difficult. Techniques used to identify initial sources of resistance have proved inadequate to separate resistant plants from susceptible ones in the segregating populations derived from crosses with them. Other more refined techniques, such as the use of ethylene formulations to simulate the damage caused by thrips, have been needed. The techniques are described in this report. Similarly, new techniques for recognizing resistance to pod sucking bugs, particularly *Acanthomyia horrida*, are being developed.

Breeding has focused on the incorporation of these and other specific characters into advanced breeding lines. Three projects in progress have involved: resistance to thrips, a major cause of crop loss through flower and bud damage; resistance to bruchids, a storage pest that destroys almost one-third of the harvested crop annually; and thirdly, the large white seed preferred in much of the savanna region of West Africa, without which many of the high-yielding disease resistant lines that have been developed are unacceptable.

The principal objectives of the soybean research continue to be to combine good seed viability and the ability of Asiatic lines to fix nitrogen in association with native rhizobia with the resistance to lodging and shattering of high-yielding lines from the USA.

Cowpea

Breeding

The primary objectives continue to be the incorporation of disease and insect resistance into a range of plant types suited to different cropping situations. Priority continued to be placed on grain types for sole crop situations but various materials were screened as an intercrop with maize. Seed size, color and testa texture are important characteristics in determining preference and are receiving increased attention. Further progress was also made in the development of lines for green pod use in more humid areas.

Cowpea emasculation inside the screenhouse.

Conventional breeding and population improvement methods were employed and breeding lines were advanced through four generations and tested at locations in West Africa representing the range of environments under which cowpea is cultivated.

With the identification of improved breeding materials and the accumulation of information regarding the principal factors affecting yields, increased emphasis is being given to the incorporation of specific characteristics such as seed size and color and resistance to thrips and bruchids into advanced breeding lines. Genetic studies are being conducted of a number of such characteristics to evolve more effective breeding strategies.

Conventional breeding

Several backcrossing series are in progress with the objective of modifying seed, plant and disease resistance characteristics. The most advanced of these are crosses of VITA-4 and VITA-5 with Bambey 26, a large white-seeded line from Senegal. The seed weights of selections from BC_3F_2 and BC_3F_3 generations were greater than maximum seed weights at Ibadan for VITA-4 and VITA-5. The selections from the VITA-5 series also show the preferred rough testa character.

Similar improvements in seed size were recorded in F_3 and F_5 generations of first backcrosses involving advanced breeding materials and in ACC 70002, a large, white-seeded line with a rough testa which is currently included in national cowpea trials. The rough testa characteristic was at a low frequency in the progeny. Selections have, however, undergone a second backcross and the original crosses have been repeated to allow further selection.

Crosses between advanced breeding lines and TVx 881-3G were discontinued due to restricted segregation for seed size in BC_1 F_2 generations and new crosses have been initiated using TVu4563, TVu4573 and TVu6945, large-seeded germplasm accessions which had a low incidence of disease in a first-season sowing.

Crossing series have also been established to transfer resistance to colletotrichum and bacterial blight to advanced breeding lines from 1977 trials, long pod fill time and late flowering to improved agronomic backgrounds, and strap or narrow leaf to climbing green pod vegetable types. All of these series will be advanced in the coming dry season for further selection.

Pedigree methods. During 1978, two-way and four-way crosses were made involving lines resistant to thrips or bruchids, large-seeded lines and agronomically superior entries in advanced and uniform trials.

In the second season the F_2 populations from crosses involving thrip-resistant lines were sprayed with etherel at 400 ppm a.i. to select for bud and peduncle retention. All of these series will be advanced through a further generation of selection in the dry season of 1979. The second cycle of the recurrent selection system described in the 1977 Annual Report was completed.

Two-way and four-way crosses (a total of 220) among breeding lines identified in the first cycle were advanced through the F_1 and F_2 generations in the dry and first seasons at Ibadan. The F_2 populations were inoculated with the major diseases and were grown without insecticide protection until 50 days after sowing to facilitate selection for preflowering pests. More than 1000 single plants selected on the basis of disease and insect resistance and plant and seed characters, were grown as progeny rows under reduced insecticide protection at Onne, Ibadan, Mokwa, Daudawa in Nigeria and Kaboinse in Upper Volta. Single plants were selected primarily for thrips and disease resistance at Ibadan from both specific and widely adapted lines and are being multiplied for preliminary trials in 1979.

A total of 171 F_5 and more advanced families were tested in preliminary trials which also included selections from the back-up population and breeding lines from the Institute for Agricultural Research, Samaru, Zaria. The most promising 96 of these with acceptable seed size are also being multiplied for advanced trials in 1979.

Fifty-two lines were compared with VITA-1, VITA-4, VITA-5, Ife Brown and other advanced lines in three 5 × 5 balanced lattice square trials in each of 10 environments in West Africa. Four lines from the back-up population were also included in the trials. The yield performances of lines with similar disease ratings but improved seed yields relative to the standards are shown in Table 1.

Table 1. Best cowpea advanced lines and accessions intercropped with cereals in 4 environments, 1978. (Seed yield kg/ha.)

Entry	Source	Yield
TVX 2394-01F	Adv. 3	1368*
TVX 2907-02D	Adv. 2	1254*
TVX 4619	Intercrop. Tr. 77	1214
TVX 337-01J	Adv. 2	1174
TVX 2912-011D	Adv. 2	1131*
TVX 1593	Intercrop. Tr. 77	1107
TVX 1461-01F	Adv. 2	1090
TVX 4576	Intercrop. Tr. 77	1080
TVX 1839-01F	Adv. 1	1064
TVX 2933-04D	Adv. 2	1045
TVX 2394-02F	Adv. 3	1025*
TVX 1999-02F	Adv. 1	1004
TVX 2946-04D	Adv. 2	994
TVX 2939-01D	Adv. 2	983
TVX 2783-02E	Adv. 2	979
TVX 2938-03D	Adv. 3	978
TVX 3217-09D	Adv. 2	971
TVX 2939-09D	Adv. 2	962*
TVX 3417	Intercrop. Tr. 77	958
TVX 2949-01D	Adv. 2	954*
Yield checks (VITAs 1, 4, 5, Ife Brown)		734

**Entries selected for uniform trials 1979.*

Several lines showed significant increases in yield over standards both within and across environments. However, as in previous years, interactions between lines and environments were highly significant. Environmental and plant data were collected in order to interpret variations in performance and the most important of these are shown in Tables 2 and 3.

Examination of the data and visual observations indicate that performance is a function of several factors. For example, although insecticide was applied, pest damage varied considerably in intensity and nature and at Funtua seed yields were depressed by heavy infestations of *Acanthomyia* during pod filling. Disease levels were low and had little effect on performance except in extreme cases such as golden mosaic in the first season at Onne on the yield of VITA-5. A close correlation between seed yield and plant size across environments indicated the importance of physical factors. Notably, seed yields were

Table 2. Cowpea advanced yield trial location, 1978. (Environmental data.)

Location	Season	Latitude (°N)	Sowing date	Day[1] length (hrs)	Rainfall (mm) Veg. period	Reprod. period	Soil analysis Clay %	pH	Seed[2] yield kg/ha-1
Onne	1st	5.0	21 Mar	12.56	266	309	17	4.2	342
Onne	2nd	5.0	18 Oct	12.24	224	43	16	4.6	894
Ibadan	1st	7.0	15 Apr	12.72	336	113	11	6.4	1251
Ibadan	2nd	7.0	30 Aug	12.48	256	174	13	6.8	1072
Mokwa	M	9.3	9 Aug	12.68	237	79	7	5.7	1019
Farakoba	M	11.1	30 Jun	13.12	427	307	-	-	955
Funtua	M	11.4	2 Aug	12.82	480	87	11	5.2	338
Kamboinse	M	12.3	28 Jun	13.18	229	228	-	-	1388
Gusau	M	12.5	31 Jul	12.88	422	0	7	5.7	879
Saouga	M	14.3	4 Jul	13.23	272	27	-	-	619

[1] *At 20 days after sowing.*
[2] *Mean of 4 standards common to all trials.*

Table 3. Cowpea advanced yield trials, 1978. (Seed yield kg/ha.)

	Onne/F	Ibadan/F	Ibadan/S	Mokwa	Farakoba	Funtua	Kamboinse	Gusau	Saouga	Mean	Percent Controls
Trial 1 (spreading)											
VITA-1	701	1320	1217	531	740	505	655	981	167	757	
VITA-4	247	1333	1047	879	1458	502	2242	929	774	1046	
VITA-5	79	1349	974	1121	1054	390	2072	1658	950	1072	
Ife Brown	379	1291	934	1053	96	94	2047	799	860	930	
TVx 289-4G	399	2056	1549	941	1039	234	1911	1037	667	1093	115
RVx 1999-01F	576	1498	1429	1017	1772	561	2218	1507	904	1276	134
TVx 1999-02E	82	2086	1278	1528	1638	407	1887	1125	1161	1244	131
TVx 2949-03D	444	1944	1333	1321	1557	705	1629	766	898	1177	124
Mean	460	1432	1301	945	1234	462	1614	1029	702		
S.E.±	51.1	163.0	129.8	151.8	138.0	126.4	271.1	169.2	126.1		
C.V. %	27.2	19.7	17.3	27.8	19.4	47.4	29.1	28.5	31.1		
Trial 2 (semi-erect)											
VITA-1	652	1167	1324	1302	687	489	805	699	169	810	
VITA-4	249	1037	1051	934	1450	295	1814	709	837	930	
VITA-5	51	1240	872	1090	1095	154	1500	714	689	823	
Ife Brown	237	1483	1164	1392	916	104	1950	831	720	977	
TVx 1193-7D	447	2173	1110	1613	1718	184	2379	744	1045	1268	143
TVx 2949-019	448	1877	1391	1509	1573	731	926	756	926	1241	140
TVx 2907-02D	607	2067	837	1408	1537	359	1018	732	1018	1232	139
TVx 2933-04D	497	1540	1254	1556	1661	452	2009	640	1051	1184	134
Mean	436	1571	1139	1263	1279	357	1808	706	767		
S.E.±	48.9	196.8	156.5	140.4	134.4	134.5	245.3	118.6	82.3		
C.V. %	27.5	21.7	23.8	19.3	18.2	65.3	23.5	29.1	41.2		
Trial 3 (erect)											
VITA-1	841	1101	1032	947	476	327	538	642	973	657	
VITA-4	226	1249	1182	1138	1237	366	1182	955	634	908	
VITA-5	85	1140	1096	632	665	575	788	903	663	727	
Ife Brown	357	1297	966	1209	763	255	1065	724	953	843	
TVx 7-5H	578	1878	908	1106	870	277	2145	443	509	968	124
TVx 1836-013G	418	1535	1409	1700	872	492	1984	949	681	1116	142
TVx 7-4K	552	1818	971	1385	1057	826	1792	539	595	1059	135
TVx 2394-02F	244	2025	1265	950	1074	280	1797	885	424	994	127
Mean	423	1439	1090	1067	952	445	1550	667	576		
S.E.±	52.5	172.8	212.7	130.1	100.6	157.1	198.4	101.0	123.7		
C.V. %	30.4	20.8	33.8	21.1	18.3	61.1	22.2	26.2	37.2		

depressed by either deficient or excessive rainfall during the period from flowering to harvest. There was, however, little relationship between soil characteristics and yield across these locations.

The linear regression of individual cultivar on trial mean seed yields accounted in most cases for the interactions between genotypes and environments. But some lines showed significant deviations from the regression line. In the case of VITA-1 this was related primarily to photoperiod effects as the addition to the equation of daylength at 20 days after sowing accounted for 76 to 94 percent of the variation in yields compared with 21 to 31 percent where only the trial mean yield was used. For other lines, which were photoinsensitive, photoperiod had no effect but analysis of the data is continuing to identify other environmental factors contributing to yield.

In 1977, two sets of materials were distributed in International Cowpea Trials (ICT). ICT.1 contained 19 breeding lines developed by IITA or by other institutions; ICT.2 contained 9 IITA lines of erect plant types. Ninety-seven sets of ICT.1 and 118 sets of ICT.2 were distributed. Results from 30 and 38 trials respectively have been returned.

In both series the environment accounted for almost 80 percent of the variation in seed yields across trials, 3 to 4 percent was due to differences between lines and the remainder due to interactions between lines and environments. In cluster analysis, for variation in seed yield, the groupings reflected the origins and known characteristics of the lines but not the geographical distributions of environments.

In Trial 1, TVx 1193-7D and 1843-1C gave the highest seed yields followed by TVx 289-4G and 66-2H, both narrow-leaved lines, and VITA-4. TVx 1193-7D has a relatively compact growth habit and has performed well in 1978 trials and will shortly be added to TVx 66-2H and 289-4G and the VITA series. In Trial 2, TVx 309-1G and 7-5H were the highest yielders and it is proposed to also describe the former as a VITA line.

Population improvement

The system of using male sterility with three generations a year and crossing of selected lines on to male steriles in the third generation was continued. New F_1 combinations of disease and insect resistant lines with male steriles of the disease and insect sub-populations were grown as F_2 bulks in the first season when some 8,000 crosses were made in each of the populations on to male steriles. The progenies were intensively selected in the second season and another cycle of crossing was conducted. For the disease sub-population the 25 parental lines included TVu's 393, 493 and 2755 with multiple virus resistance, other lines such as TVu 1190 and six recurrent selections from the 1978S population which had multiple resistance to bacterial or fungal pathogens and to the nematode, *Meloidogyne incognita*. In the insect sub-population 50 parental lines were used in which one of the several desired pest resistances was identified, as well as 24 other recurrent selections from 1978S which on preliminary screening contained suggested expressions of multiple resistance to three or more pests. In addition, a set of double crosses which involved combinations of four sources of insect resistance were crossed on to the insect sub-population male steriles, and merged with the population in the second season as a means of raising the levels of desirable new gene combinations.

The first infusion of genetic materials from the disease and insect sub-populations to the back-up population was made in the 1978 dry season by crossing F_1 rows with male steriles derived from random pollination in the previous generation. In the second season, 20 high-yielding advanced lines were used as selected parents in combination with male steriles after selection of the upper 25 percent for disease resistance and agronomic traits.

The evaluation of single plant selections made in 1977 from the disease and insect populations resulted in about 10 percent being provisionally identified as having multiple resistance to a range of diseases and pests, subject to further evaluation at IITA and in international nurseries. As described, some of these promising selections were used recurrently in the new cycle of crosses for the respective populations. The achievement of multiple insect resistance through population improvement would be invaluable for further progress in cowpea breeding.

Selections from the back-up population were entered in the F_3 breeding nursery and earlier selections from the 1974-1976 populations were respectively yield-tested in the preliminary, advanced and uniform trials. One selection, 4R-0267-1C, has performed well relative to other lines in the international trial of erect lines.

Although high-yielding lines have been derived from the back-up population in different generations, no response to selection over generations could be found in six representative generations.

Modification of the current procedure will emphasize more intensive screening and reselection of the single plant selections, screening the populations in specific environments for specific diseases or pests coupled with selection intensities of 25 percent or fewer retained, and a halt to crossing parents into the population as a whole, in favor of intercrossing amongst carefully chosen parents with multiple combinations of desired characters, to accelerate selection response in elite population subsets.

Intercropping. All entries in the 1978 advanced and uniform trials were evaluated in association with cereals in four environments, in addition to the most promising accessions screened as an intercrop in 1976 and 1977 and selections from the Institute for Agricultural Research (IAR), Samaru, Nigeria. Four replicates of International Trial No. 1 were sown with every second plot containing an unreplicated entry of the remaining lines to provide an augmented design for 100 entries using 160 plots. Cowpea was sown in 4-m length plots of 2 rows 75 cm apart or of 1 row between continuous rows of TZPB maize cultivar when it reached anthesis except at Ougadougou where single-row cowpea plots were sown at the same time as an improved short sorghum cultivar.

Despite high coefficients of variation, the best entries performed consistently well over environments. The results (Table 4) indicate that some of the advanced lines are as well adapted to intercropping as previously identified accessions. Plant types suited to intercropping under improved management (fertilized improved maize and insecticide protection for cowpeas) range from erect to spreading.

Table 4. Cowpea advanced yield trial No. 1, 1978. (Plant character.)

		Pod characters			Plant characters		
Location	Season	Pods m²	Seeds pod ¹	Seed wt*	DFF	Width	Height
Onne	1st	28.0	13.3	118	49.8	61.2	40.3
Onne	2nd		12.7	141	45.4	3.0**	37.8
Ibadan	1st	95.1	13.8	125	45.4	79.0	61.5
Ibadan	2nd	86.3	13.9	116	51.2	73.5	44.0
Mokwa	M	80.4	8.6	143	47.3	71.5	39.5
Farakoba	M	87.9	14.2	114	51.6	66.5	53.1
Funtua	M	41.4	7.8	152	54.4	40.7	32.1
Kamboinse	M	95.8	13.5	140	46.5	65.8	59.5
Gusau	M	66.7	12.4	130	57.2	29.1	25.4
Saouga	M	38.7	14.0	136	54.9	44.6	48.0

*dg seed^{-1}. **Ground cover score.*

Vegetable cowpeas. Early-generation material of crosses among vegetable and grain types, bulked within F_2 plots and F_3 rows after negative screening for Golden Yellow Mosaic virus at Onne 1977S, was reselected at Onne in the first season. Seventy-seven single plant selections were made from 27 F_3 bulks and 122 single plants were selected from 118 F_4 bulks. Ten of these selections were bush type, the remainder were climbing types.

All were grown as progeny rows at Onne in the second season, with an entry from the vegetable cowpea yield trial being entered as a check every 10 plots. Further selection for the vegetable type of pod, and for disease resistance resulted in 24 single plant selections from F_4 rows and 22 from F_5 rows. The reselections and rows will be evaluated at Ibadan and Onne in 1979.

Pathology

Emphasis continued on the genetic control of economically important cowpea diseases, the incidence and severity of which vary with ecological zone. The etiology of the diseases which predominate in lowland humid West Africa is relatively well known, though the etiology of the whitefly-borne cowpea golden mosaic is still under investigation.

Resistance to many of the pathogens of the forest belt has been identified and utilized in the breeding program, though an outstanding problem is the control of *Rhizoctonia* web blight which is a major problem to cowpea production under humid conditions. Sources of low susceptibility (as in TVu 4539) are available but, under high disease pressure, protection is inadequate. In the 1978 first season, the available wild and weedy accessions from the cowpea germplasm collection were sown at Ikenne so as to coincide with the heavy rainfall of June, conditions under which natural development of web blight is known to be favored. None of the material gave resistant reactions though several were no more damaged than TVu 4539. A detached leaf technique shows promise for the detection of small differences in susceptibility which, when combined with appropriate agronomic practices, may reduce web blight damage to tolerable levels.

Field surveys and off-site trial results indicate that disease priorities in the West African savanna, where the bulk of the crop is grown, differ considerably from those of the more humid belt, and future emphasis will be directed to the major pathogens of the semi-arid zone. The most important diseases of the intermediate savannas (9-11°N) are scab (probably *Elsinoe phaseoli*, etiology under investigation), brown blotch (*Colletotrichum truncatum* and *C. capsici*), *Septoria* leaf spot, bacterial blight, cowpea aphid-borne mosaic and, locally, web blight.

At sites further north (12-14½°N), the importance of scab and *Septoria* appears to decline, though bacterial blight, brown blotch and also the parasitic weed, *Striga gesnerioides*, are locally damaging. Sites at medium-high elevations (>1100 m) in eastern Africa share many of the same pathogens, notably scab and *Septoria*, decreasing in significance at altitudes higher than 1300 m. *Ascochyta* blight is an important problem under high humidity at medium elevations; and there is a spectrum of "yellow fleck" and "yellows" virus-like symptoms that require investigation.

Golden mosaic virus

Attempts were made to purify the whitefly-borne cowpea golden mosaic virus (CGMV) which is epidemic at Onne (IITA Annual Report 1977), so as to be able to conduct comparative serological studies with apparently similar diseases in Niger, Kenya, Tanzania and Pakistan. Purification attempts using methods which have proved valuable in America and Japan were unsuccessful. Preliminary attempts to demonstrate infectivity of purified virus preparations failed both after sap inoculation as well as after membrane feeding of whiteflies.

Investigations of the virus-vector relationship of CGMV revealed that whiteflies could acquire the virus from infected plants within 15 minutes but not in five minutes, even when the starvation time was increased from two to four hours. A feeding period of five minutes was required for successful inoculation. The determination of the incubation (latency) and retention (persistence) periods of CGMV in its vector are in progress. In an attempt to relate seasonal variation in golden mosaic development, plots of the susceptible cultivar VITA-5 were sown at monthly intervals and whitefly traps set up. Weekly trap records indicate that whitefly activity may be closely related to disease incidence which reaches a peak during the first rainy season (March-June) but is negligible later in the year (July-December).

No evidence was obtained that CGMV is seed-transmitted. Screenhouse-grown seedlings from seed obtained from diseased plants of VITA-5 were observed for eight weeks under insecticide protection, and no symptoms developed in any of 1500 plants.

Mottle virus

Sources of resistance to the beetle-transmitted cowpea mottle virus (CMeV) have recently been identified. Two isolates of CMeV, one from cowpea and the other from naturally infected Bambarra groundnut, were obtained from the Virology Unit and used in greenhouse screening of the entries in the International Cowpea Disease Nursery (ICDN). Because no sources of immunity were found, the Genetic Diversity Nursery (GDN) was also screened; results are summarized in Table 5.

Table 5. The identification of resistance to two isolates of cowpea mottle virus.

Reaction	No. of lines ICDN		No. of lines GDN	
Immunity	0		0	
Hypersensitivity[1]	1	38%	2	34%
High tolerance[2]	26		55	
Tolerance	44		76	
Susceptibility	89	61%	94	
High susceptibility	25		127	57%
Mixed	2		36	
Total	187		390	

[1]*Necrotic local lesions accompanied by systemic infection TVu 3949, TVx 1843-5C.*
[2]*Including TVus 266-1, 393, 493, 1185, 1888, 1948, 2755, 3901, 4546, VITA-3.*

Field observations indicate that there are clear varietal differences in response to scab and *Septoria*. Several lines have low scores across sites and these will be retested to ensure against disease escape by using artificial inoculation of susceptible spreader cultivars such as TVus 237-2 and 4543 for *Septoria* and TVus 1017, 2331 or 3442 for scab.

Resistance to diseases

Multilocational testing programs such as the International Cowpea Disease Nursery (ICDN) frequently provide evidence for the existence of pathogenic variants across sites, or between seasons, though differential reactions can also occur through disease escape. Though further testing is required, recent results indicate that certain cowpea genotypes (TVus 301-1, 316, 393) may possess stable resistance to rust (Table 6), and to bacterial pustule while other lines indicate that different races occur across sites, well-documented in the case of rust. Of particular note is the appearance at IITA of a new race of rust to which the formerly resistant VITA-1, VITA-3 and TVu 2755 were susceptible, though the standard susceptible TVu 2331 is apparently resistant. (Table 7.) TVu 43 and perhaps others appear to have stable resistance to bacterial pustule across five sites in Africa while the reactions of TVu 455 indicate that East and West African populations of *Xanthomonas* sp. may differ. (Table 7.)

Sources of combined resistance to five of the major virus diseases in African cowpeas have been identified. (IITA Annual Report 1977.) Cowpea virus populations vary in pathogenicity, both within and between sites. Yet recent cooperative results from the ICDN program have shown that certain genotypes possess stable resistance effective against a broad spectrum of virus pathotypes while others give isolate differential reactions. Thus, TVu 1948 possesses immunity to three pathologically distinct Nigerian isolates of southern bean mosaic virus while TVu 1985 has hypersensitive resistance to these, and immunity to a Ghanaian isolate. (Table 8.) Similarly, TVu 2480 possesses immunity to three diverse isolates of cowpea aphid-borne mosaic virus and tolerance to a fourth (in Tanzania); others give differential reactions. (Table 9.) No evidence is yet available that any one resistance mechanism is the more stable.

Entomology

Emphasis continued to be on the identification of insect resistance in the germplasm collection and in advanced generation lines. The most important pests are flower thrips (*Megalurothrips sjostedti*), pod borer (*Maruca testulalis*) and pod sucking bugs, particularly *Acanthomyia horrida*. Outbreaks of aphids on cowpea in several African countries prompted the start of work to identify resistant cultivars to this pest also. Research on insect pests was conducted on cowpea cultivated as a sole crop and as a mixed crop with maize. Further tests of the control of insect pests of cowpea with synthetic pyrethroids at low dosages were conducted on farmers' land.

Table 6. Stability of resistance to rust. (*Uromyces appendiculatus.*)

Line (TVu No.)	Pedigree	Origin	Reaction[1] Season 1976	1977	1978	Site Nsukka, Nigeria	Kabanyolo, Uganda	Ludhiana, India
301-1	56-11	Nigeria	1	1	1	1	1	2
316	56-13	Hungary	1	1	1	1	1	2
393	Taylor Blue Goose	USA	1	1	1	1	1	2
1283	Lalita-2A	Uganda	1	1	1	4	5	9
2331	Chaula	India	9	7	2	4	2	9
2755	No. 8	India	1	1	9	2	9	9
VITA-1	California Black Eye 5A	USA	1	1	9	1	7	2
VITA-3	V.U. 5 Selection	Kenya	1	1	9	2	5	9

[1]*Scores on 1-9 scale. (1 = resistant; 9 = highly susceptible.)*

Table 7. Stability of resistance to bacterial pustule.

Line (TVu No.)	Pedigree	Origin	Reaction[1] IITA, Nigeria	Nsukka, Nigeria	Ukiriguru, Tanzania	Kabanyolo, Uganda
43[2]	11-V-5-6	Nigeria	1	2	1	2
445	Black-Eye 5	USA	8	6	-	5
455	C 5714-8	USA	1	2	2	8
1029	Blue Goose	USA	1	2	2	6
1404	PI 354436	India	1	2	1	3
1433	PI 354429	India	1	2	2	2
1453	PI 145732	Africa	1	2	1	3
1630[2]	FC 31653	USA	1	2	1	3
1888	PI 291140	Australia	7	-	-	7
4540[2]	1F H27-8	Nigeria	1	2	1	3

[1]*Scores on 1-9 scale. (1 = resistant; 9 = highly susceptible.)*
[2]*Resistant also in Tanzania. (P. N. Patel, unpublished.)*

Table 8. Stability of resistance to southern bean mosaic virus.

Line (TVu No.)	Pedigree	Origin	Reaction[1] (isolates) Ife	Oyo-1	Oyo-2
393	Taylor Blue Goose	USA	Hyp	Hyp	Hyp
493	C 5714-13	USA	Hyp	Hyp	Hyp
612	Farin Dengi-2	Nigeria	Imm	Imm	Sus
990[2]	Iron	S. Africa	Hyp	Hyp	Sus
1061[2]	Groit	USA	Hyp	Hyp	Sus
1185	SVs 103A	Uganda	Imm	Imm	Hyp
1220[2]	Producer	USA	-	-	Imm
1851	Texas Purple Hull 49	USA	Tol	Tol	Hyp
1888	PI 291140	Australia	Hyp	Hyp	Imm
1948	PI 186454	Nigeria	Imm	Imm	Imm
1985[3]	Blue Goose	USA	Hyp	Hyp	Hyp
2755	No. 8	India	Hyp	Hyp	Hyp

[1]*Hyp = hypersensitive resistance; Imm = immunity; tol = tolerance; sus = susceptibility.*
[2]*Resistant also in USA. (Kuhn & Brantley, 1963.)*
[3]*Resistant also in Ghana. (Lamptey & Hamilton, 1974.)*

Table 9. Stability of resistance to cowpea aphid-borne mosaic virus.

Line (TVu No.)	Pedigree	Origin	Reaction[1] (isolates) Florida	Kenya	Nigeria
266-1[2]	Paraguay 18	USA	Sus	Sus	Tol
393	Taylor Blue Goose	USA	Sus	Sus	Seg
408-2[2,3]	1-C 2238C	USA	Imm	Seg	Seg
410[2,3]	Texas Purple Hull 49	USA	Imm	Sus	Sus
493	C 5714-13	USA	Sus	Sus	Imm
612[2]	Farin Dengi-2	Nigeria	Imm	Seg	Imm
745	New Era	Nigeria	Sus	Sus	Sus
1185	SVs 103A	Uganda	Hyp	Hyp	Tol
1888	PI 291140	Australia	-	-	Imm
1948[2]	PI 186454	Nigeria	Imm	Sus	Imm
2480[2]	PI 292909	Nigeria	Imm	Imm	Imm
2755[3]	No. 8	India	Sus	Sus	Imm

[1]*Hypersensitive resistance (Hyp); Immunity (Imm); Tolerance (Tol); Susceptibility (Sus); Segregating/Mixed reaction (Seg).*
[2]*Resistant also in Tanzania. (P. N. Patel, unpublished.)*
[3]*Resistant to the vector of CAMV, Aphis craccivora. (IITA, Rep. for 1977.)*

Pod borer (*Maruca testulalis*) is a major pest in Africa and Southeast Asia. Cowpea cultivars resistant to stem damage by* Maruca *have been identified.

Host plant resistance

Flower thrips. *Megalurothrips sjostedti*, is one of the most serious pests of cowpea in Africa. Several lines have been identified as moderately resistant to this pest. They include TVus 1509, 2870, 6507 and 7133. In order to combine resistance to thrips with high yield some of these lines were used in crosses with elite lines such as Ife Brown, TVx 289-4G and TVx 1193-7D. A total of 138 such 2-way and 4-way crosses were made.

The selective insecticide application that served to identify the parent lines consisted of endosulfan applied 50 and 60 DAP, and this did not affect the flower thrips population. While sufficiently selective to identify resistant donor lines, this technique is inadequate for distinguishing resistant from susceptible plants in segregating populations derived from crosses with the resistant parents. For this the ethylene spray technique described in the following section is being used.

Studies of the mechanism of resistance showed that 15 adult flower thrips produced 774 progeny in seven days on TVu 1509 (moderately resistant) compared with 1707 produced on Prima (susceptible).

Pod borer, *Maruca testulalis*, is a major pest of cowpea in Africa. Lines in the preliminary, advanced and uniform yield trials along with cowpea lines selected from the insect sub-population were screened for resistance to stem and pod damage first in the mesh house and later in the field. All the cultivars tested were susceptible to pod damage. However, ER-7, TN 88-63, TVx 309-1G, TVx 1319-03F, TVx 1319-04F, TVx 1905-01F, TVx 2912-013D and TVx 3213-03D showed a low incidence of stem damage. More controlled techniques for screening for resistance to *Maruca* are being developed and it seems probable that these will have to rely on artificial rearing techniques.

Pod sucking bugs are an important group of pests late in the crop's development. About six species are involved of which *Acanthomyia horrida* and *Riptortus dentipes* are perhaps the most damaging. Field trials in Nigeria in the past year indicated clearly that the synthetic pyrethroids (Decis and Ambush) do not control *Acanthomyia*. For the second year running this pest caused serious damage on yield trials at Funtua. Work continues to develop effective screening techniques to identify sources of resistance to these pests.

Aphid, *Aphis craccivora*, has long been recognized as a serious pest of cowpea in Asia. Recent observations suggest that aphids may also be seasonably important in parts of Africa. Surveys conducted in southern Nigeria indicate the presence of at least two biotypes. Cowpea lines from the International Cowpea Disease Nursery (ICDN) and Genetic Diverse Nursery (GDN) were screened for resistance to both biotypes. Resistance effective against both biotypes has been identified in cowpea cultivars TVu 36, TVu 107, TVu 408P_2, TVu 577, TVu 751, TVu 801, TVu 906, TVu 1796, TVu 2755, TVu 2962, TVu 3000, TVu 3273 and VITA-1. The resistance mechanism in some of the cultivars has been investigated; various levels of antibiosis and tolerance occur. (Table 10.) High levels of antibiosis dramatically reduce longevity of the fourth instar nymphs. (Table 11.)

Table 10. Mechanism of resistance to* Aphis craccivora. *(IITA, 1978.)

Cultivar	Resistance	Fecundity* of biotype A
TVu 408P_2	Antibiosis	0
TVu 310	Antibiosis	0
TVu 801	Antibiosis	0
VITA-1	Tolerance	220
Prima	Susceptible	481
S.E. ±		85.05
C.V. %		13.6

**Fecundity of five, 4th instar nymphs in 14 days.*

Table 11. Longevity of 4th instar nymphs of* Aphis craccivora *on resistant and susceptible cowpea cultivars and under starvation. (IITA, 1978.)

Cultivars	Resistance	Longevity in hours
TVu 408P_2	Resistant	30
TVu 310	Resistant	32
TVu 801	Resistant	28
Prima	Susceptible	240
Starved aphis	-	72
S.E. ±		36.36
C.V. %		10.11

Insecticides

Synthetic pyrethroids along with other insecticides applied as high volume and ultra-low volume were tested

Aphid (Aphis craccivora Koch) is a serious pest of cowpea. TVu 200 is susceptible to biotype B but resistant to Biotype A.

for comparative efficacy against various cowpea pests in field trials. In general the synthetic pyrethroids tested at the low dosage appear to be effective against cowpea pests. (Tables 12 and 13.)

Table 12. Comparison of insecticides applied at high volume for control of cowpea pests. (IITA, 1978.)

Insecticides	Dosage g.a.i./ha/ application	Percent damage by: Leafhoppers on foliage	Percent damage by: *Ootheca* on leaves	Percent damage by: *Maruca* on pods	Percent damage by: Thrips on flower buds	Thrips count on 10 flowers	Yield kg/ha
1. Decis	12	6.7	11.7	30.7	18.3	53.7	542
2. Decis	25	7.7	7.7	37.3	12.4	51.8	818
3. Permithrin	25	4.3	12.7	25.3	8.2	29.3	922
4. Pertithrin	50	7.7	7.0	26.7	7.0	17.4	917
5. Sumicidin	50	8.3	8.3	16.0	11.0	31.8	708
6. Sumicidin	100	5.3	8.5	10.0	6.7	26.4	519
7. Monocrotophos Combi	500	6.7	8.4	23.3	3.0	2.7	981
8. Methomyl	500	9.3	20.3	12.7	8.3	21.6	817
9. Control	-	33.3	25.0	45.3	33.4	159.7	399
S.E.±	-	0.7	1.5	1.7	1.0	6.6	33.9
C.V. %	-	38	62	35	44	78	24

*Cowpea TVx 289-4G is one of the elite lines being used to achieve resistance to flower thrips (*Megalurothrips sjostedti*)—one of the most serious pests of cowpea in Africa.*

Mixed cropping

Cowpeas known to differ in susceptibility to damage by flower thrips were compared as sole crops and as mixed crops with maize. The foliage beetle, *Ootheca mutabilis*, caused significantly more damage in mixed crop cowpea than in sole crop. Conversely, flower thrips, *Megalurothrips sjostedti*, caused significantly less damage in mixed crop cowpea than in sole crop. (Table 14.)

Growth and management

Leaf shape and light enrichment

For a number of years, IITA's cowpea breeders have been selecting lines which have the hastate leaf (narrow leaflets) character. Although some of the high-yielding lines in 1977 trials have this leaf type, no evaluation of the physiological value of this character has so far been made.

Two experiments were conducted in 1978 in which light interception and leaf area were determined for canopies of erect cowpeas having either normal or hastate leaf shapes. The canopies were separated into 10-cm layers so that leaf area distribution with height could also be determined. Comparison of light interception-leaf area relationship shows no difference between the two leaf

Table 13. Comparison of synthetic pyrethroids and organophosphorous insecticide applied at ultra low volume (ULV) for control of cowpea pests. (Test crop TVx 7-5H; trial conducted at Odo Ogun village 65 km north of Ibadan. IITA, 1978.)

Insecticide	Dosage g.a.i./ha	Percent damage by: Flower thrips on flower buds	Percent damage by: *Maruca* on pods	Insect count: Thrips/ flower	Insect count: *Maruca*/ flower	Yield kg/ha
Decis	12	21	16	5.9	0.40	1399
Cymbush	30	23	11	7.5	0.30	994
Ripeord	60	19	10	4.6	0.25	1357
Malathion	1000	28	31	10.6	0.35	847
Folithion	1000	17	5	6.6	0.33	1815
Perfektion	500	44	32	10.1	0.37	783
Control		80	49	11.7	0.63	88
S.E.±		1.4	1.3	0.4	0.01	71.4
C.V. %		23	34	53	24	36

Insecticide applied at 35, 45, 55 DAP.

Table 14. Comparison of insect damage on unsprayed cowpea as a sole crop and a mixed crop with maize. (IITA, 1978.)

Cultivars	Foliage thrips on flower buds: Sole crop	Foliage thrips on flower buds: Mixed crop	Percent damage by foliage beetle on leaves: Sole crop	Percent damage by foliage beetle on leaves: Mixed crop
TVu 1509	13.3	10.9	6.5	23.2*
ER-7	17.7	15.7	28.2	34.7*
Ife Brown	48.1	28.1*	23.9	32.1*
TVx 7-5H	26.1	15.9*	18.2	21.3
TVx 1843-1C	27.5	13.0*	9.2	23.4*
TVx 289-4G	42.9	16.6*	28.3	39.2*
S.E.±	5.6	2.4	3.9	3.0
C.V. %	46.5	35.9	49.6	25.4

**Effect of cropping system significant (5% level) within cultivars.*

shapes. (Fig. 1.) Leaf area distribution of the two cultivars was also similar although the first season canopy (sampled at flowering) was shorter than that of the second season (sampled in early pod-fill.) (Fig. 2.) These results indicate that the hastate leaf character provides no inherent physiological advantage.

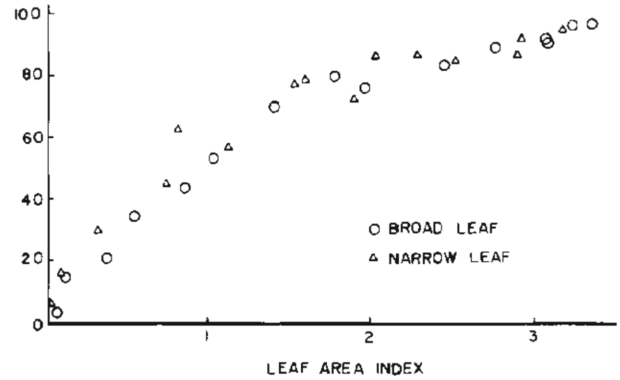


Fig. 1. The relationship between leaf area and light interception for two cowpea cultivars differing in leaf shape, grown in a field experiment during second rains, 1978.

This conclusion is borne out by studies in which supplementary light was given to the lower leaves of the same normal and hastate leaf cultivars as used above. White metal reflectors were placed beside the rows from flowering to maturity, and increased incident radiation reaching the crop by 22 percent. Seed yields were increased by an average of 32 percent and 12 percent in first and second seasons, respectively. (Table 15.) Although the interaction between leaf shape and light enrichment was significant in the first season, it was not in the second season, and could be accounted for by the 50 percent increase in yield of TVx 332-4G in the first experiment. The smaller response and overall lower yield in the second season can be traced to lower dry weights at flowering (Table 16) and shorter pod harvest periods (36 versus 21 days for first and second seasons respectively). The results indicate that cowpeas grown at Ibadan respond to supplementary light regardless of leaf shape. The general light-responsiveness of cowpea under conditions not limiting in moisture is further indicated by

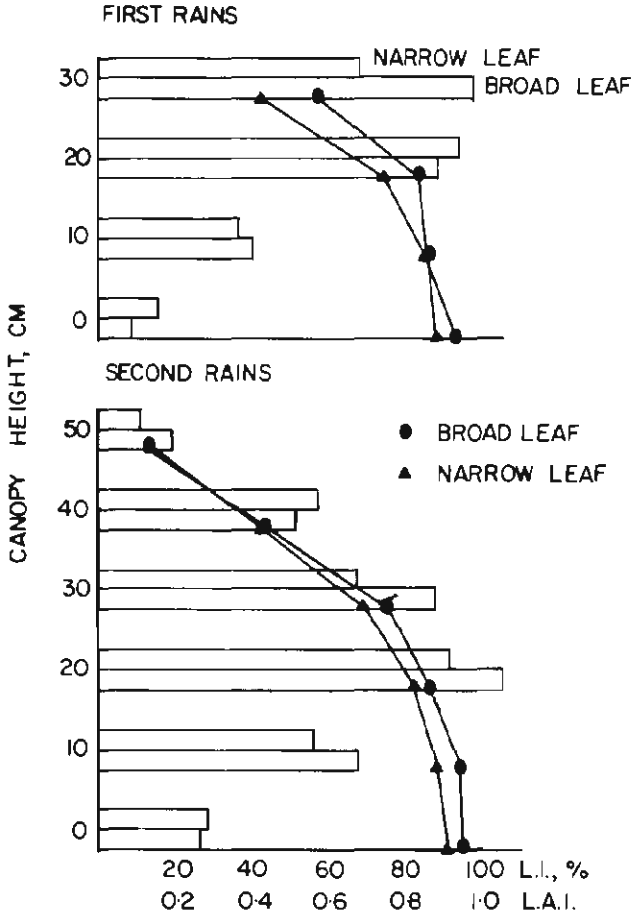


Fig. 2. Leaf area distribution in 10-cm layers of two cowpea cultivars differing in leaf shape, and the resultant light interception by the canopies for two experiments, grown in first and second rains, 1978.

high seed yields obtained at some sites in the savanna area of West Africa.

Photoperiod response

Studies in 1977 indicated that cowpea lines differ markedly in photoperiod response, and that they range in sen-

Table 15. The influence of supplementary light from white reflectors placed in the row at flowering, on seed yield of cowpea with broad or narrow leaf shape in two experiments grown in first and second seasons, 1978.

		Yield, g/m²			
	Leaf	First season		Second season	
Cultivar	shape[1]	Control	Light	Control	Light
TVx 1193-10F	B	126	149	82	95
TVx 1836-19E	B	123	162	-	-
4R-267	B	-	-	88	102
TVx 332-4G	N	154	231	91	94
YP 182-1d	N	102	128	-	-
TVx 1474	N	-	-	102	115
S.E.± (within cultivar)			9	10	
C.V. % Interaction cv. x light			12	9	

[1]*B = broad; N = narrow*

Table 16. Total dry weight and leaf area of cowpea cultivars in two light enrichment experiments, at the beginning of the light supplementation period (at flowering).

	First season		Second season	
Cultivar	Total dry weight g/m²	Leaf area index	Total dry weight g/m²	Leaf area index
TVx 1193-10F	114	1.10	59	0.77
TVx 1836-19E	98	1.35	-	-
4R-267	-	-	52	0.76
TVx 332-4G	113	1.40	38	0.54
YP 182-1d	84	0.94	-	-
TVx 1474	-	-	71	1.04

sitivity from lines which flower only between October and March at Ibadan to others whose flowering behavior is not affected by daylength. To test how the degree of photoperiod sensitivity of such lines could be characterized by field plantings in Ibadan, 15 lines were planted in April, and at 15-day intervals in four plantings starting on 1 August. The results indicate that the planting on 1 August allows discrimination between lines of different photoperiod sensitivities. (Fig. 3.) Late-flowering insensitive lines such as TVu 950 may be classed as photosensitive at later plantings. If the lines were planted in June or July, the very sensitive materials would have such a long vegetative period that they would become crowded in the field, and would be more subject to virus diseases before they finally flowered. The 1 August planting date, therefore, represents a compromise that permits seeds to be harvested even from the most sensitive lines.

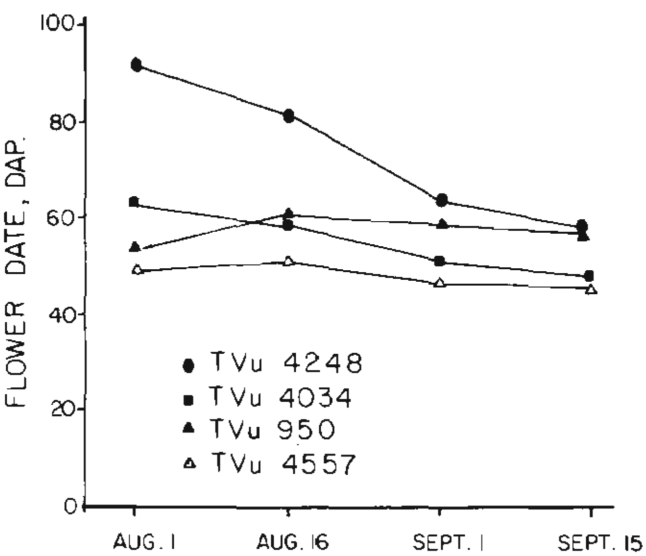


Fig. 3. Flowering date as related to planting date for four cowpea cultivars differing in photoperiod sensitivity. TVu 4248 and TVu 4034 are sensitive to photoperiod, while TVu 950 and TVu 4557 are insensitive.

Seed quality at harvest

Previous work at IITA has demonstrated that if harvest of dry seeds is delayed after the pods first mature, they deteriorate rapidly and viability declines. To determine if there are varietal differences in the rate of decline, pods of four cowpea cultivars were collected from field plots when the pods had become yellow but not dry. They were then allowed to dry or were misted with water three times a day to simulate rain at harvest. At weekly intervals, samples were taken for germination testing. Seeds of a cultivar local to the savanna zone deteriorated to 23 percent germination within one week. (Fig. 4.) This cultivar has large white, wrinkled seed, but would be maturing in very dry environments in its place of origin. The cultivar showing least deterioration under wet conditions (72% germination after 3 weeks of intermittent mist) is grown in central Nigeria and harvested in June-July. Its seeds are small, with smooth seed coat. VITA-1 and VITA-4, also included in the trial, had 46 and 56 percent germination after three weeks mist treatment. Pre-harvest sprays of the systemic fungicide benomyl gave only marginal improvement of the germination of seeds from pods subjected to the wet treatment, indicating that fungi either were not the principal causal agents of the deterioration or that they were not adequately controlled by the chemical. Detailed analyses of fungal incidence are still being summarized.

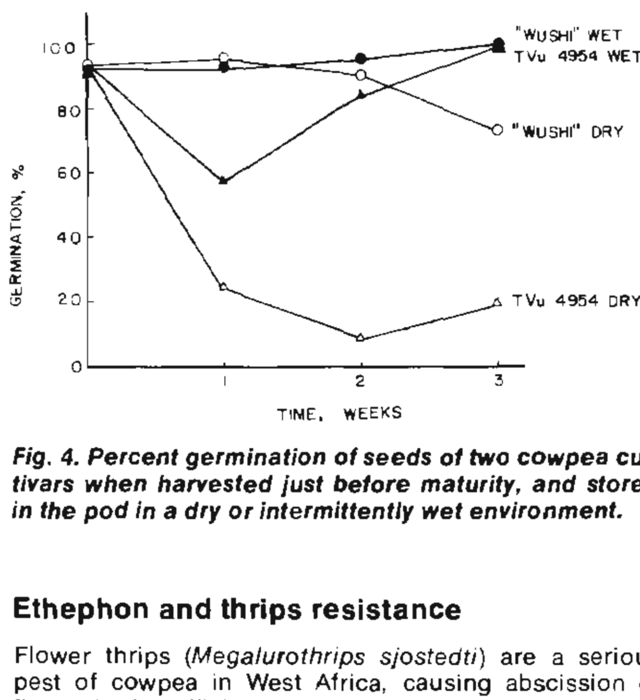


Fig. 4. Percent germination of seeds of two cowpea cultivars when harvested just before maturity, and stored in the pod in a dry or intermittently wet environment.

Ethephon and thrips resistance

Flower thrips (*Megalurothrips sjostedti*) are a serious pest of cowpea in West Africa, causing abscission of flower buds sufficient in severe cases to totally prevent flowering of the crop. It was observed that cultivars which are least susceptible to thrips are also less subject to flower bud and peduncle abscission when treated with the abscission-causing growth regulator ethephon. The chemical is sprayed on the plants about one week before flowering. Timing of the spray is critical. Applied too early, it has no effect because vegetative buds and reproductive buds on peduncles that have not begun to elongate are relatively insensitive to the chemical. Similarly if applied late, large reproductive buds and open flowers are unaffected. To ensure that all plants are treated at the critical stage of growth between these two extremes, populations segregating for flowering date can be sprayed three or four times at intervals of five to seven days.

Table 17. Correlation coefficients (r) between resistance to ethephon and to thrips damage of 28 or 30 cowpea lines assessed by various criteria in three field trials.

Ethephon Resistance Characteristics	Thrips Resistance Characteristics: 30 lines, % long peduncles	30 lines, % peduncle abscussion	28 lines, % long peduncles	28 lines, % peduncle abscussion
Expt. 1				
% flower buds retained	0.40*	−0.38*	0.53**	−0.44*
% peduncle abscussion	−0.58**	0.67**	0.68**	0.70**
Expt. 2				
% flower buds retained	0.45*	0.33	0.45*	−0.33
% peduncle abscussion	−0.64**	0.51**	−0.71**	0.53**
Delay in flowering (days)	−0.33	0.39*	0.47	0.48**

*, **Significantly different from zero; P = 0.05 and 0.01, respectively.*

To test the efficacy of ethephon sprays as a screening tool for thrips resistance, 30 cowpea lines differing in thrips resistance were sprayed with 200 or 400 ppm ethephon in two trials which were protected against insects. A separate planting of the same 30 lines was made in a thrips-infested area to evaluate their relative thrips resistance. The degree of resistance to ethephon was judged by counts of flower bud and peduncle abscission on both main stem and branches. Thrips damage was evaluated using peduncle abscission and degree of peduncle elongation.

In sensitive lines, ethephon sprays caused significant delays in flowering, whereas less sensitive lines were only slightly delayed. Delay in flowering was significantly correlated (5 percent level) with thrips resistance. Percent retention of flower buds, and percent peduncle abscission due to ethephon spray showed higher correlations with thrips resistance than delay in flowering. (Table 17.) Two lines, which are significantly earlier-flowering than the rest of the cultivars in the trials showed less thrips damage but were highly susceptible to ethephon sprays. These lines (ER-1 and TVu 6863) probably escaped thrips damage due to their early flowering. When the correlations were recalculated, omitting these two lines, the relation between ethephon resistance and thrips resistance was often improved. (Table 17.)

The average ranking of the 30 lines for thrips and ethephon resistance is shown in Table 18. The standard VITA lines and some of the new TVx lines show very low resistance scores.

The technique of ethephon spraying and thereafter checking for bud and peduncle abscission on the main stem shows promise in the identification of thrips resistance in segregating populations and parental lines. Susceptible lines that escape thrips damage by early flowering are also detected by the technique.

Table 18. Ranking for insensitivity to ethephon and resistance to thrips for 30 cowpea lines grown in three field trials.

Line	Ethephon insensitivity ranking*	Thrips resistance ranking*
1. VITA-1	16	25
2. VITA-3	21	21
3. VITA-4	20	30
4. VITA-5	29	21
5. Ife Brown	9	19
6. TVx 289-4G	25	29
7. TVx 1843-1c	15	26
8. TVx 33-1j	18	21
9. TVx 181-4G	9	11
10. TVx 332-4G	28	18
11. TVx 387-5G	11	13
12. TVx 1193-012H	6	14
13. TVx 1836-9G	4	12
14. TVx 1836-120G	7	24
15. TVx 7-5H	19	7
16. ER-1	23	10
17. TVx 1850-01E	26	17
18. TVx 1948-01F	12	28
19. TVx 1952-01E	30	27
20. TVx 1997-3D	21	16
21. TVx 1999-1D	27	15
22. TVx 2713-2c	12	9
23. 4R-267-F	8	2
24. TVu 1509	2	4
25. TVu 2870	5	1
26. TVu 6507	1	4
27. TVu 6863	24	8
28. TVu 6904	17	20
29. TVu 7133	3	6
30. TVu 8649	14	2

**Ranking here is inverted: 1 = least susceptible; 30 = most susceptible.*

Soybean improvement

The principal objective of IITA's soybean improvement effort is to develop cultivars adapted to lowland African environments. A major goal is to combine good seed storability, the ability to fix nitrogen in association with indigenous rhizobia, high yields and resistance to lodging and shattering.

Advanced generations of crosses made in 1973 and 1974 for yield improvement were ·ated. There was no significant difference among 10 cultivars tested in uniform yield trials. (Table 19.)

Bossier and Jupiter were among the best in the uniform and advanced trials; none of the breeding lines was significantly better. (Table 20.)

However, lines in the preliminary yield trials in the main and dry seasons look promising in comparison with the checks (Table 21) and will be evaluated with more preci-

Asiatic soybean (left) nodulates freely while the U.S. type is vigorous. Desirable characteristics on both types are being combined to produce good soybean lines for African conditions.

sion in advanced trials during 1979. The lines TGx 160-12E and TGx 139-5E were among the best 10 lines in both seasons.

In cooperation with INTSOY, a uniform trial was sent to 26 cooperators in Africa in 1976 and to 16 in 1977. Slopes of regressions of genotype yield on the site mean yield (Fig. 5) indicate that the variety Davis gave the highest yields across different environments.

In many locations Davis may not be acceptable as a cultivar because its height varies with location, from 19 cm to 81 cm with a mean of 38 cm. Nevertheless, because of its consistently good yield Davis is being used as a parent in several crosses to improve its seed storability and increase seed size.

In seed storability tests neither the standard laboratory germination test nor a cold-stressed germination test would accurately predict field emergence of aged seed. In the cold-stressed treatments seeds were kept in moist paper folders at 12°C for seven days, then moved to 28°C for four days before scoring the germination.

The viability of aged seed of 100 F_3 families was evaluated by a field emergence test, by standard laboratory germination and by the cold-stress germination test. Correlations between laboratory germination and field emergence and between cold-stressed germination and field emergence were 0.24 and 0.27 respectively.

Table 19. Performance of ten soybean genotypes in a uniform trial at Ibadan during the 1978 wet season.

Genotypes	Yield kg/ha	Plant height cm	Lodging score*	Shattering score*	Days to harvest
TGx 11-3E	2968	80	1	1	101
Bossier	2814	58	1	1	96
TGx 26-23D	2808	83	2	1	100
Jupiter	2705	86	2	2	101
TGx 47-5C	2696	80	1	1	99
TGm 220-1-2205	2684	47	1	1	100
TGx 13-3-2644	2625	64	1	1	100
TGx 21-2	2522	79	1	2	93
TGm 210-1-2363	2404	50	1	2	95
TGm 249-3	2194	58	1	1	96
Mean yield =	2644				
S.E.±	246				
C.V. % = 18					

**Scored on a 1-5 scale (1 = low incidence; 5 = high incidence)*

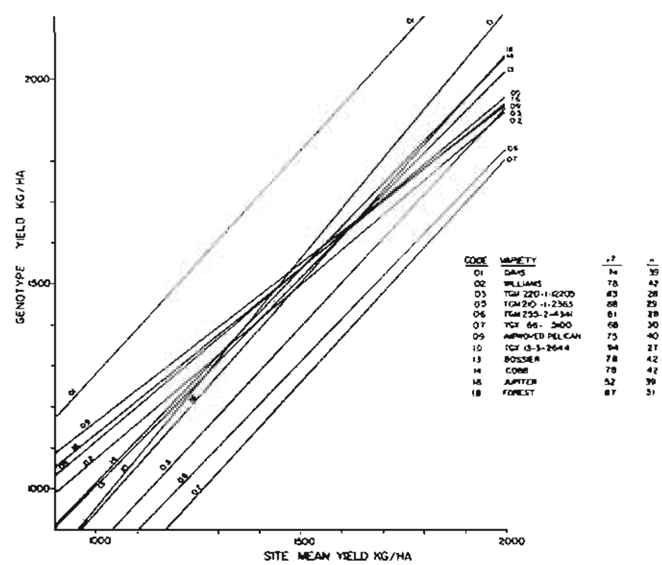


Fig. 5. Effect of moisture on soybean viability.

Role of pathogens in seed deterioration. An experiment to determine the role of pathogens in seed deterioration prior to harvest was carried out in the first wet season of 1978. Benomyl fungicide was applied as a foliar spray weekly from mid-flowering to maturity to four cultivars with contrasting storability. The seeds were harvested either promptly at optimum maturity or with a delay of two weeks. The delayed harvest reduced viability by 25 percent (Table 22) and the cultivar x harvest time interaction was significant. Seeds from untreated plants had 2 percent higher viability (Table 23) than plants treated with benomyl for prompt harvest and 9 percent for the delayed harvest. From observations that benomyl slightly reduced the incidence of fungal pathogens (Table 24) and that benomyl resulted in increases in seed viability, it seems probable that pathogens are important in the loss of seed viability prior to harvest.

Other evidence, however, suggests that pathogens do not play a major role in seed deterioration during storage. Fungal growth appeared to be completely controlled by dusting benomyl on seeds of the cultivar Bossier which had been equilibrated to 10, 13, and 16 percent moisture content before the onset of storage at 28°C. But inhibition of fungal growth did not influence the rate of decline of viability during storage. Viability fell rapidly when the moisture content of seed was high, suggesting that seed moisture content, not pathogens, is more important. Further evidence for this was obtained when embryos were aseptically extracted from four sets of Bossier seeds, i.e., seed equilibrated to 10, 13, and 16 percent moisture content and stored for nine months and from freshly harvested seed. Embryos incubated in Potato Dextrose Agar showed that embryo infection remained low (Table 25) though the viability of embryos was markedly affected by seed moisture content.

Hybridization

More than 300 crosses, including single, double, and backcrosses, have been made to incorporate seed longevity into high-yielding soybean lines and to incorporate genes for fixation of nitrogen in association with

Table 20. Performance of best soybean genotypes in three advanced yield trials at Ibadan in 1978.

Genotype	Yield-Rank ( ) kg/ha	Plant height cm	Lodging score*	Shattering score*	Days to maturity
Advanced trial 1, 1978 wet season					
Bossier	4028 (1)	62	1	1	100
M-216	3310 (2)	51	1	1	103
TGm 220-1-2205	3247 (3)	58	1	1	101
TGm 210-1-2363	3243 (4)	70	1	1	96
Jupiter	3147 (5)	96	2	1	103
No. of entries = 20					
Mean	2843	82	2	1	98
S.E.±	242				
C.V. %	17				
Advanced trial 2, 1978 wet season					
TGm 220-1-2205	3033 (1)	52	1	1	98
TGm 210-1-2363	2991 (2)	80	1	1	98
TGx 36-10C	2826 (3)	95	2	1	101
TGx 57-1C	2814 (4)	86	1	1	99
TGx 12-4E	2795 (5)	58	1	1	99
TGx 57-2C	2772 (6)	90	1	1	100
TGx 9-3F	2766 (7)	111	1	1	95
Jupiter	2741 (8)	96	3	2	101
TGx 46-3C	2733 (9)	61	1	1	99
Bossier	2649 (10)	58	1	1	97
No. of entries = 20					
Mean	2571	79	1	1	100
S.E.±	188				
C.V. %	15				
Advanced trial 3, 1978 dry season					
M-216	2360 (1)	42	1	1	102
Jupiter	2280 (2)	84	2	1	102
TGx 11-3E	2250 (3)	66	3	1	102
TGm 220-1-2205	2200 (4)	44	1	3	101
TGx 36-10C	2170 (5)	74	2	1	91
TGx 57-1C	2160 (6)	82	3	3	97
TGx 46-3C	2140 (7)	48	1	1	105
TGx 26-23D	2120 (8)	80	3	2	98
TGx 9-3F	2010 (9)	104	3	1	103
TGx 68-2C	2000 (10)	66	1	1	112
Bossier	1950 (11)	42	1	1	102
No. of entries = 15					
Mean	2000	63	2	2	100
S.E.±	114				
C.V. %	15				

**Scored on a 1-5 scale (1 = low incidence; 5 = high incidence.)*

Table 21. Performance of the best of 144 soybean genotypes grown in single row plots during two seasons at Ibadan in 1978.

Genotype	Yield g/m²	Plant height cm	Lodging score	Days to maturity
Preliminary trial, 1978 wet season (2 reps)				
TGx 38-1F	511	139	2	102
TGx 139-5E	445	108	2	103
TGx 173-2E	428	107	1	109
TGx 139-1D	415	106	2	102
TGx 9-1H	404	84	1	99
TGx 11-1H	398	90	2	103
TGx 139-2E	394	96	2	110
TGx 171-2E	386	86	1	105
TGx 160-12E	385	103	1	99
TGx 9-2H	369	123	3	98
Checks				
Bossier	305	68	1	94
Jupiter	299	109	2	101
Preliminary trial, 1978 dry season (1 rep)				
TGx 118-3E	319	80	2	92
TGx 173-1E	316	110	4	102
*TGx 160-12E	301	115	3	102
TGx 187-3E	295	96	3	102
TGx 171-4E	290	74	2	88
TGx 160-5E	274	98	4	112
*TGx 139-5E	268	110	5	98
TGx 147-4E	267	99	2	90
TGx 163-2E	265	70	2	88
TGx 37-1G	264	90	3	90
Checks				
Bossier†	207	60	1	92
Jupiter	218	100	3	92

**Genotypes TGx 160-12E and TGx 139-5E were in the top 10 in both seasons.*

†Bossier and Jupiter were replicated 10 and 9 times respectively; their standard deviations were 38 and 50.

Table 22. Effect of delayed harvest on seed germination of four soybean cultivars.

Cultivar	Prompt harvest	Delayed harvest	Difference
Bossier	87.6	54.8	32.8
TGm 294	86.1	63.1	23.0
TGm 686	89.8	75.7	14.1
TGm 685	93.2	73.1	20.1
Mean	89.2	66.7	22.5
% Reduction	-	-	25.2

rhizobia indigenous to Africa. Three breeding procedures are being used to meet the objectives: 1) pedigree, 2) backcross and 3) diallele selective mating, which is a recurrent selection scheme. The progenies of most crosses made will move through the pedigree system.

Most F_2 plants are threshed separately and F_3 families are evaluated for seed longevity by an accelerated aging test and are being screened on low-nitrogen soil for nitrogen fixation with indigenous rhizobia. Plants from promising F_3 families are selected, and advanced for further evaluation. Preliminary yield tests begin at the F_5 generation.

Compatibility

Some soybean cultivars can form effective nodules with indigenous *rhizobia*; however, at present, if high-yielding soybean cultivars are to be grown in Africa without nitrogen fertilizers they must be inoculated with *Rhizobia japonicum*.

In 1978, studies were started to identify soybean lines that nodulate effectively with native rhizobia in different ecological areas. The efficiency of the symbiosis was determined and the most promising material selected and incorporated into a breeding program.

About 250 lines in a soybean germplasm collection were evaluated for compatibility with rhizobia native to six locations in Nigeria. Sites representative of diverse climate and soils were selected. More than 90 percent of the lines

Table 23. Effect of delayed harvest and benlate on seed germination of four soybean cultivars.

	Prompt harvest			Delayed harvest		
	Benlate	Untreated	Difference	Benlate	Untreated	Difference
Bossier	89.8	85.5	4.3	59.8	50.0	9.8
TGm 294	87.5	84.8	2.7	64.3	62.0	2.3
TGm 686	90.5	89.2	1.3	78.6	73.0	5.5
TGm 685	93.5	90.0	3.5	75.8	70.5	5.3
Mean	90.3	88.1	2.2	69.6	63.9	5.7
% Reduction	-	-	2.4	-	-	8.2

Table 24. Effect of Benlate on incidence of pathogens for four soybean cultivars under delayed harvest conditions, 1978 wet season.

	Phomopsis sp.			*Macrophomina Phaseoli*			*Fusarium* sp.			*Colletotrichum truncatum*			*Aspergillus* sp.			*Cercospora kikuchii*		
	T	N	△	T	N	△	T	N	△	T	N	△	T	N	△	T	N	△
X	6.6	8.4	1.8	5.6	5.7	0.1	12.0	18.4	6.4	4.6	6.4	1.8	3.8	4.2	0.4	15.8	21.9	6.1
% Reduction		21			2			35			28			10			30	

T = Treated *N = Not treated* *△ = Difference*

Table 25. Effect of storage on rates of fungal infection of embryos.

	Viable embryos (percentage)	Infection of embryos *Aspergillus* sp.
Freshly harvested:	95	0
Stored 9 months at:		
10% M.C.	45	1
13% M.C.	0	3
16% M.C.	0	5

M.C. = Moisture content.
% = Based on observations of 100 seeds per treatment.

tested were incompatible with the local strains of rhizobia (those with ratings of 1 or 2).

However, eight lines were promiscuous and capable of forming an effective symbiosis at all six sites. Rhizobia strains were isolated from nodules collected at each location and the compatibility of the strains with the promiscuous soybean lines was then tested in sterile soil. The result showed that the promiscuous soybeans were compatible with more than 50 percent of the native strains, whereas the improved cultivars of U.S. origin (TGm 80 and 294) established an effective symbiosis with only a few of the isolates. (Table 26.)

Table 26. Compatibility of several soybean cultivars with 22 rhizobia strains indigenous to diverse environments in Nigeria.

	Compatibility rating*			
Cultivar	1	2	3	4
TGm 618	3	2	6	11
TGm 710	2	10	6	4
TGm 725	1	6	9	6
TGm 119	0	5	5	12
TGm 918	2	9	9	2
TGm 730	2	8	9	3
TGm 120	0	0	6	16
TGm 579	1	2	4	15
TGm 51	0	4	3	15
TGm 80	10	8	1	3
TGm 294	12	6	3	1

**1 = non-effective* *3 = effective*
2 = partially effective *4 = very effective*

Since many of the wild legumes in Africa are members of the cowpea cross inoculation group, it seemed probable that some soybean lines were capable of using cowpea-type rhizobia. This indeed appears to be the case. The promiscuous soybean cultivars formed an effective symbiosis with at least two of the three cowpea rhizobia strains tested; in contrast the high-yielding materials of U.S. origin did not nodulate with any of the cowpea strains. Further work conducted at Rothamsted Experimental Station has demonstrated that one of the promiscuous soybean lines forms nodules with a large number of cowpea rhizobia strains.

From a grafting experiment at IITA it was concluded that the symbiosis with indigenous rhizobia appears to be an efficient one and capable of supporting the nitrogen requirement of the high-yielding U.S. cultivar TGm 80. The shoot of TGm 80 grafted onto the root of a promiscuous cultivar TGm 918 and grown in uninoculated field soil showed the same growth and gave similar yields to TGm 80 grafted onto itself and inoculated with *R. japonicum*. (Table 27.)

This evidence shows that the present need to inoculate high-yielding cultivars with *R. japonicum* can be overcome by incorporating the promiscuity of these soybean lines into high-yielding improved cultivars. However, the success of such a breeding scheme will depend upon the ability to select plants possessing the promiscuity from a segregating population. Present techniques are not applicable because they are either destructive or tedious.

Researchers in Japan and Australia have recently shown that for some legumes most of the N_2 reduced in the nodules is translocated to the shoot in the form of ureide compounds (allantoin and allantoic acid) and plants growing on inorganic nitrogen contain only small amounts of these compounds. The possibility of using allantoin accumulation as a means of identifying plants fixing N_2 was investigated in a series of field trials. In the first experiment, two cultivars were grown on soils with moderate level of soil nitrogen and sampled at 35 DAP. Cultivar TGm 51 nodulated with indigenous rhizobia, whereas one other cultivar, TGm 280-3, had only a few nodules and received most of its nitrogen from the soil. Even though the two cultivars grew equally well and contained the same amount of nitrogen, TGm 51 contained twice the quantity of total allantoin. (Table 28.) The highest concentration of allantoin was detected in the stem tissue, but the difference in the concentration in the upper leaves between TGm 51 and 280-3 was more striking. (Table 29.) The concentration of allantoin in the

Table 27. Effect of grafting a high-yielding cultivar (TGm 80) onto the root of a promiscuous cultivar when grown in uncontaminated field soil.

Shoot	Root	Inoculum[1]	Shoot N[2] content (mg/plant)	Shoot dry[2] wt. (g/plant)	Yield (g/plant)
TGm 80	TGm 80	−	259	8.9	15.8
		+	608	18.1	23.7
TGm 80	TGm 918	−	607	18.3	24.5
		+	730	19.7	21.0
		S.E.±	42	0.99	1.27

[1]*Inoculum of* R. japonicum.

[2]*Shoot nitrogen content and dry weight at 50 days after grafting.*

Table 28. Comparative growth nodulation and allantoin content of two soybean cultivars grown under field conditions in soils containing moderate levels of N.

	Cultivar	
	TGm 51	TGm 280-3
Plant dry weight (g/plant)	3.8	4.0
Total shoot N (mg/plant)	128	121
Nodule wt. (mg/plant)	176	21
Allantoin (Ng N/plant)	3111	1468

leaves of TGm 51 was four times as great as that found in TGm 250-3.

The previous experiment indicates that the allantoin content in the upper leaves can be used to distinguish plants growing on soil N from those fixing atmospheric N_2. These observations were further verified by growing three cultivars under conditions designed to produce various levels of N_2 fixation. Table 30 demonstrates that the two promiscuous cultivars (TGm 51 and 569) nodulated without an inoculum and contained 978 and 1596 micrograms allantoin-N/g dry weight in the last developed leaf whereas TGm 80 nodulated poorly and had only 212 micrograms allantoin-N/g dry weight. The addition of an inoculum to TGm 80 resulted in good nodulation with high levels of allantoin accumulation in the last leaf. Nitrogen fertilizer (20 kg N/ha at 15 and 30 days) reduced the amount of nodulation in TGm 51 and 569 by 50 percent which resulted in corresponding decrease in allantoin accumulation in the leaves. In another trial. TGm 294-4 inoculated with *R. japonicum* produced 424 mg of nodules and 47 allantoin-N/100 g fresh weight of leaves whereas the addition of N fertilizer reduced nodulation to only 30 mg of nodules/plant and resulted in a decrease of 83 percent in allantoin accumulation. (Table 31.) These results show that plants fixing atmospheric N_2 can be identified by determining the amount of allantoin in the last fully developed leaf. This method is nondestructive and the analysis of allantoin can be made on an automated assay system in which a large number of plants can be screened.

Table 29. Allantoin concentration in various plant tissues of TGm 51 and 280-3 after 35 days of growth.

	Allantoin content (Ng-N/g dry weight)	
Plant part	TGm 51	TGm 280-3
Upper leaves	796	213
Lower leaves	468	144
Upper stem	1653	680
Lower stem	1106	618
Upper petioles	567	322
Lower petioles	371	285
Roots	862	422

Table 30. Allantoin content of the last fully developed leaf at 45 days and nodulation of three soybean cultivars grown without an inoculum, with an inoculum and under N fertilizer.

Cultivar	Treatment	Nodules (g/N)	Allantoin-N (Ng/g dry wt.)
TGm 51	None	4.82	978
	Inoculant	4.40	952
	N-fertilizer	2.73	467
TGm 569	None	3.27	1596
	Inoculant	3.20	1436
	N-fertilizer	1.60	851
TGm 80	None	0.12	212
	Inoculant	9.23	1546
	N-fertilizer	0.53	140

Table 31. Nodulation and allantoin content of last fully developed leaf of TGm 294-4 after 50 days when tested with an inoculum of R. japonicum or fertilizer with N.

Treatment	Nodules (Ng/plant)	Allantoin-N (mg/100 g fresh wt.)
Inoculum	424	47.0
N-fertilizer	30	8.0

Lima bean improvement

The objectives of the lima bean improvement program continued to be the incorporation of disease and pest resistances into high-yielding genotypes for humid and sub-humid tropics.

Selection included different types of lima bean: viny, climbing types, bush types and wild types. In addition, an interspecific hybridization program continued to introduce additional variability into *Phaseolus lunatus*.

High-yielding lines

Viny types. The viny lima bean types are high-yielding and include accessions that can be used as sources of disease resistance. However, an important limitation of the viny types is that they require support.

Nine cultivars selected from the germplasm collection on previous performance were tested in replicated trials during 1978. (Tables 32 and 33.)

Table 32. Performances of lines of lima bean uniform cultivated trial, IITA, first rainy season, 1978.

Cultivar TP1	DFF	DFRP	GM*	Fungal diseases	Seed yield kg/ha
170-33	48	82	3.0	3.0	5569
297	48	82	2.8	3.0	5502
250B	48	83	3.0	2.3	5457
183-6	49	81	3.8	3.0	5373
178-36	49	83	3.3	2.5	5045
174	48	84	3.3	2.0	4961
61A	50	88	3.8	1.3	4948
323A	48	85	3.3	3.0	4402
111A	54	98	1.5	1.5	2352
Mean	49	85	3.1	2.4	4845
S.E.±	0.4	0.6	0.3	0.2	272
C.V.%	2	21	20	14	11

DFF = No. of days to 50% plants flowering.
DFRP = No. of days to 50% plants showing ripe pods.
GM = Lima bean golden yellow mosaic.
** = Visual score on a scale of 1 to 5 where 1 indicates absence of disease.*

Table 33. Performances of lima bean lines in a uniform cultivated trial, IITA, second rainy season, 1978.

Cultivar	DFF	DFRP	GM*	GMo*	ABV*	CLS*	Stand/ 6m²	Seed yield kg/ha
170-33	51	105	4.8	2.3	2.8	2.3	33.0	397
247	54	100	3.8	2.0	2.5	2.5	30.5	945
61A	60	112	3.8	1.8	2.8	1.8	24.0	317
111A	67	112	2.0	3.0	2.8	1.8	24.0	153
178-26	59	105	4.0	2.3	2.3	2.0	37.3	352
174	53	109	3.8	1.5	2.8	2.3	33.8	468
183-6	53	106	4.5	1.8	3.0	2.5	28.5	556
250B	53	103	4.0	1.8	2.8	2.0	32.5	682
323A	55	105	3.3	1.8	3.0	3.3	31.0	860
Mean	56	106	3.8	2.0	2.7	2.3	30.6	
S.E.±	1.1	2.4	0.3	0.2	0.2	0.2	3.4	
C.V. %	4	4	15	25	16	18	23	

GMo = Green Mottle virus.
ABV = Aphid-borne virus.
*CLS = Cercospora leaf spot (*Cercospora canescens*).*
** = Visual score on a scale of 1 to 5.*

The yield potential of some cultivars is high; more than 5 t/ha despite a high level of golden yellow mosaic infection. Nevertheless a significant negative correlation r = 0.43 was found between golden yellow mosaic incidence and seed yields for the susceptible lines, suggesting that the virus adversely affects seed yields. Moreover, the onset of infection appears to be a major factor in determining the yield losses; early infection leads to higher losses than late infection.

The lower yields of the second season were probably a consequence of limited rain during the last two months of the crop and insect damage. At Onne, during the first season, the trial failed because of water logging and heavy disease pressure. A virus-like disease and web blight killed most of the plants in all lima bean trials and nurseries. Only TPI 111A, which is highly tolerant of IITA golden yellow mosaic survived but its growth was poor. The relation between the Onne virus-like mosaic and IITA golden yellow mosaic is not yet clearly established, though it appears TP1 111A has some resistance to both.

During the second season at Onne, 42 lines were tested with four controls in a preliminary yield trial with two replications. The disease pressure was very low and the yields were estimated in terms of yield per plant because of the irregular stand counts and the segregation still occurring in most of the plots. The wide spacing used (1m × 1m) eliminated all competition between the plants and guide yields ranged between zero and 31 g/plant.

The results of the Onne second-season uniform trial are shown in Table 34. Because of the bad stand establishment, data are presented for only five cultivars out of nine. The incidence of disease was low.

Table 34. Performances of lines in lima bean uniform cultivated trial, Onne, second season, 1978.

Cultivar TP1	DFF	DFRP	No. of plants/ 6m²	Yield in kg/ha
111A	51	90	36	856
250B	47	85	37	591
247	44	86	32	580
178-26	48	89	37	489
323A	45	87	31	487
Mean	47	87	27	601
S.E.±	1.3	0.8	1	60
C.V. %	6	2	14	20

Bush types. Compared with the viny types, the bush type lima beans have the advantage that they do not require any support. However, they are lower-yielding and are particularly susceptible to web blight (*Rhizoctonia*) when grown in wet conditions. High-yielding plants lodge, and in humid environments where the soil is wet even at harvest time, seed and pod rots cause serious yield loss.

A preliminary yield trial of bush types was carried out at Ibadan during the second season. (Table 35.) Because germination was poor and the lines were segregating, yields were estimated for individual plants. The wide spacing (50 × 75 cm) used eliminated competition between plants. The best lines were TPx2-1F, TPx2-2F and TP1 176-8 (control) which provided about 2-2.5 t/ha in previous yield trials. The very low yields recorded for some lines were due to the genetically inherited small seed size as well as the poor growth of these hybrids.

Sources of resistance

Sources of resistance for golden yellow mosaic (TP1 111A, TP1 10, TP1 242) and green mottle virus (TP1 240) are already known. Preliminary screening had identified some lines that appear to be resistant to root knot nematode. Two additional experiments were therefore carried out during 1978 to verify this resistance.

The lines found to be resistant to *Meloidogyne incognita* were the highest-yielding lines in the yield trials. This confirms the results obtained in 1977 showing a high negative correlation between seed yield and nematode infection.

Yield and disease resistances

Lima bean breeding. During the year, 30 new crosses were attempted. (Table 36.) The parents used were selected for yield, resistance to golden mosaic, green mottle and root knot nematode.

In addition, about 110 natural out-crosses were identified in the field during 1978. They will contribute to the number of genotypic recombinations now available for selection.

The next step will be to make a 10th group of crosses to combine GM × Gr Mo × Yield/RKN. This will be done by crossing Group 1 × Group 2; Group 1 × Group 4; and Group 2 × Group 4.

Group 8 crosses will be developed further because the wild species are a source of various useful characters including desirable morphological characters and resistance to diseases. However, there are also several undesirable characters such as small pod and seed size and high HCN concentration in the seeds (up to 4500 ppM).

Interspecific hybridization program

The interspecific hybridization program, carried out in cooperation with the Faculte des Sciences Agronomiques de l'Etat (Gembloux-Belgium), was continued. The purposes of this program are to improve the genetic variability of *Phaseolus lunatus* by introgression, from related species, of useful characters such as golden yellow mosaic resistance, drought resistance and long erect racemes.

The hybrids involved in the program are divided into three categories: *Phaseolus lunatus* × *Phaseolus ritensis*; *Phaseolus lunatus* × *Phaseolus polystachius*; and *Phaseolus lunatus* × *Phaseolus* sp. rel. to *polystachius* (Ni 402).

About 300 selected lines are available from these crosses. They include several combinations of back crosses (made to restore the fertility of the interspecific hybrid) and selfed generations (F1 to F6, B, C, Go to B, C, G4).

In addition, about 40 new combinations made at Gembloux are ready to be grown in early 1979. This brings the total number of genotypic combinations to about 50.

Observations on the interspecific hybrids during 1978 showed that not more than one back cross should be made if rapid reversion to the back-crossed parent is to be avoided. (*P. lunatus*, usually.) Infertility problems will have to be overcome by using parents with better compatibility.

Table 36. Numbers of crosses made to combine yield and diverse resistance in lima bean.

Group	No. of crosses in 1978	Total no. of crosses made	Generation
1. GM x Gr. Mo	1	5	F3
2. GM x Yield/RKN	5	40	F7
3. GM x Various	0	20	F7
4. GrMo x Yield/RKN	5	10	F4
5. GrMo x Various	2	5	F4
6. GM x GM	0	5	F4
7. Yield/RKN x Various	10	70	F7
8. Wild species x various	1	20	F7
9. Various x various	1	20	F7
Total		195	

GM = golden mosaic.
Gr Mo = green mottle.
RKN = root knot nematode.

Table 35. Performances of lines in bush preliminary yield trial, IITA, second season, 1978.

Cultivar Hybrid	Pedigree	DFF	DFRP	GM*	G.Mo*	ABV*	WB*	100 Seeds weight (g)	Yield g/plant
TPx 2-2F	10 x 195A	33	97	1.0	2.0	2.5	2.0	34.1	51.0
TP1 176-8	Control	34	97	1.5	2.0	3.0	2.0	41.5	37.3
TPx 2-1F	10 x 195A	34	96	1.0	2.5	3.0	2.0	36.0	35.0
TPxx 17-1(F)	TPx 17 x ?	34	106	2.0	1.0	2.0	2.0	34.9	28.8
TP1x 10-8(F)	TP1 10 x ?	37	106	1.0	1.5	2.5	1.5	37.3	21.1
TP1x 10-9(F)	TP1 10 x ?	36	117	1.0	1.5	2.5	2.5	40.6	13.1
TPx 27-3F	178 x Ni 516	33	113	1.0	1.0	2.0	2.0	15.1	12.2
TPxx 24-1(F)	TPx 24 x ?	36	113	1.0	1.5	2.5	1.0	16.3	11.9
TP1x 10-7(F)	TP1 10 x ?	38	106	1.0	3.0	1.5	2.0	33.7	9.6
TPx 27-2F	178 x Ni 516	34	117	1.0	1.0	1.5	1.5	15.5	8.9
TPx 27-4F	178 x Ni 516	33	116	1.0	1.0	1.5	2.0	15.2	8.5
TPxx 24-3(F)	TPx 24 x ?	41	122	1.5	2.5	1.5	2.0	18.3	7.3
TPxx 24-2(F)	TPx 24 x ?	35	118	1.0	1.0	1.5	2.0	12.8	6.7
Mean		35	110	1.2	1.7	2.1	1.9	27.0	19.3
S.E.±		1	2	0.19	0.88	0.42	0.68	8.4	5.3
C.V. %		2	2.5	23.0	74.5	29.2	52.1	44	39

*WB = Web blight (*Rhizoctonia *sp.).*
Vigor = Based on a visual score using a scale of 1 to 6 where 3 indicates standard vigor.
* *= Visual score on a scale of 1 to 5, where 5 indicates highly susceptible.*

Root and Tuber Improvement Program

Producing improved breeding materials and developing improved cultural practices for cassava, yam, sweet potato and aroids for farming systems in the lowland humid tropics are the principal aims of this program. Testing and selection of the improved cultivars are carried out in collaboration with national root and tuber improvement programs. The program also assists national programs through the exchange of breeding materials and information and by the provision of training and technical consultancy services.

Summary of 1978 results

In Nigeria, two IITA improved cassava clones — TMS 30577 and 30555 — out of the 14 tested within the country have registered superior performances over local cultivars. These two clones have been multiplied and distributed through Nigeria's National Root Crops Research Institute (Umudike) and the Nigerian federal and state ministries of agriculture.

In Sierra Leone, the three most promising cassava clones selected from the IITA breeding materials have been released by the Ministry of Agriculture and Forestry under the names of ROCAS 1, ROCAS 2, and ROCAS 3.

In Tanzania, the best 10 cassava clones selected from IITA breeding material have been evaluated in uniform yield trials. These clones have a high level of resistance to cassava green mite and yielded up to 20 t/ha under a severe green mite infestation.

In the Seychelles, all the five most promising clones selected from the IITA introduced materials exhibit a high level of resistance to cassava mosaic disease and outyield the local cultivars.

In India, IITA breeding materials exhibit a high level of resistance to cassava mosaic disease.

In Zaïre, the Program National du Manioc (PRONAM) has identified sources of resistance to the cassava mealybug (*Phenaccocus manihoti*).

Tests carried out using a newly developed enzyme assay technique for quantitative determination of cyanide, showed that some of the recently developed IITA clones have very low cyanide content.

The improved cassava mosaic resistant clone, TMS 30395, generated from both mosaic-free and mosaic-infected planting material, produced significantly higher root yields than the susceptible Nigerian local cultivar, Isunikankiyan.

Hybridization, evaluation and selection of white yam, *Dioscorea rotundata*, continued. Twenty thousand white yam seedlings were grown and the most promising genotypes were selected. Several promising clones in preliminary and intermediate yield trials were evaluated for yield, tuber shape, culinary quality and disease resistance. In white yam. selection for good root shape in early generations was advantageous. The *D. alata* clone, TDa 291, showed consistently high resistance to scorch disease at several locations within Nigeria. It is being multiplied for distribution.

Ethephon-treated white yam plants shortened the time of sprouting by half compared to that of untreated control plants. High concentrations of Trimethyl ammonium chloride (ccc), Naphthaleneacetic acid (NAA) and 6-Benzyl adenine (BA) also gave shortened sprouting time, whereas Gibberellic acid (GA_3) inhibited sprouting in low concentrations but promoted sprouting at higher concentrations.

The stability of 25 IITA improved sweet potato clones was tested in 24 different environments within Nigeria. Two clones, TIS 2498 and TIS 3247, showed superior performance over all the environments tested.

There was a highly significant correlation between shoot weevil damage and storage root damage. Clones TIS 3017 and TIS 2532 showed root weevil resistance while clones Tlb 2 and Tlb 4 were most susceptible. High heritability (82%) was estimated using the shoot weevil damage data collected in mid-dry season. Clone TIS 3017 is presently the most weevil resistant under field conditions.

Source potentials and responses of source to sink were examined in 20 sweet potato clones. Clones of TIS 2498 showed the highest source potential, followed by Tlb 2 and TIS 3295. TIS 3295 and TIS 2498 showed high "response of source to sink" as well. There was high correlation ($r = 0.6$) between source potentials and responses of source to sink. The clone TIS 2498 has been found to be the best performer for yield, stability, and resistance to virus. It is also moderately resistant to weevil damage, good in storability, high in dry matter percent (33%) and high in consumer acceptance.

The initiation of a systematic breeding program in cocoyams based on sexual propagation has been made possible by the development of methods for chemical promotion of flowering followed by artificial hybridization, seed germination and seedling establishment.

Cassava

Genetic improvement

The stability of 14 IITA improved cassava clones is summarized in Table 1. These clones were tested in 26 environments in Nigeria including locations with different soil and climatic and epiphytotic conditions during two seasons, (rainy and dry) in the years 1973-1978. The locations included IITA with 1,200 mm annual rainfall, Warri with poor sandy and acid soil and 2,700 mm annual rainfall, Mokwa with 1.000 mm annual rainfall and Onne with poor sandy and acid soil and annual rainfall of 2,400 mm. The mean yields of the IITA improved clones were higher than the 16.77 t/ha of a standard cultivar 60444. (Fig. 1.) The mean yields of TMS 30572, TMS 30555, TMS 30337, TMS 30110, TMS 30017 and TMS 30040 were above the average yield of 31.57 t/ha over all the environments. Clones TMS 30572 and TMS 30555, in general, showed superior and stable performance over most of the environments with a few exceptions. Furthermore, these two clones produce higher yields when grown under better environments.

Table 1. Cassava varietal performance in 26 environments in Nigeria in 1973-78.

Clone	Fresh yield (t/ha)	b_i	Dev. M.S.
1. TMS 30572	43.1	1.31	135
2. TMS 30555	41.0	1.78	48
3. TMS 30337	35.4	0.96	127
4. TMS 30110	35.3	1.42	289
5. TMS 30017	35.2	0.82	301
6. TMS 30040	32.1	0.82	42
7. TMS 30786	32.0	1.10	17
8. TMS 30835	30.2	1.17	58
9. TMS 30054	29.8	1.16	137
10. TMS 30157	28.9	0.73	67
11. TMS 30211	28.5	0.65	124
12. TMS 30395	27.6	0.82	90
13. TMS 30158	26.8	0.64	67
14. 60444	16.8	0.55	213

b. Stands for regression coefficient of mean yields of its variety on the environmental index.

Dev. M.S. stands for deviation mean square from the regression.

Trials in Nigeria

In cooperation with the National Root Crops Research Institute (NRCRI) of Nigeria, 50 clones (consisting of 25 IITA clones and 25 NRCRI clones) were tested in nine different locations, under two levels (no fertilizer and 60 kg of N-P-K/ha) of fertilizer application. The results from four locations (IITA, Mokwa, Warri and Onne) are summarized in Table 2. TMS 30572 gave the highest yield, followed by TMS 30555 and TMS 40764.

Promising clones. (1974 series.) The performance results of some promising clones are summarized in Table 3. These clones will be further tested in cooperation with NRCRI in different locations. The three clones resulting from the crosses with exotic sources appear to be good in performance even though they need to be further improved for resistance to Cassava Mosaic Disease (CMD) and Cassava Bacterial Blight (CBB).

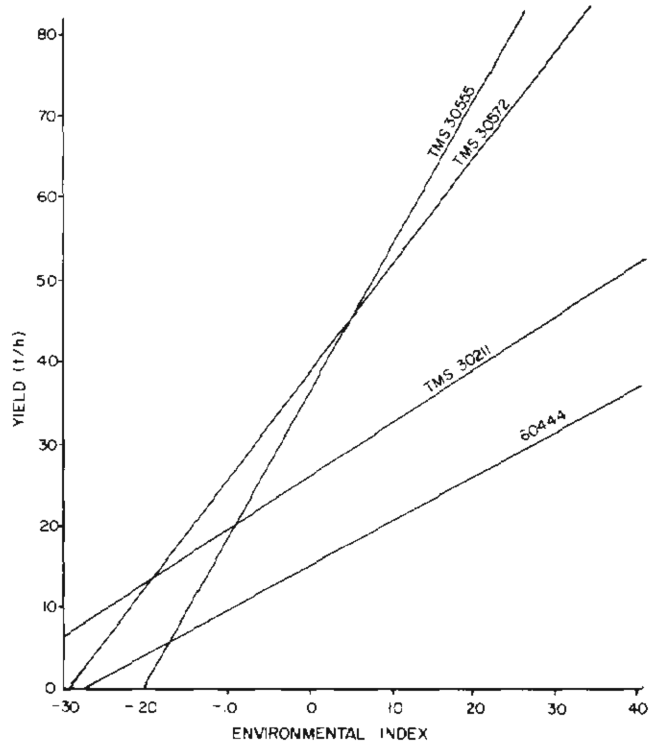


Fig. 1. Response of TMS 30572, TMS 30555, TMS 30211 and 60444 (check) to 26 varying environments in Nigeria in 1973-78.

Resistance to cassava mealybug (CMB)

Program National du Manioc (PRONAM) in Zaire identified resistance to cassava mealybug (*Penacoccus manihoti*) from three sources, TMI 6134, TMI 6154 and TMI 6096 which were originally introduced from Brazil. They are crossable with cultivated cassava and PRONAM scientists are attempting to transfer the resistance to cultivated cassava.

Resistance to cassava green mite (CGM)

From IITA breeding materials sent to the Root Crop Improvement Program in Tanzania, a total of 377 clones were raised and tested at Chambesi Station on the east coast of the mainland. There were significant differences in resistance to cassava green mite (*Mononychellus tanajoa*) among the clones tested. Fifty-eight were rated to be resistant, of which 10 clones showed a high level of resistance. CGM-resistant clones were selected for testing in Zanzibar.

Screening for low cyanide

A new enzymatic assay for the hydrocyanic acid (HCN) content of cassava, (developed by Cooke of Tropical Products Institute in London) is now routinely used in

Table 2. Cassava variety cooperative trials in Nigeria.

NR No.	Accession No.	Environments	Fresh yield (t/ha)	Dry matter %	Dry yield (t/ha)
7703	TMS 30572	8	46.0	34.7	16.0
7708	TMS 30555	8	42.9	36.6	15.7
7718	TMS 40764	4	41.3	30.9	12.8
7737	U/1421	5	39.4	30.9	12.2
7712	TMS/W 4488	8	38.6	36.5	14.1
7749	631024	8	37.5	34.2	12.8
7722	TMS/W 489	8	37.4	32.9	12.3
7750	60506	8	37.3	34.3	12.8
7736	75/764	5	36.2	31.3	11.3
7719	TMS/W 1379	8	36.0	33.4	12.0
7705	TMS/W 5594	8	35.5	31.7	11.3
7735	U/41044	5	35.3	29.5	10.4
7742	U/42046	5	34.8	31.1	10.8
7740	U/42232	5	34.5	33.0	11.4
7711	TMS/U 30395	4	34.2	35.0	12.0
7707	TMS 30337	8	34.1	36.1	12.3

Table 3. Performance of promising cassava clones. (1974 series.)

Clone	Environments	Fresh yield (t/ha)	CMD**	CBB**
40081	3	49.7	2.0	1.9
40092	3	42.9	3.0	2.0
40160*	4	35.6	3.4	3.0
40533	2	58.0	2.5	3.0
40791	4	35.2	2.5	2.7
41589*	3	36.5	3.6	2.5
41699	4	44.5	2.2	2.0
41814	3	60.5	2.5	2.0
4(2)0156	3	54.7	2.5	3.5
4(2)0267	4	34.7	2.3	2.3
4(2)0378*	3	47.4	3.3	2.5
4(2)0599	4	35.7	2.7	2.5
4(2)0850	4	49.8	1.8	2.2
4(2)1031	4	34.9	2.4	2.4
4(2)1364	3	39.3	2.5	3.5
4(2)1425	4	38.2	2.4	2.4
60506	4	26.1	3.0	2.0
60444	4	17.6	3.3	3.8

Crosses with exotic sources.
**Scale of 1-5 where 1 = resistant, 5 = susceptible.*

screening cassava germplasm materials for low HCN content. Essentially, this method involves the inhibition of endogenous linamarase, which hydrolyzes cyanogenic glucosides, and the introduction of the exogenous enzymes to ensure a complete hydrolysis of the glucosides. HCN released is measured by a spectrophotometer. The method is more sensitive (0.1 ppb), and faster (15 minutes incubation of enzyme and substrate at 30°C) than earlier methods.

Using the new method, low cyanide (LCN) selections of the previous year were reassessed at one year. Most of these clones maintained low cyanide content which ranged from 3 to 14 mg HCN/100 g fresh wt. of root pulp. Two of the 30 LCN clones contained higher HCN values of between 31 and 52 mg/100 g fresh weight. The leaves of the LCN clones were also comparatively low in HCN (24-167 mg/100 g fresh wt. of top leaves), and this is significant as cassava leaves are utilized as a vegetable in some countries.

Cassava green spider mite (*Mononychellus tanajoa*) attack causes severe chlorosis and leaf area reduction.

A preliminary investigation on a possible relationship between leaf and root cyanide using the LCN selections has shown that whereas there appears to be a correlation between total HCN content of top or middle leaves and the root pulp ($r = 0.3 - 0.4$), there is a good correlation ($r = 0.6 - 0.7$) between the leaf HCN content and total HCN content of the unpeeled root. The HCN content of the peel was 5-12 times as great as that of the pulp.

Seed viability

Cassava seeds have been collected from the field every year for seven years and held in cold storage at approximately 5°C and 60 percent relative humidity since 1972. A comparative germination of 0-7-year-old seed was made in the greenhouse at 30-37°C. The results showed no difference in seed viability between ages 0-7 years.

International cooperation

Nigeria. In cooperation with the National Root Crops Research Institute (NRCRI) of Nigeria, multilocation trials with 50 promising clones were conducted and the IITA improved cassava clones were multiplied on a large scale and distributed to ministries of agriculture, and to various public and private institutions.

Zaire. Fresh yields of the 10 best IITA clones from three different advanced yield trials at Mankewa, (alluvial area of M'vuazi river) ranged from 13.8 to 42.5 t/ha, which were 20-80 percent higher than the local check. At Mpalukidi, yields of the nine best clones ranged from 10.5 to 18.1 t/ha which were 36-135 percent better than Mpelolongi, the local check. These clones have been included in Program National du Manioc (PRONAM) multiplication plots. The best clones are 30344/6 (42.5 t/ha), 30179/2 (37.7) at Mandewa and 30174/2 (18.1) and 30179/2 (15.5) at Mpalukidi.

From a minikit trial of 250 clones, 50 selections (20 of which yielded 20 t/ha or greater) were retained. The Groupe Economie Rurale participated in the trials enabling this organization to evaluate and choose materials suitable for large-scale production. Three clones, 30599/324, D220 and 30454/218 yielded 30 t/ha or higher.

Thirty farmers organized by the Groupe Economie Rurale completed on-farm trials which identified 15 selections from a collection of 200 clones. Four clones had almost identical yield in PRONAM and farmers' trials and all 15 selections were acceptable to the farmers.

Source of resistance to cassava mealybug was identified from several related *Manihot* species introduced from Brazil.

Sierra Leone. The three most promising clones selected from IITA material were named as ROCASS 1, ROCASS 2 and ROCASS 3 and recommended for country-wide cultivation. These clones have yield potentials of between 38 and 40 t/ha which is a three- to four-fold increase over the local cultivars. Additionally, the yield of 15 tons of fresh leaves per hectare could be harvested as a leafy vegetable over a six-month period.

Tanzania. In Zanzibar, the best 10 clones from IITA material (resistant to CMD and CGM and high-yielding) were planted in trials in four locations. These clones were acceptable in consumer quality. This work was carried out jointly by FAO, IDRC and IITA. A total of 377 clones were evaluated for resistance to CGM on the mainland and 15 percent of these showed resistance to the pest.

Ghana. A total of 67 CMD-resistant individual plants were selected from 223 plants in 31 IITA families. Agronomic characteristics of the majority were acceptable. The clone, UST 12-8 resulting from TMS 42355 was named "Bankye-Borode" because the flesh pigmentation of the tuberous roots resembled the pale-yellowish color of plantain fruits. Also, its "fufu" qualities were excellent.

Liberia. Thirty-six promising clones were tested with yields ranging from 13-70 t/ha. The most promising 10 clones were selected for further testing.

Gabon. From the material supplied by IITA, 63 clones were selected and the seven best clones were multiplied for distribution. The highest-yielding clone produced 32.8 t/ha in 10 months and 28 t/ha in eight months.

Seychelles. The five most promising clones were tested and one clone gave a yield of 44 t/ha in nine months: this is twice the yield of the local cultivar. Its quality was also acceptable.

India. A total of 2199 seedlings were raised from IITA breeding material. The five most promising clones resulting from IITA material were included in the uniform trial. One clone resulting from TMS 30754 gave a yield of 16.5 t/ha compared with 12 tons from the standard cultivar M4. Its quality characteristics were acceptable.

Pathology

Productivity under CMD stress

One hundred and fifty pairs each of the improved cultivars 30211 and 30395 and 85 pairs of a local cultivar Isunikankiyan were established in the field on Egbeda series soil at IITA, Ibadan, in May to test the stability of performance of selected cultivars under Cassava Mosaic Disease (CMD) stress.

The comparisons of yield components were made on 20 pairs each of cultivars TMS 30211 and TMS 30395 at 2, 5 and 7 months after planting, and those for the cultivar Isunikankiyan were made on 13 pairs at two months after planting and 20 pairs each at 5 and 7 months after planting.

There were significant differences ($P < 0.05$) in root fresh weight, total root number and top fresh weight yields between disease-free and CMD-infected plants at 2 months for all three test cultivars. Data presented in Table 4 indicate sample mean values and standard errors for differences between sample means due to CMD infection.

Differences in yield components between disease-free and CMD-infected plants of cultivar TMS 30395 were significant at 5 and 7 months harvest, except for the top fresh weight difference which was not significant at the 5 months' harvest. The data in Table 5 indicate the difference in root fresh weight at 7 months' harvest between disease-free and CMD-infected TMS 30395 plants. The differences in dry matter between disease-free and CMD-infected plants were also significant at 2, 5 and 7 months' harvest.

The comparisons of yield components for plants of clone TMS 30211 and Isunikankiyan harvested at 5 and 7 months were made between plants with clonal CMB infection (CI) (diseased at planting) and those with vector

Table 4. Effect of CMD on root fresh weight, root number and top fresh weight of 3 cassava cultivars 2 months after planting, IITA, Ibadan, 1978.

	Fresh root mean wt/plant (g)			Root Nos./plant			Top fresh wt/plant		
Cultivar	DF	CI	S.E.±	DF	CI	S.E.±	DF	CI	S.E.±
TMS 30211	100.6	33.5	10.73	4.3	2.2	0.40	255.3	162.5	25.8
TMS 30395	75.2	17.2	8.44	4.0	1.8	0.43	323.6	215.2	20.6
Isuni	43.3	2.9	13.40	3.3	3.3	0.80	179.0	85.0	41.6

DF = *Disease-free.*
CI = *Clonal CMD infection.*
S.E.± = *Standard error of differences between paired means.*

Table 5. Effect of CMD on root fresh weight/plant (kg) of cassava cultivar TMS 30395 seven months after planting, IITA, Ibadan.

Mean wt/plant (kg)			Fresh yield (t/ha)	
DF	CI	S.E.±	DF	CI
2.96	2.02	0.33	29.6	20.2

DF = *Disease-free.*
CI = *Clonal CMD infection.*
S.E.± = *Standard error of differences between paired means.*

CMD infection (VI) due to field transmission of the CMD agent by *Bemisia* sp. The data in Table 6 indicate that all the plants with vector CMD infection yielded significantly higher root fresh weights at 5 and 7 months compared to their counterparts which had been established with clonal CMD infection. The yield depression for TMS 30211 was higher at the 7 months' harvest. Differences in total root number, top fresh weight and dry matter percentage between plants with vector CMD infection and clonal CMD infection at these two harvest dates were significant ($P = 0.05$).

Cultivar TMS 30211 is superior to the other two test cultivars in fresh and dry root yields and total root number when harvest is taken from apparently CMD-free or vector-CMD-infected plants. However, yield depression of these two components due to clonal CMD infection is greater than that for TMS 30395 at seven months (Tables 5 and 6.)

Yield depression due to clonal or vector CMD infection in cultivar Isunikankiyan is significantly higher than that in cultivars TMS 30211 and TMS 30395.

Cultivar TMS 30395 is superior to 30211 and Isunikankiyan in yield potential for top fresh weight only at the two months' harvest date; thereafter cultivar TMS 30211 is equal or superior to the other two cultivars. However, the depression in top fresh weight yield due to clonal CMD-

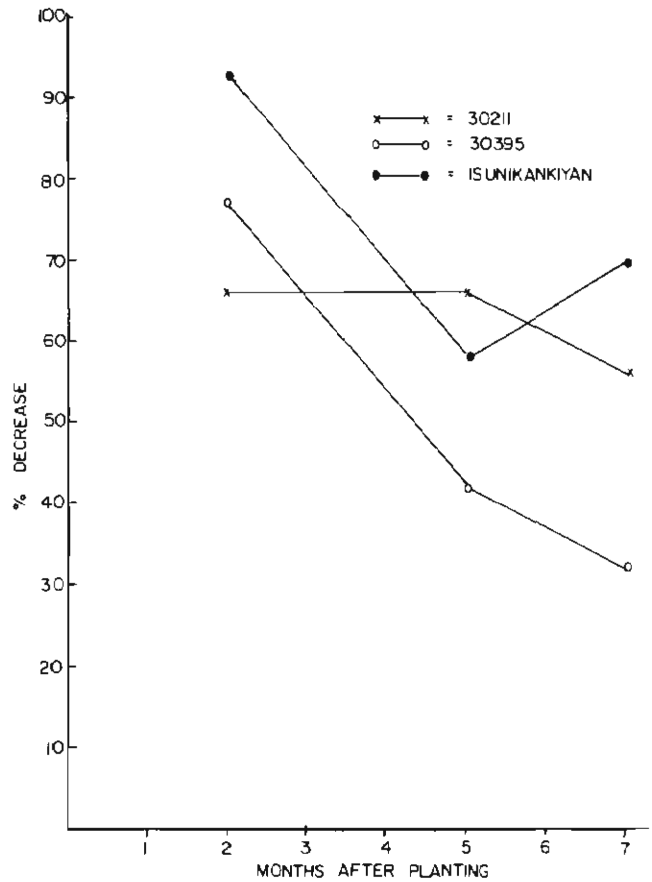


Fig. 2. Effect of CMD on root fresh weight decrease of 3 cassava cultivars. (IITA, 1978.)

Table 6. Effect of CMD severity on root fresh weight/plant (kg) of cassava cultivars 5 and 7 months after planting, IITA, Ibadan, 1978.

	Mean wt/plant						Fresh yield t/ha	
	5 months			7 months			7 months	
	VI	CI	S.E.±	VI	CI	S.E.±	VI	CI
TMS 30211	1.79	0.58	0.17	3.44	1.45	0.23	34.4	14.5
Isuni	0.36	0.15	0.08	1.43	0.44	0.13	14.3	4.4

VI = *Vector CMD infection.*
CI = *Clonal CMD infection.*
S.E.± = *Standard error of differences between paired means.*

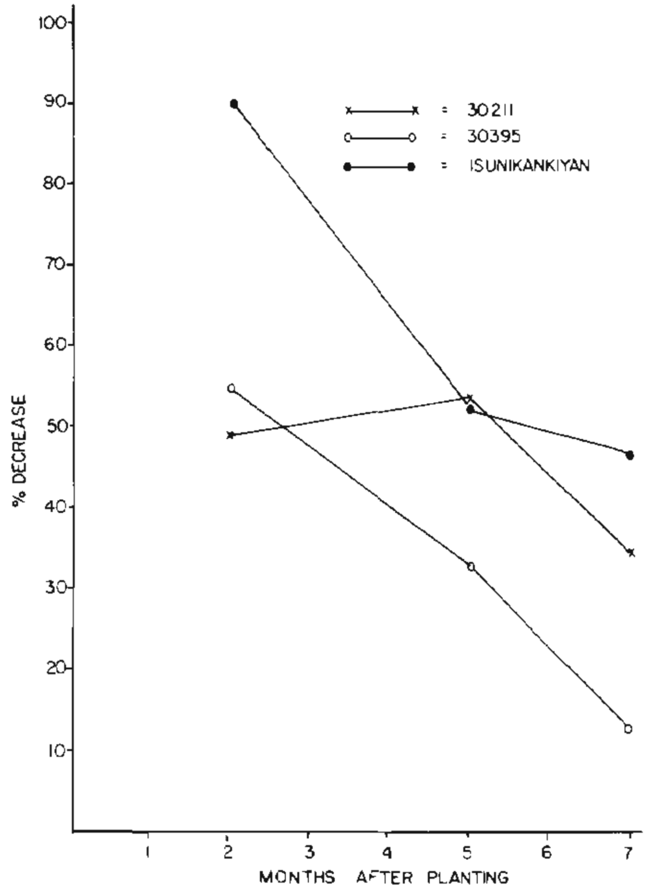


Fig. 3. Effect of CMD on root number decrease of 3 cassava cultivars. (IITA, 1978.)

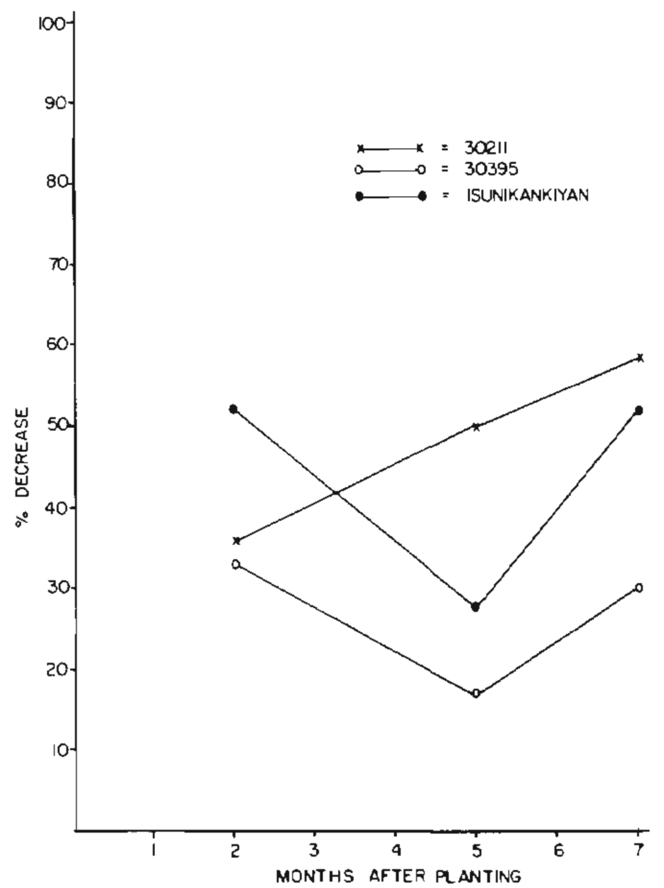


Fig. 4. Effect of CMD on top fresh weight decrease of 3 cassava cultivars. (Ibadan, 1978.)

infection is higher for cultivar TMS 30211 compared with TMS 30395 at the five and seven months' harvest (50% vs 17%, 57% vs 29%) and to cultivar Isunikankiyan (50% vs 28% and 57% vs 52%).

The data presented in Figures 2, 3 and 4 indicate that there were sharp decreases in the level of root fresh weight loss during the two- to five-month growth period for plants of cultivars TMS 30395 and Isunikankiyan with clonal CMD-infection, but no decrease in loss for cultivar TMS 30211.

Cultivar TMS 30395 and Isunikankiyan plants with clonal infection compensated significantly during the two-to-five-month growth period for losses sustained between establishment and two months after planting. Cultivar TMS 30211 plants with clonal CMD infection did not exhibit this capacity during the two-to-five month growth period, but did compensate, however, for loss in root fresh weight. root number and dry matter percentage during the five-to seven-month growth period.

The data presented in Figure 5 indicate the rate of vector CMD infection of CMD-free plants of all three cultivars over a six-month observation period. The following criteria appear to be critical for evaluation of the stability of field performance of cassava plants under CMD stress:

(1) The capacity to minimize yield depressions due to clonal CMD infection.
(2) The capacity to minimize yield depression due to vector CMD infection.
(3) The capacity to compensate rapidly for yield depressions sustained as a result of clonal or vector CMD infection.
(4) The capacity to minimize the level of vector CMD infection resulting from field transmission of the CMD agent by *Bemisia tabaci*.

Temperature effect

Four disease-free plants and eight plants with CMD infection of IITA improved cassava cultivars, TMS 30337, TMS 30040 and TMS 30555, were tested to determine the effect of temperature on growth and CMD severity. The plants of each cultivar were assembled in each of two growth chambers which had been set for the following growth conditions: Chamber 1: day temperature 35°C, night temperature 21°C, day RH% 81, night RH% 82, photoperiod 11 hours at 151.2 cal/cm^2/day; Chamber 2: day temperature 25°C, night temperature 16°C, day RH% 80, and night RH% 90, photoperiod 11 hours at 158.4 cal/cm^2/day. These regimes were selected to simulate the temperature regimes of Minna, Nigeria in January and Jos, Nigeria in September.

Each plant was seated on a shallow saucer and watered regularly over a period of 48 days.

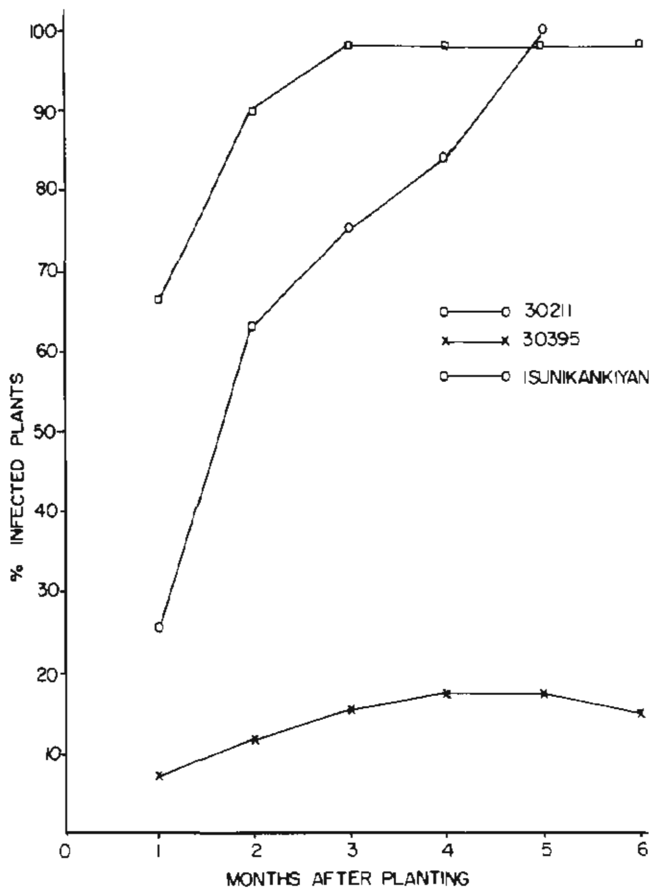


Fig. 5. Rate of field CMD infection of disease-free plants of 3 cassava cultivars. (IITA, 1978.)

The following data were recorded:

(1) Initial and final CMD severity ratings.
(2) Average internode length at the initial and final stages of the test.
(3) Average plant height at the termination of the test.

The preliminary indications are that cassava cultivars do respond differentially with respect to expression of CMD severity under different temperature regimes. Although symptom suppression usually occurs at high temperatures, it appears that this may also occur at lower temperature regimes for some cultivars. Cultivars TMS 30040 and TMS 30555 consistently showed unit increase in CMD severity at low temperatures, but unit decrease in CMD severity at high temperatures. However, cultivar TMS 30337 was inconsistent in its reaction over the temperature regimes tested, showing unit decrease of CMD severity at low temperature in some tests. and unit increase in other tests.

This phenomenon needs further investigation to determine cultivar sensitivities to temperature regimes with respect to CMD symptom expression.

Thermotherapy

The objective of this study was to determine the efficiency of thermotherapy in suppressing or eliminating the CMD agent in infected cassava plants. Young sprouts from woody cuttings of CMD-infected plants of cassava cultivars 60444, 71121, TMS 30337, TMS 30555 and TMS 30040 were grown for 30 days in growth chambers maintained under the following conditions (1) 35°C constant, 16-hour photoperiod (App. 4,000 lux) and 70 percent relative humidity; (2) 25°C constant, 16-hour photoperiod (4,000 lux) and 70 percent relative humidity; (3) 21°C constant 14-hour photoperiod (App. 3,000 lux) and 45 percent relative humidity.

The data presented in Table 7 indicate the following:

(1) At 35°C CMD symptom was completely suppressed within 30 days on 95 percent of cultivar 60444 plants and 100 percent each of the plants from cultivars 71121, TMS 30337, TMS 30555 and TMS 30040.
(2) At 21°C, CMD symptom was only partially suppressed on 37 percent each of the cultivar TMS 30337 and TMS 30040 plants, and no suppression (0%) of symptoms occurred in cultivar 60444, 71121 and TMS 30555 plants. There is presently no direct efficient method to ascertain whether suppression of CMD symptom expression at high temperature is the result of pathogen elimination.

Table 7. Effect of temperature on the CMD symptom suppression in selected cassava cultivars. (IITA, 1978.)

	% Symptom suppression			
Cultivar	35°C	No. of plants	21°C	No. of plants
TMS 30555	100	8	0	8
TMS 30040	100	8	37	8
60444	95	20	0	32
71121	100	16	0	12
TMS 30337	100	8	37	8

Tissue culture

Cassava green shoot tips and apical and lateral meristems were aseptically excised (the latter under a binocular microscope) from cassava plants which had been subjected to 35°C and 21°C respectively. Both types of plant tissue were then transferred to a modified Murashige and Skoog medium supplemented with 0.5 mg/l Benzyl Amino purine (BAP) and 0.05 mg/l Naphthaleneacetic acid (NAA), and 5 ml/l of a stock vitamin B-5 solution containing the following: thiaminehydrochloride 0.1 mg/l, pyridoxine 0.5 mg/l, pyridoxine 0.5 mg/l, nicotinic acid 0.5 mg/l and glyceine 2.0 mg/l. The growth media were further supplemented with 30 gm/l of sucrose. (*Modified medium developed by Dr. S. Sadik.*)

Excised tissues were transferred to (a) liquid medium as outlined above (b) solid medium as outlined above to which 7 mg/l difco agar was added before autoclaving.

Plant tissues in growth media were then transferred to a growth room maintained under the following conditions: temperature 21-26°C; photoperiod 12 hours and light intensity of 125-150 foot candles.

Percentage regeneration of explants to plantlets was extremely low. (Table 8.) At least one plantlet developed from shoot tip or meristem from plants subjected to 35°C exhibited characteristic CMD symptoms within 45 days

Table 8. Regeneration of heat-treated plants in solid medium.

Plant tissue	Treatment	% plantlets	% callus	% symptom free	time to regenerate
Green shoot tips	35°C (39)	12	-	80	10.6
	21°C (12)	0	0	-	-
Meristem	35°C (35)	20	-	85.7	10.1
	21°C (44)	-	11	-	11.6

Table 9. Regeneration of heat-treated plants in liquid medium.

Plant tissue	Treatment	% plantlets	% callus	% symptom free	time to regenerate
Green shoot tips	35°C (21)	19	-	100	8
Meristem	35°C (46)	21	-	100	11.1
	21°C (25)	0	0	-	-

of growth. This observation is evidence that thermotherapy at 35°C does not eliminate the CMD agent.

The data summarized in Table 9 indicate that in liquid medium 19 percent and 21 percent respectively of green and meristem tissue excised from 35°C plants developed into plantlets between 8 and 11 days. None of the meristem tissues excised from 21°C plants developed either into plantlets or callus.

Results indicate that 0.18 mg/l of NAA combined with 0.10 mg/l of BAP in liquid medium was suitable for root generation. and that 0.18 mg/l of NAA and 0.5 mg/l of BAP was suitable for shoot generation from cassava callus tissue.

Results also indicate that 0.5 mg/l of NAA combined with 0.5 mg/l BAP in solid medium appeared suitable for shoot generation.

Investigations to determine the precise combinations of growth regulator and the conditions for induction of root and shoot generations simultaneously are in progress.

Yam

Genetic Improvement

White Yam *(Dioscorea rotundata)*

During 1978, hybridization, evaluation and selection of white yam continued at IITA and at three offsite locations. At IITA, breeding populations were screened under unstaked as well as staked conditions and emphasis was placed on tuber shape and resistance to nematodes, virus and leaf spots, and on culinary quality.

In the unstaked intermediate yield trial, five hybrid clones and three germplasm selections were grown at 1 × 1m spacing. Average fresh weight yields per plant ranged from 0.7 to 3.0 kg (7 to 30 t/ha). One hybrid clone and three germplasm selections which yielded more than 1.0 kg/plant were selected for further evaluation.

In the preliminary yield trial, 16 clones were selected from the 46 clones grown in the hill trial; 41 breeding selections out of 107 were chosen for further testing.

Nematodes and foliar leaf spot diseases continued to be the major factors reducing yields in these unstaked trials. Eleven clones were compared with two local control cultivars in the staked intermediate yield trial planted at 1 × 1m spacing. Average fresh weight yields per plant ranged from 1.6 to 5.0 kg (16 to 50 t/ha) with two hybrid clones and three germplasm selections yielding more than 3.0 kg/plant. The two hybrid clones both have satisfactory tuber shape, good culinary qualities and fair disease resistance. One of these hybrid clones. W47-C248, is an early cultivar while the second, W4-B58, matures later.

In the preliminary yield trial, 236 hybrid clones were grown with two local controls and 58 were selected for advancement. In the hill trial, 57 hybrid clones were selected out of 282 entries.

Twenty thousand seedlings comprising 365 families were grown and evaluated at IITA and promising individuals were selected for 1979 hill trial.

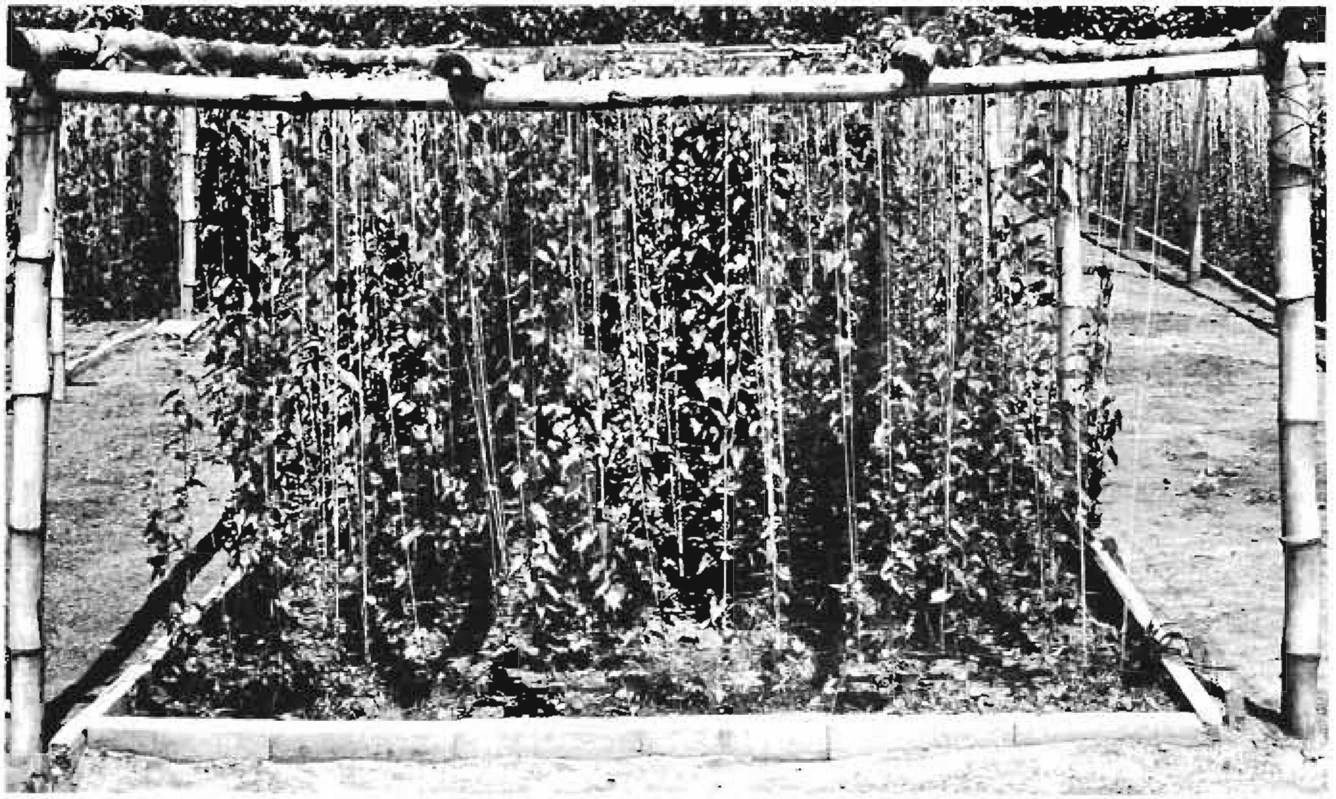
Controlled hand pollinations were made between selected parents, and population improvement continued in four base populations (two general populations and two multiple tuber populations) using recurrent selection.

An encouraging improvement is apparent when seedlings of half-sib families harvested from breeding selections which had advanced as far as the 1977 preliminary yield trial (improved seed sources) were compared with open pollinated seed collected from local cultivars in farmers' fields (unimproved seed sources). Results are given in Table 10.

At Mbiri, Bendel state of Nigeria, selections were made in the seedling nursery, hill trial and preliminary yield trial. In the intermediate yield trial average fresh weight yields per plant ranged from 1.5 to 3.6 kg (15 to 36 t/ha). All hybrid clones outyielded the local cultivar. All trials were staked and the preliminary breeding objective at this site was resistance to a foliar disease locally called "Odu."

At Mokwa in Niger state, a seedling nursery, hill trial, and preliminary yield trial were grown. Average fresh weight yields in the staked intermediate yield trial ranged from 1.5 to 2.6 kg/plant (15 to 26 t/ha) and only one hybrid clone outyielded the local control cultivar. This year the hill trial and preliminary yield trial were grown unstaked and in the future all trials will be grown without staking.

This year the offsite breeding was extended to Yandev in Benue state, with the establishment of a seedling nursery from which selections were made.



Seedlings of white yam (*Dioscorea rotundata*) in a nursery for evaluation of plant characteristics.

*Table 10. **A comparison of seedling families grown from improved and unimproved seed sources, IITA.***

Shape ratings[1]	Improved seed source		Unimproved seed sources	
	Frequency[2]	Score	Frequency[2]	Score
1	0.0	0.0	53.8	53.8
2	35.3	70.6	15.4	30.8
3	52.9	158.7	23.1	69.3
4	11.8	47.2	7.7	30.8
Average score		2.8		1.8
% of population selected for advancement based on all characters	8.2		6.3	

[1]*Subjective ratings (1-4) representing low frequency to high frequency of desirable shapes.*

[2]*Frequency of families falling into this class.*

Cluster yam (*Dioscorea dumetorum*)

In the small-scale breeding program on cluster yam, seedlings were grown and selected for tuber size, conformation, and smoothness. In the hill trial 74 clones were evaluated for flowering and vine vigor and scored for *Cercospora* severity. Tubers were evaluated for size, conformation, smoothness, fleshcolor and "hardening," a postharvest disorder which severely restricts the storage and marketing of this species. Variability for all of these characters was observed. Thirty-nine percent of the clones flowered and 20 percent produced smooth tubers with good conformation and some resistance to *Cercospora*. Fifty days after harvest 85 percent of the tubers were free of hardening after boiling for 45 minutes. The promising clones were selected for further testing.

Artificial sib pollinations within breeding families and cross pollinations between breeding families have been made to recombine favorable characteristics.

Water yam (*Dioscorea alata*)

At IITA, the most promising 25 accessions in the germplasm were compared for yield and resistance to scorch disease in a staked trial at 1 × 1m spacing. All plants were scored for scorch severity and tubers were evaluated for conformation, nematode resistance, quality and total nitrogen. Average fresh weight yields, scorch scores and total nitrogen are given in Table 11.

At Mbiri, seven accessions of water yam were compared with a local cultivar. Data were taken and results are given in Table 12. Differences for yield and scorch scores were highly significant.

Over the past two years in several localities, TDa 251 consistently performed well even under severe scorch conditions. This clone has been distributed to farmer groups and institutions, and further-multiplication and distribution are planned. The three clones TDa 178, TDa 272 and TDa 187 tested for the first time this year showed promise.

Scorch was severe at IITA this year, killing most vines by early September and significantly reducing yields. How-

Table 11. *Tuber yield, mean scorch scores and mean total nitrogen of 25 accessions of water yam, staked. (IITA.)*

Accession number	Tuber yield Fresh wt. (t/ha)	Scorch score[1]	Total N (% of dry wt.)
TDa 178	21.1	4.3	1.37
TDa 291	20.7	2.9	0.89
TDa 272	18.8	4.3	1.35
TDa 251	17.7	4.4	1.29
TDa 187	17.5	4.3	1.29
TDa 300	16.7	4.3	1.43
TDa 260	16.7	4.3	1.25
TDa 308	15.6	4.3	1.35
TDa 262	14.7	4.5	1.47
TDa 234	14.6	4.4	1.46
TDa 226	14.4	4.4	1.40
TDa 167	14.2	4.4	1.46
TDa 231	14.0	4.4	1.49
TDa 263	13.9	4.4	1.32
TDa 5	13.4	4.2	1.42
TDa 9	12.4	4.3	1.40
TDa 85	11.9	4.3	1.59
TDa 265	11.4	4.4	1.50
TDa 239	10.4	4.4	1.67
TDa 264	10.1	4.7	1.76
TDa 67	9.9	4.1	1.32
TDa 302	9.6	3.8	1.38
TDa 33	9.0	4.3	1.45
TDa 240	8.3	4.5	1.46
TDa 200	6.5	4.5	1.35
S.E.±	1.64	0.10	0.09
CV %	23	5	15

[1] *Subjective score (1-5) representing no disease to all leaves showing symptoms.*

Table 12. *Tuber yield and scorch scores of 8 accessions of water yam, staked. (Mbiri.)*

Accession number	Tuber yield Fresh weight (t/ha)	Scorch score[1]
TDa 251	26.7	2.3
TDa 167	22.9	2.4
TDa 239	19.5	2.2
TDa 226	17.1	2.3
Local cultivar (Okpogbe)	16.5	3.1
TDa 291	15.6	1.7
TDa 200	9.1	3.7
TDa 67	7.5	2.8
S.E.±	2.94	0.14
CV %	30	9

[1] *Subjective score (1-5) representing no disease to all leaves showing symptoms.*

ever, this epidemic provided a good opportunity to identify clones which are scorch resistant even under heavy disease pressure. TDa 291 had significantly lower scorch scores at IITA, Mbiri, and several other locations where it was observed. The lower yields of this clone at Mbiri are due to poor stand establishment, a characteristic of this clone which hopefully can be overcome by using larger, selected sets. The tuber conformation and culinary quality of TDa 291 are good, and because it is male flowering, it can be used as a source of scorch resistance in future breeding programs. However, it consistently had less than average total nitrogen on a dry weight basis. (Table 11.) Multiplication of this clone is proceeding as fast as possible.

TDa 297, supplied by the National Root Crops Research Institute in Nigeria as Umidike 680, and grown in an observation trial, also exhibited a high level of resistance to scorch.

Five hundred plants composed of 16 flowering clones were grown in a crossing block. Nine of these clones flowered profusely and several hand pollinations were made. A small percentage of these set fruit, but only three seeds and two seedlings were produced.

Dormancy control

Tubers of white yam, *D. rotundata*, have a natural dormancy of 2-4 months. The development of a method to break or shorten this dormancy would permit breeders to accelerate generation turnover and multiply elite materials during the dry season. Also, off-season yam production by farmers would be possible.

Six growth regulators and two growth retardants were applied as preharvest and postharvest treatments to study their effects on tuber dormancy.

Beginning nine days before harvest, three foliar applications of each chemical were made at three-day intervals using 60 ml/plant/application, sprayed with spreader sticker, five plants per treatment. The following chemicals were tested: 6-Benzyladenine (BA), Ethephon, Naphthaleneacetic acid (NAA), Gibberellic acid (GA_3), Trimethyl ammonium chloride (CCC), BA/NAA, Chloramphenicol, Cycloheximide and control (water + spreader sticker). The experiment was conducted on cultivar Nwapoko. Tubers were harvested in early November, stored under ambient conditions and observed for sprouting. Results are summarized in Table 13.

Tubers from ethephon-treated plants sprouted first 45 days after harvest, generally shortening the time to sprouting by half compared to the control. Ethephon treatments also were the first to produce 100 percent sprouting two months after harvest and had good sprout elongation.

The highest concentrations of CCC, NAA and BA also gave good results. Whereas GA_3, which has been reported to be the dormancy hormone, inhibited sprouting in low concentrations but promoted sprouting in higher concentrations. Chloramphenicol and Cycloheximide in the low concentrations also gave promising results.

The following four methods of postharvest treatment application were tried using the same chemicals as in the preharvest study:

(1) Soaking tubers in chemicals 1 time/week for 24 hours, for 5 weeks.
(2) Burying tubers in vermiculite dampened with chemicals.
(3) Applications of chemicals in lanolin paste to tuber heads.
(4) Oven treatment at 35°C, to 22 days, beginning 6

days after harvest in mid-December, 5 tubers/ treatment.

The first three postharvest treatments gave inconclusive results. Results of the oven treatment are given in Table 14.

Table 13. ***Effects of preharvest foliar treatments on the percent sprouting of white yam cultivar, Nwapoko.***

Chemicals (ppm)	Days after harvest 45	60	64	68	77	88	Elongation[1]
Water control	0	13	13	29	29	43	++
GA_3							
4	0	0	0	0	17	17	-
18	14	43	43	57	57	86	++
38	0	33	38	38	38	63	++
Ethephon							
5	20	80	80	80	100	100	++
25	57	86	100	100	100	100	+++
50	50	80	80	80	91	91	++
CCC							
5	16	33	43	56	67	67	+
50	30	75	85	100	100	100	+++
BA							
5	0	13	25	75	88	88	-
25	0	0	0	50	80	80	-
50	25	50	50	50	75	100	+++
NAA							
1	0	0	13	24	54	75	-
5	0	0	38	44	60	82	-
10	19	57	71	85	100	100	++
BA/NAA							
5/1	0	11	22	22	40	69	-
5/10	0	0	30	30	40	40	-
10/10	0	10	25	25	38	50	-
25/5	0	17	33	40	56	75	+
50/10	0	0	0	10	48	90	-
Chloramphenicol							
5	0	75	100	100	100	100	+++
25	0	50	67	83	100	100	+
50	0	0	33	44	44	67	-
Cycloheximide							
5	29	57	57	71	71	86	+++
25	0	18	20	30	67	78	+
50	0	0	0	20	40	40	-

[1]*Elongation measured 88 days after harvest; subjective score (-, +, ++, +++) representing sprouts 0-5 cm, 5-15 cm, 15-25 cm, 25-35 cm.*

Table 14. ***Effects of oven treatment of 35°C on the sprouting (%) of white yam, cultivar Nwapoko.***

Days in oven	Days after initiation of treatment 15	19	23	27	32	36	44
0	0	0	0	0	0	20	60
2	0	0	0	0	0	20	20
7	0	0	0	0	0	20	20
10	0	40	60	80	80	80	80
14	-	0	60	60	60	60	100
18	-	-	60	80	80	80	80
22	-	-	20[1]	80	100	100	100

[1]*Sprouted in the oven.*

These data indicate that 10 or more days of oven treatment accelerated sprouting by about 20 days and gave uniform and vigorous sprouting. This method can also be used for cut tuber pieces because it "heals" the cut surfaces nicely.

Although this preliminary study on preharvest and postharvest treatments was begun late in the harvest season and differences between treatments and controls are not as great as required, several treatments gave encouraging results. Future studies will be started earlier in the harvest season to see if sprouting can be induced early enough to allow a full growing cycle during the dry season.

Cocoyam

Genetic improvement

The initiation of a systematic breeding program based on sexual propagation has been made possible by the development of methods for chemical promotion of flowering followed by artificial hybridization, seed germination and seedling establishment.

Two accessions of *Xanthosoma sagittifolium* and 17 accessions of *Colocasia esculenta* (representing three distinct morphological types, *Colocasia* 1, *Colocasia* 2, and *Colocasia* 3) were field grown and treated with foliar applications of the potassium salt of Gibberellic Acid (GA_3) at the concentrations of 0, 500, 1000, and 1500 ppm applied with spreader sticker at the 3-5 leaf stage.

Cocoyam fruit not ready for harvest.

The percent of flowering plants was significantly increased by GA_3. (Fig. 6.) GA_3 treated plants flowered earlier (Table 15) and produced significantly more spadices per plant than untreated plants. (Fig. 7.)

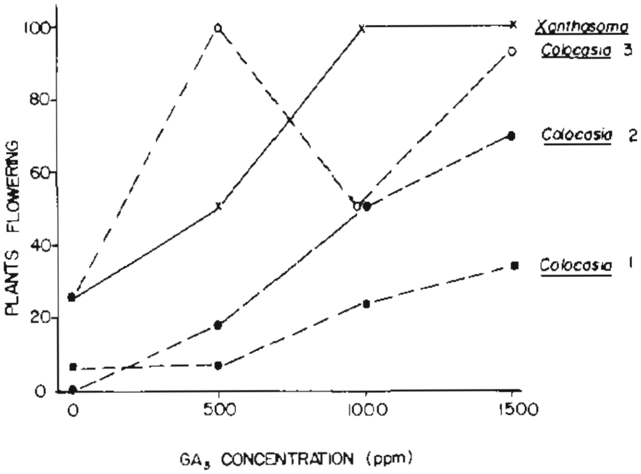


Fig. 6. Effects of GA_3 treatments on the percent of plants flowering in cocoyam.

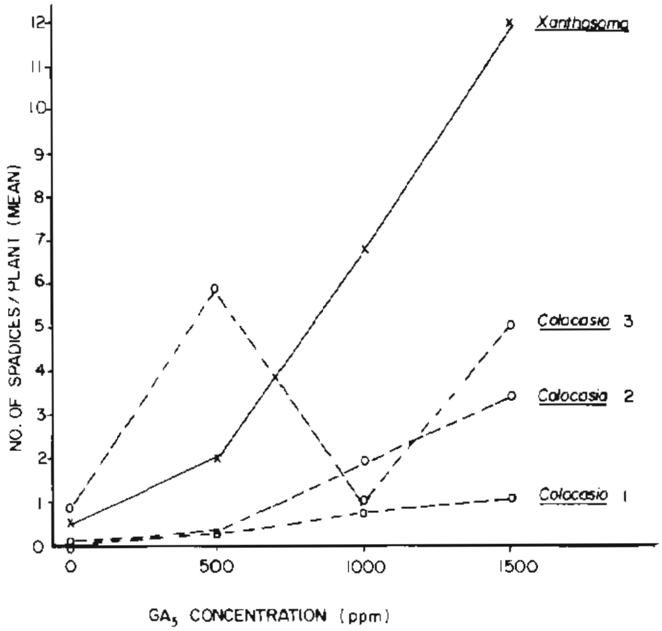


Fig. 7. Effects of GA_3 treatments on the number of spadices/plant of cocoyam.

The large number of inflorescences (spadices) which resulted from the GA treatments permitted extensive hand pollination. Pollinations within and between clones were made. Only 2 percent of the *Colocasia* pollinations produced viable seeds but in *Xanthosoma* 37 percent of the pollinations within clones and 50 percent of the cross pollinations between clones were successful. (Table 16.) More than 8000 seeds were harvested. In *Xanthosoma* the female flowers of the spadix were generally receptive 2-4 days before pollen shed, whereas in *Colocasia* the female flowers were receptive the same day as pollen shed and pollination within a spadix was possible.

Seeds of *Xanthosoma* were successfully germinated on sterile dilute soil agar (made with 7 g agar/l) at 25-28°C with 12 hours light. Germination began 7 days after sowing and seedlings were transplanted into "Jiffy-7" pellets 14-21 days after sowing and grown in the greenhouse for 50-60 days before transplanting to the field. Germination under these conditions was good (more than 50%) with no apparent seed dormancy. Although slow, establishment in the greenhouse and field was nearly 100 percent. Albino seedlings were frequently observed, making up 3-30 percent of the seedlings.

Seeds of *Colocasia* imported from the Pacific were similarly germinated, and seedlings established in the field. These will be used in a hybridization program to broaden the range of genetic variability available for selection.

More than 2,000 IITA-produced *Xanthosoma* seeds have been distributed to the Cameroon National Root Crop

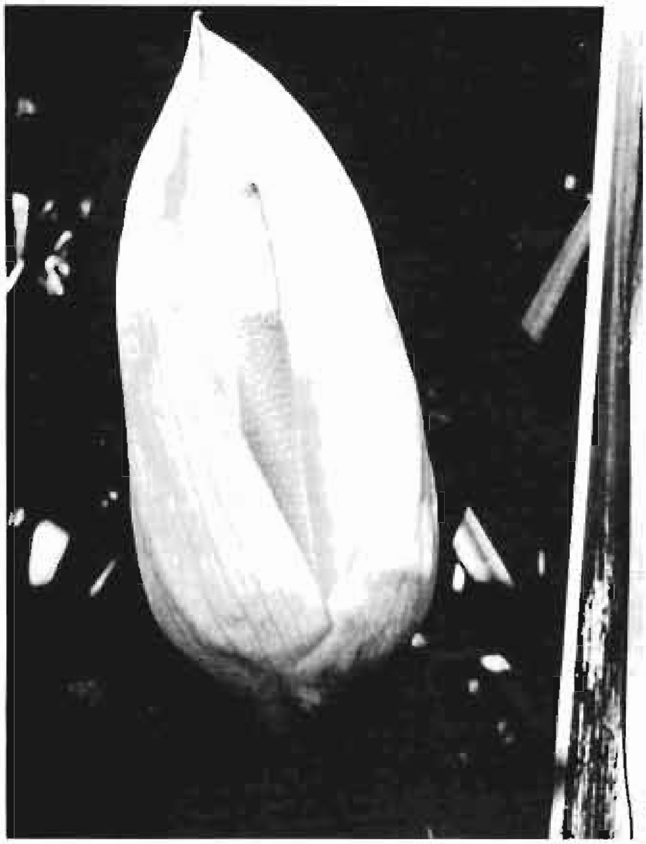
Table 16. Percent seed set resulting from artificial pollinations in cocoyam, Colocasia and Xanthosoma.

	No. of spadices		
	Pollinated	Set seed	Seed set (%)
Colocasia			
Pollinations within clones	82	2	2.4
Pollinations between clones	16	0	0.0
Total pollinations	98	2	2.0
Unpollinated controls	20	0	0.0
Xanthosoma			
Pollinations within clones	62	23	37.1
Pollinations between clones	6	3	50.0
Total pollinations	68	26	38.2
Unpollinated controls	15	0	0.0

Table 15. The effects of GA_3 treatments on the number of days from treatment to first spadix in cocoyam.

GA Conc. (ppm)	Days to flowering: Colocasia 1	Colocasia 2	Colocasia 3	Xanthosoma
0	148	NF[1]	71	193
500	116	77	66	81
1000	119	73	71	90
1500	106	73	72	88

[1]*No flowers produced.*



Cocoyam flower.

Improvement Program where serious disease problems threaten cocoyam production and a breeding program to select improved disease-resistant clones is underway.

Sweet potato

Genetic improvement

To evaluate the stability of IITA improved sweet potato clones, 25 clones were tested in 24 environments in Nigeria including locations with different soil, climatic and epiphytotic conditions during the rainy and dry seasons, from 1976 to 1978. The locations were IITA with good soil for sweet potato and with 1,200 mm annual rainfall, Mbiri with moderate soil and 2,700 mm annual rainfall, Onne with poor sandy acid soil and 2,400 mm annual rainfall, and Mokwa with sandy soil and 1,000 mm annual rainfall. The performance of the top 13 cultivars together with one standard cultivar, Tlb 4, is summarized in Table 17.

The mean yields of all IITA improved clones were above average (12.13 t/ha) over all environmental conditions, and yield of the standard cultivar and deviation mean squares from regression were not significant for all clones compared to the pooled error. The yield of all IITA improved clones exceeded the yield of the standard cultivar over all environments. Among the clones tested, TIS 2498 and TIS 3247 showed superior performance in all environments (Fig. 8) with average yields in four months of 16.38 t/ha and 15.42 t/ha respectively without fertilizers. Both clones had regression coefficients (b_i = 1.35) above 1 and insignificant deviation mean squares. Many IITA improved clones were very stable over a wide range of environments. The higher-yielding clones showed more response when grown under better environments. The clones TIS 2498 and TIS 3247 showed the highest response to the environments.

Table 17. Sweet potato varietal performance in 24 environments in Nigeria during 1976-78.

	Fresh yield (t/h)	b_i	Dev. M.S.
TIS 2498	16.38	1.35	24.11
TIS 3247	15.42	1.35	38.50
TIS 1499	14.80	1.32	14.94
TIS 2534	14.70	0.90	18.08
TIS 2544	14.56	1.00	20.05
TIS 2330	14.23	1.25	12.58
TIS 3030	13.85	1.10	11.08
TIS 3277	13.80	1.10	19.95
TIS 2532	13.66	1.07	24.11
TIS 3017	13.64	1.01	10.80
TIS 1487	13.51	1.11	5.69
TIS 1145	13.37	1.32	20.07
Tlb 11	13.01	0.89	11.76
Tlb 4	8.53	0.82	10.11
Pooled error			32.75

b_i stands for regression coefficient of mean yields of each cultivar on the environmental index.

Dev. M.S. stands for deviation mean square from the regression.

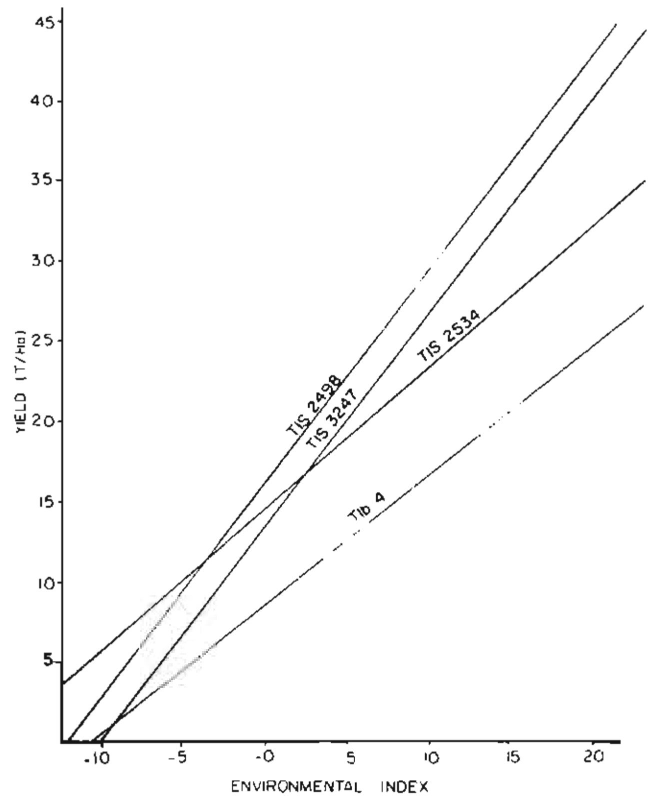


Fig. 8. Response of TIS 2498, TIS 3247, TIS 2534 and Tlb 4 (check) to 24 varying environments in Nigeria in 1976-78.

Difference in weevil damage between the susceptible sweet potato variety Tlb (left) and resistant variety TIS 3017 (right).

Performance of several promising clones selected in 1975 and 1976 and evaluated in 1978 is summarized in Table 18 and Table 19. Among the clones of the 1975 series, TIS 5270 and TIS 5081 showed good performance and among those of the 1976 series, TIS 6046, TIS 6003, TIS 6101 and TIS 6179 were good in performance. These clones will be further tested.

Resistance to weevil (*Cylas puncticollis*)

Twenty clones were planted and trained on stakes in an isolation plot in 1978 where potato had been previous cropped, and they were left until 15 January when soil was dry and weevil population high. There were significant differences among the cultivars in percent of dead plants and overall score based on plant die-back and weevil damage on above-ground parts. It was not certain whether the die-back was due mainly to weevil damage or drought. To test this, the average weevil damage scores of the tuberous root (tested over 15 environments for three years) were plotted against the 1978 above-ground plant part damage scores. (Fig. 9.) There was a highly significant relation (r = 0.79) between these two sets of data, indicating that die-back was mainly (about 60%) due to weevil attack rather than to direct drought effect and that above-ground weevil damage was closely related with tuberous root damage.

The clones which showed the least attack by weevil in this test were TIS 3017 and TIS 2532 with weevil damage scores of 1.0 for both, compared with scores of 5 for Tlb 2 and Tlb 4.

In yield trials over 15 environments for the period 1976 to 1978, clones which showed consistent resistance to weevil were TIS 3053, TIS 2328, TIS 2544, TIS 3030, TIS 2532, TIS 2153, TIS 2534, and TIS 3017.

Table 18. Promising sweet potato clones. (1975 series.)

Clone	Fresh yield (t/h)			Dry matter %	Dry yield (t/h)	Weevil** score	Virus score	Storability
	Season 1	Season 2	Mean					
TIS 5270	28.8	16.0	22.4	29.6	6.6	1.9	1.0	Moderate
TIS 5081*	27.8	15.4	21.6	29.2	6.3	1.9	0.5	V. Good
TIS 5093	24.6	13.2	18.9	29.5	5.6	2.3	0.0	Moderate
TIS 5230	18.2	12.4	15.3	29.7	4.5	0.8	3.2	Good
TIS 5192	18.9	9.9	14.4	27.4	3.9	2.3	1.0	V. Good
TIS 5090	20.3	8.2	14.3	38.1	5.4	2.7	0.0	Moderate
Tlb 4	22.0	11.5	16.8	31.0	5.2	3.4	0.8	Moderate

*Most promising clone.
**Lower score being resistant.*

Table 19. Promising sweet potato clones from advanced yield trial. (1976 series.)

	Fresh yield (t/h)			Dry matter (%)	Dry yield (t/h)	Weevil score	Virus score
	Season 1	Season 2	Mean				
TIS 6089	31.5	7.9	19.7	29.9	5.9	2.1	3.3
TIS 6046	30.1	8.9	19.5	28.7	5.6	0.9	1.0
TIS 6093	27.5	10.9	19.2	29.1	5.6	1.9	2.0
TIS 6101	27.2	10.8	19.0	25.2	4.8	1.8	2.3
TIS 6179	30.0	6.3	18.2	34.7	6.3	2.0	2.7
TIS 6169	28.2	7.1	17.7	22.4	4.0	1.7	2.5
TIS 6195	27.2	6.2	16.7	30.1	5.0	1.9	2.0
TIS 6164	24.4	5.8	15.1	35.4	5.3	1.9	2.3

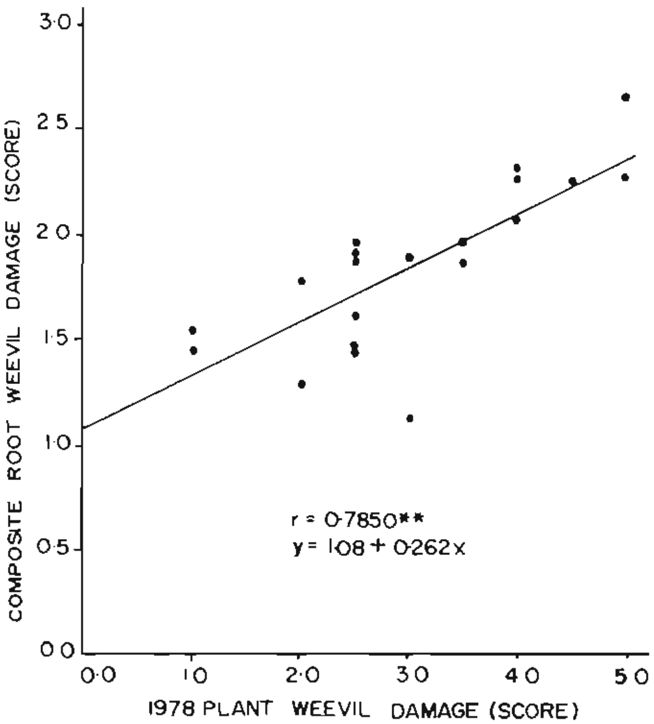


Fig. 9. Relation between the tuberous root weevil damaged score and the above-ground plant weevil damaged score.

Heritability and selection

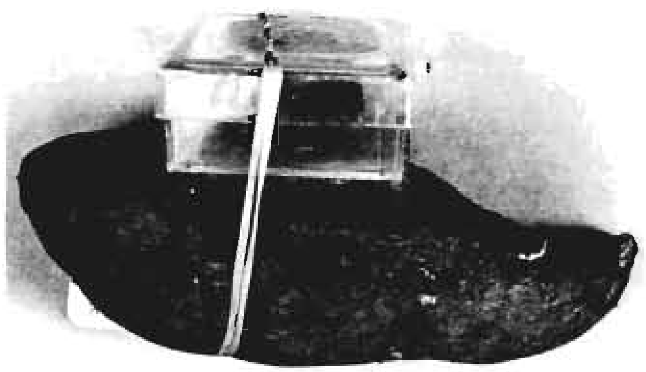
Using the plant weevil damage scores obtained from the 1978 isolation plot which showed heavy weevil infestation during the dry season, broad-sense heritability was estimated to be 82.81 percent compared with 40.26 percent and 39.26 percent from rainy season and early dry season trials respectively. (Table 20.)

Table 20. Heritability (h^2) estimates for resistance of sweet potato to weevil under the different environmental conditions.

Environment	h^2 (%)
Rainy season	40.26
Early dry season (low pressure)	39.26
Mid dry season (high pressure)	82.81

The high heritability (82.81%) indicates that heritability could and should be manipulated by testing breeding materials under favorable conditions for the development of high weevil population and for easy identification of genotypes for high level of resistance. This also suggests that selection for resistance to weevil can be done at an early breeding stage and that mass selection may be an effective method for breeding sweet potato for resistance to weevil if a favorable environment for screening is provided.

Resistance of sweet potato to drought might also be improved while selecting for weevil resistance during the dry season. Resistance of sweet potato to both drought and weevil is important in the tropics where planting materials are normally maintained as vines rather than as tuberous root and susceptible types can be lost during the dry season due to both drought and weevil attack.



A method used to screen sweet potato for weevil resistance.

Screening for source potentials

Source potentials of 20 sweet potato clones including improved and unimproved clones were tested by grafting each clone as scion onto the four tester cultivars as stock Tlb 4, Tlb 5, Tlb 10 and TIS 1499. Average tuberous root weight of the four tester cultivars grafted with a clone was defined as its source potential. Response of source to sink was also estimated by obtaining regression coefficient of yields of tester cultivars grafted with each clone on the average stock effects. The results of estimated source potentials and "response of source to sink" are given in Table 21.

Table 21. Source potentials of sweet potato clones, tested by grafting respective clone onto 4 tester cultivars.

	Source potential (g/plant)	Response of source to sink (b)
SI-301-14	90.53	0.51
TIS 2294	68.03	0.66
TIS 2366	84.63	0.71
TIS 1419	98.15	0.52
TIS 2534	87.35	0.84
BIS 18	105.78	0.60
TIS 2141	138.63	0.83
TIS 2013	86.80	0.84
TIS 3002	112.58	1.34
TIS 2322	138.23	0.45
TIS 3295	164.15	2.06
TIS 2461	147.65	1.24
TIS 3030	126.23	0.76
TIS 2498	213.28	1.55
TIS 3032	151.73	1.47
TIS 2153	109.48	0.79
TIS 3055	112.13	1.22
Tlb 3277	105.88	1.41
Tlb 2	169.35	1.16
TIS 1487	130.93	1.06

Response of source to sink was estimated by obtaining regression coefficient of the ith *clone on the average stock effects.*

Clone TIS 2498 showed the highest source potential, followed by Tlb 2 and TIS 3295. TIS 3295 and TIS 2498 showed high "response of source to sink" as well. (Fig. 10.)

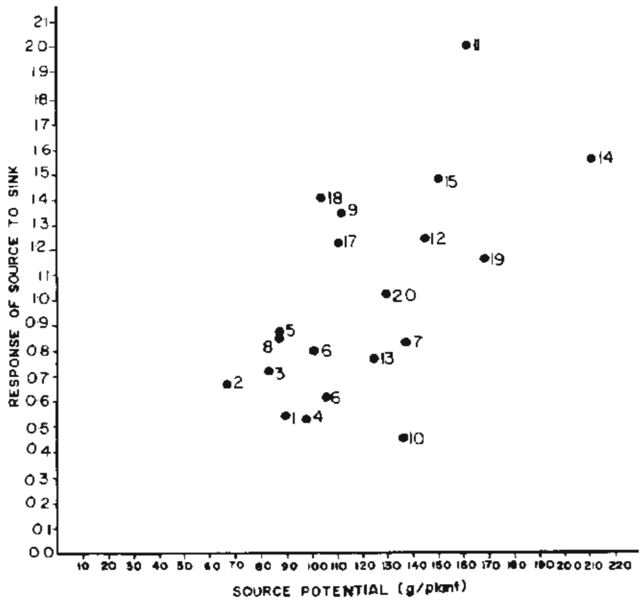


Fig. 10. Relation between source potential and "response of source to sink" for 20 sweet potato clones.

"Response of source to sink" was related to source potential as in Figure 10. The correlation coefficient between source potentials and response of source to sink was estimated to be r = 0.62 which is highly significant. Regression of "response of source to sink" on source potentials was found to be Y = 0.1012 + 0.0074** X. The clones with high source potentials showed high "response of source to sink" and vice versa. This means that the clones with large source potentials can produce more photosynthates and translocate them into tuberous root as the demand by sink increases.

Clone TIS 2498

Through trials in a wide range of environments in Nigeria for seven years, the IITA improved clone TIS 2498 has been found to be the best in yield and stability. It has shown resistance to viruses and moderate resistance to weevil under the field conditions and it has high storability. It has high dry matter percent (33.3%) and high consumer acceptance quality. It has been tested to be high in source potential and in response of source to sink.

International cooperation

Sierra Leone. IITA improved cultivars Tlb 2, TIS 1497 and TIS 3017 were named ROPOT 1, ROPOT 2 and ROPOT 3 respectively and were released as recommended cultivars for country-wide cultivation following testing for the past three years under no fertilizer condition. The average yields of Tlb 2, TIS 1497 and TIS 3017 were 17, 14, and 13 t/ha respectively in four months without fertilizers. Many new clones were selected from the seeds supplied by IITA.

Cameroon. An IITA improved cultivar, Tlb 2, which gave the highest yield during the past three years was multiplied and distributed to many farmers.

Seychelles. Many seedlings were raised from the improved seeds supplied by IITA and promising ones were selected for further evaluation.

Weevil Resistance

Cylas puncticollis and *Cylas formicarius* are the most severe pests in sweet potato production in Africa. To tackle this pest problem, a large germplasm collection was assembled from Africa, Asia and America. This has been evaluated since 1971 for resistance to *Cylas puncticollis* in both rainy and dry seasons. As a result, some high-yielding clones which showed some promise for resistance were identified.

Trial layout and evaluation

Nine clones have been selected on the basis of performance against weevil attack in previous years. These clones were planted during the first and second seasons in a randomized block design with three replications. Each block measured 7m × 10m, large enough to allow individual weevil population buildup with minimum interference from other blocks. In addition each block was separated from the other by 2m of space which was planted with cassava.

To insure a uniform initial weevil infestation, 28 weevil-infested tubers were spread in each block one week after planting. For monitoring the weevil population, two $1m^2$ areas were marked in each block where adults were counted weekly. Both trials were harvested after four months. A record of yield, number of infested tubers, stem performance and tuber depth was taken after each harvest.

Results

Population development. Figure 11 shows the difference in population buildup between the control, Tlb 4, and the average buildup observed on the nine test clones. The wet-season population development shows no significant differences between control and test clones at the end of the wet season. This result indicates that the wet season is not suitable for screening. The second-season trial ran for two months into the dry season. Buildup of the weevil population increased rapidly after the last rain, indicating clearly the importance of dry soil for reliable field screening.

Influence of the stem on the buildup of the weevil population. The curve of insect population development (Fig. 11) can be divided into a slow buildup during the first two months, influenced by the restricted breeding space in the stem and a rapid increase of the population during the second half of the growing season when tubers were available. In order to better understand the influence of the stem on population development during the first two months of plant growth, a lab-stem screening test was compared with the second-season weevil population over this time.

The stems came from the same clones used in the field trial. Ten stems of each clone were divided into three main sections: base, middle and end parts. Each stem was infested with eggs whose positions were marked.

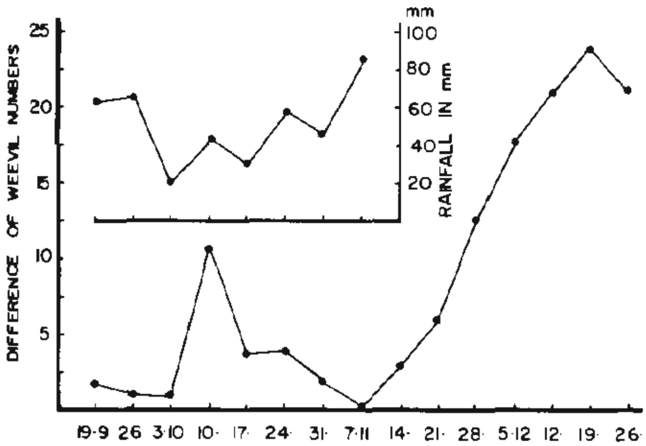


Fig. 11. Curve of insect population development.

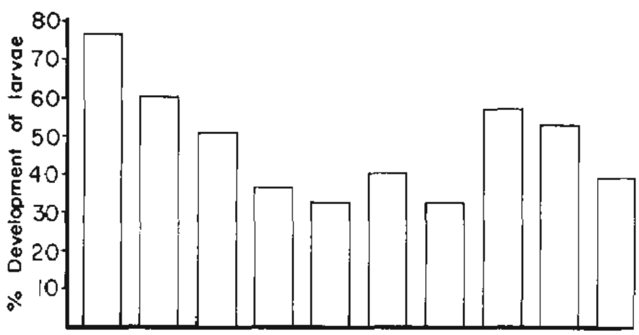


Fig. 12a. Differences of levels of weevil resistance observed in sweet potato stems in the laboratory.

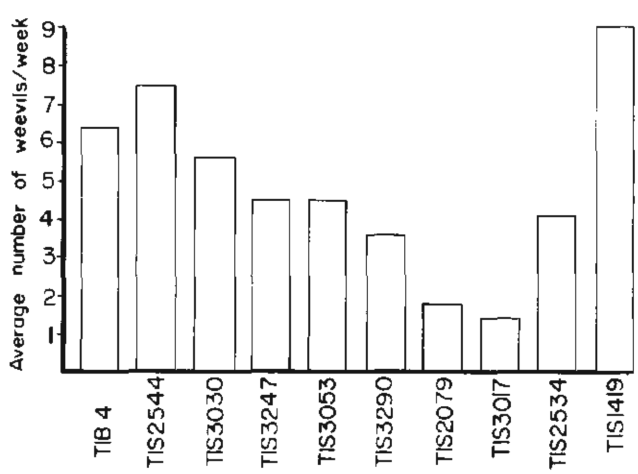


Fig. 12b. Differences in weekly weevil counts taken from the field during the first two months when sweet potato stems were only available for breeding.

Then the stems were planted in pots and cut after 17 days. Egg mortality and larvae development were recorded. In Figures 12a and b the results of the lab-stem test and the average weekly counts of weevils in the field are compared. Laboratory and field results seem to correspond in seven of 10 cases. No correspondence could be found in TIS 3017 and TIS 2534.

After having observed differences, the extent to which stem resistance influenced the increase of the weevil population during the second two months of plant growth was noted. In Figure 13 these two periods are compared by average weekly catches. The average counts of the second period are remarkably equal despite whether the counts were low or high during the first two months. This questions the value of stem resistance as a contributing factor to sweet potato weevil resistance. Otherwise, perhaps during the dry season, weevils are more mobile and tend to disperse, which might explain the uniform infestation.

The wet-season trial results indicate clearly that this season is unsuitable for screening for resistance. Differences in damage are low compared with the second-season trial although it follows the same pattern. The main causes of low infestation during the wet season seem to be wet soil (which does not crack) and lower temperatures. The second-season trial shows significant differences, which again clearly indicate that this season is more suitable for screening. The weevil population increases fast and tubers are more exposed because of soil cracks due to drought.

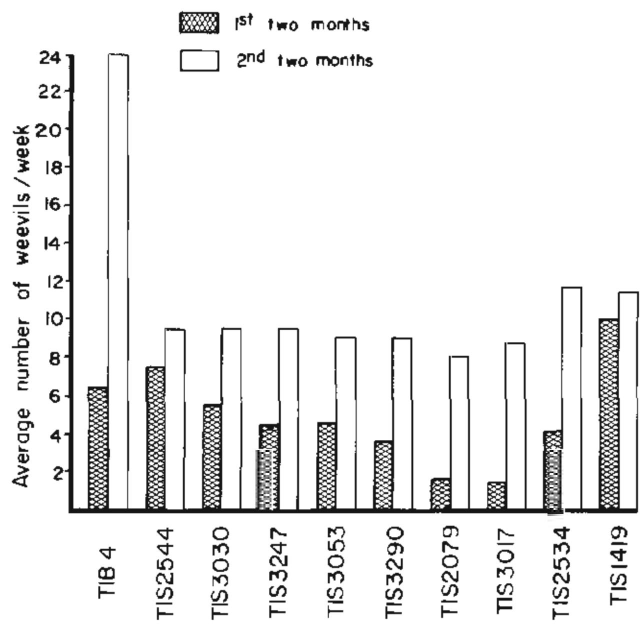


Fig. 13. Average weekly catch of weevils during 1st and 2nd two months of plant growth.

In Table 22 tuber damage is compared with other factors which possibly could influence screening results.

Four clones showed significantly lower damage: TIS 1419, TIS 2079, TIS 3030 and TIS 3017. The major factor contributing to the low damage on TIS 1419 and TIS 2079 is the fact that they root deeply. They escape damage in spite of being susceptible. In the case of TIS 3030 and TIS 3017, tubers are larger and easily exposed to weevil attack by a medium cover of soil. In spite of these factors, which normally increase weevil damage, the attack is low compared with the control. It is, therefore, believed that some chemical means are involved in the resistance.

Table 22. Weevil damage in relation to several factors influencing infestation and population buildup.

Clone no.	t/ha	Average wt/tuber (kg)	Average no. of weevils per week	Tuber depth*	Percent infested tubers
TIS 1419	16.6	0.25	11.8	deep	17.7
TIS 2079	7.7	0.2	8.0	deep	7.3
TIS 3247	24.4	0.19	8.7	shallow	33.3
TIS 3030	23.7	0.19	9.4	medium	16.7
TIS 4	17.5	0.12	24.4	shallow	73.0
TIS 2534	20.1	0.16	11.7	medium	36.7
TIS 2544	19.5	0.17	9.4	medium	32.3
TIS 3290	21.6	0.18	9.0	shallow	29.7
TIS 3053	20.5	0.24	9.0	medium	40.3
TIS 3017	23.2	0.27	8.7	medium	19.0

**shallow = 0-2 cm; medium = 2-4 cm; deep = 4-5 cm.*

Farming Systems Program

This program has the task of developing methods of crop management and land use suited to the humid and sub-humid tropics which will enable more efficient and sustained production of food crops to be technically and economically feasible in these zones. While recognizing the interactions between annual food crops, perennial crops and livestock, the Farming Systems Program focuses on the food crop components of tropical farming systems. The program places particular emphasis on incorporating in its crop production and land management research the improved cultivars emerging from IITA's crop improvement programs, and from other international and national agricultural institutions.

The farming systems in the lowland humid and sub-humid tropics are diverse, so research priorities of the program are focused on dominant agricultural typologies within major agro-ecological zones. As the program aims to develop methods of food crop production which will make the most efficient use of the farmer's natural resources (land, weather, adapted crops), major agricultural regions are characterized for research purposes in terms of land types, cropping systems, and dominant bio-technical limitations as shown in the IITA Annual Report 1977. Most parts of the region where IITA operates are occupied by the highly weathered low-land high-base status soils. The IITA station at Ibadan (3° 54′ E, 7° 29′ N) is representative of the region with high-base status soils, and the Onne sub-station (7° 01′ E, 4° 43′ N), the low-base status soils of the tropics.

The vast majority of food crops produced in the institute's mandate region — other than for intensive rice production on hydromorphic soils — are grown in various mixtures by subsistence farmers relying on shifting cultivation and bush fallow systems to replenish soil fertility. While such systems are stable when land is not a limiting factor, they tend to break down when the number of people the land must support becomes such that fallow periods are substantially reduced. Greater population and economic pressures are resulting in more intensified systems of land use, and with an absence of new technology and declining soil fertility there is falling productivity because of reduced resources committed to food crop production.

Organizational structure

The farming systems program has used the following structure in focusing its activities:

The purpose of ***Regional Analysis*** is to develop and analyze inventories of resource use and the bio-technical, physical and socio-economic environments of farming systems of the humid and sub-humid tropics. These analyses, which are highly interdisciplinary in nature, assist in the identification of limiting factors to production and resource potential and so assist in the definition of the Program's problem-oriented research.

The focus in ***Crop Production*** is to develop cropping practices which are productive, biologically stable, and economically viable, and also identify systems of crop management adapted to the conditions and needs of farmers in the humid and subhumid tropics.

Land Management has the task of developing and testing methods of land development and soil management which will economically overcome the constraints to intensified use of fragile tropical soils.

The purpose of ***Energy Management*** is to adapt and develop implements and methods which are complementary to the technology developed elsewhere in the Institute, which can help relieve the energy (largely labor) constraints to crop production and processing, and reduce postharvest storage losses.

Finally, ***Technology Evaluation*** provides the point of integration and synthesis of Farming Systems research. The purpose of this project area is to develop, evaluate and adapt appropriate systems of crop management and land use for different ecologies, drawing on the findings of Farming Systems and the Institute's crop improvement programs.

Agro-economic studies

A major agro-economic village level survey initiated in 1977 to obtain fuller understanding of the farming systems in which yam is grown as a major crop, was completed in 1978. The study covered six villages, three located in the derived Guinea Savanna, and three others in the humid southeastern forest region of Nigeria.

The major objectives of this survey were: (1) to describe the physical, biological and socio-economic environment in the survey villages; (2) to describe the farming systems, including the resource base and use; (3) to estimate costs and returns of major cropping systems and crop enterprises; (4) to identify and describe production problems and (5) to identify research priorities.

A total of 155 farmers were interviewed 2-3 times a week for 14 months. Labor utilization, other input, output and sales data were collected for all plots under cultivation during the survey period, and all fields were measured and selected yield samples were taken.

In the Lokoja area (Guinea Savanna), the villages of Tawari, Osara and Eganyi were selected. Farming in these villages is subsistence oriented with yam being the dominant crop.

In Tawari, the northernmost village in the sample, yam is followed in importance by sorghum, millet, maize and cowpea. Yam is grown on heaps and the other crops on small ridges, all on upland areas. Land is used intensively and a given plot is normally cropped over a 10-15 year period followed by 5-6 years of bush fallow (R = 70), where R is defined as:

$$\frac{\text{No. of years cropped}}{\text{Total no. of years}} \times 100$$

A distinct two-year rotation is started by yam, relay intercropped with pearl millet and African yam bean, followed by maize and cowpea, relay intercropped with sorghum. The mean farm size in this village is 2.5 ha., of which 1.1 is usually devoted to yam production. The household labor available to crop this area is 3.4 man equivalents (M.E.). The distribution of household labor requirements throughout the year is illustrated in Figure 1. In Tawari, average yam yields are 11.9 t/ha and farmers were, on the average, producing 13 tons of which 30-40 percent is normally sold. (Table 1.)

In Osara and Eganyi, yam is followed in importance by sorghum, melon, cowpea, cassava, maize, benniseed and groundnut. Farmers crop both upland areas and lowlands. The uplands are freely drained sandy soils and the dominant crops are yam, cassava and sorghum. The lowlands are waterlogged, hydromorphic soils where crops such as yam, cassava and maize are grown on high mounds. In Osara, crops are grown on ridges only, whereas, heaps are dominant in Eganyi. On both land types, there is no distinct cropping pattern, as crops are interplanted in numerous combinations and relative plant densities; however, plant densities are higher on uplands. In these villages farmers normally use long rotations on uplands, e.g., 6-7 years of cropping followed by 4-5 years of fallow (R = 60), but short rotations on lowlands, e.g., 1-3 years of cropping followed by a fallow period of the same length (R = 50). By using short rotations on lowlands, farmers increase the frequency of the years when relative soil fertility is high (i.e. the first years after fallow, which are used to produce yam, a crop which is most sensitive to soil fertility).

Table 1. Average yam yield, set rate and input-output coefficients for a sample of farmers in three villages in the southern Guinnea Savanna.

Cultivation System	Plant density/ ha	Yield kg/ stand	Yield t/ha	Set rate kg/ stand	Set rate t/ha	Output/ input relation
Tawari	3960	3.2	11.9	1.3	5.0	2.4
Osara						
Lowland	2770	3.3	12.1	1.5	5.5	2.2
Upland	4960	2.0	10.0	0.8	4.1	2.4
Eganyi						
Lowland	2680	5.6	13.8	1.1	3.0	4.6
Upland	3400	3.0	9.7	0.8	2.8	3.5

The mean farm size in Osara and Eganyi is 3.4 and 2.1 ha. respectively and the area devoted to yam 0.4 and 0.8 ha. The available household labor is 3.8 and 3.3 M.E. respectively. The distribution of household labor requirements throughout the year for Osara is shown in Figure 2.

As shown, there are four short periods when little farm work is done. Labor demand peaks in this village are not so pronounced due to the phasing of operations between upland and lowland.

In the more humid area of southeastern Nigeria, Akili, a village on the bank of River Niger in Anambra State, was chosen to represent a flood plain cropping system; Nteje was selected to represent a combined upland and valley bottom system in the derived savanna; and Ute-Okpu was

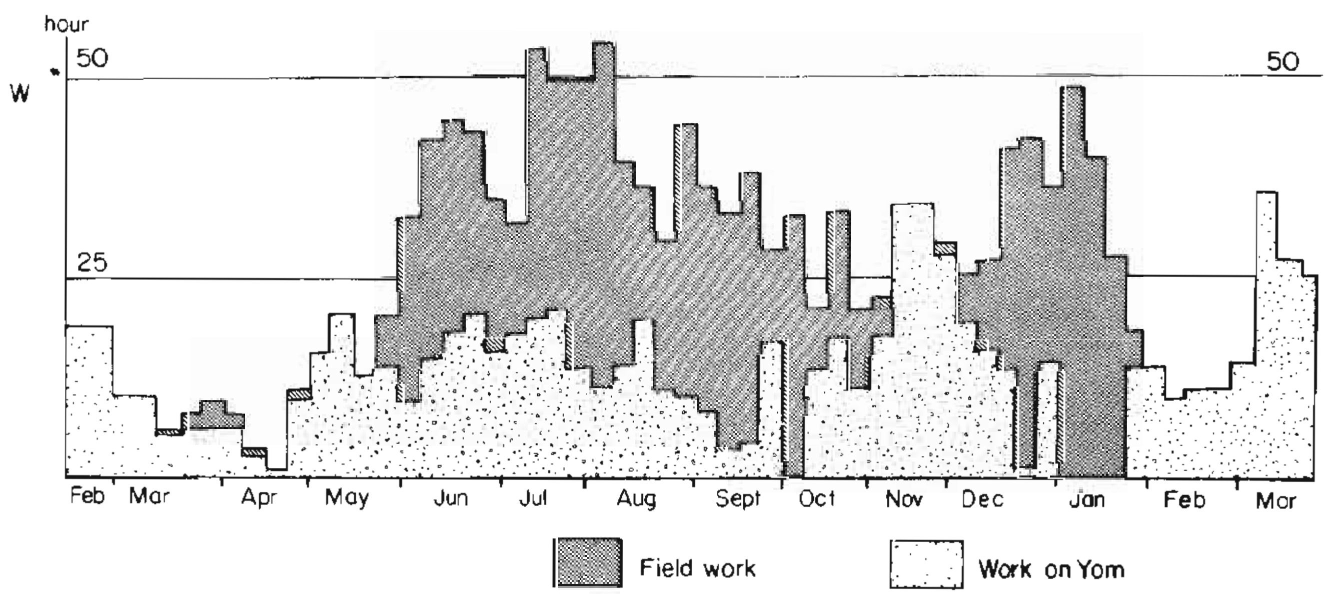


Fig. 1. Mean hours of total work and field hours spent on yam by household members in Tawari, 1977.

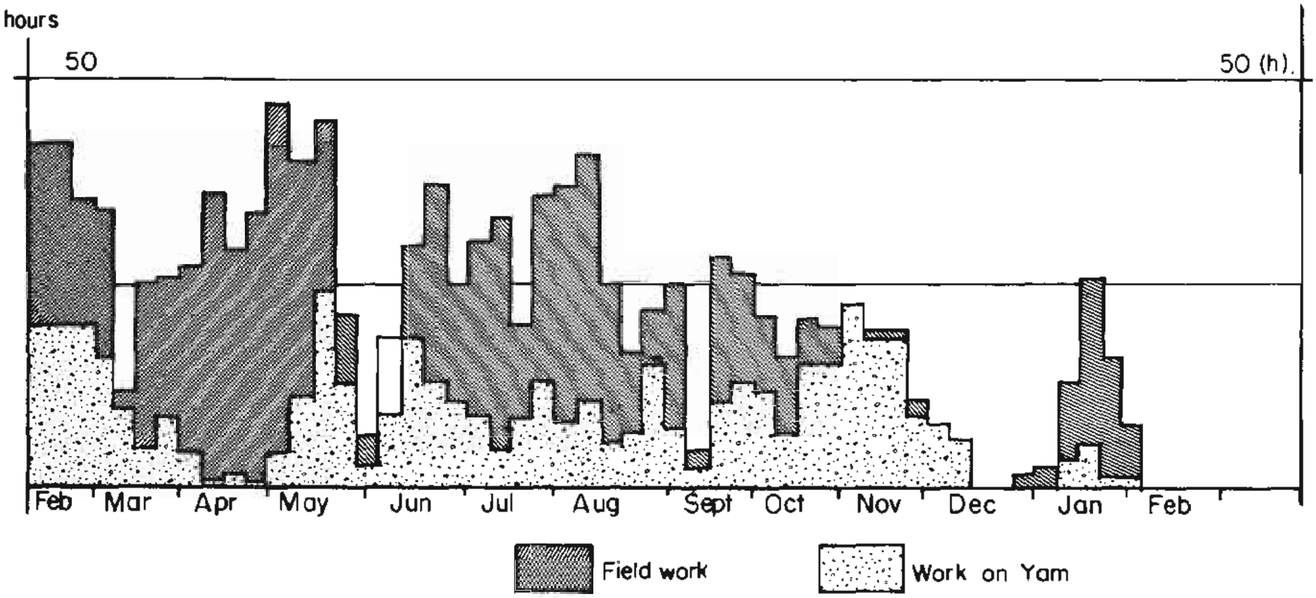


Fig. 2. Mean hours of total field work and field hours spent on yam by household members in Osara, 1977.

included to represent an upland cropping system in the rainforest zone. The relative importance of yam versus cassava in each of the villages depends on farm size, soil fertility, soil/water relationships and distance to food deficit areas.

Land area cultivated is higher in Ute-Okpu since land clearing, which is the major labor limitation, can be carried out over an extended time period. However, in Akili and in Nteje, the major labor problem is for soil preparation and this can only be carried out in one short time period of the year. (Table 2.)

Table 2. Resources base of smallholder farms surveyed in Bendel and Anambra States of Nigeria, 1977/78.

Village/ biophysical environment	Flood-plain	Upland + Valley bottoms in derived savanna	Upland in secondary rainforest
Average farm size (ha)	0.8	1.1	3.0
Average household size (persons)	6.7	6.7	8.8
Household labor capacity (ME)	2.8	2.5	3.3
Man/land ratio (ME/ha)	3.7	2.2	1.1

The crops common to all three cropping systems in the humid survey area are ware yam, seed yam and cassava contributing about 90 percent of gross farm return.

Ware yam (which yields fairly high returns to land, requires fertile soils, matures early enough to escape annual flooding and is difficult to transport) is the favored crop in Akili. This is the village with small farm sizes, rich alluvial soils and annual flooding of the farm land, and it is situated close to Onitsha, a major urban center in southern Nigeria.

Seed yam may be produced on poor soils in villages close to yam set deficit areas. These conditions apply to Nteje. Cassava provides low returns to land but high returns to labor, even on poor soils. Cassava does not mature early enough to escape annual flooding. It is traded as gari flour which can be transported at lower costs than tubers. Thus cassava is most important in Ute-Okpu, the village with the largest farms and non-flooded soils of moderate fertility. Among the three villages it is the most distant from food deficit areas. Farmers who have to cope with small farms have intensified ware yam production on the foodplain, valley bottom and compounds by using higher plant densities. (Table 3.)

During the survey year, yam yields suffered from poor rainfall distribution. This was particularly so for Nteje. On compounds and valley bottoms in Nteje, increased plant density and labor intensity did not result in significantly higher yields during the survey year when most of the farmers regarded yields as poor. The analysis of the survey data is still in process. From this information the major bio-physical, labor and financial constraints will be analyzed to identify major areas of potentially productive agricultural research.

Studies of benchmark soils

The Benchmark Soils Project was designed to provide information on carefully chosen soils, to enable their agricultural capability to be related to their morphological, chemical, physical and mineralogical properties. Pedological and analytical information gathered is being compiled and stored in the IITA Tropical Soil Data Bank. Work during 1978 emphasized gathering pedological and analytical information on the strongly weathered acid soils in the savanna and high-rainfall regions in the low-altitude tropics. Examples of some properties of selected acid soils are given in Table 4.

Table 3. Yam yields in three humid area survey villages, Bendel and Anambra States of Nigeria, 1977/78.

Village/ biophysical environment	Plant density/ha	g/stand	t/ha	g/stand	t/ha	Output/ input ratio
Floodplain	4340	4330	18.8	538	2.2	8.5
Derived savanna valley bottom	5355	1420	7.6	375	2.0	3.8
Compound	6620	1630	10.8	326	2.2	4.9
Upland in secondary rainforest	1659	5300	8.8	1091	1.8	4.9
Derived savanna seed yam production on upland	22,630	190	4.2	76	1.7	2.5

Table 4. Properties of two Ultisols (Typic Paleudults) derived from coastal plain sediments in the lowland humid tropics of Nigeria and Brazil and two Oxisols (Typic Haplorthox) derived from sedimentary materials from Congo River and lower Amazon basins under equatorial rainforest vegetation.

Horizon	Depth cm	Clay %	Org C %	pH H_2O	Exch Cations, me/100 g Ca	Mg	K	Al	Al Satn. %	Free Fe_2O_3 %
			Typic Paleudult, Onne Nigeria (2450 mm)[1]							
A_1	0-15	18	1.04	4.3	0.35	0.11	0.07	1.75	77	2.1
B_1	27-45	34	0.40	4.4	0.15	0.04	0.02	1.86	90	2.8
			Typic Paleudult, Recife, Brazil (1959 mm)							
A_1	0-25	12	0.64	5.0	0.70	0.10	0.04	0.40	30	1.2
B_1t	46-65	21	0.32	4.8	0.15	0.05	0.02	0.85	79	1.8
			Typic Haplorthox, Yangambi, Zaire (1850 mm)							
A_1	0-15	28	2.20	3.7	0.25	0.12	0.11	1.68	78	3.2
B_{21}	32-72	33	0.70	4.0	0.10	0.03	0.05	1.52	89	3.9
			Typic Haplorthox, Itaituba, Brazil (2100 mm)							
A_1	0-10	75	5.74	3.5	0.58	0.61	0.22	3.92	74	3.6
B_{21}	40-80	87	0.53	4.5	0.15	0.04	0.02	1.36	87	4.8

[1]*Figures inside parentheses are for mean annual rainfall.*

The "luxurious" equatorial rain forests such as those in the Congo and lower Amazon river basins do not reflect the extremely poor soils beneath them. Once the forest is removed, the cycle of nutrients is broken. Soluble nutrients released from the decomposed organic matter are then rapidly lost through leaching and run-off. Such losses are not so serious with isolated clearing under traditional shifting cultivation as the manually cleared and burnt area is usually so small that the lost soil nutrients are recaptured by the surrounding forest ecology.

Large-scale mechanized clearing of tropical rain forests often results in instant impoverishment of the soil. Because of poor mineralogical make-up (Kaolin, Fe and Al oxides and quartz sand), tropical rain forest soils hold little nutrients and water within the rooting depth of most annual food crops. Heavy fertilizer and lime applications are subjected to leaching losses under excessive rainfall. Extensive crop production may require carefully balanced applications of chemical fertilizers.

On the other hand, the highly weathered, fine-textured Oxisols in the cerrado (or savanna) region of Brazil could be made productive under large-scale soybean and maize cultivation even though such Oxisols (Ustox) also have very low inherent fertility and are more acidic compared with their West African "counterparts" (Alfisols). A comparison of some properties of two savanna soils derived from similar parent materials from the Brazilian cerrado and from the West African savanna is given in Table 5.

Although the initial results of utilizing the cerrado Oxisols for extensive cultivation are encouraging, soil and crop scientists working in the region are concerned with the long-term effects of mechanization, liming and chemical fertilization on the chemical and physical conditions of these Oxisols.

Crop production

Intercropping-based studies

Previous intercropping experiments coupled with field investigations have clearly shown the importance of maize, cassava and plantain on freely drained soils and rice on hydromorphic soils, as dominant components of indigenous and improved cropping systems adapted to the subsistence farmer's situation in the humid and subhumid tropics. Often, other food crops grown in association with these staples have a high degree of locale-specificity and in general contribute a minor (but

Table 5. Savanna (or Cerrado) soils derived from Pre-Cambrian basement complex rocks from Brazil and Nigeria.

Horizon	Depth cm	Clay %	Gravel %	pH H_2O	Exch. Cations, me/100 g Ca	Mg	K	Al	Free Fe_2O_3 %	Bulk Density g/cm³
				Oxisol (Haplorthox), near Brasilia, Brazil						
A_1	0-15	40	0	4.7	0.64	0.16	0.12	1.68	12.5	1.05
B_1	30-70	48	0	4.6	0.20	0.03	0.04	1.28	15.6	1.14
				Alfisol (Haplustalf), Sepeteri, Nigeria*						
A_1	0-10	7	10	6.2	8.36	2.57	0.44	0	4.5	1.55
B_1	25-36	16	60	5.6	0.67	0.38	0.12	0.25	5.7	1.77

**Clay and chemical data are expressed on the basis of fine earth (<2 mm).*
Gravel and bulk density are expressed on the whole soil basis.

important) part of the aggregate output. As a result, the program is focusing on maize and cassava based cropping systems for upland conditions in the subhumid tropics; cassava- and plantain-based cropping systems for the humid tropics; and rice-based cropping systems for hydromorphic areas.

Partial mechanization of maize/cassava intercropping. Maize/cassava intercropping forms the basis of many food crop production systems in the humid and subhumid regions of Africa. The combination is highly productive and exhibits better land utilization efficiency than the sole cropping production of either crop. However, the benefits remain restricted to small units in non-motorized cropping systems. The systems as practiced by peasants are not usually conducive to efficient mechanization, neither are there specialized machines for mechanization of such intercropping systems. However, with modifications in spatial arrangement and planting patterns, partial mechanization of the combination should be achievable with available equipment.

Intercropping, a common feature of African farming, is being studied by IITA scientists. Here, maize, intercropped with cassava, is planted at 30,000 stands per hectare.

The effect of mechanical maize planting on crop performance in intercropping was observed. The treatments were (a) sole maize machine planted on 100-cm ridges, with 25 cm along the ridge; (b) sole hand planted maize on 100-cm ridges with 100 cm along the ridge and three plants per hill; (c) machine planted maize on 100-cm ridge with 25 cm along the ridge, relay interplanted four weeks later with cassava spaced 100-cm along the ridge; (d) hand planted maize on 100-cm ridges with 100 cm along the ridge and three plants per hill, relay interplanted four weeks later with cassava; (e) sole cassava on 100-cm ridges with 100 cm along the ridge.

Significant differences in maize yield were observed only between the different methods of planting. Machine planting with 40,000 plants/ha was superior to hand planting with 30,000 plants/ha. The presence of cassava had no significant effect on yield regardless of maize planting method. (Table 6.)

Table 6. Maize and cassava yields in sole and intercropping systems.

Treatment	Yields t/ha		
	Maize		Cassava
	1st Season	2nd Season	
Sole maize machine planted	5.50	3.30	-
Sole maize hand planted	4.36	3.10	-
Maize/Cassava machine planted	5.50	-	17.92
Maize/Cassava hand planted	3.98	-	16.81
Sole Cassava			18.14
LSD 5%	436	N.S.	N.S.

Though there was some slight growth retardation of interplanted cassava, yields were not significantly reduced. The second-season maize yield was satisfactory but its relative value compared to cassava, especially in subsistence farming, is still undetermined. The feasibility of partial if not complete mechanization of maize/cassava intercropping is indicated.

Tree legumes in intercropping. The two major constraints to tree legume fallow establishment are weed competition and lack of nutrients needed for effective nodulation and rapid early growth. Because the returns from these fallows are indirect, farmers are reluctant to weed and apply fertilizers to them. If, however, weeding and fertilizer application could be done indirectly, that is, while directed to some crop from which food or cash is obtained, the legume fallow interplanted with the crops would benefit from the treatments.

Using the test legume *Leucaena leucocephala*, treatments included pure maize; maize/cassava with cassava planted between two hills of maize; maize/*Leucaena* with *Leucaena* planted in the furrow and alternating with two ridges of maize; maize/cassava/*Leucaena* with maize and cassava planted on ridges and *Leucaena* planted in the furrow and alternating with two rows of maize/cassava; and pure *Leucaena*.

The presence of *Leucaena* with maize had no significant effect on maize yield but when *Leucaena* was combined with cassava and maize, maize yield was reduced significantly. (Table 7.)

These data suggest that *Leucaena* can be established with maize but not with maize plus cassava.

In trial II a series of tree-type legumes were planted in the furrow alternating with two ridges of maize/cassava. The legumes, *Tephrosia candida*, *Cajanus cajan*, *Leucaena leucocephala* and *Glyricidia sepium* were planted the same time as maize while cassava was planted four weeks later.

Planting in the furrow was again observed to be disadvantageous, as flooding damaged or retarded the young seedlings. Because of poor planting material, cassava stand was sub-normal and cassava had little effect on legume growth. At the time of maize harvest *Cajanus cajan* was the tallest of the legumes followed by *Tephrosia candida*, *Leucaena leucocephala* and *Glyricida sepium*. The legume did not affect maize yield significantly. (Table 8.)

Table 8. Maize yield and height and girth of shrub legumes at maize harvest.

Combination	Maize yield t/ha	Legume Height (cm)	Legume Stem dia. (cm)
Maize/cassava/ *Tephrosia*	3.66	138	0.68
Maize/cassava/ *Glyricidia*	3.25	81	0.70
Maize/cassava/ *Cajanus*	3.04	168	1.28
Maize/cassava/ *Leucaena*	2.59	113	0.50
Maize/cassava	2.87	-	-
LSD 5%	N.S.	19	0.40

***Table 7. Maize yield and height and diameter of cassava and* Leucaena.**

Cropping pattern		Maize yield t/ha	Cassava Height	Cassava Diameter	*Leucaena* Height	*Leucaena* Diameter
A	Maize	2.07	-	-	-	-
B	Maize/cassava	2.25	120	1.45	-	-
C	Maize/Leucaena	2.12	-	-	116	0.66
D	Maize/cassava/*Leucaena*	1.44	115	1.51	61	0.55
E	Leucaena	-	-	-	186	1.25
	LSD 5%	0.24	N.S.	N.S.		

Tree or shrub legume for fallow should be established by intercropping maize as legume growth will benefit from the applied fertilizer and weeding for maize while food and income from the maize will be incentives for establishing legumes in this combination.

Plantain-intercropping. Intercropping trials were established at both IITA's high-rainfall station at Onne and at Ibadan. To bridge the long dry season at Ibadan, overhead irrigation was used. The crop combinations compared with sole cropping of plantain and the other crops were (a) plantain/cocoyam, (b) plantain/maize, (c) plantain/cassava, (d) plantain/maize/cocoyam, (e) plantain/maize/cassava and (f) plantain/cowpea/cocoyam. The plantain cultivar was the Horn type "Agbagba."

Plantain was spaced 3m × 2m: cocoyam and cassava were planted on mounds spaced 1m × 1m; maize 1m × 1m with 3 plants/hill and cowpea 1m × 25cm. Maize, cocoyam and cowpea were planted immediately after plantain. Cassava was planted six weeks later.

Fertilizer was applied to plantain in 10 equal side dressings with each mat receiving a total of 150g N, 150g P, 150g K and three equal side dressings totalling 120g N, 120g P and 240g K at Ibadan and Onne respectively. Maize received a preplanting application 60 kg N, 60 kg P and 60 kg K/ha and a side dressing of 20 kg N/ha four weeks after planting.

At both locations the intercrops were found to have no significant effect on plantain yield, although some growth parameters were affected. Maize slightly suppressed early plantain growth. However, the effect was overcome after maize harvest when the competition was removed. Plantain intercropped with maize was shorter at four months than the corresponding sole crop, but a difference was not observable at shooting. Cassava and cocoyam appeared to have stimulated plantain growth in the first four months but the difference did not persist through maturity and no significance can be attributed.

Because of its relatively short growing period, maize matured before plantain reached the developmental stages where interspecific competition would affect maize yield. Maize yield reduction noted in Ibadan reflected mainly the lower maize plant population density rather than competition from plantain. For cocoyam and cassava, yield reduction was greater than could be accredited to population reduction. Therefore, when intercropped with plantain, significant yield reductions noted for these crops have been attributed to competition by plantain for light, moisture and nutrients.

Land utilization was more efficient under intercropping than sole cropping. Triple cropping was also more efficient than double cropping. In Ibadan where rainfall was lower, cowpea induced undesirable drought stress on plantain and cocoyam, but effectively reduced weeding.

In general the intercrops did not affect plantain yields. Thus, the important factors to consider in intercropping combinations with plantains are the contribution of the other crops and labor and land-use efficiency.

Weed control in intercropping. Four methods of weed management: handweeding, biocontrol, chemical control, and an integrated weed management system, were evaluated in maize, cassava and yam based cropping patterns on the IITA site. Results showed that weed competition was minimized in all cropping patterns by keeping the crops weeded during the first 12 weeks after planting (WAP). Providing the first weeding was done at 3 WAP, two or three weeding frequencies were adequate to minimize weed competition. (Table 9.) Biocontrol involving use of a low-growing crop to suppress weed

Table 9. Weed control in selected mixed cropping pattern (per ha). (IITA, 1978.)

Weeding	Time[1]	Sole maize	Sole yam	Maize/ yam	Maize/ cassava	Maize/ yam/ cassava	Mean
		Crop yield (1 x 10^7 Kcal)					
1. Hoe weeding	3+5 WAP[1]	302	147	236	257	282	245
2. Hoe weeding	3+8 WAP	334	144	256	251	281	253
3. Hoe weeding	3+12 WAP	326	184	276	268	333	277
4. Hoe weeding	5+12 WAP	262	154	245	230	318	242
5. Hoe weeding	3+5+12	316	187	262	282	307	271
6. Melon + weeding	3 WAP	318	134	254	269	248	245
7. Melon fb Sweet potato –	3 WAP	308	166	250	232	288	249
8. Melon + diuron + alachlor	PE[1]	301	158	265	277	305	261
9. Sweet potato + weed	3 WAP	299	134	214	254	272	235
10. Atrazine + metolachlor	PE	311	173	269	272	288	263
11. Weed free check	—	360	203	261	310	365	300
12. Weedy check	—	282	130	219	245	307	237
Mean		310	160	251	262	300	257
S.E. ±		27.4	17.1	20.6	27.8	29.6	11.2
C.V.		15%	18%	14%	18%	17%	17%

[1] *WAP = Weeks after planting.*
PE = Pre-emergence.

growth showed that "Egusi" melon (*Citrullus vulgaris* Schrad) was effective in suppressing weeds without affecting crop yield. Although sweet potato was very competitive against weeds it also reduced yam yield. A formulated mixture of atrazine and metolachlor (Primextra) effectively controlled weeds in all cropping patterns and yields were as good as treatments that were handweeded three times.

Sole crop based studies

Yam production — staking. Staking to support the vines of yam is one of the most expensive and time-consuming practices in the management of the crop and is often suggested as a reason for the decline in yam production. Following previous observations on the potential of *in-situ* stem support for yam vines, this investigation was undertaken to determine the labor efficiency of different vine supporting methods and the arrangement of support plants. The treatments included conventional staking with upright poles, laying unpruned branches on the ground, live *in-situ* plants cut back and pruned to a single stem about 2.0 m tall, and *in-situ* plants killed by girdling and applying 2, 4, 5-T. Yams were planted on mounds spaced to give 10,000 or 13,333 plants/ha and planting was arranged so that yams from adjacent rows on either side of a *Leucaena* climbed alternate *Leucaena* stems. (Fig. 3.)

The pattern of planting was effective as many vines found the stakes and very little training was required. The man hour data showed significant differences between treatments. (Table 10.) The live pruned stakes had very high labor demand due mainly to repeated pruning to prevent support stem regrowth from shading the vines.

Yield data given are not regarded as representative of the system as poor soil resulted in variable and unsatisfactory growing conditions.

While herbicide killed *in-situ* support appears the most effective, care must be taken with the herbicide used, as yams are sensitive to high rates of 2, 4, 5-T.

Other trees and shrubs observed for potential use as *in-situ* supports were:

Glyricidia sepium which has rapid growth, reaches a height of over 3 meters in about 15 months; branches early and has multiple stems, some of which may be cut as stakes. It is fairly tolerant to 2, 4, 5-T and sometimes recovered and continued growing. Killed stems provided support for the growing season.

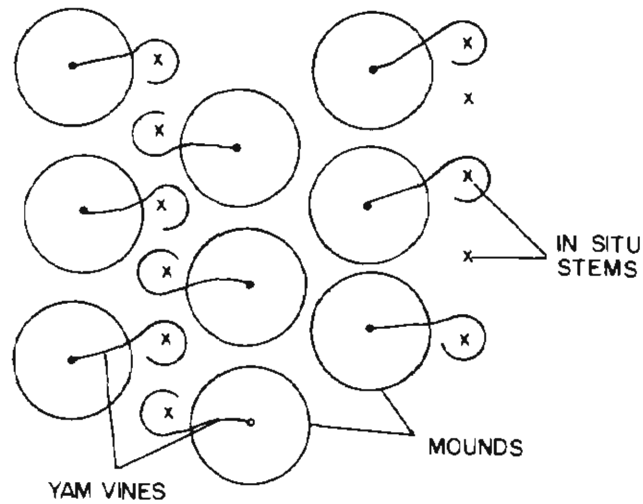


Fig. 3. Diagram of yam planting with* in-situ *stem support.

Cajanus cajan which has good growth reaching a height of approximately 2 meters in 15 months. Many small branches hinder movement and other field operations. It is easily killed by herbicide but wood is brittle, damaged by termite and wind causes lodging before yam is mature.

Tephrosia candida has good growth reaching a height of about 2 m in about 15 months. Like *Cajanus* its small branches interfere with field operations. It is easily killed by herbicide and the stem persists throughout the yam growing period.

Acio bateri is slow growing. It is less than 1.5 m at approximately 15 months, and has many low branches. Its reaction to herbicide and persistence were not tested as the plants were regarded as too small to provide adequate support.

Tectona grandis reaches a height of 3.5 m in approximately 15 months with no significant branching. The stem diameter at a height of 1 m averages 3.4 cm.

Gmelina arborea reaches a height of 4.6 m, with stem diameter of 4.6 cm at 1 m above ground at 15 months. It has a much branched crown, but the branches are high enough not to interfere in most field operations.

Cassia siamea reaches a height of 4 m with stem diameter of 3.3 cm in 15 months. It has many low branches that may require pruning.

Table 10. Effect of method of vine support on labor requirement and yield of yam.

Method of support	Spacing of *in-situ* support	Yam population densities plants/ha	Yam yield t/ha	Labor manhours/ha	Firewood/yield t/ha
Upright stakes	-	10,000	20.74	2853	
Horizontal branches	-	10,000	15.46	2605	
Live pruned, *in-situ* stems	100 cm × 50 cm	10,000	13.26		
Live pruned, *in-situ* stems	150 cm × 50 cm	13,333	21.58	2836	
Live pruned, *in-situ* stems	200 cm × 50 cm	10,000	15.26	2531	
Killed *in-situ* stems	100 cm × 50 cm	10,000	22.38	2030	45
Killed *in-situ* stems	150 cm × 50 cm	13,333	15.78	2329	27
Killed *in-situ* stems	200 cm × 50 cm	10,000	-*	-*	26
LSD 5%			3.39	618	

**Deleted because of excessive herbicide damage on three plots.*

Plant water requirements and relationships. Investigations continued on the maximum water requirement (maximum evapotranspiration) of promising crop cultivars — in this instance, the erect cowpea cultivar TVx 1193-10F.

The trends in water requirement (Fig. 4) obtained in this study are essentially similar to those revealed by previous studies, as were the ratios of maximum evapotranspiration (ET_M) to Class A pan evaporation, Eo. (Fig. 5.) Total water consumption by the crop over the growing season amounted to 285 mm on Alagba soil and 310 mm on Iwo soil which, as usual, sustained a much better growth. The mean daily water uses were 4.13 mm for Alagba soil and 4.49 mm for Iwo soil respectively. A recapitulative table (Table 11) is presented summarizing these and previous results. It may be deduced that in these environments, a mean moisture supply of 4.0 mm/day is sufficient to meet the water requirement of most of the cowpea cultivars, certainly the erect and semi-erect cultivars. Values of 3.5 mm/day and 4.5 mm/day remain the tentative figures for soybean and maize respectively.

As a follow-up on studies previously carried out in the screen house with potted plants (IITA Annual Report, 1974), the growth and yield response of maize (TZPB), cowpea (TVu 3629 and TVu 4557) and soybean (Bossier) to different moisture regimes was investigated under field conditions during the dry seasons 1976/77 (maize) and 1977/78 (cowpea, soybean). The treatments, based on the concepts of "pre-humid" and "humid" periods of the cropping season, were designed to test the feasibility of earlier planting under limited moisture conditions as a means of extending the growing season to suit given crops or cropping systems at given locations.

The results (Tables 12 and 13) indicate tolerable reduction in maize receiving only about half the maximum moisture demand for up to 4 WAP, even at intervals of 4-6 days. Cowpea and soybean subjected to the same treatment were fairly comparable in growth, at 3-4 WAP, to the plants that had their maximum water requirement from the start. It appears, therefore, that if the former plants had been restored to the ideal moisture regime of the latter for the rest of the growing season as intended, the difference in growth would have been small, if any, and yields much more comparable.

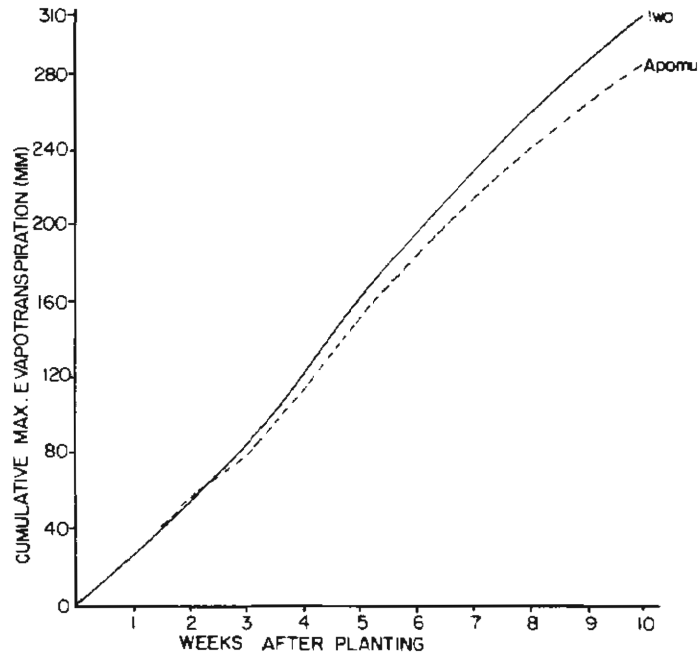


Fig. 4. Cumulative max. evapotranspiration ($E.T_m$) for cowpea (TVx 1193-10F) on two soils, Iwo & Apomu: 1st season 1978.

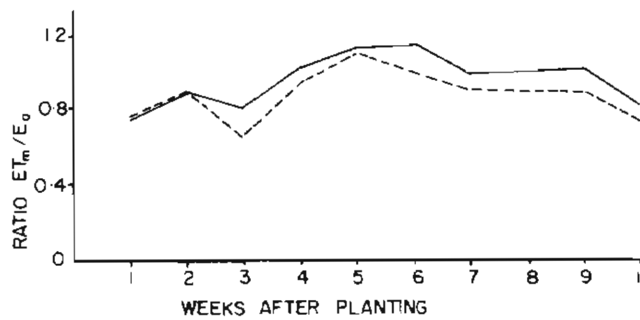


Fig. 5. Ratio of max. evapotransportation ($E.T_m$) of cowpea (TVx 1193-10F) to Class A pan evaporation (Eo): 1st season 1978.

Table 11. Yield, total and mean daily maximum evapotranspiration of various crops.

		Yield (t/ha)		Water Use (mm)		
Season	Crop	Dry Matter	Grain	Total	Mean Daily	Daily Extremes
Dry 1975/76	Cowpea* (TVu 6207)	-	1.52	311.9	4.04	2.27-5.67
Dry 1975/76	Cowpea** (TVu 6207	-	1.19	275.5	3.58	1.98-4.69
1st 1976	Maize** (TZB_{c4})	19.22	7.74	516.3	4.96	2.05-7.09
2nd 1976	Soybean** (Bossier)	-	2.93	358.2	3.77	2.53-4.84
Dry, 1976/77	TVu 3629**		2.34	321	4.28	2.95-5.68
2nd, 1977	TVu 4557**			291	3.78	2.87-4.79
2nd, 1977	TVu 4557*			317	4.12	2.83-5.12
1st 1978	TVx 1193-10F**		0.73†	285	4.13	3.42-5.42
1st 1978	TVx 1193-10F*		1.39	310	4.49	3.44-5.57

**Planted on Iwo soil lysimeter.*

***Planted on Alagba soil lysimeter.*

†Unusually low yield due to poor growth: symptoms of nutrient (R) deficiency noted.

Contrary to the trend in maize yield with intervals between moisture restoration, cowpeas suffered their largest drop in yield at the shortest interval (2 days) between irrigation. This would appear due to the fewer roots of the crop in the surface layers, where most of the smaller amounts of water added at these frequent intervals are stored, with a significant fraction thus lost in evaporation.

Light influence and relationships. Studies centered on light as a factor in crop productivity also continued in 1978. Results of the first-season experiment on the effect of planting density and geometry on the light profile in maize canopies are shown in Figures 6 and 7. It is evident that at high plant populations (> 50,000 pl/ha), the spatial arrangement of plants has little influence on light transmitted through the crop canopy. Significant gain in light transmission is achieved by manipulation of the geometrical arrangement of the plants at moderate (25,000 pl/ha) populations. This can amount to 15-20 percent, comparable to or better than that obtained by the 50 percent decrease in plant population alone, without change in planting pattern. (See 1976 IITA Annual Report.)

In view of the comparable yield at the same plant density, the obvious benefit in more efficient plant arrangements for better light transmission to the ground is the improvement in the light environment of low growing intercrops.

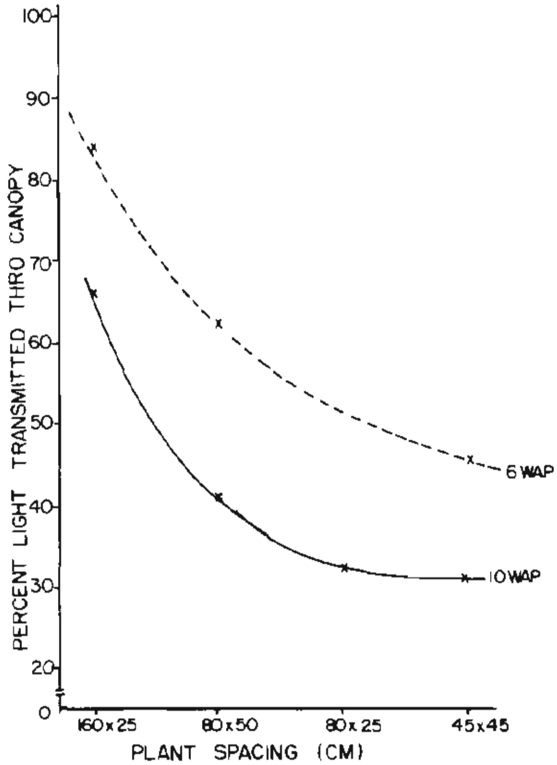


Fig. 6. Percent of incident light transmitted through maize canopy at different populations. (1st season, 1973.)

Table 12. Effect of moisture regime on maize yield at different irrigation frequencies.

		Mean yields	
Moisture regime**	Frequency	Actual (Kg/ha)	Relative* %
½ Eo, 1st 4 WAP, Eo: (tvi)	6 days	2200	71
½ Eo, 1st 4 WAP. Eo: (tiv)	4 days	2600	84
½ Eo, 1st 4 WAP, Eo: (tii)	2 days	3000	97
Eo. (All season): (tv)	6 days	2500	81
Eo, (All season): (tiii)	4 days	2800	90
Eo. (All season): (ti)	2 days	3100	100

**Yield relative to highest.*

***The amount of water added in each case is the equivalent of half or full calss A pan evaporation Eo, taken as approximate to the potential evapotranspiration.*

The results of simulated light climate on the yield of sweet potato were also largely confirmed. These are illustrated by Figure 8. The cultivar TIS 2534, although lower yielding compared to TIS 1499, suffers proportionately lower decrease in yield at the comparatively low light levels such as would prevail in an intercrop.

In addition to soil moisture, light profiles were also studied in various crop mixtures (in collaboration with the weed agronomist) to determine their efficiency in shading out and thereby controlling weed growth. Sole maize most efficiently shaded the weeds while sole yam or cassava was the least efficient, mainly because of the slow development of their canopies and the resultant maximum transmission of light to ground, resulting in maximum early weed growth. An intercrop of relatively

Table 13. Effect of moisture regime on yields of cowpea and soybean at different irrigation frequencies.

		Mean yields					
		Cowpea				Soybean	
		Actual (Kg/ha)		Relative*			
Moisture regime**	Frequency	TVu 3629	TVu 4557	TVu 3629	TVu 4557	Actual (Kg/ha)	Relative* (%)
½ Eo. All season: (tvi)	6 days	550	740	44	64	650	49
½ Eo, All season: (tiv)	4 days	520	560	42	49	650	49
½ Eo, All season: (tii)	2 days	465	430	37	37	650	49
Eo, All season: (tv)	6 days	1250	1150	100	100	1070	80
Eo, All season: (tiii)	4 days	1160	1120	93	97	1330	100
Eo, All season: (ti)	2 days	1030	1000	82	87	1300	98

**Yield relative to highest.*

***As in Table 12.*

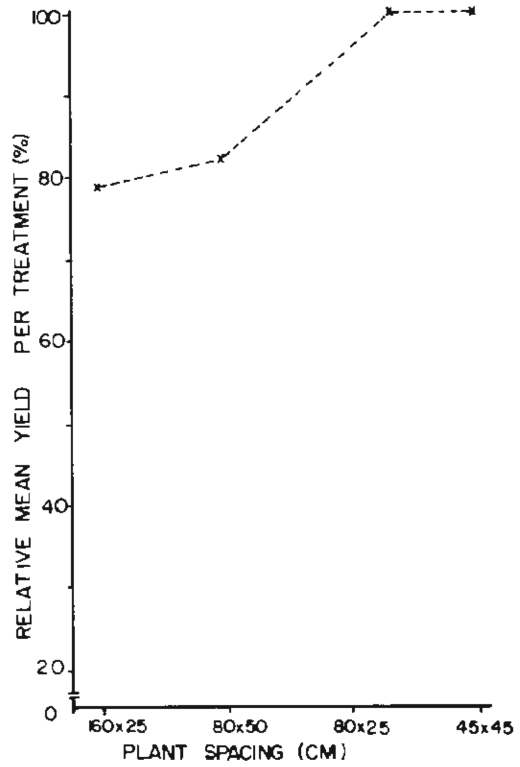


Fig. 7. Relative maize yield per plot as influenced by planting density/geometry. (1st season, 1978.)

shorter-duration and faster-canopy development, such as cowpea or *Egusi* melon, into these two crops readily recommends itself.

In the sole yam plots, the best moisture regimes were observed with the sweet potato cover; the worst in the plots. Yam-melon and weed-free yam plots were intermediate. Soil moisture in sole cassava was, on the other hand, relatively higher in association with weeds, and also with sweet potato, and on the average lowest in melon association.

On the average across the sole crops, soil moisture was highest with sweet potato as ground cover followed by the weed-free plots, with the weedy plots having the worst soil moisture regime. The general effects of the lower ground cover under the mixed crop seem to depend on time or rainfall distribution.

Soil-water relations and screening rice cultivars for drought stress. Investigations have been conducted on 20 diverse rice cultivars to relate their agronomic yields and physiological growth to soil-moisture potential. In addition to monitoring agronomic criteria, plant-water status (leaf water potential, diffusive resistance, and saturation deficit) and rooting pattern were also investigated. Grain yield ranged widely among these cultivars, and was related to rooting patterns and to leaf-water status. (Table 14.)

Leaf-water potential measured under field conditions can be used as a criterion for tolerance to drought stress.

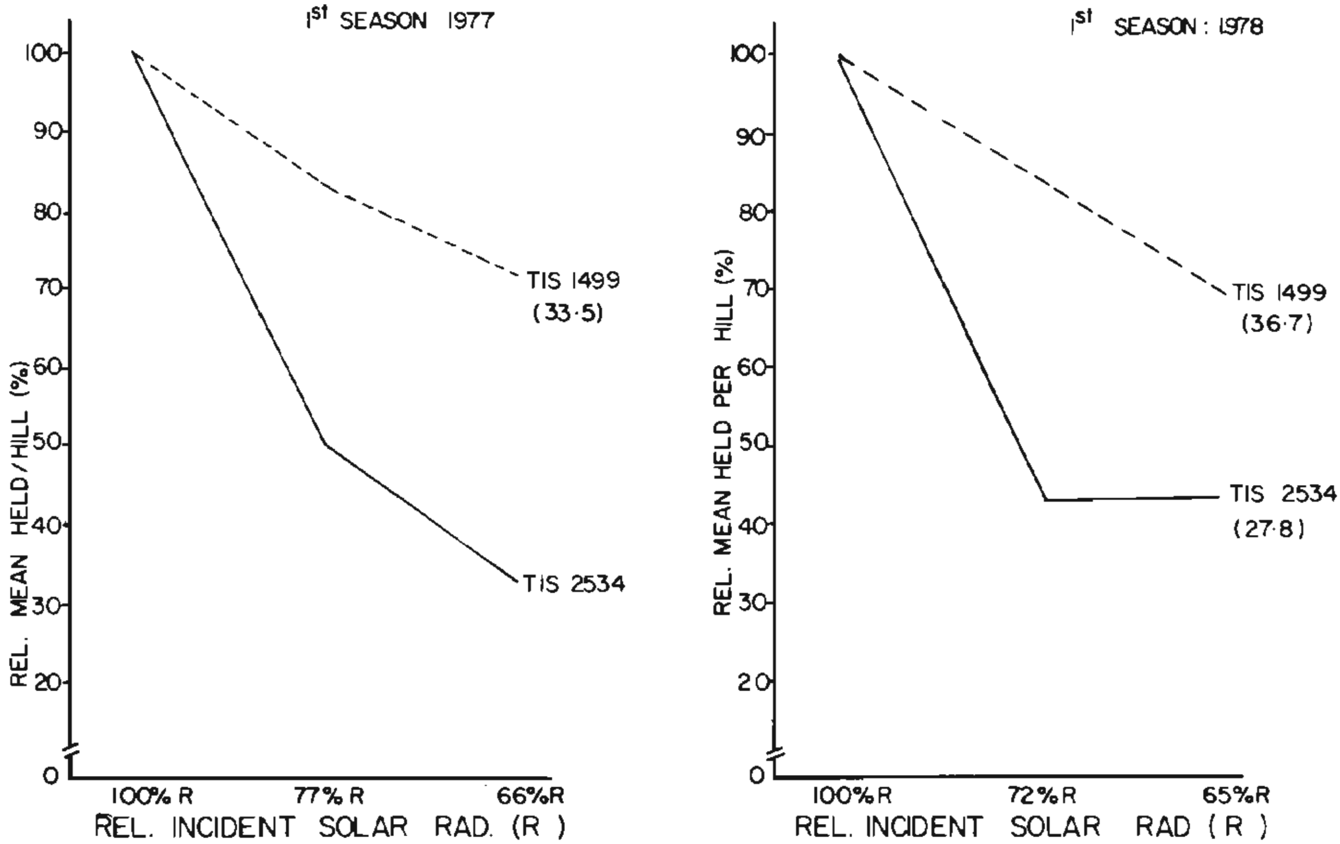


Fig. 8. Rel. mean yield of two varieties of sweet potato with reduction in solar radiation incident on the crops. (Yields in t/ha at full sunlight given in bracket, 1978 crop late planted, partial overlap into 2nd season.)

Table 14. Grain yield and growth characteristics of rice cultivars as affected by soil moisture regime.

Cultivar	Grain yield (t/ha)			Root density (mg cm-3) at flowering in the planting row					
	I*	II	III	I	II	III	I	II	III
				0-5 cm depth			15-30 cm depth		
63-83	2.6	3.0	4.3	7.7	6.0	7.0	0.1	0.1	0.3
IB 43	1.3	1.3	1.5	7.9	7.8	7.8	0.2	0.7	0.3
OS 6	1.0	1.3	1.7	1.4	5.5	10.4	0.02	0.0	0.5
IB 6	3.2	3.4	3.7	12.5	10.8	10.5	0.1	0.2	0.4
IRI529-680-3	1.6	2.5	2.6	15.6	25.6	30.5	0.1	0.0	0.0
C 22	1.1	1.6	2.0	21.9	18.9	19.2	0.003	0.1	0.0
IRAT 13	1.5	1.6	2.3	11.9	8.3	14.4	0.03	0.0	0.6
TOS 4688	0.6	1.5	2.0	-	-	-	-	-	-
IR 380-29	0.6	2.9	3.6	10.5	14.2	16.5	0.02	0.1	0.0
IET 1444	0.2	0.8	1.2	19.8	17.0	14.3	0.1	0.0	0.0
SE 302G	0.5	1.7	2.1	5.7	6.8	7.9	0.03	0.0	0.0

***Density measured at 10-20 cm depth from the center of the plant.*

**I Water level 71 m deep.*
II Water level 30 cm.
III Water level 15 cm.

Maize yield in relation to soil temperature and moisture regimes. Effects of day or night ambient temperature, soil temperature, and drought stress on maize growth are being investigated in growth cabinets and under field conditions. The effect of temperature stress during the seedling stage on final grain yield was investigated by transplanting the stressed seedlings under field conditions. Grain yield, dry matter production, and plant height decreased with an increase in night temperature. (Tables 15a-c.)

Similarly, the lowest grain yield was obtained by a temperature regime of 40/20 with soil moisture stress. (Tables 15b and 15c.)

Plantain cultivar collection and evaluation. Until the middle of 1978, cultivars in the collection consisted of material obtained in Ghana and Nigeria. Since then the collection has been enriched by introduction of selected material from Ivory Coast (Table 16) and Cameroon (Table 17). These accessions offer new material for evaluation in the effort to identify superior cultivars.

Potentially high-yielding cultivars identified in the collection were multiplied and evaluated. Two clones of the

Table 15a. The effect of day/night ambient temperature during seedling stage on maize.

Temperature regime °C	Grain yield g/plant	Stover yield g/plant	Harvest index %	Ear height cm	Days to 8 leaf stage
33/16	182	586	31	128	35
33/23	184	49	33	114	29
33/30	155	23	29	101	25

Table 15b. Effect of day temperature on maize.

Temperature regime °C	Grain yield g/plant	Stover yield g/plant	Harvest index %
30/20	117	475	24.7
35/20	113	461	24.6
40/20	107	541	19.7

Table 15c. The effect of temperature regime and moisture stress on maize.

Temperature regime °C	Grain yield (g/plant)		Stover yield (g/plant)		Harvest index (%)	
	I	II	I	II	I	II
35/20	128	100	304	265	42	38
40/20	97	69	249	193	39	36

I Unstressed.

II Stressed.

Table 16. Musa sp. accessions collected from IRFA, Ivory Coast.

IITA acc. No.	Common name	Description	Acc. No. IRFA-Ivory Coast
78.01	Km 5	AAA banana (wind resistant)	95
78.02	Nzizi	ABB cooking banana	31
78.03	Simili Radjah	ABB cooking banana	51
78.04	Champa Madras	ABB cooking banana	25
78.05	Popoulou	AAB Hawaii plantain	69
78.06	Mattuiq	AAB banana (early flowering)	97
78.07	Madre del Platanar	AAB plantain (no fruits)	104
78.08	Nselouka	AAB plantain (French)	121
78.09	Njock Korn	AAB plantain (Semi-dwarf/ French)	133
78.10	Px3	AAB plantain (False Horn)	151
78.11	3 Vert	AAB plantain (French-Horn)	116

common false horn "Agbagba," cultivars ix and x were evaluated in three trials. They were found to differ only in number of neutral flowers. Yields and other characteristics were similar.

Another selection, "Ogoni Red," was found superior to Agbagba both at the high-rainfall station at Onne and with supplementary irrigation at Ibadan. (Table 18.) The taller plant height and later maturity were, however, regarded as disadvantages, especially where wind damage is prevalent.

Table 17. Plantain accessions collected from IRAF-ONAREST, Cameroon.

IITA acc. No.	Common name	Description
78.13	Nothing but Red	Giant, no fruits
78.14	Big Ebanga	Giant False Horn
78.15	Ngomba	French-Horn
78.16	Plantain No. 3	French-Horn (green)
78.17	Batard	French-Horn (green)
78.18	Njock Korn	Semi-dwarf French (green)
78.19	Ovang	French (black)
78.20	Plantain No. 2	French (black)
78.21	Plantain No. 17	French (wine-red)
78.22	Cantebalon	French (green)
78.23	Kelong Mekitu	French (green)
78.24	Amou	French (green)
78.25	Bobby Tannap	French (green) short fingers
78.26	Moto Mo Liko	French (white green chimaera)

Table 18. Comparison of the two "Horn" plantain cultivars, Agbagba and Ogoni Red, in two locations.

Cultivar	Agbagba			Ogoni Red		
Location	Onne	Ibadan	Mean	Onne	Ibadan	Mean
Days to 50% shooting	269	235	252	281	303	292
Plant height at shooting (cm)	306	390	348	314	451	383
Number of fruits	33.0	39.0	36.0	53.6	79.1	66.4
Bunch weight (kg)	10.3	17.3	13.8	13.6	24.4	19.0

Six Horn and three French plantain lines were selected for multiplication and further evaluation. The characteristics of the lines are summarized in Tables 19 and 20.

Plantain yield decline. Though plantain persists for many years through sucker regrowth, the perennial nature of the plant has not been exploited economically. Under field conditions the ratoon crop yield falls below economic levels after the first or second harvest. This behavior is not entirely intrinsic because plantain grown in small backyard plots (where the nutrients and soil organic matter contents are regularly renewed by addition of household refuse) remains productive for many years.

During 1978, studies were begun to determine external factors influencing yield decline. Data gathered thus far are inconclusive.

Table 20. Yield potential of French plantain cultivars selected at IITA.

	Obubit Ntana 2 (76.14)	Obubit Ntana 1 (76.23)	No name (76.25)
Days to shooting	256	215	210
Plant size	medium	small	small
Number of hands	7.3	6.2	7.0
Total number of fruits	83	74	80
Number of fruits first-hand	13.0	12.3	12.3
Bunch weight (kg)	22.7	19.6	18.7

Pest management

Studies in weed management

Weed control in maize. Evaluation studies were begun to identify suitable postemergence herbicides for salvage operations in maize if a recommended preemergence herbicide should fail as a result of a prolonged dry spell soon after herbicide application.

Chemicals tested included 2,4-D and bentazon singly and in combination with other herbicides. Although 2,4-D at 0.75 kg/ha and 1.0 kg/ha effectively controlled *Euphorbia heterophylla* L., *Talinum triangulare* and *Commelina* spp., the herbicide severely depressed crop yield. (Table 21.) The best weed control together with good crop yield was with a formulated mixture of atrazine and metolachlor sprayed preemergence (2.0 kg/ha) followed with a postemergence application of bentazon at 1.0 kg/ha. Pendimethalin at 2.5 kg/ha effectively controlled *Rott-*

Table 19. Yield potential of Horn plantain cultivars selected at IITA.

	Line X (74.93)	Osoboaso (75.06)	Ishiokpo Red (76.11)	Ogoni Red (76.12)	Ntanga (76.41)	Orishele (76.54)
Days to shooting	240	230	235	305	280	270
Plant size	medium	small	medium	giant	medium	medium
Number of hands	9.9	8.0	9.5	12.7	7.5	8.0
Total number of fruits	39	56	62	79	68	54
Number of fruits first-hand	9.7	10.3	12.0	11.8	11.0	12.0
Bunch weight (kg)	17.3	15.5	20.5	24.4	18.7	21.6

boellia exaltata and other grasses in maize grown in a loamy sand with pH 6.2 and 1.6 percent organic matter. This herbicide was, however, not effective on such weeds as *Commelina benghalensis* L. var. *benghalensis* J. K. Morton and *Acanthospermum hispidum* DC. A tank mixture of pendimethalin plus atrazine, each at 2.0 kg/ha applied preemergence broadened the weed spectrum controlled by the mixture. (Table 22.) The best maize yield was observed in this treatment. Maize yield was reduced by 68 percent where weeds were not controlled.

Weed control in cowpeas. Studies aimed at identifying suitable herbicides for weed control in cowpea were continued partly to control *Euphorbia heterophylla* (wild poinsettia) and partly to broaden the crop uses of some promising herbicides. Bentazon, applied postemergence, injured cowpeas and caused severe yield reduction. (Table 23.) Alachlor at 2.0 kg/ha, and metribuzin at 0.4 kg/ha were also injurious to cowpea. The best crop yield coupled with good weed control was obtained with the preemergence application of metolachlor 2.5 kg/ha,

Table 21. Herbicide evaluation in maize, first season. (IITA, 1978.)

Treatment	Rate (kg/ha)	Time[3]	Weed Rating BL	Weed Rating G	Weed dry wt. (t/ha)	Injury[4] rating	Maize yield (t/ha)
1. Atrazine – metolachlor[1]	2.5	PE	88	93	0.45	0	5.04
2. Terbutryn	3.0	PE	82	65	0.87	0	3.95
3. Terbutryne	3.0	Post E	0	0	1.71	63	1.41
4. Metolachlor + chlorbromuron[1]	2.5	PE	68	87	0.60	5	4.20
5. Atrazine – metolachlor[1] fb bentazon	2.0fb1.0	PE fb Post E	91	85	0.09	0	5.14
6. 2, 4-D	0.75	Post	51	0	0.12	6	3.74
7. Cyanazine + 2, 4-D	1 – 0.75	Post E	81	25	0.97	22	2.66
8. Atrazine + cyanazine	1.5 + 1	PE	7	8	0.99	0	4.17
9. Atrazine + alachlor[2]	2.4	PE	88	88	0.48	0	4.16
10. Pendimethalin	2.0	PE	45	80	0.91	0	4.75
11. Atrazine + pendimethalin	2.0 + 2.0	PE	91	91	0.71	0	4.35
12. Asulam – atrazine[1]	2.0	Post E	57	27	0.60	33	1.52
13. Weed free	-	Weekly	100	100	0	0	4.92
14. Weedy check	-	-	0	0	1.89	0	3.67
LSD							0.45
C.V.							15%

Maize planted 18/4/78, harvested 24/8/78.

[1] *Mixed formulation marketed by CIBA-Geigy under the trade name Primextra.*

[2] *Products marketed as mixed formulations.*

[3] *PE = Preemergence, PP = Preplant, PPI = Preplant incorporated, Post E = Postemergence, DAP = Days after planting, DAE = Days after Emergence.*
BL = Broad leaves, G = Grasses.

[4] *Rating scale: 0 = No weed control or crop injury.*
80 = Satisfactory to good weed control.
100 = Complete weed or crop destruction.

Table 22. Rottboellia control in maize, first season. (Agenebode, 1978.)

Treatment	Rate (kg/ha)	Time[1]	Weed ratings[1] BL 1st	BL 2nd	G 1st	G 2nd	Rott-boellia (t/ha)	Maize yield (t/ha)
1. Pendimethalin	2.5	PE	85	83	95	84	472	3.44
2. Pendimethalin + atrazine	2.0 + 2.0	PE	100	94	92	82	159	3.76
3. Standard weeding	-	3 + 5 WAP	94	94	23	20	2000	3.26
4. Weedy check	-	-	0	0	0	0	2985	1.13
5. Weed free	-	Weekly	100	100	100	100	-	3.47
LSD (0.05)							533	1.0
C.V.								21%

[1] *See Table 21 for explanation. Weed rated at 26 and 50 DAP.*

pendimethalin 2.5 kg/ha and DCPA 10.0 kg/ha. Dinitramine at 1.5 kg/ha was also effective in controlling weeds without depressing crop yield. One properly timed hoe weeding gave a crop yield comparable to two hoe weedings or keeping the plot weed free until harvest. Nuvacron 0.5 percent was sprayed weekly in all cowpea trials to minimize insect damage.

An earlier study indicated that only pendimethalin and metolachlor were tolerated by most cultivars tested, but results of this year's first-season trial showed that across all cultivars, pendimethalin at 2.5 kg/ha and metolachlor at 2.0 kg/ha gave crop yield that did not differ significantly from yields of the weed-free and hoe-weeded treatments.

Alachlor at 2.0 and 3.0 kg/ha depressed yield of all cowpea cultivars tested. (Table 24.) The yield depressing effect of alachlor was more severe in VITA-4 than in the other cultivars tested. (Fig. 9.)

This study was repeated in the second growing season. Alachlor at 2.0 and 3.0 kg/ha caused some foliar injury in all cultivars and severe stand reduction was noted in

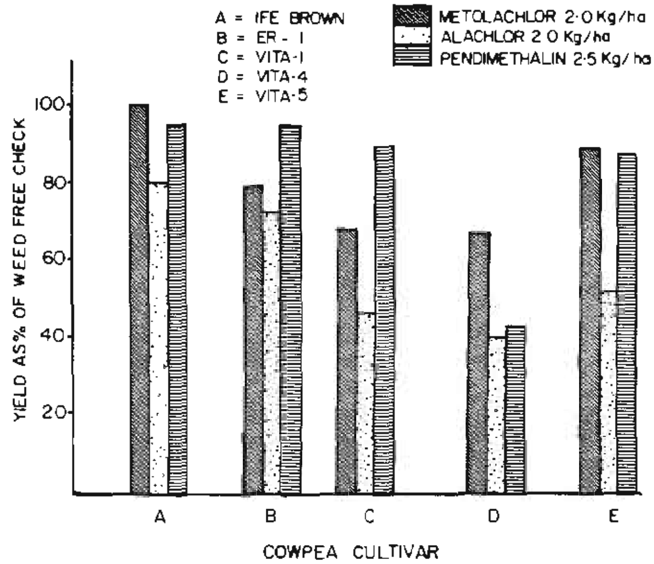


Fig. 9. Response of cowpea cultivars to herbicides.

Table 23. Weed control in cowpea, first season. (IITA, 1978.)

Treatment	Rate (kg/ha)	Time[1]	Weed ratings BL	G	Grain yield (t/ha)
1. Alachlor	2.0	PE	69	48	0.17
2. Dinitramine	1.5	PE	77	63	0.82
3. Metribuzin	0.4	PE	40	65	0.54
4. Metolachlor fb bentazon	2.0 + 1.0	PE fb Post	59	68	0.40
5. Metolachlor	2.5	PE	58	70	1.30
6. DCPA	10.0	PE	34	91	1.10
7. Pendimethalin	2.5	PE	83	91	1.03
8. Hoe weeding	-	21DAE	0	0	1.27
9. Hoe weeding	-	14 – 28 DAE	100	100	1.46
10. Weed free	-	-	100	100	1.31
11. Weedy check	-	-	0	0	0.25
LDS (0.05)					0.27
C.V.					54%

[1]*See Table 21 for explanations.*

Table 24. Response of cowpea cultivars to herbicides, second season. (IITA, 1978.)

Treatment	Rate kg/ha	Time	Grain yield (t/ha) Ife Brown	ER-1	VITA-1	VITA-4	VITA-5	Mean[1]
1. Metolachlor	2.0	PE	0.39bcd	0.64ab	0.73b	0.89a	0.52abc	0.63
2. Metolachlor	3.0	PE	0.54abcd	0.56ab	1.15a	0.99a	0.63abc	0.77
3. Alachlor	2.0	PE	0.29cd	0.39b	1.01ab	1.08a	0.31bc	0.62
4. Alachlor	3.0	PE	0.44abcd	0.32b	0.86ab	0.60a	0.35bc	0.51
5. Metobromuron + Metolachlor	2.5*	PE	0.69abcd	0.51ab	1.17a	0.88a	0.74ab	0.80
6. Metobromuron + Metolachlor	4.0*	PE	0.90a	0.62ab	1.20a	0.97a	0.65abc	0.87
7. Pendimethalin	2.5	PE	0.51abcd	0.67ab	1.10ab	1.27a	0.84a	0.88
8. Pendimethalin + Metobromuron	2 + 2	PE	0.78abd	0.82a	0.83ab	0.89a	0.65abc	0.79
9. Weed free	-	-	0.68abcd	0.83a	1.10ab	1.31a	0.84a	0.87
10. Weedy	-	-	0.28d	0.33b	0.87ab	1.13a	0.20c	0.56
Mean			0.55	0.57	1.00	1.00	0.57	-

**Formulated mixture.*

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

VITA-4. This stand reduction was pronounced in all cultivars when alachlor was applied at 3.0 kg/ha.

There were marked differences among cultivars in their response to weed competition. Uncontrolled weed growth caused the greatest yield reduction in VITA-5 (79% reduction in yield) and the least yield reduction in VITA-4. Weed weight at crop harvest was correspondingly low in VITA-4. The cultivars VITA-1 and VITA-4 which are semi-erect, leafy, broadleaved and indeterminate competed better with weeds than the semi-prostrate, indeterminate VITA-5 or the erect, determinate ER-1. (Fig. 10.)

Weed control in cassava. Some preemergence herbicides, such as fluometuron, diuron and a formulated mixture of atrazine plus metolachlor, identified in an earlier trial (IITA, 1977) as promising for weed control in cassava, were further evaluated together with additional formulations. In addition, an improved, profusely branching cassava cultivar (TMS 30395) was used for the study. Diuron and flumeturon used singly and in combination with metolachlor or alachlor effectively controlled annual broad leaves and grasses. (Table 25.)

Weed control in yam. White yam (*Dioscorea rotundata*) is very sensitive to weed competition. In a study on weeding frequency, uncontrolled weed growth caused more than 70 percent reduction in yam tuber yield. Up to 30 percent reduction in yield occurred if yams were not weeded during the first two months from planting. (Fig. 11.) The third and fourth months after planting corresponded to the onset of new tuber initiation in white yam.

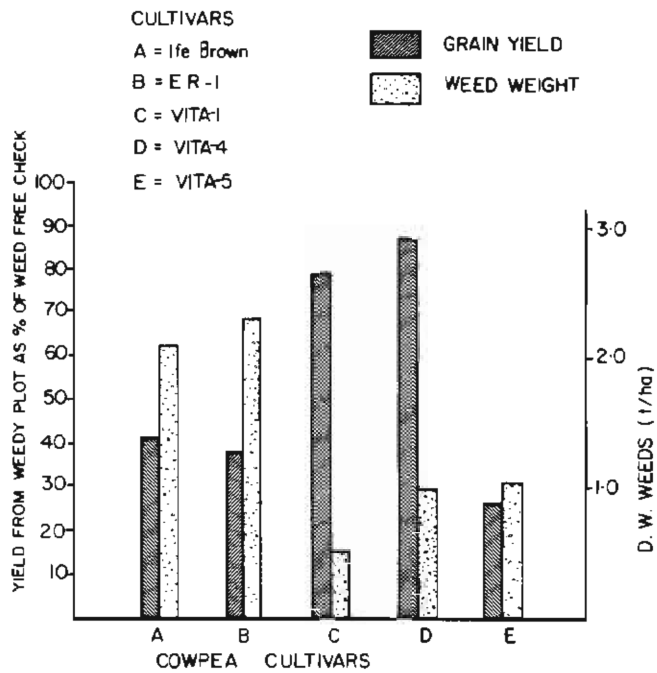


Fig. 10. Response of cowpea cultivars to weed competition.

Weed control — no tillage system. Continuous no-tillage crop production practices lead to a buildup of

Table 25. Weed control in cassava (cv. TMS 30395). (IITA, 1977.)

Treatment	Rate (kg/ha)	Time	Weed Control: Broad leaves 1st	Broad leaves 2nd	Grasses 1st	Grasses 2nd	Stand establ. (%)	Fresh weight roots (t/ha)
1. Fluometuron	3.0	PE	92	82	90	84	100	26.4
2. Fluometuron + alachlor	1.5 + 2.0	PE	91	87	77	67	100	18.9
3. Fluometuron + alachlor	2.0 + 2.0	PE	84	83	95	90	100	25.2
4. Fluometuron + metolachlor	1.5 + 2.0	PE	87	79	93	96	94	25.6
5. Atrazine + metolachlor[1]	2.5	PE	92	89	93	94	94	22.7
6. Atrazine + metolachlor[1]	3.0	PE	83	82	96	92	94	22.1
7. Atrazine + alachlor	1.0 + 2.0	PE	86	88	86	80	94	17.6
8. Diuron	3.0	PE	92	90	86	81	94	24.2
9. Diuron + paraquat[2]	2.8	21 DAP	90	89	78	57	94	24.3
10. Diuron + alachlor	2.0 + 3.0	PE	88	89	84	79	100	22.1
11. Fluorodifen	3.5	PE	72	87	84	82	100	22.3
12. Hoe weeding	-	21 + 56 DAP	100	89	95	93	100	20.6
13. Hoe weeding	-	21 + 49 + 84 DAP	98	100	88	100	94	21.9
14. Weedfree check	-	Weekly	100	100	100	100	94	23.4
15. Weedy check	-	-	0	0	0	0	94	13.9
S.E.±								3.3
C.V.								27%

Plots rated at 30 and 70 DAP.

[1]*See table 21 for explanations.*

[2]*Formulated mixture by ICI marketed as Gramuron.*

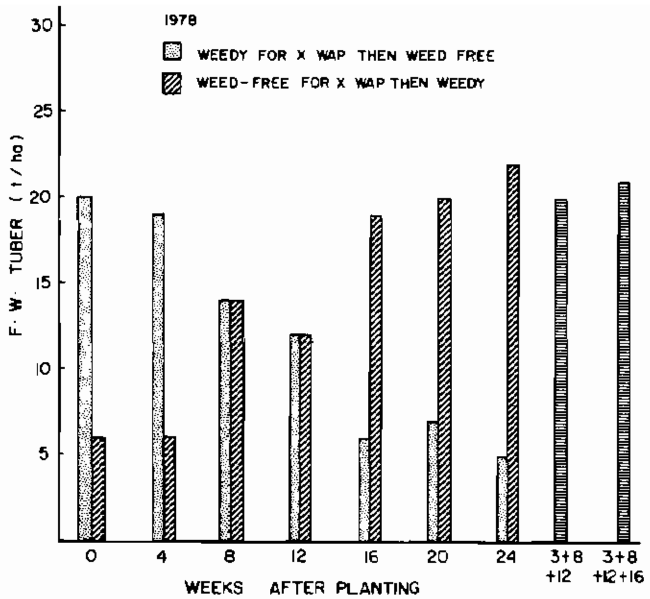


Fig. 11. Effect of duration of weed competition on tuber yield in yam.

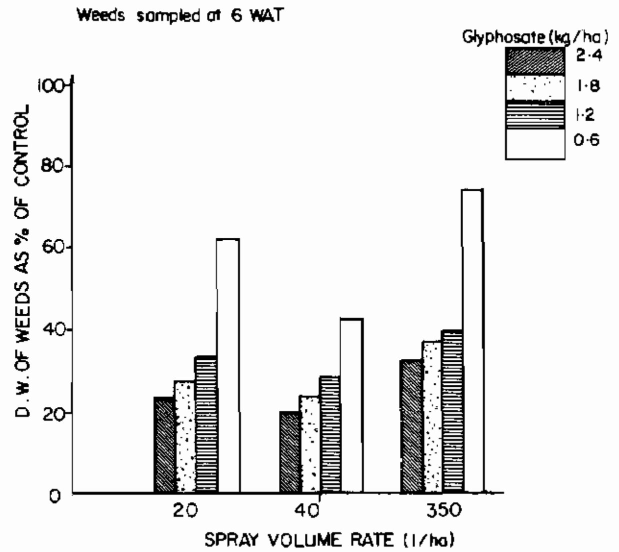


Fig. 13. Effect of volume rate on herbicide efficacy.

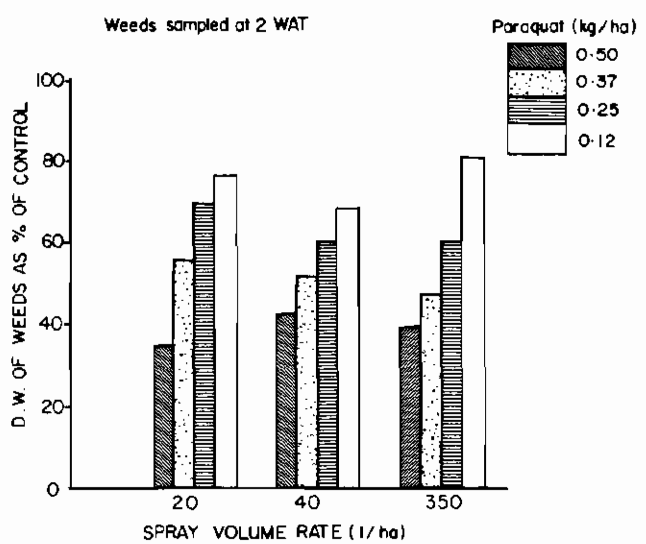


Fig. 12. Effect of volume rate on herbicide efficacy.

perennial weeds such as *Panicum maximum*. Jacq., *Andropogon* spp., *Imperata cylindrica* P. Beauv. and *Pennisetum purpureum* Schum., and broad leaves such as *Talinum triangulare; Alchornia laxiflora*, (Benth) Pax & K. Hoffn, *Newbouldia leavis* (P. Beauv.) Scem ex Bureau, *Combretum hispidum* Laws. and *Ficus* spp. These weeds are not controlled with the commonly used no-till weed control package involving preplant application of paraquat followed with a preemergence application of a selective herbicide. Studies were initiated to identify herbicides that will effectively control these perennial weeds. A trial carried out in a field that has been under no-till maize for more than three years showed that glyphosate was effective in killing both perennial grasses and broadleaved ones in the no-till plots.

The efficacy of glyphosate and paraquat was compared using a controlled-droplet-applicator (CDA) herbicide sprayer calibrated to spray at 20 and 40 1/ha and a CO_2-powered conventional small-plot sprayer calibrated to spray at 350 l/ha. The herbicides were sprayed on a three-week-old flush of annual weeds in a conventionally cultivated field. Herbicide response was assessed by sampling the vegetation at 1, 2, 4 and 6 weeks after treatment. There was no difference in paraquat effect applied with the CDA or conventional sprayer across the herbicide rates studied. (Fig. 12.) Glyphosate is a slow-acting herbicide and visible injury does not often occur until 2-3 weeks after treatment. Glyphosate was more effective at 40 l/ha than at 20 and 350 l/ha spray volumes. (Fig. 13.) The difference caused by spray volume is most pronounced at very low herbicide rates suggesting that there is greater interception and retention of glyphosate at the 40 l/ha than at other spray volume rates.

Generally, the selective postemergence rice herbicides, bentazon and propanil, were more effective on weeds at the high spray volume (350 l/ha), than at lower spray volume. Foliar injury and reduction in weight of rice plant was also greater at the high spray volume rates.

Nematology

Winged bean. Four lines of winged bean (*Psophocarpus tetragonolobus*) were exposed to infestations of root-knot nematode (*Meloidogyne incognita*, race 2) and reniform nematode (*Rotylenchulus reniformis*) in concrete microplots 0.23 m^2 × one meter deep. Plants were thinned to one plant for each microplot, supported on individual bamboo or wire trellises and grown for 120 days during the dry season. Adequate moisture was maintained throughout the growing period. No fertilizer was applied.

Aggregate bean yield for the four lines was reduced by 10.7 and 3.6 percent for root-knot nematode and reniform nematode respectively. (Table 26.) Roots of inoculated plants were found to be seriously infested by one or the other nematodes when examined at the termination of the trial. (Table 27.)

The available winged bean germplasm at IITA was greenhouse tested for resistance or susceptibility to root-knot nematode attack. Seeds were planted in individual pots in washed river sand and inoculated at emergence with 10,000 eggs per pot. The plants grew in sand held at 26°C ± 1 by being set in an automatically controlled temperature table. Above-ground plant parts grew at ambient temperatures.

Table 26. The influence of plant-parasitic nematode attack on winged bean (*Psophocarpus tetragonolobus*).[a] Treatment difference in percent per plant.

Treatment	Top wt. %	Seed wt. %	No. seeds %	Wt/ seed g	No. pods %
Control	100	100	100	100	100
M. incognita[b]	89.9	89.3	86.7	103.7	95.6
R. reniformis[c]	121.8	96.4	85.8	112.1	100

[a]*Means of four replications each treatment.*

[b]Meloidogyne incognita, *race 2.*

[c]Rotylenchulus reinformis.

Table 27. Infection index of plant-parasitic nematodes on the winged bean, *Psophocarpus tetragonolobus*.[a]

Bean line	Root-knot index[b]	Reniform index[c]	Control
TPt-1	4.5	3.7	1
TPt-2	4.5	4.2	1
TPt-3	5.0	NT[d]	1
TPt-4	4.9	NT[d]	1

[a]*Means of four replications each treatment at 120 days.*

[b]*Root-knot index: 1 = no galling, 5 = maximum galling.*

[c]*Reniform index: 1 = no roots infested, 5 = maximum infestation.*

[d]*NT = Not tested.*

All 12 lines of winged bean were highly susceptible to *Meloidogyne incognita*, race 2. Eight lines were highly susceptible to *Meloidogyne javanica* (the remaining four lines did not germinate or there was insufficient seed). All winged bean lines tested were slightly more susceptible to attack by *Meloidogyne incognita*, race 2 than to attack by *Meloidogyne javanica* as determined by root gall ratings and egg production.

Cassava. In IITA's Root and Tuber Improvement Program, about 100,000 cassava seedlings are field grown each year for evaluation of agronomic characteristics and disease resistance or susceptibility. To determine the incidence of root-knot nematode (*Meloidogyne incognita*) infestation and to evaluate the general degree of susceptibility of the seedling lines, rogued seedlings from selected lines were rated for root-knot galling seven months after planting.

Root-knot nematode was generally distributed throughout the field. The mean infestation rate was slightly less than moderate. Of the 40 lines examined, eight (or 20%) had no galling. None was heavily galled. Of the total 483 plants examined, 23.7 percent had some degree of root-

Table 28. The incidence of root-knot nematode on selected seedling cassava breeding lines.

Cassava family[a]	Number of plants	Root-knot index[b] 1	2	3	4	5	Infection ratio %
80039	13	12	1				15
80128	15	15					0
80131	20	18	2				10
80134	28	28					0
80135	12	12					0
80284	14	14					0
80362	12	12					0
81363	12	12					0
81544	10	10					0
81801	11	11					0

[a]*Roots lifted seven months after planting.*

[b]*Root-knot index: 1 = no galling, 5 = maximum galling.*

Table 29. Inoculum rate and terminal plant-parasitic nematode population densities after one year on greenhouse-grown cassava, and influence of nematodes on growth of cassava.

Nematode	Inoculum rate	Terminal population density/liter soil[a]	Root-knot index[b]	Fresh root weight, g	Dry top weight, g
M. javanica	30,800[c]	9,550	1.72	866	304
Nema mix					
M. incognita	780[d]	4,267	2.0	934	308
P. sefaensis	3,600[e]	383			
M. incognita	56,800[c]	7,335	2.96	1,103	394
M. incognita	500[c]	23	1.6	1,575	405
R. reniformis	15,000[f]	0	-	1,617	395
Control	0	0	1.0	1,691	391

[a]*Nematodes per liter of soil based on 3 x 115 cm³ samples per pot. Means of five replications.*

[b]*Root-knot index: 1 = no galling, 5 = maximum galling.*

[c]*Eggs per pot.*

[d]Meloidogyne incognita, *race 2 juveniles.*

[e]Pratylenchus sefaensis *mixture of adults and juveniles per pot.*

[f]*Mixture of immature females, males and juveniles per pot of* Rotylenchulus reniformis.

knot galling. Testing under controlled conditions will be necessary to determine whether the breeding lines showing no infestation possess a high degree of resistance or were escapes.

Several breeding lines with apparent resistance are shown in Table 28.

In a growth response trial, cuttings of cassava line 30211 were rooted in washed river sand in 30-cm plastic pots. The pots were held in a controlled temperature table at 26°C ± 1. The sand and roots were held at a constant temperature while the plants' tops grew at ambient greenhouse temperature. Water was added as needed and fertilizer was added weekly as 500 ml per pot of 10g NPK/10l of water. Plant-parasitic nematode inoculum was added four weeks after sprouting of the cuttings. The kinds of nematodes and rates of inoculum are given in Table 29. Each treatment was replicated five times. The cuttings were limited to one stem each.

No *Rotylenchulus reniformis* was recovered from sand, roots or storage roots. *Pratylenchus sefaensis, Meloidogyne javanica* and *Meloidogyne incognita*, race 2 were maintained on cassava at moderate-to-low levels. Root-knot galls were observed only on roots and none on storage roots superficially or when peeled. None of the plants showed heavy root galling.

Parasitism by *Meloidogyne javanica* and a mixture of *Meloidogyne incognita*, race 2 and *Pratylenchus sefaensis* reduced fresh storage root weight of the cassava plants. Fresh root weight was reduced 49 and 45 percent and dry top weight by 22 and 21 percent for *Meloidogyne javanica* and the nematode mixture respectively.

Meloidogyne incognita, race 2 at high and low inoculum rates did not reduce dry top weight. Fresh root weight was reduced by 32 percent at the high inoculum rate while at the low inoculum rate, the nematode population barely sustained itself and root weight was 7 percent below the control mean.

Although *Meloidogyne incognita*, race 2 produced a higher mean root-knot index, the fresh root weight reduction was less than the lighter gall producing *Meloidogyne javanica* attack. (Table 29.)

The low initial rate of inoculum of *Meloidogyne incognita*, rate 2 as eggs and as juveniles in the nematode mix with the great difference in the terminal populations suggests an interaction between the species.

Effects of crop residue management on plant parasitic nematodes. Determining the effect of different plant residues on soil microflora and microfauna is one of three major objectives of the Crop Residue Management and Evaluation Experiment. The population means of all plant-parasitic nematodes were higher than the previous three years and 1,642 percent higher than the preplant mean. The maize crop had the highest mean population of plant-parasitic nematodes (mostly *Pratylenchus*) followed by soybean, cassava and cowpea in declining order. (Table 30.)

In the fourth year of the trial the distribution of means of plant-parasitic nematode populations was below that of the no mulch control treatment. One exception was mixed bean husks which had nearly three times as many nematodes as the control plots. As in previous years, the nematode population changes under the several mulch treatments were mixed. Soil populations of plant-parasitic nematodes were generally consistent under soybean tops, rice straw, maize cobs and cassava stems in having lower mean populations in relation to the control plot means. (Table 31.)

The pin nematodes (*Paratylenchus* spp.) were occasionally found associated with soybean roots, sometimes in large numbers. Trace numbers of the ring nematode (*Criconemoides* sp.) and the false spiral nematode (*Scutellonema clathricaudatum*) were also found.

Cover and conservation crops

Use of fallow legumes for controlling *Imperata cylindrica*. Besides nutrient regeneration and rebuilding of soil physical properties, fallow legumes are useful in providing conditions favorable to certain crops and cropping systems. These fallow species can compete favorably with undesirable fallow species — for example, against *Imperata cylindrica*, a noxious weed in the derived savanna zones of West and Central Africa. This method of smothering *Imperata* is regarded as one of the cheaper methods of controlling this weed. Tests with various legumes have identified *Stylosanthes guianensis* as the most promising suppressor of *Imperata*. Stylo can be established in *Imperata*-infested fields by drilling without plowing or herbicide application. Effective as this method is, peasants in subsistence agriculture are unlikely to adopt it because the benefits are indirect. To overcome this problem a system of establishing stylo with maize or maize/cassava is being developed.

Stylo establishment in fields of maize that were plowed, harrowed and fertilized was much better than where it was drilled or broadcast with or without previous *Imperata* suppression with paraquat or glyphosate. Maize yields in this experiment were below normal due to com-

Table 30. Summary of all plant parasitic nematodes on all crops at the mulch management trial.[a]

Time of sample	Cassava	Soybean	Maize	Cowpea	Mean all crops	Control	Population change %
Preplant	291	230	175	319	254	213	100
1975	1,774	1,509	4,623	791	2,194	2,366	856
1976	390	838	2,789	447	1,116	1,142	439
1977	1,086	2,176	8,619	1,512	3,348	5,704	1,318
1978	1,575	3,970	10,133	1,002	4,170	6,613	1,642
Mean[b]	1,206	2,123	6,541	938	2,707	3,956	1,066

[a] *Mean numbers of nematodes per liter of soil based on 66 samples for each crop. Sample size was 294 cm^3 of soil.*

[b] *Preplant nematode population means excluded.*

Table 31. Ranking of all plant-parasitic nematodes with mulch treatments on all crops for two growing seasons for the years 1975, 1976, 1977 and 1978.[a]

Nematode percentage of control					Plant-parasitic nematodes[b]			
1975	1976	1977	1978	Treatment	1975	1976	1977	1978
80	45	177	200	Sawdust	1,613	913	3,596	4,064
86	35	167	158	Soybean tops	1,736	716	3,387	3,206
87	43	143	161	Rice straw	1,761	876	2,902	3,259
88	72	132	178	Elephant grass	1,778	1,463	2,666	3,605
93	49	152	118	Maize cobs	1,883	995	3,087	2,391
95	33	137	101	Cassava stems	1,918	669	2,781	2,055
100	56	174	326	Control (no mulch)	2,027	1,142	3,519	6,613
106	60	100	125	Andropogon straw	2,139	1,217	2,027	2,537
108	31	135	139	*Panicum* straw	2,190	623	2,743	2,813
108	40	143	166	*Typha* straw	2,193	813	2,891	3,367
117	49	230	824	Bean husks	2,365	985	4,663	16,707
123	42	88	193	*Pennisetum* straw	2,488	844	1,795	3,910
126	86	143	236	Maize stover	2,545	1,745	2,896	4,775
130	43	129	238	Pigeon pea tops	2,631	863	2,606	4,821
136	63	373	222	Clear plastic	2,750	1,282	7,558	4,510
148	73	228	169	Pigeon pea stems	2,996	1,473	4,612	3,435
169	37	110	125	Mixed twigs	3,428	754	2,231	2,539
174	48	212	152	*Eupatorium* tops	3,520	989	4,298	3,074
201	62	100	155	Rice husks	4,074	1,262	2,030	3,146
222	107	244	200	Black plastic	4,501	2,178	4,948	4,055
242	65	128	175	Oil palm leaves	4,904	1,313	2,601	3,539
264	71	185	142	Fine gravel	5,353	1,441	3,755	2,869
137	55	165	205	Mean	2,763	1,116	3,345	4,150

[a] *Mean numbers of nematodes/l of soil based on 528 samples for each treatment. Sample size was 294 cm³ of soil.*
[b] *Principal nematodes were root-knot, root lesion and spiral nematodes.*

Table 32. Maize production in live mulch, first season. (IITA, 1978.)

Treatment	D.W. weed (t/ha) Grasses	Broad leaf	Grain yield (kg/ha)
1. Bare soil (sprayed with paraquat 0.6 kg/ha) at planting.	1.31	0.37	2.20ab
2. Straw mulch (sprayed with paraquat, 0.6 kg/ha) at planting	3.13	0.74	3.31a
3. *Desmodium triflorum*	3.69	0.81	2.39ab
4. *Arachis prostrata*	0.89	0.3	2.20ab
5. *Indigofera spicata*	4.46	1.01	2.34ab
6. *Psophocarpus palustris*	0	0.08	2.45ab
7. *Centrosema pubescens*	3.31	0.70	2.12b
8. *Paspalum notatum*	0	0.06	2.58ab
9. *Axonopus compressus* (killed with glyphosate at planting).	8.26	1.69	3.07ab

Means followed by the same letter in the same column are not significantly different at the 5% level of Duncan's Multiple Range test.

petition from stylo and unseasonal dry periods. The stylo attracted rodents that damaged maize, but this was most devastating on cassava where all plants were killed after tuber development began.

During the dry season the *Imperata* in fields that were not plowed presented a fire hazard.

Though the maize/cassava combination is traditional in many areas where *Imperata* is common, the combination is not suggested for the establishment of stylo. Damage to cassava from rodents attracted and protected by stylo renders efforts to grow cassava futile.

Live mulch crop production. The development of crop and land management practices that will guarantee crop production in the humid and sub-humid tropics on a sustained basis without irreversible deterioration in soil structure and composition and without a buildup of weeds is one of the goals of farming systems research at IITA. While no-tillage crop production depends heavily on at least two herbicide components to be successful, it is by no means the only option available to the small tropical farmer who in some situations may be confined to terrains that are not accessible to motorized equipment. An alternative is to plant crops in strips directly into live mulches (low-growing grasses and legumes) that are very competitive with weeds but do not compete with the crop to the point of reducing yield. Several indigenous legumes and grasses were grown and maize planted into the established cover crops. The live mulch treatments and crop yield data are shown in Table 32. Plots were weeded twice in the maize growing season. Weed weight was lowest in the plots with *Psophocarpus palustris* and *Paspalum notatum* as live mulch. The highest maize yield was obtained from the straw mulch plot. This yield did not, however, differ significantly from maize yield in any of the live mulches. An exception was *Centrosema pubescens* in which maize yield was low. *Psophocarpus palustris* shows promise as a live mulch provided its aggressive growth habit can be profitably controlled.

Land management

Research in land management focuses on nutritional and physical aspects of land management, and also on methods of forest or bush clearing and subsequent land development. Land clearing for the Hydrology and Watershed Management Project, which covers an area of 50 hectares at the IITA site, was started at the end of 1978. The Project is designed to investigate the impact of alternative methods of land clearing and subsequent soil management on crop production, hydrological, chemical, physical and biotic properties of the soil. More emphasis in 1978 was devoted to soil fertility management problems of the strongly acid ultisols from the humid region. In soil microbiology emphasis was given in 1978 to maximizing biological N-fixation in grain legumes, particularly soybeans.

Biological nitrogen fixation

Rhizobium culture collection

A collection of cultures of microorganisms represents a storehouse of information and a genetic resource base. In recognition of the importance of *Rhizobium* cultures in improving food crop production and soil fertility, a collection of cultures of *Rhizobium* spp. has been established. Some of the authenticated strains of rhizobia in the collection are shown in Table 33, indicating their sources at IITA accession numbers.

Nitrogen fixation in cowpeas

Indigenous cowpea rhizobia are sufficiently effective in supplying the required nitrogen for the present yield levels of cowpea. However, the exact quantities of fixed nitrogen are unknown. Two field experiments were conducted to quantify nitrogen fixed in cowpea as affected by mineral nitrogen and to select the least expensive, yet reliable, of three methods for future work.

In the first experiment, the field was cropped three times to maize to provide a low, uniform soil nitrogen level. Nitrogen fixed in four cowpea cultivars, and for comparison purposes, a lima bean cultivar, was estimated at 5 and 10 WAP, using the "difference" method in which rice served as the non-fixing control. In this method, the nitrogen in the nodulated legume less the nitrogen in the non-fixing rice is taken as the amount of nitrogen fixed by the legume/*Rhizobium* symbiosis. For this reason, all plant roots must be exposed to the same pool of soil nitrogen. This is best accomplished when soil N is low and uniform. The results are shown in Table 34. By comparison to cowpeas, lima bean is a poor nitrogen fixer although 10 weeks was probably too early for optimum fixation.

In the second experiment, the field was cropped four times to maize prior to establishing the experiment. Nitrogen fixation in four cowpea cultivars as influenced by fertilizer nitrogen (0, 25 and 100 kg N/ha) was investigated using three methods: (i) the "difference" method using maize, soybean and *Celosia argentia* as non-fixing or non-nodulating controls, (ii) the "A" value technique involving ^{15}N fertilizer and (iii) the acetylene-ethylene assay. Nitrogen was applied prior to planting. Ammonium sulfate enriched in ^{15}N (from Monsanto Mound Laboratory, USA) at a nominal enrichment of 40 percent atom excess (a.e.) of ^{15}N was diluted and mixed with

Table 33. Cultures of authenticated soybean (IRj) and "cowpea" (IRc) rhizobia in the IITA collection.

Accession number	Original identity	Host species	Source/Location
IRj 18	110	Soybean	Dr. Weber. USDA, USA.
IRj 100	-	Soybean	Bambey, Senegal.
IRj 101	46	Soybean	Dr. Zayed, Zambia.
IRj 102	67	Soybean	Dr. Zayed, Zambia.
IRj 103	M230	Soybean (HLS223)	Dr. Chowdhury, Tanzania.
IRj 104	M207	Soybean (IH 192)	Dr. Chowdhury, Tanzania.
IRj 105	M216	Soybean (IH 192)	Dr. Chowdhury, Tanzania.
IRj 108	61A76	Soybean	Dr. Brill, USA.
IRj 109	-	Soybean	Dr. Brill, USA.
IRj 110	SM35	Soybean	Dr. Brill, USA.
IRj 111	SM31	Soybean	Dr. Brill, USA
IRj 112	110	Soybean	Dr. Brill, USA.
IRj 113	110 Mut	Soybean	Dr. Brill, USA.
IRj 114	3407	Soybean	Rothamsted Exp. Sta., U.K.
IRj 115	3410	Soybean	Rothamsted Exp. Sta., U.K.
IRj 116	3425	Soybean	Rothamsted Exp. Sta., U.K.
IRj 117	G2SP	Soybean	ORSTOM, Senegal (Spect')
IRj 118	-	Cowpea	ORSTOM, Senegan (Spect')
IRj 119	G3	Soybean	ENSA, Abidjan, Ivory Coast.
IRj 120	G8	Soybean	ENSA, Abidjan, Ivory Coast.
IRj 121	110	Soybean	Dr. Weber, USDA, USA.
IRj 122	136	Soybean	Dr. Weber, USDA, USA.
IRj 123	138	Soybean	Dr. Weber. USDA, USA.
IRj 124	CB1809	Soybean	Dr. Weber, USDA, USA.
IRj 125	142	Soybean	Dr. Weber, USDA, USA.
IRj 126	122	Soybean	Dr. Weber, USDA, USA.
IRj 127	143	Soybean	Dr. Weber, USDA, USA.
IRc 128	-	Cowpea	IITA
IRc 129	-	Lima bean	IITA

"cold" fertilizer to 3 percent a.e. in fertilizer to be added at the 25 kg N/ha rate and to 1 percent a.e. at the 100 kg N/ha rate.

Composite mean values of N_2 fixed have been determined (Table 35), showing good agreement between the different method and the "A" value method. High values of efficiency of fertilizer use were found in the non-nodulating soybean isoline, indicating that maize or *Celosia* would be a better non-fixing control for cowpea for

Table 34. *Measurement of the fixation of atmospheric nitrogen in cowpea and lima bean using rice as a non-fixing control.*

		Mean N content of shoots, %		N fixed, kg/ha at	
Crop	Cultivar	5 weeks	10 weeks	5 weeks	10 weeks
Rice	OS-6	3.63	1.77	-	-
Cowpea	VITA-3	4.32	3.35	18.7	104.2
	TVu 3629	4.25	3.19	10.9	105.7
	TVx 309-1G	4.59	3.06	13.8	84.9
	TVu 4557	4.07	3.15	13.7	123.2
Lima bean	TP1 80	4.21	2.98	5.8	24.4

Table 35. *Mean values of N_2 fixed by cowpeas and soybean as determined by three methods.*

		Mean values of N fixed (kg/ha) at the indicated soil fertilizer rate		
Method	Cultivar	– N	25 N	100 N
Acetylene reduction	VITA-3	69	79	14
Difference	ER-1	53	46	23
	VITA-3	124	105	45
	Ife Brown	82	77	44
	TVu 4552	44	47	9
	Nod. soybean	195	157	110
"A" value	ER-1	n.a.[a]	42	24
	VITA-3	n.a.	101	63
	Ife Brown	n.a.	82	40
	TVu 4552	n.a.	45	14
	Nod. soybean	n.a.	145	94

[a]*Not applicable.*

different method determinations. Conversely, the best non-fixing crop for soybean is clearly the non-nodulating isoline. The determinations of N_2 fixed by VITA-3 cowpea with the acetylene reduction method gave values markedly lower than the other methods, and considering total crop nitrogen and mineral nitrogen availability, these values are too low.

Symbiotic nitrogen fixation

Soybean rhizobia (*Rhizobium japonicum*), which effectively nodulate soybeans, are few or absent in many African soils. Consequently, many soybean cultivars nodulate poorly when grown without inoculation in soils without a known history of soybean cultivation although a few "adapted" cultivars are adequately nodulated under similar conditions. In order to characterize and test the symbiotic effectiveness of indigenous rhizobia nodulating soybeans, 60 rhizobial isolates were obtained from nodules of two U.S. (TGm 80 and TGm 294-4) and two Asiatic (Malayan and Orba) cultivars grown in soils from four locations in Nigeria (Onne, Ibadan, Yandev and Samaru). The rhizobia were used to inoculate the hosts of derivation as well as cowpea, *V. unguiculata* cv. TVu 3788, grown under bacteriologically controlled conditions.

All isolates nodulated the hosts of derivation as well as the cowpea, indicating their relatedness to the cowpea miscellany. The symbiotic effectiveness of the isolates on their respective cultivars was generally low compared with the same cultivars receiving combined nitrogen (0.05% KNO_3). Total nodule mass produced by most host/strain combinations was generally small, although some treatments were moderately high. In general, however, isolates from Orba and Malayan were more effective on their hosts of derivation than were isolates from TGm 80 and TGm 294-4. Degrees of symbiotic effectiveness exist and must be considered as important criteria in assigning species rank to these rhizobia.

Because appropriate rhizobia (strains of *R. japonicum*) effectively nodulating soybean are generally few in tropical soils without any history of cultivation of this crop, there is a great potential for achieving high yields of soybean in these regions by the introduction of known effective strains of rhizobia in the form of inoculants. To achieve this, it is important to screen *Rhizobium* strains in the field and select those which can compete with native soil rhizobia and other microorganisms and effectively nodulate their host leading to optimum yields.

Several rhizobial strains were evaluated in terms of nodule production, nodule efficiency, and contribution to plant growth and grain yield with a view to selecting the best strains under field conditions.

In one experiment conducted during the second season of 1978, the performances of 12 strains of *Rhizobium japonicum* and one multistrain soybean commercial inoculant (Nitragin Co., USA) were evaluated in a field soil low in nitrogen and containing few soybean rhizobia using three soybean cultivars: TGm 80 and TGm 294-4 (US cultivars) and Orba (Indonesian cultivar). Uninoculated and high-N treatments were included as controls.

At 5 WAP nodule numbers were nearly doubled compared to 2 WAP. Uninoculated plants and plants receiving supplemental nitrogen were sparsely nodulated but Orba was clearly nodulating better with indigenous rhizobia. Nodule dry weights in all the cultivars increased nearly 25 times in the inoculated treatments between 2 WAP and 5 WAP. Responses to both inoculation and 100 kg N/ha were apparent in shoot dry weights. Uninoculated plants looked nitrogen-deficient and this was more apparent in TGm 80 and TGm 294-4 than in Orba. None of the strains showed ineffective nodulation.

Between five and seven weeks, nodule numbers increased in all the host cultivar-*Rhizobium* strain combinations. Nodule dry weights increased 5-6 fold, but Orba had greater nodule dry weight/plant compared to the U.S. cultivars, although nodule numbers in Orba were low. Nodule mass in Orba was, therefore, greater in all the treatments. The response to inoculation was generally more prominent in TGm 294-4 in terms of shoot dry weight. Although nitrogen (150 kg N/ha) treatment showed the maximum shoot dry weights, several inoculated treatments were close to the nitrogen values. Percent nitrogen content of tops in the inoculated treatments was nearly double that of the uninoculated treatment in TGm 80 and TGm 294-4, but there was no corresponding increase with Orba. Total N content (mg N/plant) in the inoculated treatments increased 2-3 fold in TGm 80, 2-4 fold in TGm 294 and 1-2 fold in Orba. (Table 36.)

Table 36. Symbiotic performance of single and multistrain inoculants at seven weeks.

	TGm 80				TGm 294-4				Orba			
	A	B	C	D	A	B	C	D	A	B	C	D
Nodule number	1	97	111	7	6	82	98	5	15	56	87	23
Nodule dry weight (mg)	14	471	645	45	46	376	424	29	286	549	648	275
Total activity, C_2H_4 (μ mol/plant/h)	5	40	41	11	5	31	32	8	30	45	63	24
Specific activity, (n mol C_2H_4/ mg d.wt. of nods/h)	218	104	79	242	228	96	169	200	117	91	171	72
Shoot dry weight (g)	8	11	9	16	6	10	11	14	10	14	13	121
Percent Nitrogen (Shoot)	1.8	3.2	2.8	2.7	1.6	3.0	2.7	2.1	3.3	3.2	3.2	3.1
Nitrogen content (mg/shoot)	140	343	276	405	100	311	290	294	320	458	421	621

A = Uninoculated; B = Inoculated with single strain; C = Multistrain Nitragin Commercial inoculant; D = Nitrogen (150 kg N/ha).

At 9 WAP nodule numbers in most treatments remained the same as at seven weeks, but nodule dry weights showed further increases and total and specific activities of nodules declined indicating onset of the cessation of nitrogen fixation in most if not all nodules.

The response to inoculation is also clearly reflected in the pod weight and grain yield. (Table 37.)

In another experiment, two soybean cultivars (TGm 80 and TGm 294) and eight *R. japonicum* strains were tested during the first season of 1978. Uninoculated and high-nitrogen treatments (200 kg N/ha) applied in two doses, (80 kg N/ha after planting and 120 kg N/ha at mid pod-fill) were also included, making a total of 10 treatments.

Because of the high soil nitrogen (0.22% N), nodulation in the inoculation treatments was delayed. At four weeks sparse nodulation was noticed with IRj 101, 102, 110 and 116; other strains formed no nodules. By six weeks good crown nodulation was evident with those sparsely nodulating at four weeks; other strains showed signs of inconsistent nodulation. Although effective nodulation was apparent, no differences in dry weights of tops between inoculated and uninoculated treatments were found during the major part of the growth period. Despite the lack of clear response to inoculation until the 11th week (in terms of dry weight ot shoots) significant increases in grain yield were noticed particularly in TGm 80 inoculated with IRj 101, 102, 110, 116 and 121. Fertilizer nitrogen (200 kg N/ha) also showed increases in grain yield. The effect of supplemental nitrogen in the inoculated treatments was not obvious because of the initial high soil N in the field.

Past work showed that *G. max* cv. TGm 294-4, when grown in pots, formed fewer nodules in Apomu loamy sand (Psammentic ustorthent pH 5.8) than in Egbeda sandy loam (Oxic paleustalf, pH 5.4). Although both soils had been first inoculated in 1974, the Apomu soil had had only one inoculation whereas the Egbeda soil had had three. To determine the effect of surviving rhizobia on nodulation and grain yield, TGm 294-4 was planted in both soils with these treatments: (i) uninoculated, (ii) inoculated with the original, Nitragin commercial inoculant, (iii) inoculated with a pure strain, IRj 18, and (iv) uninoculated, fertilized with 120 kg N/ha in two equal applications.

In the Egbeda soil, re-inoculation in 1978 produced no significant effect on grain yield and nodule efficiency. In the Apomu soil, even though plants were nodulated in the uninoculated treatment and the nodules were effective, re-inoculation with Nitragin inoculant or IRj 18 increased grain yield by 20.1 percent and 17.5 percent,

Table 37. Soybean grain yield (t/ha) response to inoculation with* Rhizobium japonicum *and fertilization with nitrogen.

	TGm 80 (Bossier)	TGm 294-4	Orba
Uninoculated	1.64	1.07	2.12
IRj 18	3.12	2.84	2.62
IRj 101	2.78	2.94	2.25
IRj 102	2.97	2.84	1.85*
IRj 110	3.03	2.52	2.36
IRj 111	2.81	2.94	1.73*
IRj 112	3.17	2.87	2.65
IRj 113	2.79	3.06	2.74
IRj 119	3.18	2.87	2.55
IRj 123	2.87	3.15	2.52
IRj 125	3.17	2.58	2.35*
IRj 126	3.12	2.86	2.42
IRj 127	2.53	2.31	-
Nitragin	3.03	2.87	2.62
Nitrogen, 150 kg N/ha	2.72	2.68	2.67

s.e.d. between two cultivar means at the same inoculation level ± 0.438

s.e.d. between two inoculation means for the same cultivar ± 0.328

CV percent 13

**Poor stands. Yields on area basis not representative.*

respectively. Nitrogen fertilizer was as effective as both inoculation treatments. It is concluded that even though the pH of the Apomu loamy sand is adequate for rhizobial survival, re-inoculation is required to increase grain yield.

To study the survival and competitive ability of *R. japonicum* in acid soils, several isolates were screened for symbiotic competence in the greenhouse using a highly acid soil from Onne (Oxic paleudult, pH 3.7). The two best strains were selected and genetically marked with either streptomycin or spectinomycin resistance at >200 ug/ml antibiotic. No loss of symbiotic effectiveness by the mutant strains relative to their "wild-type" parents was detected in a Leonard jar experiment.

The two antibiotic resistant strains were employed in a field trial at Onne in the highly acid soil and for comparison purposes in a slightly acid soil at IITA (Oxic paleustalf, pH 5.4); both soils contained fewer than five indigenous rhizobia/g prior to planting. Two cultivars, TGm 80 and TGm 294-4, and four treatments were used: (i) uninoculated, (ii) inoculated with IRj 101 spc, (iii) inoculated with IRj 114str, and (iv) fertilized with 150 kg N/ha in two doses. Lime at 1 t/ha was applied to half of the plots in the highly acid soil.

The results presented in Table 38 show that both cultivars in the uninoculated minus lime treatment produced little nodule and shoot dry matter; grain yields were also poor (0.3-0.4 t/ha). Lime application induced significant increases in nodule dry weights and grain yields, although only a small response was observed in terms of shoot dry matter production. These results demonstrate the ameliorating effect of lime on the soil acidity complex.

Antibiotic resistance assays for nodule strain identity (ca. 700 nodules typed from this location) showed that 100 percent of the nodules were produced by the antibiotic resistant strains. This also demonstrates that the small numbers of indigenous rhizobia in the soil were poor competitors for nodulation with the introduced strains. In the uninoculated and nitrogen treatments, only 68 percent of the nodules were due to indigenous strains with the remaining 32 percent containing one or other of the inoculant strains. This level of contamination was probably aggravated by rain splash and run-off caused by heavy rains.

At six weeks, a duplicate experiment without liming treatments on the slightly acid soil at IITA revealed similar treatment differences to those described for the Onne trial, although shoot and nodule dry weights were of a higher order of magnitude due to the more favorable soil conditions. (Table 39.) However, at the final harvest there were no significant differences between treatments in terms of grain yield. The results for nodule strain identity (ca. 400 nodules typed) were also similar to those for the Onne experiment. In the uninoculated and nitrogen treatments, less than 10 percent of the nodules assayed were found to contain antibiotic-resistant strains confirming that the absence of significant differences in grain yield between treatments was due to late nodulation by effective naturalized strains in the uninoculated treatment.

Table 38. The shoot dry matter production, nodule dry weights and grain yield of two soybean cultivars grown in an acid soil at Onne and receiving different inoculations and two levels of lime.

	Mean[b] shoot dry weight (g/plant) at six weeks on soybean cultivar		Mean[b] nodule dry weight (mg/plant) at six weeks on soybean cultivar		Mean[b] grain yield (kg/ha) on soybean cultivar	
Treatment[a]	TGm 294-4	TGm 80	TGm 294-4	TGm 80	TGm 294-4	TGm 80
Lo 1°	2.55	2.23	26.8	5.5	396	331
L_1 1°	2.97	2.87	65.3	57.0	913	848
Lo N	3.82	3.69	1.4	1.1	1002	795
L_1 N	4.61	4.30	50.3	14.0	1241	1387
Lo str	5.44	6.32	228.0	226.0	1616	2075
L_1 str	6.51	6.13	240.5	262.8	1753	1963
Lo spc	5.73	5.75	237.8	187.8	1582	1932
L_1 spc	6.16	5.18	258.0	223.8	1800	1953

[a]*Lo—No lime; L_1—Lime applied at 1 t/ha; N—Nitrogen fertilizer applied in two doses: 50 kg/ha at planting and 100 kg/ha after 6 weeks; 1°—uninoculated; str—inoculation with streptomycin-resistant strain, IRj 114str; spc—inoculation with spectinomycin-resistant strain IRj 101 spc.*

[b]*Means are derived from four replicates each consisting of 10 plant values.*

Table 39. The shoot dry matter production, nodule dry weights and grain yield of two soybean cultivars grown in a slightly acid soil at IITA and receiving different inoculation treatments.

	Mean[b] shoot dry weight per plant (g) at six weeks on soybean cultivar		Mean[b] nodule dry weight per plant (mg) at six weeks on soybean cultivar		Mean[b] grain yield (kg/ha) on soybean cultivar	
Treatment[a]	TGm 294-4	TGm 80	TGm 294-4	TGm 80	TGm 294-4	TGm 80
Io No	5.63	5.37	90.4	38.4	2215	2102
Io N	7.44	8.68	21.9	6.7	2300	2259
IRj 114 str	8.07	7.45	328.3	296.2	2298	2335
IRj 101 spc	8.12	7.39	280.7	249.9	2372	2332

[a]*Legend as for Table 38.*

[b]*Means are derived from five replicates each consisting of 10 plant values.*

Fertility Management of Ultisols, Alfisols and Entisols

Ultisols

Long-term liming experiment. The liming experiment at Onne is being continued in its third year with five rates of lime (0, ½, 1, 2, 4 t/ha) applied initially in 1976. Maize (cv. TZPB) and cowpea (cv. VITA-1 and VITA-4) were used as test crops. Maize received moderate rates of N, P, K, Mg, S, and Zn, whereas cowpea received all nutrient elements except a lower rate of N. Maize yield during 1977 and 1978 (Table 40) showed that the maximum yield shifted from the treatment which received a low rate of lime (0.5 t/ha) to the treatment that received a high lime rate (4 t/ha) after two years. The maximum yields of maize were 3.6 t/ha in 1977 and 3.8 t/ha in 1978.

However, the plots that received 0.5 t/ha of lime still maintained about 80 percent of the maximum yield in the third year despite a significant decline in soil pH and exchangeable Ca levels. (Table 41.) The rapid loss of applied Ca through leaching from the surface layer (0-15 cm) under high-rainfall conditions at Onne (2450 mm p.a.) suggested that it is not feasible to apply high rates of lime to this coarse-textured, kaolinitic Ultisol.

Table 40. Relative yield of maize during 1977 and 1978 from Onne liming trial.

Lime	Relative grain yield, %	
(t/ha)	1977	1978
0	54	63
0.5	100	77
1	95	75
2	97	93
4	95	100

Table 41. Changes in soil pH (H_2O) exchangeable Ca (me/100 g) and effective CEC (me/100 g) in surface soil (0-15 cm) 2 years after liming.

Lime	Initial*		After 2 years		ECEC	After 2
(t/ha)	pH	Ca	pH	Ca	Initial*	years
0	4.7	0.56	4.3	0.37	2.77	3.39
0.5	5.0	1.36	4.3	0.48	3.08	3.18
1	5.2	1.70	4.4	0.74	2.91	3.55
2	5.6	2.50	4.8	1.23	3.24	3.35
4	6.3	6.43	5.2	2.07	7.25	3.39

**4 weeks after liming.*

Nutrient leaching losses. Downward movement of nutrient ions such as NO_3^-, K^+, Ca^{++}, Mg^{++} and NH_4^+ occurs during leaching. Reliable data on leaching losses of fertilizer, particularly nitrate in the humid tropics are scanty.

Exchangeable Al gradually reappeared in plots that received moderate and high rates of lime. (Table 42.) However, exchangeable Al of the surface soils of all four lime treatments remained far below the reported critical level of 44 percent for maize. The shift in maximum yield (Table 40) after two years could be explained by the high sub-soil acidity in the low-lime plots as indicated by a high degree of Al saturation. (Table 42.) The high Al and low available nutrient levels in the sub-horizons apparently inhibited better root development, limiting the nutrient and water supply to the plant.

Studies are being conducted at IITA to evaluate the effect of soil physico-chemical characteristics, rainfall, evapotranspiration cropping and fallow system on downward movement and leaching losses of nutrients.

Tension-drained lysimeters using undisturbed soil profile cores from Onne high-rainfall station are being constructed. In laboratory leaching experiments, using undisturbed soil cores of 100-cm depth, $Ca(NO_3)2$ or a mixture of $Ca(NO_3)2$ and KNO_3 were applied at the bare surface. The column was then leached with deionized water for 72 days at rates corresponding to the distribution and total amount of rainfall at Onne (2420mm p.a.) by means of a peristaltic pump. Bulk density and porosity were determined to calculate column volume (water in the macropores).

Nitrate leached readily through this kaolinitic Ultisol profile accompanied mainly by Al^{3+} and Ca^{++} ions; however, there was little K^+ leaching even though a moderate amount was applied. These data indicated preferential retention of K^+ by soil. This leaching and retention of cations can be explained in terms of ion exchange selectivity. The leaching sequence followed the reverse order of the cation selectivity sequence of the soil determined in separate experiments. (Figs. 14 and 15.) The selectivity sequence followed the order $K = NH_4 > Ca = Na > Mg$. The delayed appearance of the K^+ peak indicated the soil has high K affinity.

It is also important to note the agreement between the measured distribution of exchangeable Ca in the column after leaching and the calculated values based on cation exchange data using Walter's equation of chromatographic transport for the Onne soil profile. Such a relationship suggests that downward movement of Ca ions in the kaolinitic Ultisols could be predicted from cation exchange data. (Fig. 16.)

Table 42. Changes in exchangeable Al and Al saturation 2 years after liming.

Lime	Exch Al (me/100 g)			Al saturation, %		
	Initial*	After 2 years		Initial*	After 2 years	
t/ha	0-15 cm	0-15 cm	15-30 cm	0-15 cm	0-15 cm	15-30 cm
0	1.27	1.50	1.65	45	44	47
0.5	0.82	0.83	1.60	27	26	46
1	0.45	0.97	1.58	16	27	47
2	0.06	0.60	1.20	2	18	36
4	0.04	0.23	0.82	0.5	7	26

**Measured at four weeks after liming.*

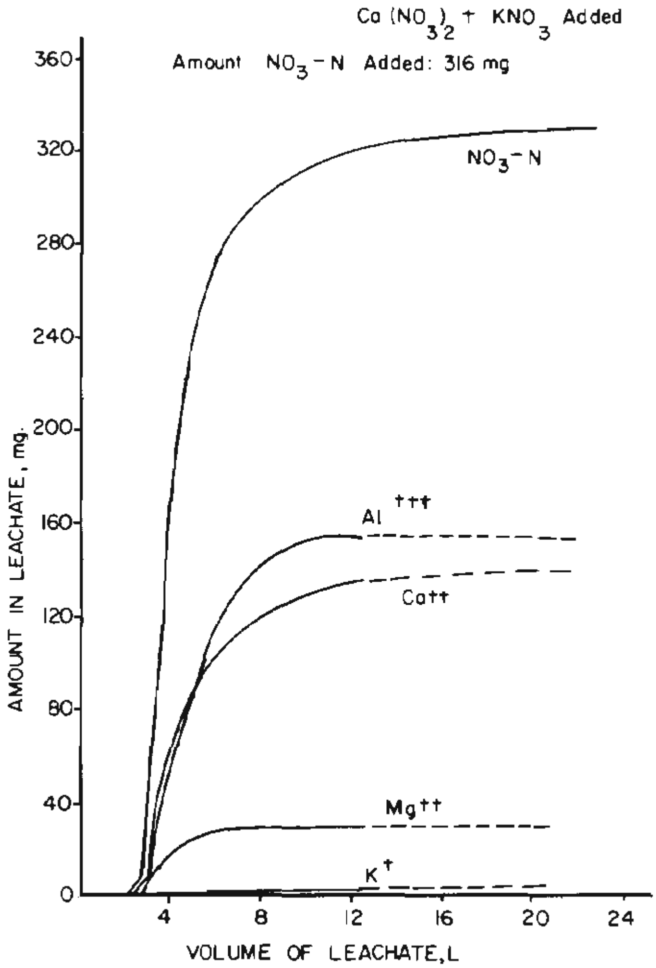


Fig. 14. Cumulative leaching curves of Onne soil profile treated with a mixture of $Ca(NO_3)$ and KNO_3.

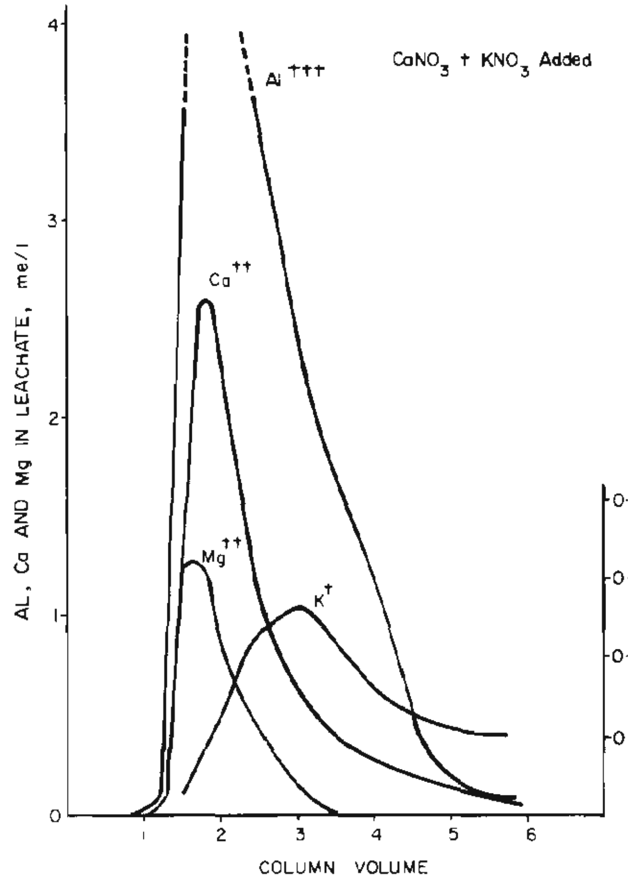


Fig. 15. Concentration of leachate as a function of column volume.

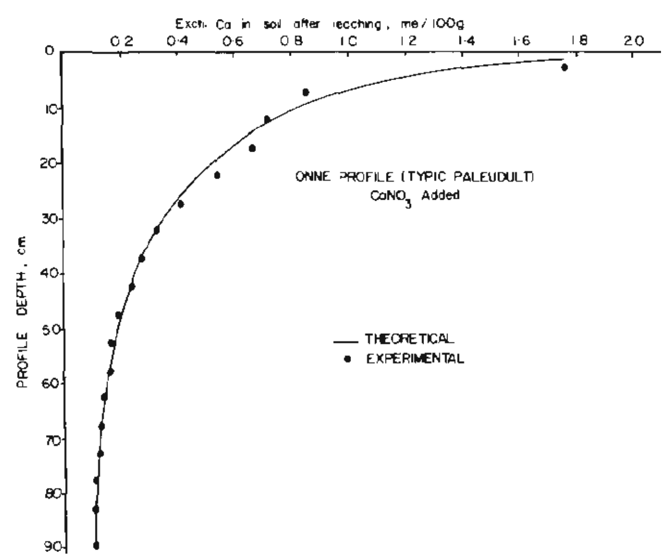


Fig. 16. Vertical distribution of Ca in the leached Onne profile.

Fallow residue management

A field trial was established at Onne to provide a better understanding of the importance of the traditional practice of burning the fallow residues during land preparation particularly on acid soils. The composition of the preburn fallow vegetation and the plant ash from the Onne site (predominantly *Anthonata*) and, for comparison, that from a site at Ikenne (predominantly *Eupatorium odoratum* and *Rottboellia exalta*) is shown in Table 43. From both locations, very noticeable is the high percentage of P, cations and micro-nutrients in the plant ash. During the burning not all of the plant material was ashed; a large percentage of the woody material was retained as unburnt but charred material, and part of the N is retained in the plant ash and the charred material.

At Onne, the maize from the burnt plots showed more vigorous early growth, but there was no beneficial effect from burning on grain yield. (Table 44.) The better yield observed in the mulch treatment may be attributed to better N retention in the fallow residue which gradually decomposed during the cropping period and acts as a slow release N source. One major beneficial effect from the burning exercise is that it provides a clean seed bed for planting. Retaining the fallow residue as mulch made planting more difficult. Addition of Mg, Zn and liming had no effect in this trial. Apparently, by using the traditional method of land clearing with minimal soil profile disturbance, there is no lime response on this highly acid (pH4.29, Al saturation 60%) soil with or without burning the fallow residue.

Table 43. Chemical composition of mixed preburn fallow vegetation and plant ash from Onne (Typic paleudult, over 6 years fallow) and Ikenne. (Oxic paleustalf, 5-6 years fallow.)

Location	Material	Estimated dry wt. kg/ha	N	P	K	Ca	Mg	Mn	Zn	Fe
			%					ppm		
Onne	Preburn vegetation	10100	2.14	0.30	2.18	1.40	0.69	859	35	209
	Plant ash	563	0.91	1.04	3.53	5.94	1.65	2500	470	6700
Ikenne	Preburn vegetation	5610	1.90	0.11	0.89	0.87	0.52	143	25	128
	Plant ash	430	0.69	0.29	1.78	3.53	1.93	1240	456	7800

Table 44. Effect of fallow residue management and nutrient combination on grain yield of maize TZPB grown on Onne soil. (Typic paleudult.)

Nutrient combination	Residue management Mulching	Burning	Mean
	t/ha		
Control (no fertilizer)	1.74	1.19	1.46
NPK	3.41	2.72	3.07
NPK Mg Zn	2.87	2.80	2.84
NPK Mg Zn + Lime	3.49	3.00	3.25
Residue management mean	2.88	2.43	
LSD.05 Residue management means	0.67		
LSD.05 Nutrient combination means	0.48		
LSD.05 Between nutrient combination for some residue management	0.67		

Fertilizer rate, Kg/ha
N—200; P—40; Mg—30; Zn—5
Lime 1000

Maize magnesium response in Ultisols

Magnesium deficiency has been observed occasionally on maize and cassava at Onne. A trial to determine the Mg requirement for maize production was conducted on land cleared in 1976 and used for maize cropping in 1977. Results of 1978 first-season maize cropping confirm the need for additional Mg at Onne. (Table 45.) A rate of 20 kg Mg/ha appears to be adequate.

Alfisols and Entisols

Long-term fertilizer trials. Two experiments were initiated in 1972 at the IITA site in Ibadan on Egbeda soil (Oxic paleustalf) and Apomu soil (Psammentic usthorthent). A maize-sweet potato annual cropping cycle was used from 1972 until 1975. Starting in 1976, the second-season sweet potato crop was replaced by cowpea to evaluate its N-contribution to the system.

With adequate fertilization, high maize and cowpea grain yields were observed in 1978 at both locations. (Table 46.) At both locations responses to N and P applications were observed during the first three years of cropping after land clearing. Despite seven years of intensive cultivation, no responses to K, S and micro-nutrients were observed on the Egbeda soil. For continuous production involving a maize-cowpea annual cropping, a rate of 80 kg N/ha and a rate of 30 kg P/ha appears to be more than adequate on the Egbeda soil. On the Apomu soil, maize started to show a significant response to K application in 1976 and cowpea grain yield showed response in 1977. For continuous crop production involving a maize-cowpea annual cropping, the annual fertilizer application of 200 kg N/ha, 30 kg P/ha and a minimum of 40 kg K/ha is apparently needed.

Table 45. Effect of Mg application on grain yield of maize TZPB grown in Onne (Typic paleudult).

Mg rate (kg/ha)	Maize grain yield (t/ha)
0	3.14
10	3.01
20	3.68
40	3.36
LSD.05	0.59

Table 46. First-season grain yield of maize cultivar TZPB and second-season grain yield of cowpea cultivar VITA-4 in 1978 as affected by fertilizer application.

Soil type treatment	Egbeda soil Maize	Egbeda soil Cowpea	Apomu soil Maize	Apomu soil Cowpea
	t/ha			
$N_0 P_0 K_0 S_0$	2.67	1.33	1.03	1.25
$N_0 P_2 K_1 S_0$	4.85	1.71	1.86	0.39
$N_1 P_2 K_1 S$	5.70	1.71	4.54	1.27
$N_2 P_2 K_1 S$	5.62	1.54	6.04	1.43
$N_2 P_0 K_1 S$	2.52	1.21	4.03	1.23
$N_2 P_1 K_1 S$	5.18	1.75	5.63	1.20
$N_2 P_2 K_0 S$	5.36	1.84	4.61	1.09
$N_2 P_2 K_2 S$	5.55	1.56	5.20	1.03
$N_2 P_2 K_1 S_0$	5.55	1.63	6.00	1.11
$N_0 P_0 K_0 S_0$*	2.17	1.17	1.67	1.10
$N_2 P_2 K_1 S$*	5.32	1.47	5.07	1.20
LSD.05	1.15		1.02	

**Maize crop residue removed.*
Fertilizer rates kg/ha
Egbeda soil $N_1 = 80$ $N_2 = 160$
Apomu soil $N_1 = 100$ $N_2 = 200$
$P_1 = 30$ $P_2 = 60$, $K_1 = 40$,
$K_2 = 80$, $S = 15$

Removal of the maize crop residue since 1972 showed some detrimental effect on crop yield on the Apomu soil in 1977. The same effect began to show on the Egbeda soil in 1978.

Continuous cropping with and without fertilizer applications has a significant effect on some of the soil properties. (Table 47.) The low levels of extractable P in both soils without P application and the high P levels with continuous P application are noticeable. With and without fertilizer application the Apomu soil showed extremely low levels of organic C, total N and extractable K levels with continuous cropping.

Continuous fertilizer application on both soils also reduced soil pH, although the decline was less with the use of urea and calcium ammonium nitrate.

Fertilizer-weeding trial on Araromi soil

As part of the maximum yield/cultural trial to determine the yield potential and fertility management problems of the benchmark soils, a fertilizer-weeding trial was conducted at Isoya in cooperation with the soils department of the University of Ife. In 1978, the third cropping year, maize already showed significant responses to N, P and K, with N as the major limiting nutrient. (Table 48.) The maize yield also responded more to weeding with no fertilizer application. The three years' results show that with adequate fertilization and weeding, a maize yield of about 5.0 t/ha can be maintained on this soil.

Tops as nitrogen source

Two field trials were carried out on an Apomu soil (Psammentic usthorthent) in Ibadan to evaluate the value of *Leucaena leucocephala* tops as N– source for maize. Young tops and leaves were used in one trial applied as mulch or incorporated in the soil. Maize yield response to addition of fertilizer N and *Leucaena* tops is shown in Table 49. Addition of only *Leucaena* tops or in combination with 50 kg N/ha appears to be most effective in increasing maize grain yield. Little difference was observed on the effect of method of application of the *Leucaena* tops on maize yield, although incorporation in the soil appears to be more effective.

Table 48. Effect of fertilizer application and weeding on grain yield of maize cultivar TZPB grown in Araromi soil. (Rhodic paleudalf.)

Treatments	Grain yield (t/ha)
No fertilizer, no weeding	1.70
No fertilizer + weeding	2.73
NP + weeding	3.30
PK + weeding	2.75
NK + weeding	3.29
NPK no weeding	4.62
NPK + weeding	5.23
LSD.05	1.75

N = 120 kg N/ha; P = 60 kg P/ha; K = 40 kg K/ha.

Table 49. Effect of application of nitrogen and Leucaena tops on grain yield of maize cultivar TZPB grown on Apomu soil. (Psammentic usthorthent.)

N-rate KgN/ha	*Leucaena* top added fresh weight (t/ha)	Applied as mulch incorporated maize grain yield (t/ha)		Mean
0	0	2.62	2.53	2.58
0	5	2.55	2.78	2.66
0	10	3.48	3.44	3.46
50	0	3.11	3.35	3.23
50	5	3.44	4.14	3.79
50	10	3.62	4.19	3.91
100	0	4.42	4.65	4.53
100	5	4.67	4.82	4.75
100	10	4.25	4.55	4.40
Mean		3.57	2.83	

In another trial maize was planted in between rows of 1 and 1½-year-old *Leucaena* trees which were closely planted in rows spaced 4 m apart. Before planting the maize, the area between the tree rows was disked to trim

Table 47. Some chemical properties of Egbeda soil (Oxic paleustalf) and Apomu soil (Psammentic usthorthent) surface soil (0-15 cm) from long-term fertility trial sampled in 1978.

Soil type	Treatment			pH-H_2O	Org C. %	Total N %	Bray P-1 ppm	Exchangeable Ca	Exchangeable K	Exchangeable Mg
								me/100 g		
Egbeda	N_o	P_o	K_o	5.95	1.44	0.18	2.0	5.64	0.44	1.23
	N_o	P	K	6.18	1.33	0.22	34.8	4.87	0.44	1.05
	N	P	K	5.40	1.54	0.20	28.5	5.47	0.44	1.09
	N	P_o	K	5.73	1.49	0.24	3.2	5.23	0.44	1.16
	N	P	K_o	5.45	1.45	0.18	24.8	5.01	0.27	0.96
Apomu	N_o	P_o	K_o	6.10	0.70	0.06	5.6	1.86	0.11	0.32
	N_o	P	K	6.00	0.73	0.08	30.5	2.39	0.17	0.46
	N	P	K	5.63	0.90	0.08	33.7	2.46	0.16	0.43
	N	P_o	K	5.70	0.72	0.07	5.0	1.67	0.16	0.43
	N	P	K	5.45	0.78	0.08	28.1	2.12	0.11	0.37

Annual fertilizer application rate since 1972 in kg/ha N = 120-160; P = 60; K = 40 for Egbeda soil; N = 120-200; P = 60; K = 40 for Apomu soil.

the *Leucaena* roots and at the same time the tree tops were pruned to a height of about 1½ m. The amount of pruned tops averaging about 3½ t/ha fresh weight (supplemented to make the desired rates) was applied as mulch or removed from the plots depending on the treatments.

The grain yield of the maize grown in the plots between the pruned *Leucaena* rows, and response to the mulch treatment and N application can be seen in Table 50. High yields can be obtained with a mulch rate of 10 t/ha or with a combination of 5t mulch/ha with 50 kg N/ha. The suitability of this "corridor method" of intercropping maize and other crops with *Leucaena* for continuous cropping will be further evaluated.

Table 50. Effect of application of nitrogen and* Leucaena *tops on grain yield of maize cultivar TZPB grown between pruned rows of* Leucaena *plants.

Leucaena top fresh weight added (t/ha)	N Rate (kg/ha) 0	50	100	Mean
	grain yield (t/ha)			
0	2.11	2.57	3.38	2.69
5	2.73	3.17	3.45	3.12
10	3.22	3.26	3.43	3.30
Mean	2.69	3.00	3.42	

N contribution from grain legumes

The rotation trial conducted on an Iregun soil (Oxic haplustalf) at the IITA site in Ibadan since 1975 was completed in 1978. Four rotation patterns were tested: maize-maize, maize-cowpea, maize-pigeon pea, maize-soybean. Maize was grown as the first-season crop and followed by grain legumes in the second season. Four N rates, 0, 45, 90 and 135 kg N/ha were applied to the first-season maize. Results of four years' observations indicated significant residual effect of applied N. With N rates >45 kg N/ha there was no difference in maize yield between the four rotation patterns. A beneficial effect of rotation with the grain legumes on the maize yield was mainly observed in the no nitrogen treatment. (Fig. 17.)

After three years of rotation with no N application, the first-season maize grain yield was highest in the following order: maize-cowpea>maize-soybean>maize-pigeon pea>maize-maize.

The beneficial effect from rotation of maize with cowpea and soybean was also confirmed by the results of another rotation trial conducted since 1977 on an Egbeda soil (Oxic paleustalf) at IITA site in Ibadan. After two grain legume crops, the second-season maize grain yield (Table 51) was observed in the following order: maize-cowpeas>maize-soybeans>maize-maize rotation. Large differences are particularly noticeable in the no N treatment.

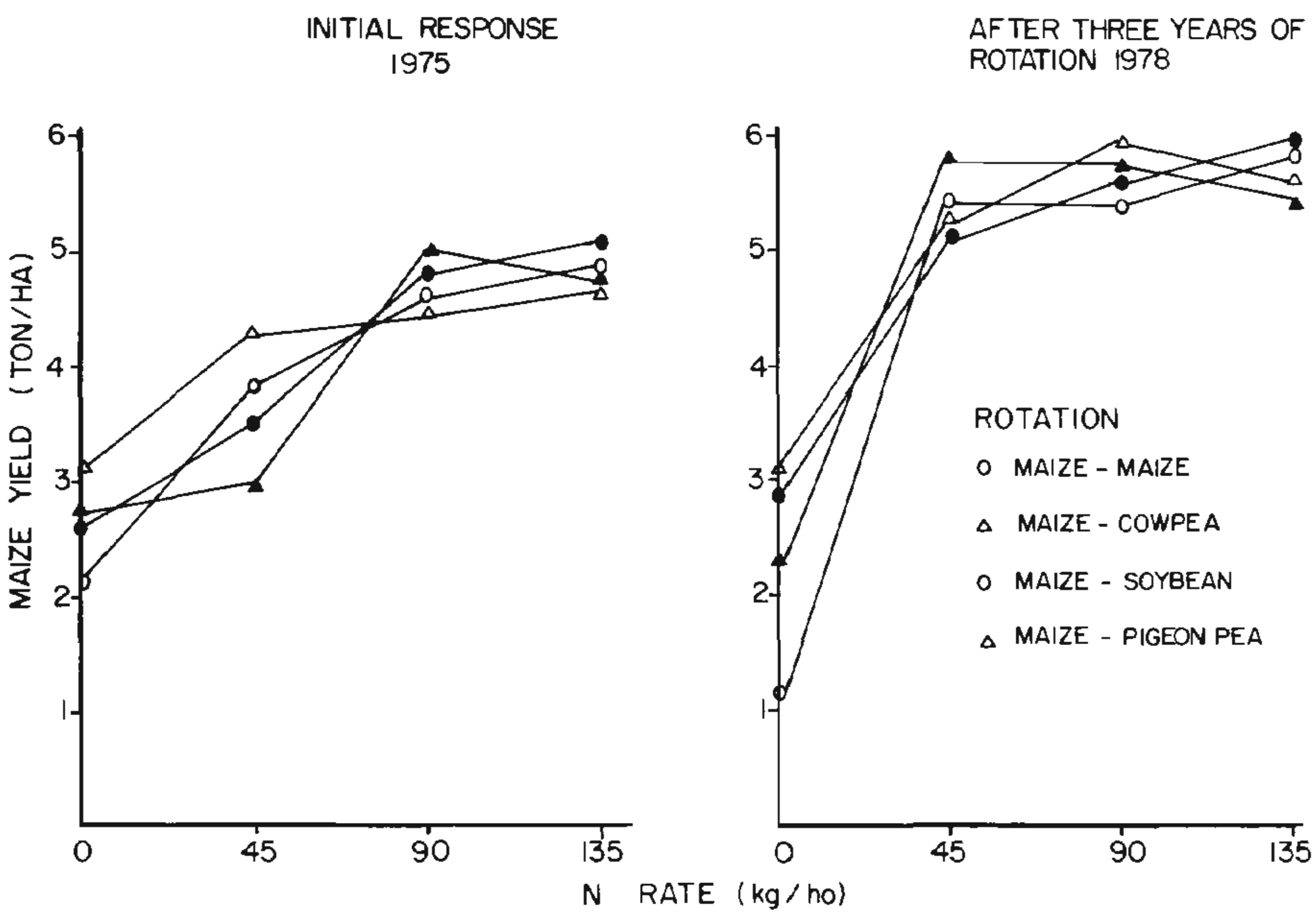


Fig. 17. Effect of three-year rotation on first season maize (TZPB) grain yield.

Table 51. Effect of N-rates and rotation on grain yield of maize cultivar TZPB grown during second season on Egbeda soil. (Oxic paleustalf.)

N-rate kgN/ha	Maize-Cowpea	Maize-Soybean	Maize-Maize
	Maize grain yield (t/ha)		
0	2.91	2.43	2.18
45	4.28	3.99	3.73
90	5.03	4.54	4.94
Mean	4.07	3.65	3.62

N only applied to maize crop.

N-requirement of a maize-cassava mixed cropping system. The trial was conducted on an Alagba soil in Ikenne to study the N requirement for a continuous maize-cassava mixed cropping system. The land was recently cleared from *Eupatorium odoratum* fallow. No N response was observed on the mono or mixed cropped maize on this newly cleared land. N application depressed the tuber yield of the mono cropped cassava, but not that of the mixed cropped cassava. Mono or mixed cropped maize showed no yield differences when planted at 1m × .33 m with one plant/hill or at 1m with 3 plants/hill. Yield of mixed cropped maize showed only slight reduction contrary to the cassava tuber yield which was more affected by mixed cropping. Higher gross income can be realized from mixed cropping maize (TZPB) and cassava than from double cropping medium-maturing (TZPB) and early-maturing (TZE) maize.

Nitrogen-tillage interaction. To study the N × tillage interaction on soils derived from sedimentary material, a trial was set up at Ikenne on an Alagba soil (Oxic paleustalf). The plot was cleared from a three-year *Eupatorium odoratum* fallow. Maize cultivar TZPB was planted in the first season and cultivar TZE in the second season. Only a small response to N was observed after *Eupatorium* fallow. (Table 52.) There was also no difference in maize yield whether the plant residue was left as mulch tillage or plowed in with conventional tillage. In the second season a more distinct response to N application was observed. Maize grain yield was also observed to be slightly higher with conventional than with minimum tillage.

Table 52. Effect of tillage x N interaction on grain yield of maize grown on Alagba soil (Oxic paleustalf) at Ikenne.

N-Rate KgN/ha	First season (TZPB) Min. till	Con. till	Mean	Second season (TZE) Min. till	Con. till	Mean
	(t/ha)					
0	5.44	5.48	5.46	1.73	1.99	1.86
30	5.74	5.81	5.78	2.30	2.42	2.36
60	6.12	5.81	5.97	2.22	2.39	2.30
90	5.96	5.87	5.91	2.25	2.27	2.26
120	5.85	5.99	5.92	2.41	2.56	2.48
150	5.90	6.04	5.97	2.38	2.60	2.49
Mean	5.84	5.83		2.22	2.37	

NH_4-N volatilization loss. With minimum tillage, only a small portion of the surface soil is tilled and fertilizer

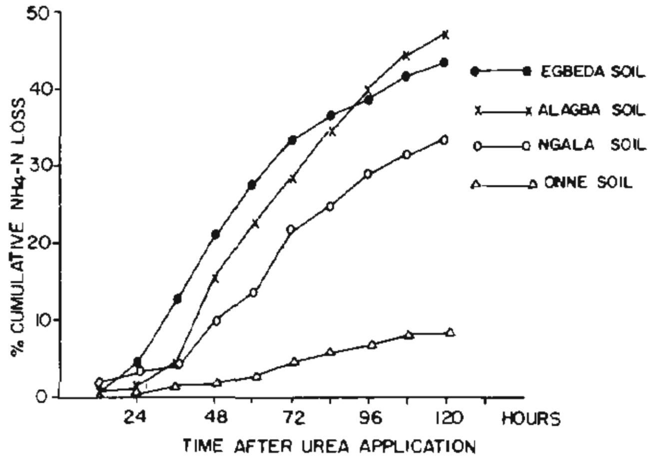


Fig. 18. Effect of soil types on NH_4-N volatilization loss of surface applied urea.

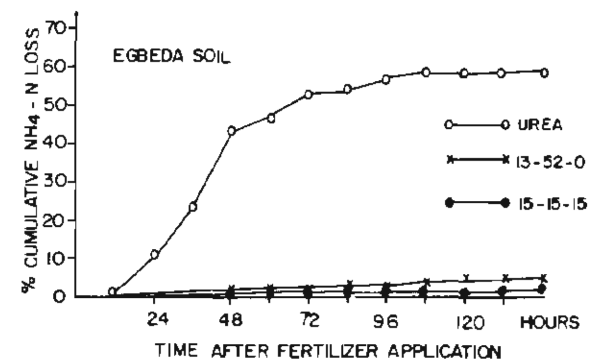


Fig. 19. Effect of N fertilizer source on NH_4-N volatilization loss.

incorporation is considered difficult; most of the fertilizer is therefore surface applied. Since surface applied N fertilizers in the tropics may be subjected to volatilization loss, field and laboratory observations were therefore carried out to investigate factors affecting NH_4-N loss.

Soil type appears to have a strong effect on NH_4-N volatilization loss from surface-applied urea. In a laboratory measurement of 24°C using four soil types and urea surface broadcast at a rate of 20 mg N/38.5 cm^2, higher NH_4-N loss was observed on sandy loam Egbeda soil (pH 5.8) and Alagba soil (pH 6.1) than on the clay soil from Ngala (pH 7.3). (Fig. 18.) The lower loss from Ngala soil may in part be attributed to its high CEC (28.9 me/100 g). The highly acid Onne soil (Typic paleudult, pH4.8) shows the least loss. NH_4-N volatilization loss increased with increased rate of urea application but can be effectively reduced by deep placement. Most of the volatilization loss was observed 2-4 days after application.

Volatilization losses are also affected by the N source. (Fig. 19.) Field measurements on an Egbeda soil, where urea, 15-15-15 and 13-52-0 (MAP), were applied at the soil surface at a rate of 750 mg N in a narrow band of 4 mm wide and 10 cm long, over a period of five days, showed that about 60 percent of the Urea-N was volatilized. During the same period the N loss from 15-15-15 and 13-52-0 was less than 5 percent.

Problems related to acidification of Alfisols

The relatively high-base-status Alfisols could be acidified to a condition detrimental to crop growth under continuous cultivation with moderate-to-high rate of chemical fertilization, particularly with acidifying fertilizers such as ammonium sulfate. An experimental area of approximately one hectare covering the sandy, gravelly Ibadan series and the slightly more clayey Egbeda series, was under cultivation of cowpea and cassava for five years with relatively low rates of chemical fertilization.

The experiment started in 1976 under continuous maize (TZPB). The crop received 180 kg N as ammonium sulfate, 40 kg K as KCL and 30 kg of P as triple superphosphate each season. Two crops of maize were planted each year. Continued application of $(NH_4)_2SO_4$ resulted in rapid drop of soil pH after three years. (Table 53.)

Maize grain yield declined with time, particularly during the third year. (Table 54.) The range of grain yield from 20 sub-plots was also given to indicate the lack of uniformity of the one-hectare field.

Results from plant analysis showed that the rapid decline of yield was not only because of the increase in soil acidity but also because of magnesium deficiency resulting from continuous NH_4+ and K^+ applications. (Tables 55 and 56.) High Mn uptake (Table 55) may also affect the normal growth. The severely affected plants showed typical acidity injury in leaf and roots in early stages of growth. The leaves of the moderately affected plants showed acute magnesium deficiency symptoms.

Table 53. Change in soil pH (0-15 cm) due to ammonium sulfate application. (Soil sample taken in April each year before fertilization.)

Year	Range	Mean
1976	5.8-6.8	6.3
1977	5.1-5.8	5.4
1978	3.8-4.9	4.2

Table 54. Maize grain yield (t/ha) as affected by high rate of N application as $(NH_4)_2SO_4$.

	1st Season		2nd Season		Total
Year	Range	Mean	Range	Mean	Mean
1976	1.88-5.37	3.73	3.06-5.79	4.70	8.43
1977	2.40-5.37	4.07	0.81-3.34	2.15	6.22
1978	0.51-3.07	1.72	0-2.76	1.37	3.09

Table 55. Chemical compositions of maize leaf sampled from plots with varying degree of acidification.

Leaf symptoms	N	P	K	Ca	Mg	Mn
	.............%				....	ppm
Severely affected	3.03	0.32	3.42	0.09	0.05	1572
Moderately affected	3.60	0.32	3.54	0.32	0.07	1623
Normal	3.05	0.31	3.00	0.45	0.20	343

Table 56. Chemical properties of the soil (Ibadan series) under secondary forest and under cultivation with $(NH_4)_2SO_4$ application.

Soil	pH	Exchange cations, me/100 g.			
(0-15 cm)	H_2O	Ca	Mg	K	(Al + H)

Five-year cowpea and cassava with low rates of fertilizer applications followed by three years of maize with 180 kg N (Am. sulfate), 40 kg K (KCl) and 30 kg P (TSP) per season.

A comparison between the cultivated plots and the soil under secondary forest showed that soil pH and exchangeable Mg reached very low levels because of a heavy rate of ammonium sulfate application. (Table 56.)

The rapid losses of exchangeable Mg and Ca were anticipated. Ion exchange studies showed that the exchange complex of kaolinitic Alfisols and Ultisols have high selectivity to K^+ ions over Mg^{++} and Ca^{++} ions. Continuous applications of $(NH_4)_2SO_4$ and KC1 fertilizers would therefore result in displacement of Mg^{++} and Ca^{++} from the exchange sites. Moreover, other factors such as loss of surface soil and organic matter due to soil erosion, decrease in CEC due to lowering of soil pH, and crop removal also contribute to the decline of available Mg and Ca in the soil.

Sulfur status of selected soils

Earlier investigations have shown that sulfur fertility management appears to be a problem for certain soils in the region, particularly those from the savanna region. For comparative purposes and also for better understanding of the factors affecting the sulfur sorption capacity of tropical soils, the sulfur sorption isotherms were determined for a selected number of benchmark profiles from the savanna and humid areas which were derived from contrasting parent materials. Figure 20 illustrates the sulfur sorption isotherms of two Alfisol profiles (Mokwa grassland from the savanna and Alagba — NIFOR from the humid forest zones) and one Ultisol profile (Onne from the humid forest zone) from Nigeria, all derived from sandy sedimentary parent material. There is no distinct relationship between climate under which the soils were developed and their sulfur sorption capacity. The sulfur sorption capacity of these soils and others studied appeared to be more related to soil texture, active Fe and Al content and soil pH. Generally soils developed from volcanic parent materials have higher sulfur sorption capacities. The presence of high concentrations of phosphorus was also shown to reduce the sulfur sorption capacity of the soil.

Fe toxicity in rice

To study the cause and remedy of Fe toxicity in rice under flooded conditions, a dark grey, hydromorphic soil (Aeric Tropaqualf, Adio series) from IITA's site and a reddish, well drained upland soil (Ustoxic Paleustult, Nkpologu series) from eastern Nigeria were flooded in pots (8 kg soil) for two weeks prior to transplanting. Two rice cultivars, Vijaya (susceptible) and Gissi 27 (tolerant) were used.

The following treatments were included: $CaCO_3$, TVA-slag (Ca-silicate), straw ash, ground straw, and check. All

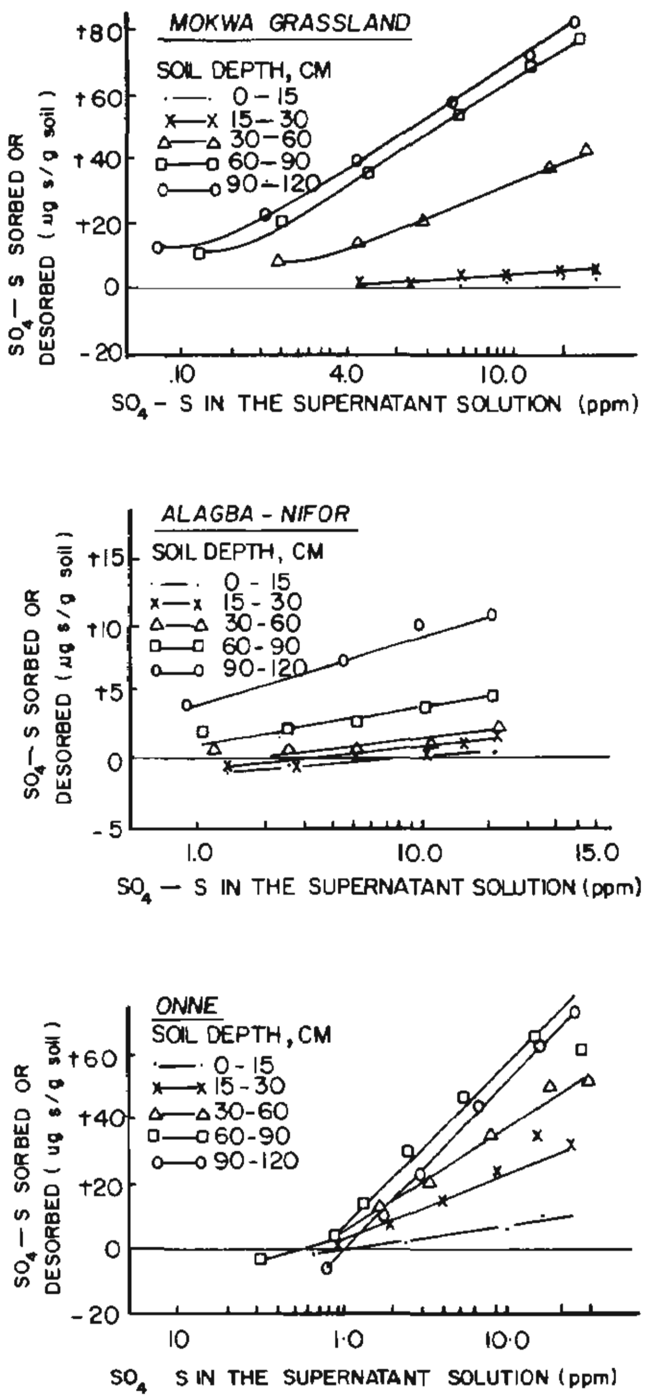


Fig. 20. Sulfate sorption isotherms of Alfisols and Ultisols from Nigeria, developed from sedimentary parent material.

pots received uniform and adequate N, P, K, S and Zn applications.

Good plant growth was obtained in the hydromorphic soil (Adio) with only slight orange-colored symptoms observed on Vijaya. On the other hand, both cultivars showed severe orange-colored symptoms in the flooded upland soils having a relatively high total free Fe_2O_3 content. Gissi 27 turned orange less than Vijaya in the flooded Nkpologu soil and showed appreciable recovery during the later stage of growth. Lime and Ca-silicate (TVA-Slag) treatments at a rate of 1000 mg/kg soil gave no beneficial effects on Vijaya grown in the Nkpologu soil; but the effects were much better on Gissi 27. In general, ash treatment gave the highest dry matter yield on both soils for both cultivars.

Plant tissue analysis indicated that considerable differences existed between the two cultivars with respect to Fe and Mn concentrations in plant. On both cultivars the concentration of Mn was below the reported critical toxic level, whereas the concentration of Fe in leaf in all cases exceeded 300 ppm. There was no clear relationship between the symptoms of turning orange and the Fe and Mn contents in the plant, suggesting that the critical level of these minerals may differ considerably among cultivars with different degrees of tolerance. There was no significant relationship between the degree of leaf orange coloration and the mineral nutrient content in plant tissue. Yield of both cultivars growing in the hydromorphic soil from IITA was consistently 30-50 percent higher than that growing in the flooded upland Ultisol from eastern Nigeria, although both soils received adequate fertilization. The difference in growth is apparently due to the higher soluble Fe concentration in the flooded Ultisol (Nkpologu soil) as shown in Table 57.

Table 57. Concentration of Fe and Mn (ppm) in soil solution measured at 40 days after flooding. (Soil solution collected at bottom of the pot.)

	Paleustult (Nkpologu)		Tropaqualf (Adio)	
Treatment	Fe	Mn*	Fe	Mn
Check	197	7	75	58
$CaCO_3$	115	3	55	37
Ash	178	5	53	37

**The Nkpologu soil derived from sandstone contains very low level of free Mn oxides.*

Results from this experiment also confirm that Fe (or Mn) toxicity of rice growing on hydromorphic valley bottom land is mainly caused by high levels of soluble Fe and Mn ions supplied by interflow of seepage water from upper slopes rather than from the reduction of Fe or Mn oxides *in situ*.

Evaluation on rock phosphate sources

In a greenhouse experiment, the relative effectiveness of two African rock phosphates (Morocco rock, MR, and Togo rock, TR) was compared with the more reactive North Carolina rock (NCR) and with triple superphosphate (TSP) using two strongly acidic Ultisols from Nsukka (Ustoxic paleustult) and Onne (Typic paleudult) having initial pH (H_2O) of 4.7 and 4.3, respectively. The effect of liming on rock P availability was examined.

Results showed that liming soils to pH near 5.5 depressed P uptake by maize from rock P sources but increased P uptake from TSP source. Without liming, the relative effectiveness of the 4 P sources was in the order of NCR>TSP>>MR>TR; with liming, the sequence became: TSP>NCR>>MR>TR. The two African rock P samples are poor sources of P for direct application under both acid and limed conditions.

Soil management

Agricultural hydrology and soil physics

(Soil and water conservation and land development)

On-going projects on the physics of soil erosion, rooting characteristics as affected by soil physical conditions, effects of temperature stress in the seedling stage on maize grain yield, plant-water relations of rice to develop criteria for screening varieties against drought tolerance, comparative studies of tillage systems for upland crops and for rice, and actual and potential evapotranspiration of root crops were continued. These research projects have the long-term goals of delineating soil physical problems to crop production in the humid tropics, and of developing cultural practices to solve these problems.

In addition, two new projects were initiated during 1978. A study of the effects of a range of methods of land development has been planned to investigate their effects on the hydrological balance (runoff rate and amount, evapotranspiration, and deep seepage), soil erosion, changes in soil physical properties, and on crop production. This study is being conducted on a watershed basis. Another study planned is the investigation on soil erodibility. Erodibility on some 20 major soils of Nigeria will be investigated by a rainfall simulator, and then related to soil properties (organic matter, texture, structure, and permeability). Estimates of soil erodibility obtained from soil characteristics will be compared with experimental data obtained on field run-off plots.

A brief summary of the results of on-going experiments follows.

Soil Erosion

Runoff per unit area generally decreased with increase in slope length (Table 58), though total runoff increased with an increase in plot size. Considerable spatial variations in water runoff were also attributed to slope shape: convex, concave or complex.

Soil loss, however, did not follow any definite trend in relation to slope length. Long slopes did not necessarily lose more soil compared with short slopes. (Table 59.)

Slope shape remaining the same, soil loss increased exponentially with increase in slope steepness for a given slope length. This type of information is necessary for designing contour lengths and graded channel terraces. These results indicate that within-terrace soil erosion is affected more by soil characteristics and its management rather than by contour length. These observations support the previously reported conclusion that the most effective means of controlling soil erosion may be through soil management.

Soil erodibility by sprinkling infiltrometer. The results of a field investigation on determining soil erodibility (K) by using a sprinkling infiltrometer were compared with the estimated K from soil physical properties. (Table 60.) K factor estimated from Wischmeier's nomograph compares favorably with the results obtained from field runoff plots. However, results obtained from one or two simulated storms give K factor 2 to 15 times higher than the actual values. These results have important practical implications as realistic values of soil erodibility can only be obtained by field measurements. Investigations with rainfall simulator, however, are important to assess relative soil detachability and relate it to routinely determined soil physical and chemical properties.

Table 58. Effect of slope length on water runoff (mm p.a.) 1978. (Plot width is 4 m.)

Slope	Slope length (m)					
%	5	10	12.5	15	20	37.5
1	187.9	245.3	-	188.2	96.4	-
5	578.5	288.8	-	231.7	165.7	-
10	508.0	302.7	247.6	189.9	160.3	95.7
15	403.3	265.7	272.1	205.9	164.8	86.4

Table 59. Effect of slope length on soil loss (t/ha p.a.), 1978.

Slope	Slope length (m)					
%	5	10	12.5	15	20	37.5
1	4.5	2.8	-	6.5	2.2	-
5	143.4	94.5	-	127.4	52.0	-
10	219.1	229.6	318.8	235.8	163.5	217.4
15	190.7	212.4	120.6	288.8	306.0	127.4

Table 60. Comparison of soil erodibility determined by sprinkling infiltrometer with that estimated from soil physical properties.

		Soil erodibility (K)		
Plot	Slope %	EI_{30}	AI_m	Soil physical properties
1	1	0.10	0.20	0.04
2	1	0.31	0.87	0.10
3	1	0.04	0.11	0.08
4	1	0.02	0.06	0.06
5	1	0.05	0.14	0.04
6	5	0.23	0.58	0.04
7	5	0.13	0.40	0.06
8	5	0.07	0.20	0.10
9	5	0.16	0.48	0.09
10	5	0.08	0.22	0.10

Soil erodibility using laboratory rainfall simulator. The laboratory rainfall simulator developed in collaboration with the University of Ghent and FAO can produce rainfall intensities ranging from 80 to 160 mm hr^{-1}, and a D_{50} of 3.2 to 4.3mm. This simulator was used to investigate soil detachability of Egbeda and Ibadan series. Runoff and soil loss of Egbeda and Ibadan series at different times after initiating the test are shown in Table 61. Structurally unstable Ibadan soil lost 5 times more soil by splash than Egbeda soil series, though differences in water runoff were only 30 percent. This simulator is therefore a useful tool to obtain relative differences in soil detachability and to investigate the effects of management systems (such as mulching, aggregate size, or addition of conditioner).

Tillage systems

After 19 consecutive crops of maize on permanent tillage plots established since 1971 on an Alfisol at IITA, maize

Table 61. Comparison of detachability of surface soils of Egbeda and Ibadan series.

Time (min)	Egbeda				Ibadan			
	Runoff		Soil loss		Runoff		Soil loss	
	I	II	I	II	I	II	I	II
	Percent of total							
5	3.9	0	6.2	0	4.1	2.8	4.7	3.0
10	11.0	0	16.3	0	12.0	5.5	17.2	3.4
15	19.8	0	31.1	0	20.3	9.8	25.6	5.1
20	29.1	0	41.0	0	28.2	15.6	32.0	11.4
25	38.7	0	50.0	0	36.4	22.5	38.2	27.9
30	48.2	0	59.3	0	44.6	38.4	44.1	39.7
35	57.2	0	66.4	0	53.7	42.2	52.1	49.5
40	65.8	0	72.5	0	63.2	54.8	61.6	61.4
45	74.2	0	78.3	0	72.6	69.2	70.8	76.4
50	82.1	0	83.2	0	81.9	84.4	78.4	86.7
55	90.6	0	89.3	0	91.0	100.0	87.2	100.0
60	100.0	0	100.0	0	100.0	-	100.0	-
Total in 60 minutes	9.9 liter	16.8 g			12.1 liter	4.3 liter	79.3 g	1.98

I Bare.
II Mulched.

grain yield in the first season was not affected by tillage treatments. However, maize grain yield under different levels of N application was more with no-tillage than with conventional plowing. (Fig. 21.) Significant differences in grain yield at low levels of N application, in favor of no-tillage, may be attributed to better soil physical and chemical properties in no-tillage than in plowed plots. The accelerated soil erosion over the past nine years resulted in a deterioration of soil quality with conventional plowing. Observations were made on runoff and erosion, soil bulk density, penetrometer resistance, aggregate analyses, pF curves, hydraulic conductivity, root distribution, earthworm activity and leaf area index. Comparison of soil physical properties under tillage systems as depicted in Table 62 shows the beneficial effects of the no-tillage system.

Table 62. Soil physical properties (0-10 cm) as affected by tillage methods.

Soil characteristics	No-tillage	Conventional tillage
Moisture retention at 0.1 bar (%)	22.4	19.6
Bulk density (gcm^{-3})	1.24	1.46
Hydraulic conductivity ($cm\ hr^{-1}$)	1.42	8.4
Penetrometer resistance ($kg\ m^{-2}$)	1.0	2.1
*Runoff (%)	3	35
*Soil loss (kg/ha)	14	837

**Runoff and soil loss from a storm of 53 mm received on 24th September, 1978.*

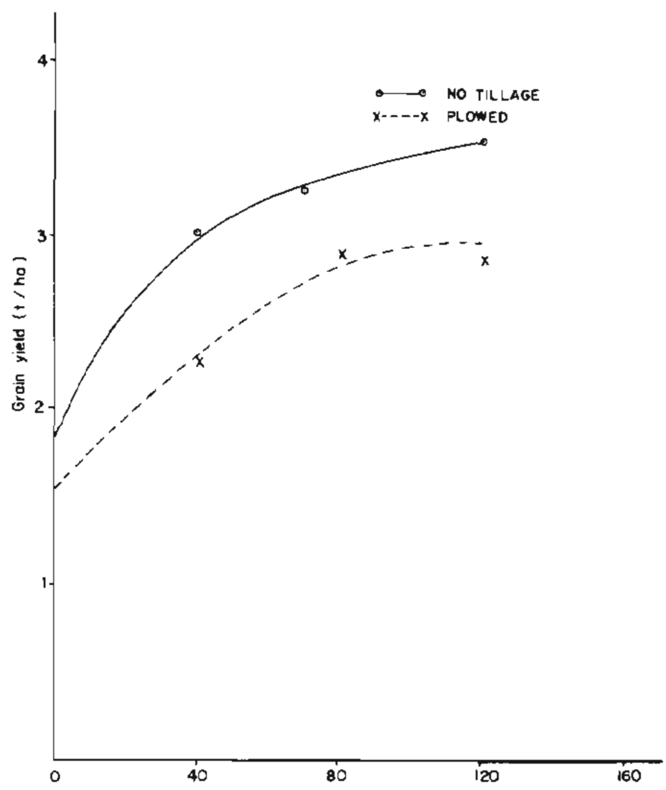


Fig. 21. Maize grain yield under different levels of N application and tillage systems.

The effect of tillage systems was also investigated for lowland rice. There were no significant differences in grain yield in no-tillage and conventionally tilled treatments, although subsequent crops showed slightly lower yield in no-tillage plots and the crop exhibited some nutrient deficiency symptoms. (Table 63.) Even though equivalent rice yield is obtained with the no-tillage system, there is a considerable saving in energy input and time required for land preparation. This implies that rice yield per unit input was more with no-tillage than with conventional plowing. Since continuous submergence is a control measure for some weeds, slashing the weeds at

Table 63. Effects of tillage system, nitrogen level, and moisture regime on grain yield of rice (kg/ha).

Nitrogen rate kg/ha	Grain yield: Saturation	Continuous flooding
0	3,910	4,910
50	4,860	6,010
100	6,030	6,350
150	6,890	7,340
F test for tillage	n.s.	
F test for N	33.65**	
F test for moisture	33.43**	
S.E.±	685	
C.V. (%)	11.8	

Rice grain yield with no-tillage system was not significantly different than with conventional plowing.

transplanting followed by continued submergence may be a feasible cultural system for rice production.

Rice grain yield with no-tillage system was not significantly different than with conventional plowing. Tillage studies on crop growth were also conducted on an Ultisol in eastern Nigeria. Initial results with maize at a high level of liming indicated that it may be necessary to incorporate lime in the soil for better root growth. (Table 64.) However, because of high humidity caused by frequent rains at harvest, dry maize may not be a desirable crop for this region. Cassava tuber yields, without liming and fertilizer, were equivalent with the two tillage systems. Yam, cassava, and rice may be more appropriate crops for this ecosystem than maize or cowpea.

Table 64. Maize grain yield (kg/ha) under two tillage systems for an acidic Ultisol at Onne.

Cropping Sequence	Conventional Tillage: Non-Adjusted†	Conventional Tillage: Adjusted	No-Tillage: Non-Adjusted	No-Tillage: Adjusted
Maize-maize	2683	4054	3966	5105
Maize-cowpea	2665	4485	3809	5259
Maize-pigeon pea	2933	4679	3984	5362
Maize + cowpea	2141	3293	3398	4534
Mean	2605	4128	3789	5065

	F Test: Non-Adjusted	F Test: Adjusted
Tillage	13.7	20.1*
Cropping sequence	4.9*	8.6**
Tillage × cropping sequence	0.16	0.58

†Adjusted to one ear per plant.

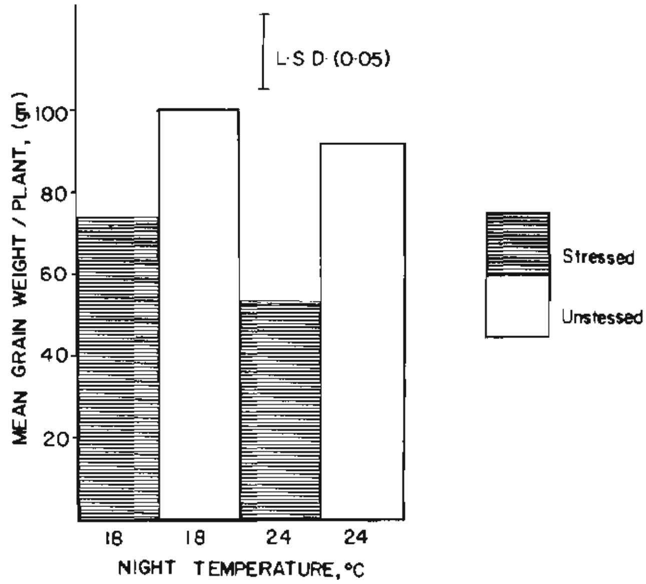


Fig. 22. The grain yield of pioneer × 306B maize cultivar as affected by moisture stress and a night temperature range 18-24°C, both imposed at the floral initiation phase.

Screening rice for drought tolerance

Greenhouse, lysimetric, and field investigations of some 20 rice varieties have indicated that leaf-water potential is related to rooting depth, root-mass distribution in the profile, and with grain yield. Determination of leaf-water potential, therefore, can be used as a criterion for routinely screening rice varieties against drought stress.

Temperature stress/maize yield

Maize stressed in the seedling stage and transplanted in the field under optimum conditions produced less yield than unstressed maize. Similar is the effect of high night temperature at flowering stage on maize grain yield. (Fig. 22.) This implies that seedlings grown on ridges, with periodical supra-optimal soil temperature regime, may suffer considerable yield losses. Screening maize cultivars for tolerance to high ambient and soil temperature may help alleviate this environmental hazard in the tropics.

Energy Management-Crop Engineering

Particular emphasis is paid in energy management to the resolution of three prime physical constraints to productivity:

(1) Energy. The drudgery of traditional farming.
(2) Time. The limitation of the extent of farming per season.
(3) Logistics. Transport and handling of inputs and produce.

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

Auto-feed "punch" planter. Priority was given to redesigning the "jab" planter into a more simplified and lower-cost auto-feed "punch" planter. This hand-held tool plants maize, cowpea, soybean, sorghum, etc., through a dessicated mulch and into untilled soil. The slide contains a hole dimensioned to fit the size and quantity of seed required per hill; it meters the seed out of the hopper and feeds it through the funnel and into the jaw at the bottom. This jaw opens after the jaw point reaches the depth to deposit the seed.

This punch planter is suitable for seeding into lands newly cleared from bush, and containing stumps, stones and similar impediments to a rolling or rotary tool. It is thus best suited to a small farmer's needs on one or two hectares of land, or for filling in odd vacant holes of a larger field planted with the rotary-injection-planter.

Rotary injection planter (RIP). A rolling or rotary form of the punch or injection planter comprises a series of five or six jaws around the periphery of a wheel and into which the metered seed is dropped from a central hopper.

The action of rolling the planter along the surface of the field inserts the point of the jaw through the mulch and into the soil where the jaw is automatically opened by the closing lever to deposit the seed at a precise depth and in-row spacing. In the standard design an in-row spacing of 25 cm has been provided, and alternative metering rollers are available for maize, cowpea, soybean, sorghum and other grains.

Rate of planting is increased from the 17-24 hr/ha with the punch planter (40,000 hills/ha) to 8-12 hr/ha with the RIP. Also the RIP involves less drudgery and need for concentration. The RIP's cost, however, is likely to be four times that for the hand-held auto-feed punch planter.

Evaluation of the rotary injection planter. Evaluation of the RIP over two seasons' operation on a farmer's field at Fashola-Oyo in the semi-savanna area of southwestern Nigeria provided an opportunity for comparing the no-till system of farming with the traditional manual method. Table 65 indicates the reduction in time and thereby the corresponding increase in productivity achievable using hand tools with a no-till farming system.

4-row rotary injection planter. The success of the RIP led to development of a tool for planting upland rice at the considerably higher stands desired (about 160,000 hills/ha). The no-till method ha in earlier trials proved promising as a low-energy farming system for rice, particularly for upland rice. The major problem was planting the high population of hills required per hectare.

A 4-row model of the RIP was developed which when drawn over the herbicide-dessicated stubble and weeds of the field injected the seed through the mulch and into contact with the soil. In the trial, covering and compaction thereafter did not prove advisable due to the very high moisture content of most rice soils. It was found preferable to leave the seed in the depression but in contact with the soil so that a subsequent shower of rain would lightly cover it.

Table 65. Comparison of manpower requirements for no-till and conventional farming systems at Fashola, southwestern Nigeria, using only hand tools during 1978.

Field operations performed	First-season man-hrs/ha Conv.	First-season No-till	Second season man-hrs/ha Conv.	Second season No-till
A. FIELD PREPARATION:				
a) Burning	4	4	-	-
b) Clearing/slashing	132	-	76	-
c) Manual tillage-ridging	127	-	85	-
d) CDA spray—contact herbicide		8		6
B. SEEDING MAIZE AND COWPEA:				
a) Manual planting (low population)	35		35	
b) Planting—RIP (rotary injection planter) 25 × 75 = 53,000/ha		13*		9
C. PEST CONTROL:				
a) Manual weeding—once	190		150	
b) CDA spray—pre-emerge herbicide		9		5
c) CDA spray—insecticide, cowpea × 3		2		2
D. FERTILIZER APPLICATION:				
a) Banding by hand along rows	25		25	
b) Broadcasting—using a hand-cranked broadcast machine		3		3
Total	513	39	371	25
Yields maize/cowpea (kg/ha)	600/500	1773/2020	500/400	1112/1870

Note: Two additional men were used to lay ropes and line up the planting rows during the first season. The line of stubble provides ample lining for the second and subsequent seasons' planting.

The rate of planting (seeding) 160,000 hills/ha (25 cm × 25 cm) varied from 8 to 12 man-hours, depending upon the moisture content of the soil. In wet soils requiring frequent cleaning of spouts the rate went up to 15 and 20 man-hours/ha, but still considerably less than manual seeding which requires around 300 man-hours/ha. (Table 66.)

Development of the Chief range for the intermediate farmer. Field performance at the farmer level (Tables 65 and 66) indicated the extent of increase in productivity achievable by the small farmer (4-5 ha) without recourse to conventional mechanization or tractorization. For the intermediate farmer working up to 15-20 ha, each season it is necessary to take his weight off his feet to enable him to sit while farming his land. A practical prime mover for the purpose so far being a 5-h.p. gasoline engine (as for small motorcycles and pumps), a small 5-h.p. tractor (with both 2-wheel and 4-wheel capability) has been developed with a comprehensive range of implements for this level of farming. Now with two years and a total of about 1,000 hours of almost daily use behind it, the Chief has proven itself remarkably strong, easy to manufacture and maintain, and comfortable to handle in the field. The Chief has two speed ranges (and reverse): one for field work and the other for road transport duties. It is equipped with necessary implements for use as:

A. An operator-seated tractor for uplands:
   (1) Road transport with its 500-kg capacity trailer.
   (2) CDA herbicide spraying 4 m wide.
   (3) No-till planting — two rows simultaneously.
   (4) Simultaneous spraying and planting 2 m wide.

B. An operator-walk-behind tractor for rough, difficult, boggy fields.
   (1) Rotary tillage and ridging — 1 m wide.
   (2) Rotary brush-slashing 0.6 m wide.
   (3) Plowing in rice paddies.

During 1978 prospective manufacturers received copies of the drawings for the Chief. (See IITA Annual Report, 1977.) Some already have prototypes made and are testing them. Manufacturers are arranging to supply the tractor in a knocked-down form for assembly locally, and also in materials-kits including the appropriate jigs and fixtures for local fabrication of the components from raw material.

Cassava harvesting

The Ransomes potato harvester was selected after much study as perhaps the most suitable for development into a harvester for cassava in large-scale mechanized plantations. During two years of development the harvester has been simplified and strengthened to cope with the lifting of a 1.5 m ridge.

Substantial roots are lifted by the blade onto the elevator which shakes out the soil while supporting the weight of the crop on the reinforced center support now incorporated. Twin, rubber-covered elevator rods replace the earlier full-length links which sagged and broke under the load of a heavy ridge.

Table 66. Man-hour (and tractor-hour) inputs for growing a crop of upland rice compared for "zero tillage" and minimum-tillage systems.

	Minimum tillage		Zero tillage	
Field operations performed	Tractor hrs/ha	Man hrs/ha	Tractor hrs/ha	Man hrs/ha
A. TILLAGE/PRE-SOWING:				
(a) Rotary tillage (2-wheeled tractor)	25	25		
(b) CDA spraying of herbicide			-	9
B. SEEDING:				
(a) Broadcasting pre-germinated seed	-	4	-	
(b) Direct planting—4-row RIP				12
C. PEST CONTROL:				
(a) CDA spraying of post-emergence herbicide	-	9	-	
(b) CDA spraying of pre-emergence herbicide				9
(c) CDA insecticide spraying		-		-
D. FERTILIZER APPLICATION:				
Broadcasting fertilizer in three applications	-	4	-	4
Totals tractor/man-hrs/ha.	25	42	nil	34
Yields (kg/ha)	6634		6598	

Note: (a) Cultivar used was BG 90-2.
(b) Total man-hours bear comparison with the typical 700 to 900 man-hr requirement of traditional manual rice farming.
(c) Lodging reduced the yield of the tilled-broadcast crop slightly whereas the direct planted crop stood erect despite heavy winds.

This cassava lifter is developed for the small-scale cassava farmer. The spring-loaded jaws grip the stem as the fork of the lever is eased around it and tighten with the pressure of lifting.

During trials, broken roots were less than 2 percent; and the only skinned roots were the very large ones — usually less than 3 percent! The harvester has worked equally satisfactorily with cassava planted either on ridges or on the flat.

Cassava lifter for the small farmer. The development of a simple hand lever to gently ease the cassava root out of the soil can enable at least a five-told increase in productivity as experience and skill with the tool are developed. With this tool the effort of lifting is reduced to one-third that usually required and further eliminates the need for maintaining a tight grip on the stem. Spring-loaded jaws grip the stem as the fork of the lever eases around it, and these jaws tighten with the pressure of lifting. The stems need to be cut about 50 cm above the soil surface before harvesting.

Postharvest engineering

Much of the year's activities were concentrated on the procurement, installation and evaluation of postharvest processing equipment. (Threshers, mills etc.)

The main research effort was concentrated in studies on the performance of yams and paddy under freely ventilated storage conditions. The yams steadily dehydrated, losing some 30 percent weight in this way over eight months. The dehydration arrested most of the fungal development normally encountered in traditional storage barns. Sprouting was, however, not influenced by the higher degree of ventilation and some 70 percent of all tubers had sprouted after four months.

Paddy rice proved to dry rapidly under freely ventilated conditions and would come into equilibrium with atmospheric conditions in about 8-10 days. The stacking of panicles and/or stems to allow optimal exposure at minimal cost is being further examined.

The investigations on insecticide performance on maize cobs in cribs were further pursued. Very high levels of basic infestation were evident in 1978 at the site of the trials. In addition, experiments at varying intervals of spraying meant that considerable cross infestation occurred. It indicated that pirimiphosmethyl as an emulsifiable concentration, sprayed periodically on the outside of cribs remained effective for a remarkably short period. It showed that under conditions of high infestation, a mortality of more than 90 percent of the insects can be expected a day or two after application, but after four weeks, the mortality rate would be no more than 30 percent due to reinfestation, and obvious deterioration of the chemical. However, if all cribs in a particular location are treated simultaneously, with most adults killed, a slower buildup results and the spray interval of one month, as previously suggested, appears to be optimal.

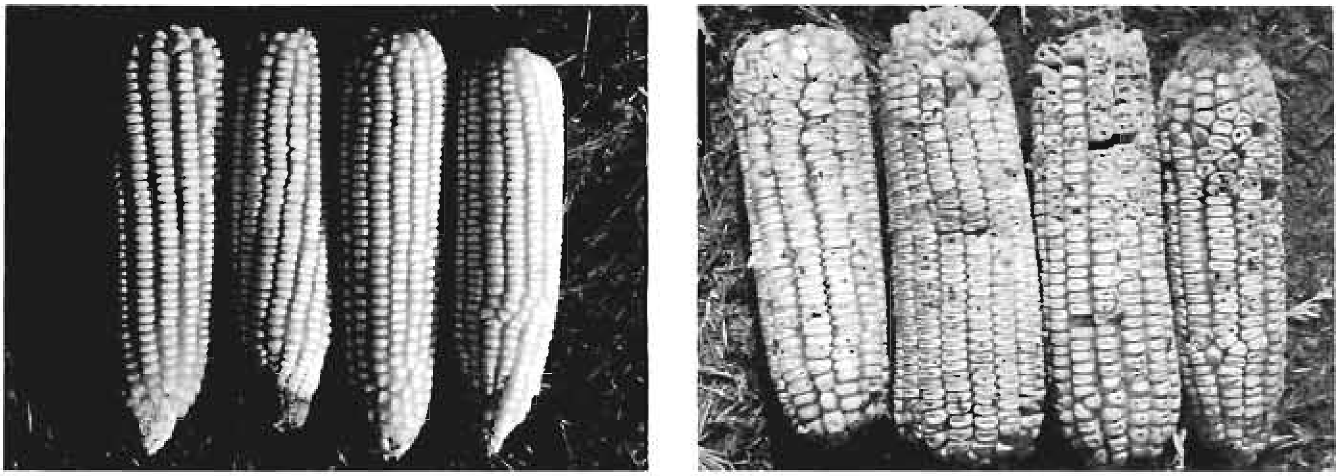
Insects during maize storage

This project was initiated in cooperation with the Tropical Products Institute (U.K.), with the object of gaining detailed information on the buildup of insect pests in maize storage cribs. In particular, the study is to investigate the composition and behavior of infesting populations and to try to establish what are the limiting factors, biotic and physical, controlling the rate of pest buildup.

The infesting populations have proved to be larger and more complex than are generally recorded in the literature. About 40 species of Coleoptera and six species of Lepidoptera have been identified from cribs at IITA, while a further 20 species of Coleoptera await determination; although many of these species are not of economic importance, the list includes some 20 actual or potential pests. The dominant species are, predictably, *Sitophilus zeamais* and *Sitotroga cerealella*, the former being abundant throughout the storage season and the latter for only a short period.

In association with the pests, 10 species of Hymenopteran parasitoids and three predatory bugs, including Heteroptera and Anthocoridae, have been frequently recorded. Parasitism in the cribs seems to be generally negligible in the early stages of storage but becomes more significant later in the season, *Sitotroga* being particularly heavily attacked. There is an indication that *Cathartus quadricollis* (Col., Silvanidae) is being controlled to some extent at the field-to-store stage by a Eulophid. Large populations of mites and psocids have also been observed; the former are composed mainly of scavenging species, but an egg predator, *Blattisocius* sp., has commonly been found in association with *Sitotroga*. There is a marked succession in the occurrence of both pest species and their dependent parasites and predators.

Limited studies carried out to date suggest that preharvest infestation in the field may be very important to subsequent pest buildup in storage. More than 90 percent of cobs collected in field samples had been attacked by Lepidopteran larvae (mainly *Cryptophlebia*, *Eldana*, *Mussidia* and *Pyroderces*); such attack was often followed by severe moulding and the damage to the sheath and silks apparently facilitates the entry of Coleopteran pests. When cobs without visible grain damage were selected



Maize in storage is rapidly destroyed by insect pests. The freshly harvested maize on the left is virtually undamaged; that on the right, after three months in a storage crib, shows numerous insect emergence holes.

at harvest, they produced less than two pests per cob during a week's incubation, as against 12 per cob (plus an average of 3 parasitoids) for damaged ones.

Most of the adult insects apparently leave the cobs at the time of harvest or dehusking and so active migration to stores seems to contribute significantly to initiation of infestation. Cribs filled with material that had been fumigated at harvest were reinfested so rapidly that at the time of the first sampling, two weeks later, total numbers of insects were as high as in untreated cribs, although at the first, the species composition of the population was different.

Technology Evaluation

Continued emphasis was given in 1977 to the integrated evaluation of IITA research findings emerging from its activities, and studies of the diffusion of IITA-generated technology were initiated.

Evaluation of medium-duration maize cultivars. Seven on-farm trials were conducted in three locations to compare the performance in different environments of TZE, the new early-maturing, medium-duration maize cultivar developed at IITA. As a first-season crop, TZE has great potential for green maize sales to break the "hungry season" gap in nutritional and financial terms. Furthermore, when uncertain and short rains are a problem in the second season, medium-duration maize can reduce the risk of the second maize crop.

Trials results showed that: (1) Where the maize matured, it matured on time, and in all cases it matured earlier than existing cultivars (both local and improved) by a minimum of three weeks; (2) Poor stand development was experienced due to reasons being currently investigated; (3) The later the planting the poorer the performance; (4) A potential for green maize sales in the second season exists although the extent is being further investigated; (5) Where a recommended standard of crop and land management (Group Farm) was followed, maize yields compared favorably with experiment station results; (6) Widespread sole-cropped, second-season maize is grown in Oyo State. More trials are needed to assess the performance of different maize cultivars in different environments in both the first and second seasons.

"Unit" farms. In 1977, knowledge of the management of valley bottoms and associated uplands (toposequences) had reached a stage where an attempt could be made to integrate and synthesize research results into practical farming systems. Five unit farms were established, with each farm being on a similar toposequence. The five unit farms corresponded to five levels of technology. (IITA Annual Report, 1977.) A unit farm has defined resource constraints and is developed and operated as a whole farm unit by an employed farmer under the direction and supervision of one or more agricultural investigators. The farming systems are based upon new technologies and organizational patterns which are considered to be potentially more productive than systems in current use.

Table 67 illustrates by season the most suitable location along the toposequence, the major crops included in the cropping systems, and crop combinations and sequences included in the farm plans during the first and second seasons of 1977 and 1978.

The farm labor available on each farm consists of a farmer and one assistant. Management decisions (e.g., cropping mixtures, sequences, input levels, planting time, etc.) are made by collaborating scientists. A field assistant is assigned to monitor and supervise all farm activities. The average yields for some major crops included in the cropping systems of the five unit farms are presented in Table 68.

The Improved TZPB cultivar performs significantly better than the local cultivar in the first season even when fertilizer is not applied, although with the use of fertilizer even greater yields are achieved. However, the medium-duration improved cultivar (TZE) does not yield a measurable output unless fertilizer is included in the production package. Another important result is that with improved maize cultivars, there is not a significant difference between the yield of sole-cropped maize and maize interplanted with cassava. For rice, the yield of the semi-dwarf BG 90-2 is substantially greater than the local cultivar and the response to fertilizer quite dramatic.

The profitability of all farms has been low in each of the two years of operation. This is largely due to the excessive use of hired labor during competing labor demands by different crops. Alternative crop combinations and more efficient general labor management are necessary to avoid this. The labor requirement for rice production has been extremely high, resulting in low financial returns. A major proportion of labor use went into bird scaring which is a major problem in using small areas of hydromorphic valley bottoms for rice production.

The total area under crop can be increased quite dramatically using improved hand implements and machinery. However, the improved equipment was used in association with a zero-till land management system involving high levels of chemical input. Because the optimum levels of fertilizer and herbicides are not yet well defined, total profitability of the high technology systems was reduced.

Weeds are a major problem at all levels of technology. Herbicides are expensive. In addition, their use must be supplemented by some hand weeding. Both cowpea and cassava yields have been unsatisfactory because of herbicide damage.

Hydromorphic soils. The objectives of this study were to examine crop and land use systems existing on hydromorphic soils and associated uplands, to identify production constraints and to identify priority research areas. The findings reported here are from the Ede area in the Oshun River Basin of southwestern Nigeria, one of the three locations currently being studied.

All farmers in the area studied had diversified cropping systems but for those operating on the uplands, cassava and yam were the most important crops; whereas, in the lowlands, yam and okro were the two most important crops. The proportion of farmers growing different crops in the lowland and on the upland is shown in Table 69. Crops are grown for both sale and consumption; there was not a consensus on which was most profitable. The most important crop sold, however, is okro followed by yam and cassava. Yam and cassava followed by maize were the crops mainly produced for consumption purposes.

The most important feature of the cropping pattern is the distribution of the same dryland food crops throughout the toposequence. The cropping sequence which usually extends over 2-3 years begins with early maize and ends with cassava which is stored in the ground unweeded. Most crops grown in the valley bottoms and on the lower and upper slopes are planted on low heaps with mulch between the rows. Farmers make heaps on the lowland largely to protect crops from water, whereas on the upland, the practice is connected more generally with achieving a better yield.

Table 67. Most suitable location along toposequence of major crops.

	Management Level				
	I	II	III	IV	V
Upper slopes					
1st Season	-	Maize/ cassava	-	-	Maize
2nd Season	-	Cassava	-	-	Maize
3rd Season	-	Maize/ Cowpea	-	-	Cassava
Transitional zone					
1st Season	-	Yam	-	-	-
2nd Season	-	Yam	-	-	-
1st/2nd Season	-	Plantain/ cocoyam	-	-	-
Valley Bottom					
1st Season	-	Rice	-	-	Rice
2nd Season	-	Rice	-	-	Rice
Dry Season	-	Vegetables	-	-	Not used

Table 69. Proportion (percent) of farmers planting crops on lowland and upland areas of an Ede catena, 1978.

	Lowland	Upland
Yam	100.0	100.0
Cassava	100.0	94.1
Okro	100.0	94.1
Early maize	73.9	100.0
Late maize	69.6	94.1
Plantain	91.3	64.1
Cocoyam	21.7	29.4
Melon	65.2	58.8
Pepper	86.9	88.2
Tomato	69.6	76.5
Gbagba	78.3	64.7
Beans	17.4	29.4
Sugarcane	17.4	-
Groundnut	4.3	11.8
	n = 23	n = 17

Table 68. Average maize and paddy yields (kg/ha), 1977-1978.

Management Level	1st Season Maize	Cultivar	2nd Season Maize	Cultivar	1st Season Rice	Cultivar
I	1280*	Local	530*	Local	905	Local
II	2080*	TZPB	Minute*	TZE	2035	BG90-2
III	2600*	TZPB	1090*	TZE	4015	BG90-2
IV	2420**	TZPB	1200**	TZE	3580	BG90-2
V	2650**	TZPB	1170**	TZE	3280	BG90-2

**Maize/Cassava*

***Maize, Sole crop*

Farmers felt that good weed control, followed by soil fertility, were the most important factors for achieving good yield. The lowlands are considered more difficult with heaping and weeding about one-third more difficult than on uplands. On both upland and lowland, the limiting factor to farm size is labor. Fertilizers are used in small quantities — primarily on yam and maize. However, less than 50 percent of the farmers had ever used fertilizer. None of the farmers had used pesticides and none reported any contact with extension personnel.

Although farmers argue that higher returns can be achieved from the lowland, their attention to risky upland farming reflects an effort to ensure basic food supplies. The persistent cropping of cassava, even on wet soils, suggests the continued significance of subsistence demands in farm decision making.

Other Activities

Virology Unit

Cassava mosaic disease (CMD)

Recent research at IITA has shown that a virus can be transmitted from CMD-infected plants by means of sap inoculation to *Nicotiana benthamiana*, causing severe systemic leaf crinkling and curling. From this host, the virus also proved to be readily sap-transmissible to certain other solanaceous test plants like *N. tabacum* "Samsun NN," and *N. glutinosa*. *N. clevelandii*, *N. occidentalis* and *Datura stramonium*. In spite of repeated attempts, virologists were unable to mechanically transmit the virus from experimental alternate hosts back to cassava.

It is likely that the isolated virus is the causative agent of CMD because a similar virus could be isolated from *Manihot glaziovii* plants around IITA showing typical symptoms of cassava mosaic. Furthermore, despite further efforts, the virus could not be isolated from cassava plants which were not showing typical CMD symptoms.

Also a common weed plant, *Fleurya aestuans* (Fam. Urticaceae), was identified as a possible alternate host of CMD. On two occasions a virus was successfully transmitted from virus infected plants to several *Nicotiana* species with identical symptoms as the virus isolated from cassava. No such virus could be isolated from a number of symptomless plants of this species collected randomly in cassava fields. Also, it has not been possible to transmit this virus back to *F. aestuans*, nor to *M. glaziovii* or cassava.

Although successful transmission back to cassava is necessary to prove that the virus isolated from different hosts is indeed the causal agent of CMD, the evidence so far suggests that the isolated virus might be the causal agent of CMD, because the virus could be isolated only from plants with well-defined symptoms, both in case of cassava and *F. aestuans*. But since this virus is likely to be restricted to phloem tissues, mechanical transmission may be possible only in certain test plants. Another explanation for the apparent inability to get the virus back to its original host may be that alternate host passage modifies the virus with respect to virulence properties because only a certain component is isolated which on its own cannot infect cassava.

Transmission experiments using the natural vector of CMD may provide the ultimate answer to the partly unsolved problem of the etiology of this disease. This investigation is hampered by difficulties encountered in finding whiteflies which could feed and survive on these experimental hosts. The major and most unexpected problem, however, has been that none of the whiteflies collected from cassava so far proved to transmit CMD, nor did the available whitefly cultures.

Scientists in East Africa succeeded in mechanically transmitting an agent from mosaic-diseased cassava to *N. clevelandii* and the virus was called cassava latent virus (CLV) because it could not be transmitted back to cassava. The symptoms on various test plants caused by the virus at IITA were identical to those described for CLV from East Africa. Also, the type of virus particles involved, being doublet particles, is additional evidence that the same or similar virus is involved in Nigeria.

A cassava selection made from a farmer's field which was free from CMD symptoms was further propagated and grown out for the second year; even then there were only minor CMD symptoms in a few plants. Apparently, this selection represents a genotype with a high level of natural resistance.

Viruses of maize

Maize streak virus (MSV) was purified from maize and an antiserum was then prepared. Also a streak virus was purified from *Panicum maximum*. In serological tests using the MSV-As, the *Panicum* isolate was found to be closely serologically related to the maize isolate. Also in transmission experiments, the *Panicum* isolate induced typical streak symptoms in maize.

Purification of streak virus from rice using the same purification procedure did not yield any detectable virus. Back transmission experiments from rice to maize using the maize streak virus vector, *Cicadulina triangula*, also proved negative, whereas transmission from maize or weed sources to rice always gave typical streak symptoms in rice, identical to those in naturally infected plants. *Brachiaria deflexa* streak in micro-precipitin tests reacted positively to the same titer with the maize streak virus antiserum as maize streak did. It also proved to be readily transmissible to maize and rice using *Cicadulina triangula*. IITA's MSV-resistant materials proved to be resistant to these wild grass isolates.

Progress on the etiology and identification of new virus diseases of maize consisted of the isolation, characterization and development of adequate resistance screening techniques for three virus diseases not earlier found or fully identified. They are maize dwarf mosaic virus (MDMV, reported on in 1977, but now identified as similar to strain A Johnson grass strain), a virus transmitted by *Peregrinus maidis* and a virus transmitted by *Cicadulina triangula*, which also transmits the streak virus in Nigeria.

Maize dwarf mosaic virus, until now only once isolated from maize at IITA, (IITA Annual Report, 1977) probably has no epidemic potential, because no other infected plants have yet been found. No transmission could be achieved with *Rhopalosiphum maidis*, an aphid species which is always abundantly present on maize and which is reported as a vector of this virus. Furthermore, no transmission could be achieved using *Myzus persicae*. MDMV, however, is an important virus disease of maize throughout the maize growing areas in the tropics and subtropics.

In resistance screening experiments it was found that IITA's improved maize populations contain only a few plants that are susceptible to the virus isolate under study, but a randomly collected local maize selection as well as IITA's maize streak resistance sources proved to be uniformly moderately susceptible to this virus.

The virus transmitted by *Peregrinus maidis* is yet to be properly identified. It is likely that a virus similar to the one described as causing hoja blanca (white leaf) of maize in Venezuela is involved because in Nigeria also, this virus occurs in *Rottboellia exaltata* and proves to be readily transmissible to and from this species, but not to rice, using *P. maidis* as the vector. A vector culture has been set up and preliminary resistance screening experiments have shown that IITA's streak resistance sources and some of IITA's improved maize populations are resistant to this virus.

The *Cicadulina triangula* transmitted virus was isolated from the *Cicadulina* culture used at IITA in the streak resistance screening program, after a sub-culture had been freed from the streak virus. The disease this culture transmits (chlorotic stunt) was known, but its etiology was not understood. Probably because of its continuous presence in the mass screening culture of *C. triangula*, resistance screening has taken place in the process of developing streak resistant maize at IITA. This could explain why streak resistance was found to be highly correlated with chlorotic stunt resistance.

Rice

After having been reported first from Kenya and later from Sierra Leone and Ivory Coast, rice yellow mottle virus has now been isolated and identified from rice at IITA. An antiserum was prepared to rice yellow mottle virus and a set of 11 cultivars found to be fairly resistant to RYMV in Sierra Leone were tested for resistance to the isolate. Most of these cultivars also proved to be quite resistant to the Nigerian type of this virus.

Virus diseases/legumes

From cowpea, two new aphid-transmitted viruses have been isolated of which at least one proved to be of importance in 1978. One virus obviously represents a so-called cucumovirus occurring in most cowpea growing areas of the world. Serology, for ultimate proof of the identity of the virus, was found to be difficult because no detectable level of antibodies was obtained from rabbits injected with purified virus preparations. A remote serological relationship was found to exist between this virus and a common strain of cucumber mosaic virus, which had earlier been reported from cowpeas in Nigeria.

***Virus causes CMV symptoms on test plant,* Nicotiana benthamiana.**

The second virus commonly found in cowpea, was also found to cause a serious die-back disease in lima bean. Its exact identity is still to be established; but in host range characters it is similar to cowpea aphid-borne mosaic virus.

Also from cowpea, a virus belonging to the so-called Carla-virus group (straight, rigid rods, 650 mm) was isolated by separation from the two other virus isolates which were identified and characterized as a cucumovirus (CMV) and a cowpea aphid-borne mosaic-like virus. It is assumed that this latent virus is of seed-borne nature. Separation was easy because both CMV and CABMV are aphid-transmitted and the latent virus is not. The latent virus was separated through *Phaseolus vulgaris* 'Beka' in which it induces a prominent leaf rugosity and yellowing. After purification, an antiserum was prepared to this virus. The virus did not react with an antiserum to cowpea mild mottle virus, belonging to the same group, which was described from Ghana.

Soybean at IITA and in areas in Nigeria where this crop is grown on a limited scale proved to be comparatively free from virus diseases. However, in one of the areas where soybean is grown (Plateau and Benue States), a virus disease was observed at low incidence in most farmers' fields. The virus isolated from those plants probably represents a virus of soybean not earlier described, for no evidence was obtained in serological and physio-chemical characterization studies (purification, electron-microscopy) that any virus known to infect soybean elsewhere is involved. The virus was found to represent a spherical particle (about 25 mm), sedimenting as two components and (like the earlier mentioned cucumovirus from cowpea) not yielding a detectable level of antibodies in a rabbit injected with purified preparations. The soybean variety "Malayan" proved to be highly susceptible to this virus.

Virus diseases/root and tuber crops

The identity of commonly occurring virus disease of *Dioscorea rotundata* (white yam) and *D. cayenensis* (yellow yam) was recently further elucidated by finding that the viruses involved are identical in terms of host range and both serologically related to or identical with virus reported from *D. cayenensis* in Ivory Coast in 1977. Its possible relationship to a similar virus from *D. floribunda*, *Dioscorea green banding virus*, in Puerto Rico, is yet to be established. The experimental host range of the yam virus, consisting of *N. benthamiana* only, could be extended with *N. clevelandii*. Purification attempts from *N. benthamiana* were yielding reasonable quantities of virus, and antiserum can be expected.

The aphid-transmitted component of sweet potato virus disease can, with difficulty, be mechanically transmitted to *N. benthamiana* in which it gains a fairly high concentration as concluded from infectiosity tests on *Ipomoea setosa* as well as from preliminary purification experiments yielding fair amounts of virus.

Comparing the virus serologically with the whitefly transmitted sweet potato mild mottle virus reported from East Africa would be an important step in explaining the relationship between the sweet potato virus disease in Nigeria and East Africa.

A new and economic screenhouse, with good temperature control not reliant on air-conditioning, has been developed. The design principles are presently being worked out for larger-scale screenhouses to be built in the near future at IITA and manufactured in a precut easily assembled version.

Genetic Resources Unit

Exploration within Africa and the collection of rice, food legume and root crop germplasm remained the chief objectives of the Genetic Resources Unit (GRU) in 1978. From 12 exploration missions in eight African countries, the plant explorers gathered 5,332 samples of germplasm. Other organizations donated a further 2,514 samples to IITA so that 7,846 new accessions were acquired during the year.

In keeping with arrangements made in 1978, the GRU collected 1,225 samples of germplasm in Africa for genetic resource centers in other parts of the world. (Especially ICRISAT, CIAT and ICARDA.) In return IITA expects to receive material collected by those centers in their own regions. By an earlier arrangement, collections of African rice are routinely exchanged with IRRI, IRAT and WARDA after they have been grown at IITA for seed increase and positive identification.

At the end of 1978, the GRU held a stock of 15,499 items of viable germplasm, and there were 5,879 more samples in transit to it from exploration missions and donors. (Tables 70 and 71 which exclude the holdings of *Abelmoschus*, *Zea* and *Sorghum*.)

These collections represent more than 60 crop species or their wild and weedy relatives. During the year 12,778 items of this germplasm were grown for maintenance or evaluation of IITA, and 4,820 samples of food legume germplasm were distributed to 294 scientists in 26 countries around the world. (Table 72.)

Table 70. Stocks of legume germplasm held by or in transit to the GRU in December, 1978.

	Stock at IITA	In transit	Totals
Food legumes:			
Vigna unguiculata	6928	1082	8010
Voandzeia subterranea	398	1873	2271
Sphenostylis stenocarpa	57	12	69
Phaseolus lunatus	1121	58	1179
Cajanus cajan	238	55	293
Glycine max	288	22	310
Psophocarpus tetragonolobus	27	-	27
13 other cultivated species	216	700	916
Food legumes total	9273	3802	13075
16 wild *Vigna* species	75	-	75
7 other wild legume species	31	30	61
Wild legumes total	106	30	136
Total—all legumes	9379	3832	13211

Table 71. Stocks of rice and root crop germplasm held by or in transit to the GRU in December, 1978.

	Stock at IITA	In transit	Totals
Rice:			
Oryza sativa	1628[1]	1160	2788
O. glaberrima	1015	155	1170
O. barthii	50	25	75
O. punctata	7	3	10
O. longistaminata	38	27	65
Collections not identified	231	144	375
Totals, rice	2969	1514	4483
Roots:			
Dioscorea spp. as clones			
rotundata	253		
cayenensis	32		
alata	223		
dumetorum	32		
bulbifera	14		
esculenta	4		
Cultivars not identified		76	
Wild species not identified	61		
Total, *Dioscorea*	619	76	695
Manihot esculenta	2290		2290

[1] Includes 509 non-African collections.

An agreement was made with the Indian National Bureau of Plant Genetic Resources to exchange cowpea germplasm. In 1978 the GRU sent 2,678 cowpea cultivars to India and hopes to receive about 2,000 Indian cultivars in return.

The GRU continued to receive strong support from the International Board for Plant Genetic Resources. The Board made a substantial grant toward the cost of a −20°C seed store of 88m³ volume which was delivered to IITA in 1978. The store will be commissioned in 1979 for

Table 72. Food legume germplasm distribution by the GRU in 1978.

Destination	Cowpea	Soybean	Pigeon pea	Lima bean	Winged bean	Others	Totals
11 African countries	28	12	6	6	37		89
Nigeria	50	17	4	41	23	38	173
Uganda	412						412
U.S.A.	415		4		7	11	437
India	2678		3	10	5	4	2700
Australia	39		2		2		43
Philippines	40		1		2	10	53
3 European countries	13	1	2	1	15	3	35
6 Countries in Oceania and West Indies	5		5	2	36	3	51
Scientists at IITA	503	73	32	36	92	91	827
Totals	4183	103	59	96	219	160	4820

the long-term preservation of African rice and cowpea germplasm.

Exploration and collection

All planned missions except those for Guinea and Cameroon were successfully concluded and all that remained to be done at the end of the year was to import the collections through Nigerian Plant Quarantine.

Cowpeas. Special efforts were made in 1978 to collect early cowpeas in Nigeria, Togo and Benin during July and August. Most of the 477 cultivars gathered will be photoinsensitive and of special interest to breeders. The exploration during 1978 confirmed that Nigeria is the center of genetic diversity of cowpeas and the African center of production, and more exploration in and near Nigeria is warranted. It seems likely that a comprehensive world collection of diversity in the crop will have fewer than 15,000 accessions. Most will have been gathered within three years.

Bambarra groundnut. In Africa as a whole, Bambarra groundnut may be the third most important food legume after *Arachis* and cowpea. It is widespread and genetically diverse, and its wild progenitor is present in West Africa.

Lima bean. Only 74 cultivars of Lima bean were collected and only 94 were donated to IITA (from Taiwan) in 1978, bringing the total germplasm of this crop to 1179 accessions. It appears that relatively little genetic diversity is available within Africa. Centers of production in Africa seem to be in a few well-defined, small regions such as around Kafanchan, Zonkwa and in the southeast within Nigeria.

During 1978 the GRU collected the following for other genetic resources centers:

For ICRISAT:
57 cultivars of *Cajanus cajan*
240 cultivars of *Arachis hypogaea*
20 cultivars of *Cicer arietium*
For ICARDA:
95 cultivars of *Vicia faba*
40 cultivars of *Lupinus termis*
22 cultivars of *Lens culinaris*
For CIAT:
238 cultivars of *Phaseolus* spp.

Rice. *O. glaberrima* is widespread throughout West Africa as a weed or minor crop. There is much evidence that the crop is declining in West Africa, mostly because it is displaced by *O. sativa*. There appears to be little genetic diversity (though this needs to be confirmed by evaluation) and what there is can probably be adequately preserved in a collection of a few thousand accessions. The GRU now has 1170 accessions.

In contrast to *O. glaberrima* diversity in African cultivars of *O. sativa* is impressive. For example, 581 samples were collected from various environments in the Gambia, and 376 came from Egypt. IITA now has 2,279 *sativa* collections from Africa.

Altogether 150 collections of wild rice species including *O. barthii*, *O. punctata* and *O. longistaminata* have been gathered.

Root crops. There are three main reasons why only 166 collections of root crop germplasm were made in 1978:

(1) There is relatively little genetic diversity in these vegetatively propagated crops.
(2) Vegetative material is bulky and difficult to handle.
(3) Collections gathered outside Nigeria must be grown and maintained in the country where they originated.

To overcome these problems the GRU can collect the seeds of yams and cassava, but not those of sweet potatoes or aroids. Within Nigeria arrangements have been made with state ministries of agriculture to collect bulk samples of the seed of each cultivated yam species in small, well-defined locations (a single village). By this means, instead of cloud cultivars, a mass sample of the genetic diversity in a known area is gathered. Seed from such samples can be stored, at least for the medium term, at IITA and the breeding value of the collection can be determined during evaluation. The same field sampling method is recommended for cassava.

Evaluation

Minimum descriptor lists have been determined for all the major crops handled by the GRU. The list for rice is the one recommended by the IBPGR rice advisory committee.

During 1978 the unit continued to gather data on stable characters in its collections, and a program of routine evaluation of elite or special feature legume and rice materials for their reactions to nematodes was started. As well as the data gathered during evaluation, a standard set of descriptors is available to describe the provenance of germplasm collected by the GRU.

Training Program

Categories of training offered through this Program reflect the concerns of the planners of IITA who anticipated the desirability of establishing cooperative relationships with universities and providing research supervision for postgraduate students. The arrangement also included the means whereby agricultural technicians and research workers could be upgraded in their skills and trained in new technology, provision for training of extension personnel to become more effective trainers and communicators and, finally, a program to assist the doctoral graduate in his orientation toward problem-solving research in humid and sub-humid tropical zones.

In 1978, 22 Master's students and 20 Ph.D. students conducted thesis research at IITA under the Degree-related Research Training Program. The universities at which they were registered include the following:

Africa
University of Ibadan, Nigeria.
University of Nigeria, Nsukka.
University of Science & Technology, Kumasi, Ghana.
National University of Zaire, Zaire.

Europe
Faculty of Agriculture, Gembloux, Belgium.
Reading University, England.
Catholic University of Louvain-la-Neuve, Belgium.
Catholic University of Leuven, Belgium.
University of Hohenheim, Germany.
University of Manchester, England.
University of London, England.

North America
Kansas State University, U.S.A.
University of Manitoba, Canada.

Cooperative relationships with universities were further encouraged through the Vacation Student Research Scholarship Program by which final-year students in faculties of agriculture in Africa conduct research projects for the period of their last long academic vacation as undergraduates. IITA received 21 vacation scholars in 1978 from the following universities:

National University of Benin, Republic of Benin.
University of Ghana at Legon, Ghana.
Njala University College, Sierra Leone.
University of Ife, Nigeria.
University of Ibadan, Nigeria.
University of Nigeria, Nsukka.

M. M. Msabaha, a research scholar from Tanzania, conducted his research on cassava breeding at IITA.

Through the Non-Degree-related Research Training Program, 56 agricultural technicians, researchers and communications personnel from 21 countries of Africa, Asia, and North and South America were received for training at IITA. The periods of the training programs arranged for each person ranged from two weeks to nine months.

Group courses provided the context for training of research workers and extension supervisors from national programs. During the year, *168* group course participants were received for training in the following areas:

	Language	*Participants*	*Countries*
Training Course and Workshop for Soil and Water Conservation Research, 9 January-3 February.	English	26	16
Maize Production Technology and Extension, 6 March-23 June.	Eng/ French	28	13
Short Course in Maize Production Training for Nigerian Extension Personnel, 12-16 June.	English	27	1
Tropical Root Crops Production Technology and Extension, 1 May-30 June.	Eng/ French	33	14
Grain Legumes Production Technology and Extension, 11 September-8 December.	Eng/ French	29	14
Fertilizer Use in the Tropics (IITA/IFDC), 20 November-8 December.	English	25	14

A building designed for training activities was constructed during the year. It provides office space for training personnel and includes two classrooms for bilingual use, a study/audio tutorial room and a large covered work and storage area that is used in conjunction with the various field-related activities of the crop production courses.

Postdoctoral Fellowships Program

IITA awards as many as 15 postdoctoral fellowships each year to agricultural scientists with newly-acquired Ph.D. degrees. Through these fellowships the Institute seeks to increase and strengthen the body of agricultural scientists with experience in dealing with problems of food crop production in the world's humid and sub-humid tropics. Most fellowships are for a period of two years. Twenty-four postdoctoral fellows were in residence at IITA for all or part of 1978. Of these, 16 are citizens of nations located in the world's humid and sub-humid tropics; 11 are from African countries.

Library/Documentation Center

During the year, 1,822 volumes of books, 1,750 volumes of periodicals and about 160 pamphlets and reprints were acquired. Moreover, 82 microfiches, 282 slides and 33 cassettes on relevant topics were acquired. These brought the total collection of the Library and Documentation Center by December 1978 to 13,822 books, 18,250 volumes of periodicals, 2,650 pamphlets and reprints, 3,414 microforms, 1,587 slides and 33 cassettes. A portable Kodak Ektalite 120 microfiche reader was also purchased to supplement the larger 3M "400" Reader/Printer.

Epidemics of cassava bacterial blight caused by *Xanthomonas manihotis* were reported in more African countries in 1978 than in previous years. Consequently, the Library and Documentation Center compiled the volume of summary of publications of the disease with the title: "Cassava Bacterial Blight: Abstracts of Literature." A supplement to the main volume was later issued.

The revised version of the Bibliography on Farming Systems in Africa was submitted to a commercial publisher and it will be on sale soon.

A supplement to the Library's "Bibliography of Plantains and other cooking Bananas" was published in *Paradisiaca* newsletter of the International Association for Research on Plantain and Other Cooking Bananas, No. 3, 1978.

The first of a series of guides to the Library's collection was issued in 1978 titled: Guide to Publications on Maize available in the Library.

The International Grain Legume Information Center (IGLIC) published in 1978 three issues of the quarterly *Tropical Grain Legume Bulletin* and had the other number in press. IGLIC also published in 1978 the Abstracts of World Literature on Winged Beans (*Psophocarpus tetragonolobus*) spanning the years 1900-1977.

In addition it submitted for printing the Abstracts of World Literature on Bambarra Groundnuts (*Voandzeia subterranea*) covering 1900-1978.

In March 1978, the Center launched a current awareness service titled: *Grain Legume Current Titles* (GLCT). This is a bi-weekly designed to regularly inform grain legume scientists and research workers of relevant new literature, particularly books and articles in journals received in the IITA library as well as advanced computer searches from two major data bases in the United States and Canada.

As in previous years, the Library and Documentation Center provided ample opportunities for practical training for seven postgraduate students and the same number of undergraduates from the Department of Library Studies of the University of Ibadan. Research and undergraduate students of agriculture and related disciplines, mostly from three Nigerian universities, also used the facilities of the Library extensively in 1978.

Inter-library cooperation continued, particularly the exchange of publications and photocopy requests between the library and those of FAO, CIAT, IRRI, ICRISAT, AVRDC and WARDA, as well as major scientific libraries in Nigeria.

Conference/Visitors' Center

The following international conferences, seminars or workshop programs were held during the year:

4-7 January	AAASA Workshop on Plant Genetic Resources — 35 participants.
19-20 April	Research Committee of the Board of Trustees.
21-22 April	Executive Committee of the Board of Trustees.
24-26 April	Meeting of the Board of Trustees.
26 June-1 July	Cassava Bacterial Blight Terminal Workshop — 45 participants.
3-7 July	International Weeds Society Conference — 87 participants.
21-25 August	USAID Africa Agricultural Conference — 40 participants.
23-27 October	FAO/IAEA/IITA Meeting on the Utilization of Induced Mutations for Crop Improvement — 47 participants.
11-15 December	SCOPE/UNEP/IITA Meeting on Nitrogen in Agricultural Eco-Systems — 48 participants.

Visitors

About 385 visitors came to IITA during 1978 for visits of varying durations, and the Conference Center hosted some 100 groups of visitors, varying from 12 to over 200, and covering a wide range of people — from primary school pupils to groups of chartered accountants, senior agriculturists and administrators. Farmers are showing an increasing interest in familiarizing themselves with the activities of the Institute, and school groups demonstrate a keen interest in observing the technical achievements at IITA.

Personnel

ADMINISTRATION

W.K. Gamble, *Ph.D., director general*
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E.A. Onifade, *security superintendent*
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J.M. Ferguson, *fabrication services officer*
A.C. Butler, *building/site services officer*
M.O. Yusuf, *construction/site engineering services officer*
H.C. Kinnersly, *heavy equipment services officer**

Left during the year

COLLABORATION AND TRAINING

FARMING SYSTEMS PROGRAM

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Pandey, S.J. *Agronomy Program for Agro-Services System.* Paper given at Second Annual Cassava Workshop, Umudike, Nigeria. January 1978.

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Pandey, S.J. *An Educational Program for the Nigerian Farmers.* Paper given at Second Annual Agro-Service Workshop, Kaduna, Nigeria. October 19, 1978.

Pandey, S.J. *Nutrient Requirement and Fertilization of Sorghum, Pearl Millet and Wheat with Reference to West African Savanna.* Paper given at the "Fertilizer use in Tropics" IITA. December 1978.

Singh, B.R. *Input distribution and logistics.* Paper given at Second Annual Agro-Service Center Workshop, Kaduna. October 1978.

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Sulzberger, E.W. *The NAFPP Communication Network.* Paper presented at the Second Annual Nigerian Agro-Service System Workshop, Kaduna. November, 1978.

Utulu, S.N. and I.O. Akobundu. *An Evaluation of CDA Herbicide Sprayer in a Tropical Environment.* Presented at the International Weed Science Conference, IITA, Ibadan. July 3-7, 1978.

Wijewardene, R. *Systems and Energy in Tropical Small-Holder Farming.* A.S.A.E. Winter Meeting, Chicago, Illinois, U.S.A.

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Williams, L.B. *Some Economic Implications for a Fertilizer Industry in Developing Countries.* A paper presented at the Workshop on Fertilizer use in the Tropics, IITA. December, 1978.

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Williams, L.B. *An Inputs Delivery System.* A paper presented at the Maize Production Training Course, IITA. May, 1978.

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Wilson, G.F. *Fallow Crops and Food Cropping Systems in the Tropics.* Presented at the Third General Meeting of AAASA, Ibadan, Nigeria. April 9-15, 1978.

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Winch, F.E. *The Unit Farm Approach As a Method of Technology Evaluation.* IITA Friday Seminar. July, 1978.

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GRAIN LEGUME IMPROVEMENT PROGRAM

Nangju, D., H.C. Wien and B. Ndimande. *Improved Practices for Soybean Seed Production in the Tropics.* Seed Production Conference Nottingham, England, 1978.

Pulver, E.L., F. Brockman, D. Nangju and H.C. Wien. *IITA's Program on Dinitrogen Fixation.* Meeting of Advisory Group on Potential Uses of Isotopes in the Study of Biological Dinitrogen Fixation, Vienna. 1978.

Singh, S.R. and D.J. Allen. *Pests, Diseases, Resistance and Protection in Vigna unguiculata (L) Walp.* International Legume Conference, Kew. July 1978.

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Summerfield, R.J. and H. C. Wien. *Photoperiod and Air Temperature Effects on Grain Yield of Economic Legumes.* International Legume Conference, Kew. July 1978.

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ROOT AND TUBER IMPROVEMENT PROGRAM

Breyne, H., H.C. Ezumah and K. Ndoyi. *Weed Problems of Food Crops in Zaïre.* Paper presented at the International Weed Science Conference, IITA. July 1978.

Ezeilo, W.N.O. *Intercropping with Cassava in Africa.* Paper presented at the International Workshop on Intercropping with Cassava, Trivandrum, India, 1978.

Ezumah, H.C. and A. Knight. *Some Notes on the Mealybug, P. Manihoti Incidence on Manioc (Manihot esculenta) in Bas Zaïre.* International Workshop on the Cassava Mealybug.

Hahn, S.K. *Breeding Cassava for Resistance to Cassava Bacterial Blight.* Paper presented at the IDRC/IITA Workshop on (CBB), IITA, Nigeria. June 26-30, 1978.

Hahn, S.K. *Breeding of Cassava for Resistance to Cassava Mosaic (CMD) and Bacterial Blight (CBB) Diseases in Africa.* Paper presented at the International Symposium on Diseases in the Tropical Food Crops. Louvain-la-Neuve, Belgium. September 4-8, 1978.

Hahn, S.K. *Cassava Improvement in Africa.* Paper presented at the 4th AAASA meeting, Ibadan, Nigeria. April 9-15, 1978.

Hahn, S.K. *The Improvement of Cassava and Sweet Potato through Breeding.* Paper presented at the IITA/IDRC/MANR/RRS Regional Root and Tuber Crops Improvement Workshop, Freetown, Sierra Leone. August 28-30, 1978.

Hahn, S.K. *Breeding of Root and Tuber Crops at IITA.* Paper presented at the FAO/IAEA/IITA Regional Seminar on the Utilization of Induced Mutations for Crop Improvement in Africa. IITA, Ibadan, Nigeria, 1978.

Leuschner, K. *Preliminary Observations on the Mealybug (Hemiptera pseudococcidae) in Zaïre.* Paper presented at the Cassava Protection Workshop, CIAT, Colombia, 1978.

Leuschner, K. *Whiteflies: Biology and Transmission of African Mosaic Disease.* Paper presented at the Cassava Protection Workshop, CIAT, Colombia, 1978.

Leuschner, K. *Insect Pest Control in Root Crops in Africa.* Paper presented at the Conference on Plant Protection by the German Agency of Technical Cooperation.

Leuschner, K. and W.A. Overhott. *A Potential Threat to Cassava Production in West Africa.* Paper presented at the IITA/IDRC/MANR/RRS Regional Root and Tuber Crops Improvement Workshop, Freetown, Sierra Leone. August 28-31, 1978.

Terry, E.R. *Integrated Control of Cassava Bacterial Blight (CBB) in Africa.* Paper presented at the IDRC/IITA Workshop on CBB, IITA, Ibadan, Nigeria. June 26-30, 1978.

Terry, E.R. *The Development of a Pathology Program for a National Root Crops Improvement Program.* Paper pre-

sented at the IITA/IDRC/MANR/RRS Regional Root and Tuber Crops Improvement Workshop, Freetown, Sierra Leone. August 28-31, 1978.

Terry, E.R. *Vegetatively-borne Root Crops Pathogens and Techniques for Their Elimination.* Paper presented at the International Symposium on Diseases of Tropical Root Crops, Louvain-la-Neuve, Belgium. September 4-8, 1978.

Terry, E.R., G. Persley and S.C.A. Cook. Eds. *Cassava Bacterial Blight in Africa.* Proceedings of an Interdisciplinary Workshop, IITA, Ibadan, Nigeria. June 26-30, 1978.

Terry, E.R. *A Dioscorea rotundata Virus Disease in Nigeria.* Paper presented at the International Seminar on Yams, Buea, Cameroon. October 1-6, 1978.

Wilson, J.E. *The Improvement of Yam (Dioscorea spp) through Breeding.* Paper presented at the IITA/IDRC/MANR/RRS Regional Root and Tuber Improvement Workshop, Freetown, Sierra Leone. August 28-30, 1978.

Wilson, J.E. *Progress in the Breeding of Yam (Dioscorea spp).* Paper presented at the International Seminar on Yams, Buea, Cameroon. October 1-7, 1978.

Wilson, J.E. *Developments in the Propagation of Yam (Dioscorea spp.)* Paper presented at the International Seminar on Yams, Buea, Cameroon. October 1-7, 1978.

Pacumbaba, R.P., H.C. Ezumah and L. Tekafima. *The Present Status of Cassava Bacterial Blight in Zaïre.* Paper presented at the IDRC/IITA Workshop on CBB. IITA, Ibadan, Nigeria. June 26-30, 1978.

CEREAL IMPROVEMENT PROGRAM

Buddenhagen, I.W., 1978. *Varietal Improvement in Relation to Stability and Environmental Balance in Tropical Peasant Agriculture.* Paper presented in International Congress of Plant Pathology Symposium, Munich, W. Germany, August 1978.

Virmani, S.S., 1978. *Some Results of Varietal Screening for Tolerance to Iron Toxicity in Liberia.* Paper presented at the 1978 IRRI Conference, Los Banos, Laguna, Philippines, April 17-28, 1978. (Mimeo).

Virmani, S.S., 1978. *A Retrospect and Prospect of Rice Varietal Improvement Research in Relation to Increasing Rice Production in Liberia.* Paper presented at Seminar on Agricultural Self-sufficiency and the Scientific and Technological Experience, University of Liberia, May 5, 1978. (Mimeo).

GENETIC RESOURCES UNIT

Steele, W.M. and K.L. Mehra. *Structure, Evolution and Adaptation to Farming Systems and Environments in Vigna.* A paper presented at the International Legumes Conference, Kew, London. July-August, 1978.

McCarthy, V. and W. Steele. (Eds.) *Crop Genetic Resources in Africa.* Proceedings of an AAASA Workshop. IITA, Ibadan, Nigeria. January, 4-6, 1978.

Sharma, S.D. *Conservation of Rice Genetic Resources in Africa.* AAASA/IITA Workshop on Crop Genetic Resources in Africa. IITA, Ibadan, Nigeria. January, 4-6, 1978.

Perez, A.T. *The International Genetic Resources Conservation Center for Major Food Crops Based in Nigeria.* Presented at the 14th Annual Conference of the Agricultural Society of Nigeria, Benin City, Nigeria. July 2-7, 1978.

Steele, W.M. *Crop Genetic Resources Conservation at IITA.* Presented at AAASA/IITA Workshop on Crop Genetic Resources in Africa. IITA, Ibadan, Nigeria. January 4-6, 1978.

BIOMETRICS DEPARTMENT

Gilliver, B. *Sampling Techniques.* Paper presented at the IITA Workshop for Village-level Socio-economic Studies.

Gilliver, B. *Experimental and Survey Designs for the Estimation of Crop Losses.* Paper presented at the FAO/IITA Workshop on Crop Losses and Horizontal Resistance.

Gilliver, B. *Regression Analysis — Its Application and Limitations in Crop Loss Programmes.* Paper presented at the FAO/IITA Workshop on Crop Losses and Horizontal Resistance.

Gilliver, B. *Information Sciences/Genetic Resources Programme.* Paper presented at the Workshop on Crop Genetic Resources in Africa.

Gilliver, B. *Design of Field Experiments for Erosion Control and Soil Management.* Paper presented at IITA Soil and Water Conservation Workshop.

Major Seminars

(Given at the Institute by IITA scientists or by visiting scientists during 1978.)

26 May	*Tissue Culture Research at IITA.*	**Dr. S. Sadik.**
2 June	*Influence of Gama Irradiation on Rice Seedling Vigor.*	**Dr. A. Abifarin.**
9 June	*Weevil Resistance in Sweet Potato.*	**Dr. K. Leuschner.**
16 June	*Soil & Water Conservation Research. (Venue: West Bank IITA Watershed Experimental Site)*	**Dr. R. Lal.**
23 June	*The Stripe Review and Farming Systems Research at IITA.*	**Dr. J. Flinn.**
30 June	*Insect Resistance in Cowpeas.*	**Dr. S.R. Singh.**
7 July	*Focussing Farming Systems Research on Smallholder Agriculture.*	**Dr. J. Flinn.**
14 July	*Virus Research at IITA.*	**Dr. H. Huttinga.**
21 July	*Opportunities for Rice Development in West Africa.*	**Mr. J. ter Vrugt.**
28 July	*Unit Farms as a Methodology for Technology Evaluation.*	**Dr. F. Winch.**
4 Aug.	*Factors Affecting Sulfur Status of Tropical Soils.*	**Dr. B.T. Kang.**
11 Aug.	*Rice Cultivation in Problem Soils.*	**Dr. A. Tanaka.**
18 Aug.	*Production Physiology in Field Crops.*	**Dr. A. Tanaka.**
25 Aug.	*Maize Physiology Research in the Humid Tropics.*	**Dr. M. Quin.**
1 Sept.	*Promising Technology.*	**Dr. D. Nangju.**
6 Sept.	*No-Till Farming.*	**Prof. S. Phillips.**
8 Sept.	*Insect Resistance in Maize.*	**Dr. Guthrie.**
15 Sept.	*Screening Cowpeas for Tolerance to Soil Acidity.*	**Dr. W. Horst.**
22 Sept.	*Resistance to Streak Virus in Maize.*	**Dr. P.E. Soto.**
28 Sept.	*No-Till Farming.*	**Dr. G. Triplett.**
29 Sept.	*Rice-based Cropping Systems in Sierra Leone.*	**Dr. I.C. Mahapatra.**
2 Oct.	*Role of Pubescence in Aphid and Leafhopper Resistance of Phaseolus* and Potato.	**Dr. W.M. Tingley.**
13 Oct.	*Present Status of Cowpea Breeding in IITA.*	**Dr. B. Smithson.**
27 Oct.	*Some Ideas of Induced Mutations for Crop Improvement.*	**Dr. C.A.T. Gustafsson.**
3 Nov.	*I Dare You — To Be Different.*	**Mr. J.H. Owen.**

NOTES

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