International Institute of Tropical Agriculture

1977 ANNUAL REPORT

TABLE OF CONTENTS

FOREWORD

The International Institute of Tropical Agriculture has as its major task to carry out research toward improving the quality and quantity of selected food crops of the humid and subhumid tropics.

Because IITA is located in the transition zone between tropical rain forest and tropical savanna (at Ibadan, Nigeria) the Institute's researchers can bring their skills to bear on the problems of both zones.

Research at IITA is centered around four major programs. Central to all the research effort is the Farming Systems Program whieh becomes the testing ground for improvements in materials and methods developed in the Grain Legume Improvement Program, the Cereal Improvement Program and the Root and Tuber Improvement Program. An equally important area is the Training Program which provides a wide range of opportunities for the improvement of professional ability in research and development. Additional research support components whieh are essential to the productive output of the program are also an integral part of IITA.

Through cooperative programs with other international agricultural research institutes, national programs and training aetivities, the improvements in materials and methods are made available to farmers in the tropical areas which IITA serves.

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

W. K. Gamble
Director General

IITA BOARD OF TRUSTEES

THE WEATHER AT IITA IN 1977

For crop production, the adverse weather conditions that seem to have characterized the current decade again occurred in 1977. Rainfall at IITA was below average and poorly distributed. This resulted in a shorter-than-normal cropping season. Insolation was, in general, also comparatively lower-than-normal, day time hours were cooler than normal while warmer temperatures prevailed at night. A summary of weather parameters for 1977 at IITA is given in Table 1.

Rainfall and Evaporation. Two major storms in January 1977 yielded a total of 53.0 mm of water, about eight times the annual average for that month; however, there was no rainfall in February. Thus, despite a 5 percent decrease in cumulative evaporation compared to the average, the potential water balance[1] over the latter part of the 1976-77 dry season remained strongly negative as is usual for this time of year. A total of 20.0 mm of rainfall in March made the month the driest in the last 25 years, representing only 20 percent of the corresponding long-term mean. The cumulative deficit in rainfall stood at 48 percent at the end of this period.

April was marked by intermittent upsurges of the harmattan which followed nearly every rain. There was little improvement in water balance as precipitation continued to fall far short of 'normal' while there was a 12 percent increase in evaporation. A more favorable distribution of rains (particularly in the last third of the month) however, resulted in sufficient improvement in short-term moisture conditions to enable planting of the now delayed first-season crops. These conditions were sustained through the first half of May.

The first 10 days in June brought yet another period of moisture deficit. Rainfall during the period amounted to 29 percent of evaporative demand.[2] Precipitation during the rest

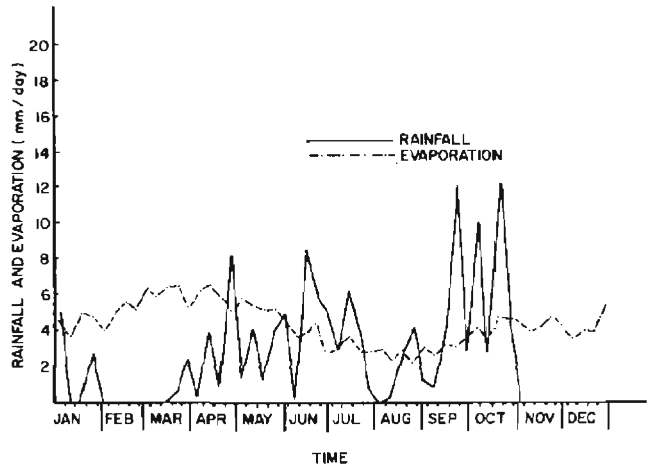


Fig. 1. Weekly mean rainfall and evaporation (IITA, 1977).

Table 1. Summary of climatic data for 1977 – IITA, Central Station.

Month	Total rain-fall mm	Total evapo-ration mm	Solar radia-tion Gm-Cal/	Temperature C		Rel-Hum. %		Mean Temp C	Mean Rel-Hum. %
				Min.	Max.	Min.	Max.		
Jan.	53.0	133.61*	350.70	22.6	31.6	43	97	21.1	70
Feb.	0	146.72	411.57	22.2	33.2	31	96	27.7	64
Mar.	20.0	170.41	429.26	23.5	35.3	28	92	29.4	60
Apr.	94.0	175.30*	441.84	23.6	33.5	43	93	28.5	69
May	101.30	168.82	458.25	22.7	31.5	56	97	27.1	77
June	146.5	115.85*	365.80	22.7	28.9	67	98	25.8	83
July	94.6	97.31	308.20	22.3	27.5	71	96	24.9	84
Aug.	59.5	84.36	274.72	21.1	26.7	71	98	23.9	82
Sept.	141.0	96.98*	342.55	21.6	28.4	66	98	25.0	82
Oct.	207.0	135.16*	412.23	22.0	29.6	59	98	25.9	73
Nov.	0	134.12	471.16	22.0	31.9	42	96	27.0	69
Dec.	0	134.48	371.60	20.4	31.8	36	94	'26.1	65

**Values adjusted for days with missing data.*

1. Defined as the difference between rainfall and pan evaporation.

2. Taken to be equal to pan evaporation.

of the month was frequent and adequate, resulting in sustained favorable moisture conditions for the first time in the year, despite the overall water deficit. This trend continued through July. The characteristic decline in August rainfall (Fig. 1) was more pronounced than 'normal' but less accentuated than the situation in 1976. Most of the 59.5 mm of rain in August was concentrated in the second half of the month.

Soil moisture thus remained favorable during the period; timely second-season planting was therefore possible. The departure in cumulative rainfall to this point remained high — minus 34 percent.

The first third of September was marked by another drought spell which ended with a 14.8 mm rainfall on the 12th. This commenced a period of consistent rains in which moisture balance ranged from adequate to highly positive. The positive moisture balance lasted through October, one of the two months of the year with above-average rainfall. Some of the rains within the period were intense. Mean intensities upward of 70 mm/hr sustained over 30 minutes were observed on two occasions — the first on 17 September and the second on 17 October. A peak intensity of 96.0 mm/hr was measured on 4 October. No serious erosion was, however, observed on the station because of good ground cover.

The second cropping season at IITA ended early and abruptly. The last rain for the year fell on 26 October, and was followed by a period of rapid depletion of soil moisture reserves induced by high evaporative demand. The total rainfall for the year was 916.9 mm, making 1977 the third driest in 25 years of weather records proximate to the IITA site.

Sky Conditions and Solar Radiation. A curious short-term interplay between the dry and dusty harmattan and the moist, southwest monsoon, observed during the first four months of the year as each air mass alternately advanced into and retreated from the area. Sky conditions during the period were therefore marked by an unusual alternation between haze and clouds. Insolation was generally moderate with monthly values of global radiation (Fig. 2) ranging from 3 percent (January) to 6 percent (April) below average.

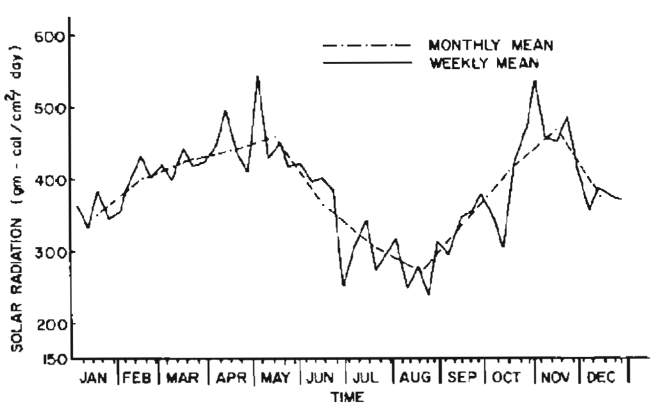


Fig. 2. Weekly and monthly mean solar radiation (IITA, 1977).

There was an improvement in insolation in May when a 4 percent departure was observed as generally broken clouds in the morning yielding to scattered cloud cover in the afternoon. June, however, experienced a pronounced decline (− 12 percent) due to extensive cloudiness. This decline continued through July (− 13 percent) and reached a peak in August with a − 17 percent departure from the mean. The first cropping season was therefore not only plagued by a below-normal rainfall, but also by a comparatively poor light climate. The second season fared better: global radiation in September was 342.6 g-calcm^{-2} day^{-1}, (5 perent below average) while October and November values were 4 percent and 12 percent respectively above average.

Temperature and Relative Humidity. Temperatures in 1977 were, on the average, lower during the day (0.3 C) in parallel with the lower radiation input (Fig. 3). Night-time hours were, however, generally warmer than 'normal' with departures ranging from plus 2.5 C in January to plus 0.1 C in December; they average 0.90 C above normal over the year. The absolute maximum temperatures of 37.0 C, were observed on 7, 13, 15, 24 and 26 March; the lowest minimum, 15.0 C, was recorded on 31 December.

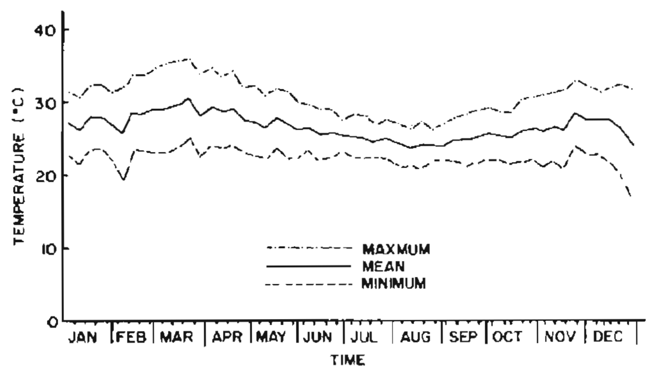


Fig. 3. Weekly mean max., min., and mean temperatures (IITA, 1977).

Relative humidities were variable. Low daytime values in March (lowest: 12 percent on 13 March) and April (lowest: 20 percent on 2 April) were associated with the late incursions of the harmattan. Departures in monthly mean values however, were mostly positive compared to the corresponding multi-annual averages, with notable exceptions in March, April and November (Fig. 4).

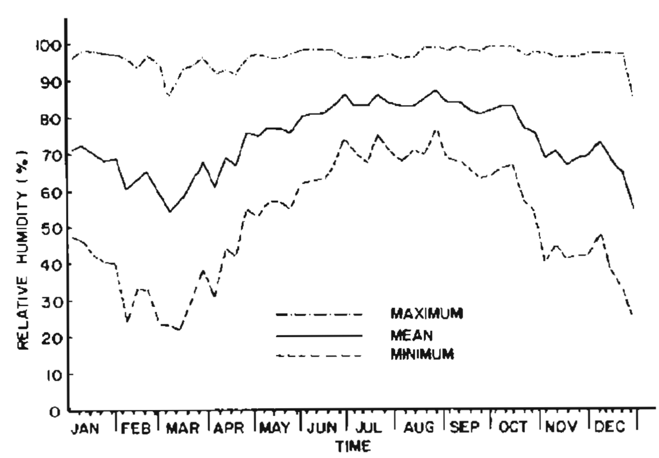


Fig. 4. Weekly mean max., min., and mean relative humidity (IITA, 1977).

CEREAL IMPROVEMENT PROGRAM

Maize

Genetic improvement

Introduction and evaluation of new germplasm. Efforts to enrich the IITA germplasm collection were continued during 1977. About 350 materials consisting of inbred lines, composites, synthetics and hybrids were introduced and evaluated at IITA. The total number of accessions now available at IITA is 705. Materials introduced this year included several inbred lines and synthetics from the USA, assorted materials from Brazil, composites and synthetics from Cameroon, some lines and hybrids from IRAT, Ivory Coast, Mexico and several maize cultivars from CIMMYT. All these introductions were grown, evaluated and multiplied by sib mating at IITA. Materials found to be promising have been utilized in ongoing sub-projects with different objectives.

Of the germplasm introduced and evaluated in the breeding nursery in 1976, 82 accessions were found to be promising. These materials along with TZB and TZPB check cultivars were further evaluated in two yield trials in 1977 first season.

All the USA germplasm tested in the trial yielded significantly lower than TZPB check cultivar. Only one accession, Tuxp. Caribe-2, gave a yield equal to TZPB. In another trial in which Indian early materials were tested, only one entry, Indian Yellow mixed, yielded higher than TZPB check.

Development of early maturing composites. A major activity during 1977 in this project was to identify high-yielding full-sib families generated during 1977 which would mature in about 85-90 days and would have a good level of resistance to tropical rust and blight diseases. A total of 117 full-sib progenies and 44 varietal and full-sib crosses were tested in replicated yield trials at three locations in Nigeria, and in Togo, the Republic of Benin and Upper Volta. Sixty-five full sibs and crosses were selected and tested again in a trial in the second season at Ibadan. Table I gives the average yield and days to flowering of selected entries at various locations. The highest-yielding full sib which gave about the same yield as TZB composite yielded 126 percent higher than the Upper Volta check cultivar in the early season at Ibadan. In the second season, the highest-yielding full-sib cross yielded 74 percent higher than TZB and 116 percent higher than the Upper Volta checks. The early-maturing full-sibs were about 10-12 days earlier than TZB in flowering and about 25-26 days earlier in maturity.

Based on the data from multilocation testing, 11 early-maturing cultivars have been reconstituted and multiplied by sib mating. The most promising cultivars in 1978 trials will be released to the national programs. In Nigeria, the selected four cultivars will be tested by state ministries of agriculture in the pre-minikit trials and in the minikit trials on the farmers' fields.

In the second season of 1977, the promising early-maturing families were crossed to three sources of opaque-2 gene and two sources of resistance to maize streak virus. F_1 seed of early X streak resistant and early X opaque-2 source, will be planted as two bulks to make further selections in 1978.

Plant type selection and low-density performance. The selection for efficient plant type under low population was initiated in 1976. One-hundred-and-fifty full sibs and 150 half sibs generated and selected in 1976 were tested in a replicated trial at normal plant density (55,000 plants/ha). The same set was also planted as ear-to-block for developing a new set of full sibs at Ibadan. Full-sib families were selected and only these families were utilized to develop a new set of full sibs. Grain yield of some of the selected families tested in a trial in 1977 is given in Table 2.

Table 2. Grain yield of five selected families in TZPB (EPS) – Ibadan.

Pedigree	Pedigree	Grain yield kg/ha
TZPB	F.S. 138	5831
TZPB	F.S. 55	5547
TZPB	F.S. 92	5432
TZPB	F.S. 45	5371
TZPB	F.S. 59	5371
TZPB	Control	4664

Table I. Grain yield (kg/ha) and days to flower of selected early-maturing families.

						Republic of Benin			Republic of Togo		
Pedigree	Yield	First-season flowering	Pedigree	Yield	Second-season flowering	Pedigree	Yield	Days to maturing	Pedigree	Yield	flowering
BPT F.S.18	4840	47	IWM x IPA	5250	44	B.P.F.S. 27	4620	134	ATPF FS 8	4444	40
IPA F.S.7	4560	48	ATP x IND	5060	45	ATPF F.S.27	4230	130	MAPB x ATPF	4428	41
IWM x IPA	4520	48	BTP F.S.18	4400	44	ATPF F.S.19	3880	128	ATP x IND	4236	42
ATP x IND	4510	47	BTPF x IPA	4380	44	B.P.F.S.8	3870	130	PB FS 12	4056	41
TZB	4600	58									
Upper Volta	2140	46									

The highest-yielding full sib (TZPB F.S. 138) yielded 5831 kg/ha which is 25 percent higher than TZPB check cultivar included in the same trial. Mean of selected 20 families was 5170 which is about 11 percent higher than the yield of TZPB. The new set of full sibs developed in 1977 will be grown in 1978 for yield evaluation and for initiating the second cycle of selection for efficient plants. Only those families which give promising performance are selected to initiate new cycle of selection again under low plant density.

In addition to TZPB Composite, F_2 generation of Tropical × USA germplasm developed in 1976 was also planted in 1977 to select for efficient plants under wide spacing. TZB and TZPB were used as the tropical material and corn belt hybrids as USA germplasm.

Plants with the USA hybrid type architecture possessing field tolerance to tropical rust and blight diseases were selected and subjected to dry matter analysis to determine grain/stover ratio. Selected full sibs and half sibs will be evaluated for yield in a replicated trial in 1978.

Another approach for achieving better physiological efficiency in tropical maize was to select for prolific (two ears/plant) plant type. Preliminary studies show that frequency of plants with high efficiency and high yield occurs more often in the prolific families. Plants with two good size ears with no or few unproductive extra ear initials or ear proliferation were selected from 1976 TZPB plantings. These 162 ears were grown under wide spacing (75 cm × 100 cm) as half-sib families and a second round of selection for two-eared plants was done in 1977 first season. One hundred plants each of selected ears were planted as half-sib families in 1977, second year under wide spacing. Selection for two-ear plants was done in the selected families. Selected plants were selfed and selfed ears from plants which had two reasonably good ears will be grown as ear-to-row in 1978 to develop – S_2 lines and full-sib families among prolific plants.

Development of populations resistant to maize streak virus. Since the sources of resistance identified in 1976 and confirmed in 1977 were not vigorous and were agrooomically unaccepted, the major thrust during 1977 was to combine high-yield potential and resistance to streak. In addition to the two sources of resistance, IB 32 and La Revolution, several other S_1 and S_2 lines from the base population TZY were identified which were segregating for a high level of resistance.

All such lines of IB 32, IB 33 and IB 34 were planted in the screenhouse and were subjected to streak inoculation. The resistant plants were bulk-sibbed in the screenhouse. The sib seed was planted in two large blocks in the field as yellow and white grain bulks. Further recombination was accomplished by plant-to-plant selective sibbing utilizing agronomically superior plants. One-hundred-and-sixty-two ears in white and 212 ears in yellow bulk were finally selected and planted as ear-to-row using wide spacing for individual plant selection in the selected families. All the 374 ears were also planted in the screenhouse to monitor the resistance to streak. Based on family reaction to streak in the screenhouse, full sibs among agronomically superior plants were produced in both yellow and white populations in the field, and 189 full sibs in white and 292 full sibs in yellow population were finally retained. All 481 full sibs in white and yellow grain population were tested in a replicated yield trial and also were planted in the screenhouse to test the yield potential and level of resistance. There were several full-sib families which yielded more than 3000 kg/ha and were having a rating of 2.0 (resistant) for streak in the screenhouse. Ten best families in the white population and 10 in the yellow population have been chain-crossed to develop TZSR (white) and TZSR (yellow) composites. Enough seed of these composites is being produced for multilocational testing during 1978 second season.

Several single crosses of maize were produced by crossing some other introduced, inbred lines which were found to be promising in the 1976 introduction nursery.

In addition, selected plants in agronomically superior full-sib families have been selfed to produce S_1 lines. A large number of materials sent from IITA to the national maize program in Zaire are better than their improved cultivar which was planted every 15 rows along with these materials.

Conversion program. Seventeen high-yielding tropical composites including TZB, TZPB, 096EP6 and S123 from Nigeria and 10 CIMMYT experimental cultivars were tested earlier and found promising in Africa. UCA from Tanzania, C4 from Ghana, and Madagascar cultivar from Zambia were selected for converting these cultivars to streak resistance. The streak resistant full sibs exhibited epidemiological field resistance under natural inoculation and spread.

In the screenhouse where inoculation is ensured, some F_1 rows showed uniform intermediate reaction to streak, where as many showed segregation for susceptibility. The agronomically superior plants in all F_1 ear-to-row were self-pollinated in the field. These S_1 lines will be grown ear-to-row in the field and will be inoculated by releasing viruliferous leafhoppers and the selected plants in the selected S_1 lines will be crossed to develop a new set of full sibs.

Borer resistance. Two bulks, white and yellow grained, made from the survival plants under high natural infestation of *Sesamia calamistis* borer at Umudike were planted at Ibadan in 1976 and agronomically superior plants were selfed and utilized in developing full-sib families.

Selected plants in families showing a good level of resistance in two replications were either selfed or crossed to generate new set of full-sib families and 75 full sibs in white and yellow grain populations were finally retained. These full-sib families were planted in the replicated trial for yield evaluation in the dry season 1977 at Ibadan. The top 50 percent will be selected and the remnant seed will be planted at Umudike in 1978 for the next cycle of selection.

International testing. Maize is widely grown in several ecosystems all over Africa with different stress situations limiting maize yields. An international program that aims to produce elite germplasm with wide adaptation cannot safely rely upon selection and testing in any one location. International testing of full-sib families generated in two high-yielding base populations TZB and TZPB was initiated in 1977. Full-sib progenies were sent to Cameroon, Republic of Bénin, Togo, Guinea Bissau, Upper Volta, Sao Tome, Sierra Leone and Liberia.

These were also grown at Ikenne and Onne (high-rainfall areas), Mokwa and Ibadan (transitional and savanna areas), Zaria (Guinea savanna area) and Umudike in Nigeria. In addition, materials for specific objectives were also sent to five countries. For example, streak resistant material was sent to Ghana and Tanzania, high lysine material to Liberia, and promising germplasm to The Gambia and Burundi.

Families selected by such an international testing network would be combined with an objective of developing a widely adapted Tropical White Intermediate Dent (TWID) composite. A new set of families will be developed and sent again to various locations for the second cycle of selection.

With the same objective, the 28 most promising composites, developed at IITA or identified through introduction nurseries and CIMMYT trials of 1976, were selected and tested in a yield trial at several locations. Table 3 gives the performance of promising composites at two locations. Milho Maya, La Maquina 7422, Tlaltizapan 7322 and Poza Rica 7422 were found to be promising at both the locations.

Based on these results and other observations at IITA, three composites designated as TZ 7801, TZ 7802 and TZ 7803 and two hybrids have been entered in the national zonal maize trial to be conducted at 16 locations in 1978 first season. The trial is being coordinated by the National Cereals Research Institute (NCRI), Ibadan.

Table 3. Grain yield (kg/ha) of promising composites tested in 1977.

Pedigree		Ikenne	Samaru
Milho Maya		3733	6021
La Maquina	7422	3543	5945
Tlaltizapan	7322	3486	5813
Poza Rica	7422	3926	5715
Poza Rica	7437	4439	4878
TZPB		3810	4781
Western Yellow		3162	4481
S123		2209	5317
LSD 5%		1219	438

Population improvement. The recurrent selection program to increase the frequency of desirable genes was continued in 1977 in the four base populations, namely TZB, TZPB, TY Yellow and TZ Opaque.

TZB. Two-hundred-and-sixty-five S_1 lines developed in 1976 were evaluated in replicated yield trial at Ibadan and Mokwa in Nigeria. Based on the data for yield, usable ears, ear height and tolerance to diseases and insects 45 lines were selected. Performance of the selected lines, as compared to base population TZB is given in Table 4. Remnant seed of these lines was planted in the dry season of 1977 recombination. Recombined ears will be planted in early season 1978 for selfing the selected plants to initiate the eighth cycle of selection in this composite.

TZPB. During the first season 1977, 125 S_1 lines produced in 1976 were tested in replicated trials at two locations, Ibadan and Samaru. Twenty-eight lines were selected and remnant seed planted in isolation for recombination. The yield and other agronomic characters of some lines selected in 1977 trial are given in Table 4.

TZ Yellow. One-hundred-and-eighty-five S_1 lines of TZY were planted in a trial and 25 lines were finally selected. Remnant seed of these lines which was kept in seed store showed very poor germination. Open pollinated ears of selected lines will therefore be used for initiating new cycle of selection in this composite.

TZ Opaque. A modified S_1 line recurrent selection scheme was used to improve TZO2 composite. Recombined ears were planted ear-to-row in the first season 1977 to self the agronomically superior plants. One-hundred-and-thirty S_1 ears were selected and these were evaluated in a replicated trial in the dry season of 1977. Severe lodging due to bad weather was experienced. Lines selected on the basis of yield and other agronomic characters will be used for next cycle of selection in 1978.

CIMMYT international testing. Three Elite Variety Trials (ELVT), namely ELVT 18, 19 and 20 received from CIMMYT, Mexico, were planted in the second season 1977. These trials could not be planted in the first season due to late release. All the data collected from these trials have been returned to CIMMYT for compilation.

In a similar cooperative activity 160 F_1 ear-to-rows of promising composites crossed to downy mildew resistant materials were grown at IITA in the dry season 1977, for the NCRI Ibadan. These F_1 crosses were grown at IITA for advancing to F_2 generation by selective sibbing. The F_2 seed produced will be returned to NCRI for further work in 1978 to produce populations resistant to downy mildew disease.

Table 4. Performance of some of the selected S_1 lines of TZB & TZPB tested in 1977 for population improvement.

	TZB				TZPB		
Pedigree	Yield kg/ha	Days to flower	Ear height	Pedigree	Yield kg/ha	Days to flower	Ear height
30/2	4530	55	142	148/1	4875	61	108
71/1	4285	53	147	161/1	4820	58	110
150/2	4265	56	140	156/2	4585	61	105
127/1	4265	54	125	38/3	4585	56	105
79/1	4150	56	131	57/3	4440	58	103
100/1	4150	55	129	73/2	4430	60	105
TZPB Bulk					5515	55	125

Development of inbred lines and hybrids. During the year 260 S_2 lines of TZB, 60 S_2 lines of TZB and 61 lines from NCRI were grown in the top-cross nursery for crossing to TZPB tester. Researchers rejected 86 lines on the basis of field observation and 120 lines were finally retained. Top crosses of these lines will be tested in a trial at two or three locations in 1978 early season to select the top 10-20 lines based on their general combining ability. In the meantime, 10 lines were selected on the basis of field observation and 20 assorted single crosses were produced in the dry season of 1977 using the remnant seed of these lines. In addition, 15 single crosses were produced by crossing some other introduced, inbred lines which were found to be promising in the 1976 introduction nursery. These single cross hybrids will be tested in a yield trial and compared with TZB and TZPB composites in 1978 early season.

Maize physiobreeding

During the first season of 1977, as part of the breeding program, 171 full-sib entries from within the Tropical Maize Composite, TZB, were planted at wide spacing for further selection. During the grain fill period, 47 of these entries were selected on the basis of acceptable plant type with respect to height, plant canopy and size and number of ears. Within each full-sib, 10 individual plants were selected on the same basis. These 470 plants were harvested at about the time of black layer maturity. Grain weight per plant (GW) and Harvest Index (HI) were calculated for each individual plant, (grain at 12 percent moisture content, stover dried at 80 C to constant dry weight). The key points to emerge from the analysis were:

1. GW was positively and highly significantly correlated with total plant dry weight (PW), r = 0.8433.
2. The regression HI on PW gave a non-significant relationship, r = 0.0156.
3. GW was positively and highly significantly correlated with HI, r = 0.5407.
4. GW was positively and highly significantly correlated with grain numbers per plant, (r = 0.670) and to a lesser extent with grain size, (r = 0.152).

From these relationships some high-yielding plants with higher efficiency were identified. The high-yielding high efficiency group (HY-HE) were defined as those plants with grain weight greater than 300 g per plant and HI greater than 53 percent. Only 32 plants (7 percent of the population) were identified. Twenty-three of these plants were among the 10 best yielding full sibs. The remaining nine were located in eight other full sibs.

Data on ear height, plant height and leaf numbers above and below the ear showed no association of a particular plant type with the HY-HE group. However, one feature that was common to all but two of the plants was the presence of mature second ears.

Because of the association of HY-HE with prolificacy, a study similar to the one described above was made in a population bred specifically for prolific plants, (TZPB, two-eared population, third cycle of half-sib selection). Twenty-one entries were selected, with 10 plants per selection. The same relationships as those described earlier were found again. A HY-HE group of 17 plants (8 percent of the population) was selected on the same basis as before. Once again no particular plant character with respect to height, leaf number and ear position or relative sizes of ears could be associated with HY-HE plants.

Since the incidence of HY-HE was of low frequency in these maize populations such plants could arise by chance because of more favorable growth conditions at random places in the wide-spaced planting, indicating that HY-HE may not be a heritable trait.

Maize physiology

Factors influencing yield of maize. Maize yield differences between temperate and tropical areas have been attributed in part to higher night respiration losses associated with the higher night temperatures of the humid tropical zone. To explore the advisability of germplasm selection for low night respiration rates, overnight dry weight loss was measured in the field in a maize stand at intervals spanning the life of the crop.

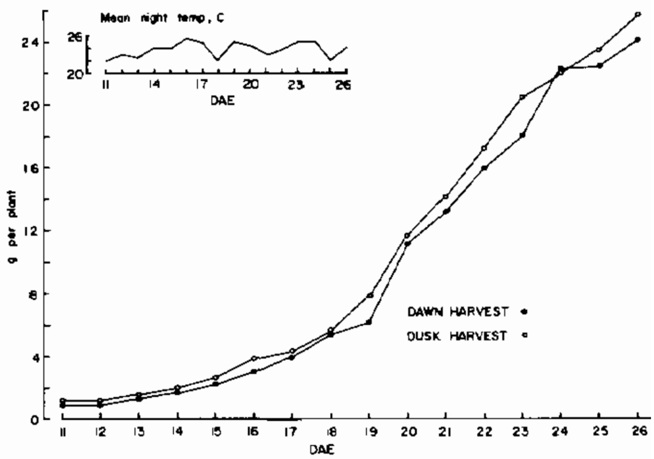


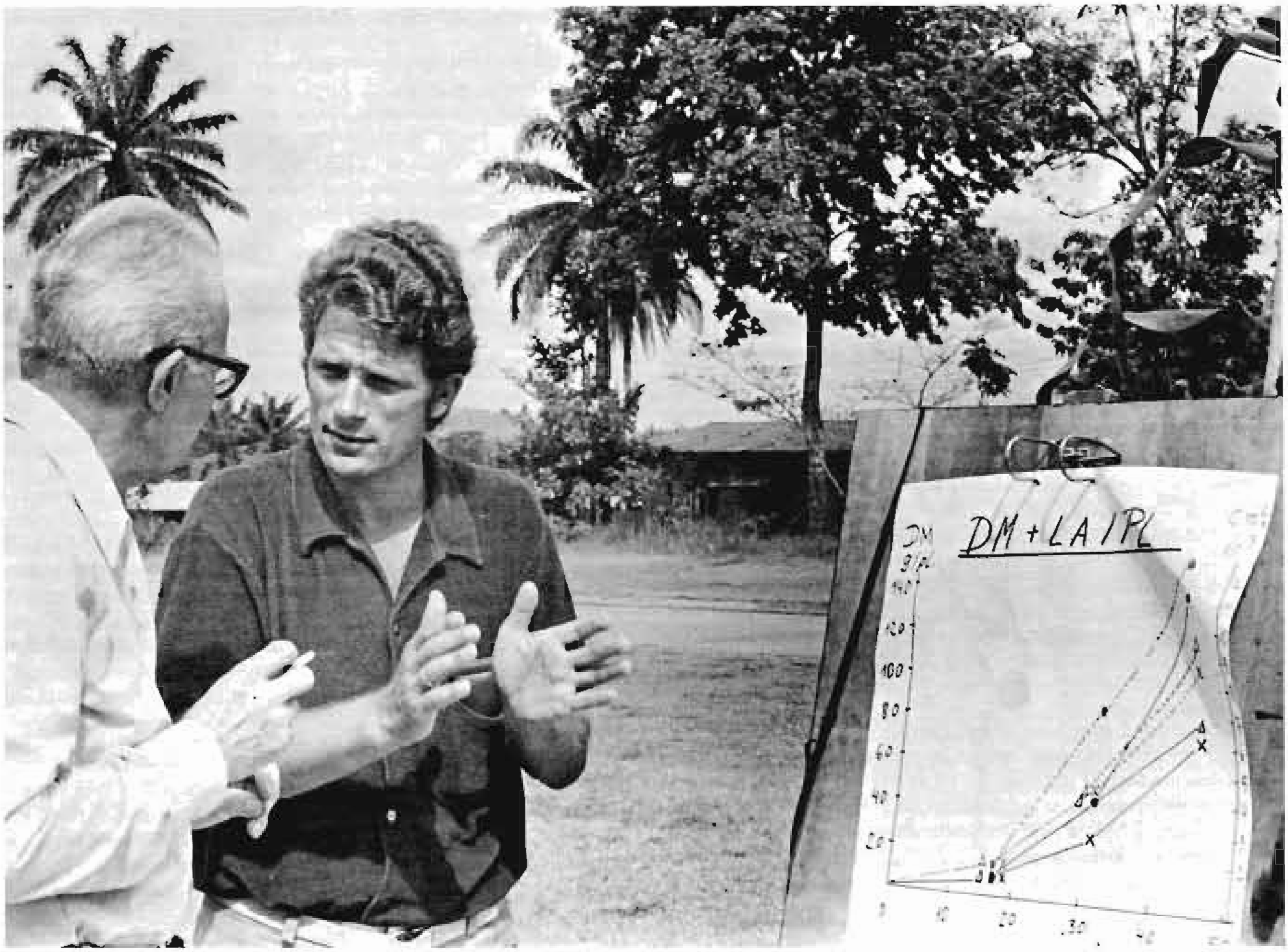
Fig. 1. Dawn and dusk total plant dry weights of maize plants from 11 to 27 days after emergence. Each point is mean of 10 replicates each of 10 plants. Each dawn dry weight is plotted directly under previous day's dusk dry weight.

The results showed that maize in the humid tropical environment is a conservative plant with respect to carbon consumption for respiration. Figure 1 shows the dusk-to-dawn dry weight decrease of the whole plant. Thus maize yield differences between the temperate zone and the humid tropics cannot be attributed to high night respiration losses. Screening for even more conservative carbon consumption is considered to be unimportant.

Influence of radiation on ear development and grain survival. One factor which reduces potential yield of tropical maize is the abortion of grains. This is observed in the field by the incidence of barren second ears on two-eared plants and by abortion of terminal grains on the cob of the first ear. An understanding of factors leading to grain abortion and the way in which selection could be made against that character was required. Previous work had indicated that the environment of the ear with respect to radiation was of importance, and this was investigated.

Two approaches were used to vary light receipt of the ear. Results of the artificial shading experiment showed no significant differences in grain numbers per plant irrespective of light receipt of the ear, but the significant increases in grain yield were found to be a result of thinning at time of silking.

The main findings of the experiment are summarized in Table 5. The key difference between the plant stand in the



A strategy for achieving a better physiological efficiency in tropical maize, such as selecting for prolific plant type, is being pursued.

Table 5. Yield and ear characteristics at maturity of maize plants grown at wide spacing (T1), close spacing (T2) and at close spacing thinned at silking (T3).

T	Spacing between plants	% two-eared plants	Grain weight per plant* (g)
1	1 m	82	274.1 a
2	50 cm	10	145.6 c
3	50 cm thinned to lm	72	180.2 b

T	Grain weight per ear (g)	No. of rows per ear	No. of grains per row	Total no. grains per ear	200 grain weight (g)
First ear characteristics*					
1	169.6 a	14.1 a	40.0 a	562.3 a	61.4 a
2	142.1 b	14.4 a	37.1 b	533.9 b	57.4 b
3	149.1 b	14.6 a	37.4 b	546.9 b	55.8 b
Second ear characteristics**					
1	100.7	13.9	28.9	406.3	55.3
2	41.7	13.0	18.5	235.0	47.4
3	49.3	13.7	17.5	248.3	44.3

Values marked with same letters in a column are not significantly different at $P = 0.05$.

**Value of n for mean grain weight and first ear characteristics is 24.*

***Values of n for second ear characteristics are 24 (T_1), 2 (T_2) and 15 (Y_3).*

close planting (T2) and the thinned plants (T3) was in the incidence of second ears. Only 10 percent of the plants in T2 supported two ears whereas in T3, 72 percent of the stand had two mature ears per plant at final harvest. This was the source of yield improvement in T3. Table 5 shows that the characteristics of both first and second ears in T2 and T3 are very similar in respect of grain numbers and grain size. As shown in Table 6, the percentage partitioning of dry weight in various plant parts was similar in all cases. As a result of thinning, there were significant increases in the weight of leaves below the first ear and in the lower stem.

Table 6. Percent distribution of dry weight in various plant parts at final harvest (c. time of black layer formation) in three spacing treatments.

	Percent of dry weight in					
	Leaf	Stem	Husk	Core and shank	Tassel	Grain
T1	8.3	21.0	13.1	11.8	0.9	44.3
T2	9.2	23.5	11.0	10.8	1.1	43.9
T3	8.1	23.5	10.8	12.3	0.9	44.1

It was concluded that while radiation environment of the ear does not directly influenee ear development, the environment of the leaf canopy immediate to the ear is very important. It apparently produced the additional assimilates that were used in grain development and probably provided some type of hormonal stimulus to ensure that grain survival rather than grain abortion occurred.

The effect of leaf removal on wide- and close-spaced plantings of maize was also examined. Leaf removal markedly altered the incidence of mature two-eared plants in both wide- and closer-spaced plantings (Table 7). Removal of middle leaves at time of silking had the most severe effect, but other treatments also reduced second ear incidence. This experiment did not produce any clearer understanding of the underlying causes of grain abortion and no information was gained on how the overall plant type of tropical maize should be modified to reduce grain abortion.

*Table 7. Percent frequency of two-eared plants in maize stands grown at 75 cm and 50 cm between plants, (Variety, Pioneer X105A) with various leaf removal treatments.**

	Spacing between plants	
Treatment	75cm	50cm
No leaf removal	50.4	41.2
Leaf removal at silking		
Lower leaf	42.5	40.3
Middle leaf	26.0	9.2
Upper leaf	35.8	19.0
Leaf removal c.10 days after silking (dry silks)		
Middle leaf	37.8	31.0
Upper leaf	44.3	25.2

**Leaf at first ear node called 0. Nodes above, +, nodes below, —. Lower leaf was from —3, —4 and —5 nodes, middle leaf was from 0, —1 and —2 nodes and upper leaf was from +2, +3, +4 nodes.*

Maize streak virus (MSV)

Host plant resistance evaluation. About 30,000 plants representing maize germplasm from many sources were evaluated in four large screenhouses. Plants were exposed to viruliferous leafhoppers from germination to flowering. A susceptible check (Upper Volta or TZB) and a resistant check (IB 32) were planted every 10th and 11th row to monitor the level and timing of transmission and the virulence of the virus.

Several maize populations from CIMMYT were evaluated for their reaction to maize streak virus. All the populations were highly susceptible, thus selection of tolerant plants was not possible.

Several elite experimental cultivars from CIMMYT which are high-yielding and well adapted in several African countries were evaluated with the idea of combining resistance and yield. None of the four cultivars tested had any tolerant plants and are at present in a conversion program to introduce resistance to MSV.

Various S_1 lines from Tropical Late White Dent selected under field conditions in Tanzania were evaluated using the screenhouse method and inoculation technique (48 hours with two vectors/plant). The entries tested were S_1 lines whose field reaction to MSV was designated as "slow spread." Regardless of the method used no tolerant plants were identified in any of the S_1 lines tested.

Development of inbred lines. Several plant selections from TZ Yellow population and La Revolution have been selfed and tested for their reaction to MSV under screenhouse conditions. TZ Yellow S_3 lines which have a uniform reaction to MSV have been produced; these will be re-exposed to develop S_4 lines, and eventually selfed to establish inbred lines. Plant selections from La Revolution have been selfed to generate S_2 lines, these lines will be selfed for two more generations to develop S_4 lines. The reaction of several of these lines is presented in Table 8.

Table 8. Reactions of S_3 and S_1 lines of TZ Yellow and La Revolution under screenhouse conditions, IITA, 1977.

	Total plants	Severity rating			
Lines	tested	1	2	3	4-5
TZ Yellow					
3-1	13	13			
3-3	14	14			
3-4	13	13			
3-6	14	14			
9-7	15	15			
9-8	14	14			
9-10	16	16			
9-11	16	16			
TZB (susceptible check)	14				14
La Revolution					
2-3	11	8		3	
'2-4	14	8	6		
2-5	12	10	2		
TZB (susceptible check)	13				13

Reaction of resistant selections made in Kenya and IITA. Selections of La Revolution, Mauritius Local 330, and Kenya Local 317 were tested using the screenhouse method. The reaction of La Revolution ranged from highly resistant to moderately resistant, Mauritius Local 330 was moderately resistant, and Kenya Local 317 was highly susceptible. The IB 32, and the cross IB 32 × La Revolution (F_1) from IITA were tested against the coast isolate of maize streak in Kenya; IB 32 showed little resistance. The IB 32 × La Revolution had 22 plants resistant to highly resistant and 12 plants susceptible to moderately susceptible.

Rice

Genetic improvement

In 1977, several cultivars were introduced from the Institut de Recherches Agronomique Tropicales et des Cultures Vivrieres (IRAT), West Africa Rice Development Association (WARDA) and outside Africa, especially from the International Rice Research Institute (IRRI) for screening and selection under various West Africa (primarily in Ghana, Liberia, Nigeria and Sierra Leone) ecological conditions. A modest hybridization program was continued especially for dryland cultivars. These crosses involved parents already screened from 1971-74 under African conditions and found to possess some desirable attributes, for example, blast resistance, iron toxicity resistance, diopsid fly resistance, pale yellow mottle virus resistance, etc.

Multi-location screening and selection. Several F_2 to F_3 lines were screened and selections made under dryland, hydromorphic, swamp and irrigated conditions. Continuous, disruptive and simultaneous selections are practiced within and among the programs in Liberia, Nigeria and Sierra Leone.

In general selections were made against drought, iron toxicity, iron deficiency, leaf scald, brown spot, leaf and neck blast, sheath blight, sheath blotch, sheath rot and other panicle diseases. Some of the physiological and agronomic characters being considered are good vigor, large panicles, big grain size, good grain quality, non-shattering clean grains, plant type and growth duration. From the three main sites the following lines and families were selected: 928F_3, 363F_4, 143F_5, 64F_6. Several of these lines were higher-yielding than their checks; an example are some F_4 lines at IITA (Table 9).

Table 9. Grain yields of some promising cultivars in comparison with 0S.6 and IET.1444.

Pedigree	Plant	Grain yield g/hill: Test cultivars	Checks: 0S.6	Checks: IET.1444
TOx 340-NIBI-N14-NIB	T	54	43	32
TOx 475-NIBI-N12-NIB*	I	20	13	13
TOx 490-N17-NK7-NIB	SD	27	17	10
TOx 500-N12-NK1-NIB*	T	37	29	22
TOx 502-N124-NK5-NIB	T	28	19	21
TOx 502-N133-NIBI-NIB*	T	55	40	41
TOx 502-N133-NK2-NIB	T	57	40	41
TOx 503-N15-NK1-NIB	I	27	27	25
TOx 504-N17-NK2-NIB	I	27	14	19
TOx 504-N114-N14-NIB	I	44	29	29
TOx 504-N114-NK8-NIB	T	41	35	28
TOx 507-N18-NK1-NIB	T	37	32	36
TOx 516-N17-NK1-NIB	SD	36	24	28
TOx 516-N133-NK3-NIB	T	39	30	31

**F3 families which were also promising in Sierra Leone.*
T is Tall, I is Intermediate and SD is Semi-Dwarf.

Preliminary variety and advanced line trials. Several sets of trials were carried out under dryland, hydromorphic swamp and irrigated conditions. A summary of some of these follows.

Dryland rice. Analytical screening with dense and wide spacing at two levels of fertility to obtain genotype interactions of their variables with drought and disease pressures showed merit in 1976 at Shonga, Nigeria and Nyankpala, Ghana. In 1977, 200 cultivars were evaluated at two fertility levels (0 and 40 kg/ha NPK) and two spacings (rows 30 cm and 15 cm apart) in comparison to LAC 23 at Suakoko. Cultivars Azucena, 63-83, E425, IR 3273-P 339-3, TOx C1-47-1-3-LS_1, Iguape Cateto, 180B/6/b, Line 13d × R75 no. 1293 and Line 13d × Moroberekan nos. 1713 and 2117 showed positive response of above 20 percent to fertilization. When no fertilizer was applied, several locally bred lines performed better than LAC 23.

At IITA in the dry season, with periodical drought, 35 cultivars were tested at 30×30 and 15×15 spacing. The drought and disease stress were severe at 15×15 resulting in zero yield for ADNY 11, BG 90-2, BPI-76/9 × Dawn and C22. The cause was different: drought for ADNY 11, leaf blast for BG 90-2, neck blast for C22 and a combination of drought and blast for BPI 76/9 × Dawn. However, all these cultivars produced moderate yields at 30×30. Several other cultivars also showed differential performance. Colombia 1, for example, produced moderate yield at 15×15 cm. The results of such screening indicate that cultivars can be identified for different purposes such as peasant farming, large-scale farming and resistanee to mild and severe stresses.

Short-duration preliminary variety trial. In a preliminary variety trial both in Nyankpala, Ghana, Makassa, Sierra Leone, and Ibadan, Nigeria, cultivars were evaluated. The data on Tables 10, 11 and 12 show the best 10 in each location. These will be used as parents and for replicated yield trials in 1978. Two of the entries IB 101 and TOs 4120 were top yielders in two locations. TOs 4120 was free of any major deficiency at Makassa. TOs 4153-B-2 was top-yielding at both IITA and Nyankpala, Ghana.

Medium-duration preliminary variety trial. Many cultivars were evaluated at Nyankpala, Ghana, Makassa, Sierra Leone and Ibadan, Nigeria. The best 10 at each location are shown in Tables 13, 14, 15. LS(24)-5-NI-4 was outstanding in two locations. The best will enter the regular yield trials in 1978.

Screening of promising dryland lines. Two groups with short and medium growth duration were planted in Ikenne, but

Table 10. Best 10 short-duration dryland/hydromorphic cultivars screened at IITA, 1977.

Cultivar	Kg/ha	Growth duration
TOs 4153-B-2	5300	115
TOs 4031	4790	115
TOs 4120	4240	107
IR 1746-226-1-1-4	4160	115
13a²/103F3/591/5/3	3890	110
TOs 2405	3720	105
IB 101	3570	95
M55	3570	110
IB 94	3490	95
IRAT 10	3430	100
IB 98	3400	94
IRAT Line No. 852	2460	88
IRAT Line No. 689	2310	88

only the short-duration cultivars could produce filled panicles. The medium-duration cultivars suffered severely from drought

Table 11. Best 10 short-duration dryland cultivars screened at Makassa, Sierra Leone, 1977.

Rank in yields	Cultivars	Yield kg/ha	Growth duration	Height (cm)
1	IRAT 8	2535	116	107
2	No. 2057	2072	116	101
3	IB 96	1948	103	88
4	IRAT Line 1713	1892	103	105
5	TOs 4120	1889	109	88
6	(ADNY 202) 11/133/6/1/2 (check)	1836	116	82
7	IB 101	1662	103	85
8	E 425	1523	115	102
9	IB 34	1451	115	131
10	TOx 364-B	1423	116	111

Table 12. Best 10 short-duration cultivars in a preliminary variety trial. Nyankpala, Ghana, 1977.

Cultivars	Kg/ha	Growth duration	HT in cm
TOs 4153-B-2	3334	123	113
M55	3084	122	102
IRAT 10	3084	100	110
IB 34	3084	108	110
13a²/103 F_5/591/5/3	2917	118	103
E 425	2834	109	106
IB 96	2667	103	110
IAC 25	2542	110	108
Aus 8	2500	100	119
IB 98	2434	110	103

Table 13. Best 10 medium-duration, dryland cultivars screened at IITA, 1977.

Variety	Kg/ha	Growth duration
IRAT Line No. 2811	4920	120
IRAT Line No. 1840	4840	129
IRAT Line No. 1293	4320	123
IRAT Line No. 2057	4240	125
IRAT Line No. 1713	4190	125
LS (24)-5-NI-4	3450	131
TOx CI-13-1-5-LS 1	3350	120
E 425	3180	117
IB 65	2940	122
Iguape Cateto	2910	120

Table 14. Best 10 medium-duration dryland cultivars screened at Makassa, Sierra Leone, 1977.

Rank in yield	Cultivars	Yield kg/ha	Growth duration	Height (cm)
1	Ngovie	2072	119	122
2	TOxC1-18-LS3	1943	132	100
3	TOxC1-9-LS3	1879	119	112
4	LS(1)-5 Bulked	1729	119	100
5	ROK3 (check)	1645	153	128
6	194/1/2	1524	125	88
7	63-83	1372	119	95
8	M1069/1/2	1347	125	114
9	M133/6/1/2 (ADNY 202)	1339	125	92
10	C46-15 (ADNY)	1334	–	126

and brown spot in August. No yields could therefore be recorded from this latter group, except from the IRAT Lines, which matured earlier than expected.

Several entries considered promising are shown in Table 16. Data are means over two replications. Six entries outyielded the check entry TOs 4688.

Short- and medium-duration dryland cultivars. At Abakaliki in Nigeria 35 short-duration cultivars and 18 medium-duration cultivars were evaluated. The six top-yielding cultivars in each maturity group are shown in Table 17 and 18.

Table 15. Best 10 medium-duration dryland cultivars screened at Nyankpala, Ghana, 1977.

Rank in yields	Cultivars	Kg/ha	Growth duration	Height (cm)
1	IAC 1391	4333	132	131
2	FARO x 56/30	4167	123	108
3	Besewar	3500	117	125
4	IRAT 13	3333	113	95
5	TOx 95-LS 4	2833	137	115
6	LS (24)-5-NI-4	2833	144	111
7	LS (1)-5-2	2667	120	118
8	Perola	2667	118	98
9	ROK 3	2667	120	111
10	TOx 95-LS5	2501	136	126

Table 16. Grain yield and days to maturity of promising entries at Ikenne, Nigeria, 1977.

Variety	Grain yield (kg/ha)	Days to maturity
E425	4760	117
IB 94	3530	97
IB 96	3310	92
180B/6/b	3160	93
TOs 4120	3090	110
IB 95	3050	92
IRAT Line 2811	2980	115
TOs 4688 (check)	2940	110

Table 17. Grain yield days to maturity, height in cm of short-duration dryland rice at NORCAP, Abakaliki, Nigeria, 1977.

Cultivars	Grain yield (kg/ha)	Days to maturity	Height (cm)
TOs 4688	2246	107	84
TOs 4031	2092	107	97
IB 97	1706	98	85
IB 98	1692	98	79
M4	1650	113	88
TOs 2405	1648	107	94

Table 18. Grain yield, maturity and height for medium-duration dryland rice at NORCAP, Abakaliki, Nigeria, 1977.

Cultivars	Grain yield (kg/ha)	Days to maturity	Height (cm)
Perola	1858	112	108
LS (1)-18-1	1537	112	94
IAC 5544	1404	112	99
LS (1)-26-1	1254	112	96
OS 6 (check)	1146	112	93
Lac 23	1125	120	103
TD 58	1113	112	97

Dryland replicated yield trial at Ibadan, Nigeria. Some other short-duration cultivars were evaluated for their yielding ability. The results are shown in Table 19.

Hydromorphic rice. At IITA 49 cultivars were evaluated under hydromorphic condition. The top 13 are shown in Table 20.

Evaluation of Abakaliki and Nyankpala, Ghana. In a preliminary yield trial at Abakaliki, Nigeria, 13 cultivars were supplied to a cooperator. The grain yield results, maturity and heights are presented in Table 21. ADNY 11, a line which is often found among the best under irrigated conditions in Sierra Leone trials, was the highest yielder in Abakaliki. A similar set was tried in Nyankpala where TOs 4153 was the top yielder (Table 22), while IR1833-208-2-1-1 performed well in both locations.

WARDA IET. Cultivars from the West Africa Rice Development Association (WARDA) were evaluated under hydromorphic condition. The best of the lot were grouped into four categories based on suitability for a given ecological condition. These will enter the preliminary variety trial and will also be used for crosses next season.

Screening under boliland/hydromorphic condition in Sierra Leone. Forty cultivars were tested, including a check cultivar CP4, at the Gbomsamba boliland site. Results are shown in Table 23. Most of the cultivars suffered from general chlorosis and deterioration of vigor as the experiment progressed. CP4 outyielded all the test cultivars.

Swamp rice. Inland valley swamps are increasing in importance in West Africa especially in Liberia and Sierra Leone.

Table 19. Grain yield of short-duration dryland cultivars at Ibadan, Nigeria.

Cultivars	Grain yield (kg/ha)
54B/6/14/b	3800
180B/6/b	3470
TOs 4120	3210
TOs 4688 (check)	3080
TOs 4031	3000
M133/6/1/2	2950
TOs 2405	2910
IAC 25	2040
$13a_2/103F_3/591/5/3$	1920
M4	1740
Average	2410

L.S.D. 5% = 543 kg
C.V. = 13.32%

Table 20. Grain yield of 13 cultivars under hydromorphic condition at IITA, 1977.

Cultivars	Grain yield (kg/ha)
Columbia 3	5490
IR 1529-430-3	5310
Columbia 1	5310
Juma 1	5100
TOs 4622	4760
Columbia 2	4260
BP176/9 x Dawn	4160
TOs 2583	4060
TOs 4138	4040
IR 3880-10	3910
IR 1529-680-3-2	3880
IR 1529-677-2	3760
ADNY 11	3760

Table 21. Grain yield and agronomic characteristics under hydromorphic conditions at NORCAP, Abakaliki, Nigeria, 1977.

Cultivars	Yield in kg/ha	Days to maturity	Height (cm)
ADNY 11	5162	120	85
IR 1833-208-2-1-1	5000	120	85
C22	4833	120	107
IR 1163-135-2-2	4750	125	89
IR 8	4645	130	72
IR 937-55-3	4625	125	75
IR 1529-430-3	4500	120	74
IR 1529-680-3-2	4416	120	77
BPI 76/9 x Dawn	4166	120	92
IR 1529-677-2	3834	120	76
MRC 172-9	3791	125	72
LS (6)-2-2	3084	120	84
IR 1545-339	2792	120	73

Table 22. Top 12 cultivars in a hydromorphic preliminary trial. Nyankpala, Ghana, 1977.

Cultivars	Kg/ha	Growth duration	Height in cm
TOs 4153	3833	121	100
IR 2734-F_3B-20-1	3250	122	105
IR 2035-242-1	3167	132	111
TOs 4148	3167	129	125
IR 3880-10	3083	141	108
IR 737-55-3	3083	113	88
TOs 4631	3083	128	84
LS (6)-2-2	2000	127	80
TOs 4138	3000	139	104
IR 3304-23	2917	141	96
B8101-81-28-2	2917	117	115
IR 1833-208-2-1-1	2917	116	80

Table 23. Promising cultivars screened at Gbomsamba boliland/hydromorphic site, Sierra Leone, 1977.

Cultivars	Yield kg/ha	Duration (days)	Height (cm)
CP 4 (check) 1	1898	188	–
IR 937-55-3	1849	130	81.0
529 cmd-10-3-6	1576	111	–
TOs 4622	1345	111	–
BPI 76/9 x Dawn	1198	111	–
MRC 172-9	1166	111	–
B8iD-Si-28-2	1102	128	–
LS (6)-2-2	1069	128	–
BPI 76 (N.S.)	1066	111	–
ADNY 8 (Colombia III)	970	128	–
IR 1163-135-2-2	901	131	94.2
BPI 761 x Dawn	888	111	–
IR 1545-339	820	111	–
B9954-Si-72-3	808	128	–

The swamps usually are poorly drained and suffer from iron toxicity and other soil nutrient imbalances.

Initial evaluations. During 1977, in Liberia 806 cultivars derived from International Rice Observation Nursery, WARDA IET and RERETA were evaluated in initial evaluation trials under inland valley swamp or irrigated conditions at Suakoko in comparison to IR5 and Suakoko 8. Thirty-one cultivars appeared promising in comparison to the checks. Most of the promising cultivars were intermediate in height and medium-maturing, and few were even tall but did not lodge at N60 P40 K40 fertility level. These results indicated that in the agro-ecological conditions of Liberia, high yields are not necessarily correlated with semi-dwarf plant type.

Evaluation in Nigeria. In the IBRD project area of Ofiavu, Imo State, various fields suffer from iron toxicity, blast and poor water control, resulting occasionally in drought stress for the standing crop. From a group of 18 selected cultivars known to have a wide adaptability, including the local check cultivar IR5, five cultivars could be identified as superior to IR5. They were Brengut, CI68-134, Mahsuri improved, Suakoko 8(2526) and Pelita I/1. From a second batch sown later in the year, cultivars 4445 from Colombia performed best.

In another screening, 26 entries were evaluated in about 50 cm of water. The eight most promising eultivars are shown in Table 24. These, plus others, will be entered into regular yield trial next season.

Evaluations in Sierra Leone. Under the non-improved swamp with toxicity problems at Magbobontor site in Sierra Leone, 30 cultivars were tested including two check cultivars, Gissi 27 and ADNY 301. Results are presented in Table 25.

Release of Suakoko 8. A cultivar 2526, identified earlier to be promising for cultivation in iron toxic swamps was released as a variety which was designated as Suakoko 8 by the Ministry of Agriculture, Republic of Liberia. This cultivar was superior to IR5 in iron toxic swamps. Under farmers' field conditions, this cultivar outyielded IR5 by 15 to 20 percent in Bong, Nimba, Lofa and Grand Gedeh Counties but in Cape Mount County and Saclepea area of Nimba County, IR5 was found superior.

There are indicators that farmers prefer Suakoko 8 with regard to its long slender grains, better cooking quality and palatability in comparison to IR5 but under high-fertility conditions, it has shown lodging.

Irrigated rice

National rice observation nursery in Liberia. During the dry season 1976-77, 84 riee cultivars identified as promising in the initial evaluation trials were evaluated at three fertility levels ($N_0 P_0 K_0$, $N_{40} P_{40} K_{40}$, and $N_{80} P_{80} K_{80}$) in comparison to IR5. Most of the cultivars showed specific adaptation to the fertility level and 24 were selected for yield testing.

During the 1977 wet season, 81 cultivars were evaluated under three fertility levels at Suakoko, Foya, Zleh Town and Cestos Project in comparison to IR5 and Suakoko 8. Fertility levels used were the same as in the dry season except at Cestos Project where these were modified to $N_0 P_0 K_0$, $N_{50} P_{25} K_{30}$ $N_{100} P_{50} K_{60}$. Most of the cultivars tested showed promise in comparison to IR5 and Suakoko 8 only at one of the locations and at one or two of the fertility levels. However, cultivars IR2071-588-4-5-5, IR2588-132-1, BR51-118-2, C168-134, 4445 c, Mahsuri, IR2055-473-2-1, IR4422-28-3, and B151-b-kn-19-3-1 were superior to the check cultivars at more than one location. These will be evaluated in the coordinated yield trial during 1978.

Table 24. Promising "swamp" cultivars screened under 50 cm depth of water at IITA, Nigeria, 1977.

Cultivars	Kg/ha	Days to maturity
Improved Mahsuri	4840	135
C4-63G	4580	130
IM 16	4330	140
IR 480-5-9-3-3	4050	145
Banjul Koyo	3810	140
Brengut	3740	130
Tuba	3710	140
Suakoko 8 (2526)	3680	140

Table 25. Performance of cultivars under non-improved swamp at Mogbolontor, Sierra Leone, 1977.

Cultivars	Yield kg/ha	Growth duration (days)	Height (cm)	Reaction to iron toxicity	Reaction to lodging
2526 (Suakoko 8)	6740	145	152	R	S
Bagbadin	5568	194	169	R	M
Bakutu	5363	200	182	M	S
BD 2	5304	145	167	S	S
Brengut	5298	145	133	M	R
CP4	5215	200	182	M	S
Papanel	5097	219	182	R	S
Pamatis	4942	219	188	M	S
ROK 5	4734	149	159	S	S
ADNY 5	4566	124	113	M	R
Mange 2	4251	131	99	M	R
C13H3	4241	131	165	M	S
ROK 4	4225	146	165	S	S
ROK 7	4198	134	158	M	S
Indian Panel	4064	227	187	R	R
Ngovie	3884	116	143	S	M
Huallaga	3702	124	103	S	R
Parmatis	3424	200	178	M	S
Sokpoent	3178	219	196	R	R
ADNY 302	2763	200	186	M	S
M-58	2519	124	156	S	R
A3-88	2494	134	177	S	M
A2-260	2267	131	155	S	R
Check cultivars:					
Gissi 27	5380	186	149	R	R
ADNY 30I	5996	200	189	M	S

R = Resistant, M = Moderate, S = Susceptible

Table 26. Promising cultivars screened under irrigation at IITA in comparison with BG-90-2, 1977 May sowing.

Cultivars	Grain yield (kg/ha)	Days to maturity
BG 66-1	6760	125
IR 26	6110	125
IR 3454-102-3-2	5140	130
IR 937-55-3	4400	115
IR 4219-35-3-3	4120	135
IR 5	4070	140
IR 1833-208	3940	125
BG 90-2 (check)	3920	125
4454 Columbia	3920	130
TOs 103	3560	115

Table 27. Promising cultivars screened under irrigation at IITA in comparison with BG 90-2, 1977 July sowing.

Cultivars	Grain yield (kg/ha)	Days to maturity
BG 94-2	4590	120
IR 2688-43-4-5	4590	130
B 4591-BN-4-5-6-3	4580	130
IR 2035-475-2-1	4490	135
IR 2033-435-2-1	4490	135
IR 2863-38-1	4460	135
IR 2035-120-3	4440	125
IR 2153-26-3-5-2	4410	120
BR 51-199-1	4240	125
IET 2885	4230	130
BG 90-2 (check)	4180	125
IR 2055-473-2-1	4090	125
A 12-167-3	4020	130
IR 2053-275-6-3	4020	135

Table 28. Grain yield and agronomic characters of rice cultivars in yield trial at Mange, Sierra Leone, January sowing 1977.

Cultivars	Grain yield (kg/ha)	Duration (days)	Diseases Leaf blast	Brown spot	Leaf scald
PUSA 2-21	823	112	7	5	4
IR 1754-F5B-5	859	122	3	4	3
IRAT 9	996	128	3	5	2
Columbia 2	1130	132	4	5	3
JXK 34-278	1639	125	3	5	3
CRS 95-JR 1123	1658	137	4	4	2
BZ 17-29	2198	124	4	4	3
JXS 52-102	2335	122	4	4	3
CR 138-802-10	2380	126	4	4	3
HG 60-49	2470	132	4	4	3
SG 61-233	2536	124	3	5	3
JK 34-178	2835	127	3	5	3
DJ 684D	3062	134	3	5	2
HK 32-162	3187	126	3	4	3
73-230	3326	126	3	4	3

LSD (0.05) = 486
Cultivar 73-230 produced the highest grain yield.

Table 29. Grain yield of rice cultivars under irrigated conditions at Mange, Sierra Leone, June 1977 sowing.

Cultivar	Grain yield kg/ha
ADNY 11 (check)	2552
CR 70 x PANKAJ 280 (CR 1003)	2559
CR 44-117-1	2875
PXJ 722 (CR 1007)	2964
CR 70 x PANKAJ 330 (CR 1001)	2977
CR 44-119-1	3062
CR 44-118-1	3123
PANKAJ	3162
CR 44-115-1	3205
JAG x NC 2 (CR 1013)	3294
PXJ 713 (CR 1010)	3355
CRS 95-JR 952	3379
PXJ 609 (CR 1006)	3498
Jagannath	3570
IR 665-23-3-1 F1 (IR841-65 x C46-15)	3690
JAG x NC 118 (CR 1012)	3700

LSD (0.05) = 458
Cultivar = 9.9%

Initial evaluation trial. At IITA, two batches of cultivars were screened; one contained 103 sown in May and another 202 cultivars sown in July. Ten were selected from the former and 14 from the latter (Tables 26 and 27) for further evaluations in a replicated yield trial.

Replicated yield trials. There were many replicated yield trials carried out in different places especially in Sierra Leone. An example is a yield trial in January sowing at Mange (Table 28).

During June-November at the same site some other cultivars were entered in a replicated yield trial. Many cultivars were significantly higher-yielding than ADNY 11, the check (Table 29).

Outstanding lines. IR1416-131-5, identified in Liberia and ADNY 11 reselected in Sierra Leone, as high-yielding, blast resistant cultivars, can be recommended for cultivation for improved, non-iron-toxic swamps and irrigated conditions with good water control. ADNY 11 was reselected from Colombia lines. It remained immune to neck blast for several seasons and yielded well in both irrigated and hydromorphic conditions in West Africa.

Management

Effect of seed soaking on dryland rice. In an experiment at IITA pre-germinated rice remained viable for 30 or more days when stored at room temperature. The seed was soaked for 24 hours and then incubated for a further 24-hour period before drying. The dried, germinated rice was seeded in a prepared dryland seedbed at two-day intervals. Some yield reduction was noted from the plots planted five days after germination, but then yields were quite stable from plots planted through the next 15 days. The major difference in plant physiology was in number of tillers, and this probably accounts for most of the yield difference.

Seedlings from the germinated rice emerged in two or three days while seedlings from dry rice planted at the same time emerged in five to seven days. This could give an advantage to the germinated seedlings during seasons of little rainfall.

Yield and plant characteristic data are given in Table 30.

Table 30. Effect of sowing different days after pregermination on growth and yield of rice.

Days after germination	Tiller number	Panicle number	Total grain weight
3	36	36	111
5	31	31	86
15	30	30	90
17	29	28	63
31	29	27	72

Effect of date of planting dryland cultivars in Liberia. The response of LAC 23 (white) to the spacing and fertility level as affeeted by the date of emergence was determined. LAC 23 emerging on June 19-20 yielded higher and responded to fertilization and spacing whereas the LAC 23 emerging July 10-12 yielded considerably less and responded neither to fertilization nor to closer spacing.

Effect of spacing on dryland cultivars. This experiment was conducted at Warri under high-rainfall, dryland conditions and depleted sandy soils.

Single seeds were dibbled 10 cm apart within the rows, while the rows were 15 and 30 cm apart in the two treatments (Table 31).

Table 31. Yields of close and wide spacing of dryland rice at Warri, Nigeria, 1976/77 season.

Cultivar	15 x 10 cm (kg/ha)	30 x 10 cm (kg/ha)	% Increase over close spacing
	1600	2530	58
Moroberekan	1010	1530	51
OS 6	1670	2230	54
IAC 5544	1850	2300	24
Iguape Cateto	1680	2080	24
TOs 4138	1530	1880	23
TOs 4157	1410	1670	18
Mean	1535	2032	32

Stand establishment and weeding. At IITA this experiment was carried out by the research trainees under the supervision of the rice agronomist. There were six methods of planting and sub-plots of hand weeding and herbicide application. The results are shown in Table 32. There were no significant differences among the methods of planting. However, there was a strong interaction between the six treatments and the two methods of weeding. Hand weeding gave significantly higher yields than the herbicides Preforam and Stam F 34T.

Table 32. Stand establishing, dryland rice. Yields in kg/ha IITA, 1977.

Treatment	Hand weeding	Herbicide	Average
1. Dibbling 30 x 30 cm	1779	1362	1571
2. Dibbling 30 x 30 cm	1750	1350	1550
3. Dibbling 20 x 20 cm	1542	1075	1308
4. Continuous row 30 cm apart	1571	1221	1396
5. Continuous row 20 cm apart	1583	1612	1600
6. Broadcast and raked in	1608	1262	1433

LSD 5% weeding = *0.123 kg*
LSD 5% treatments = *0.805 kg*
CV = *18.86%*
LSD 5% interact = *0.114 kg*
Plot size = *24 m²*

Management experiments in Sierra Leone. There were a total of 21 experiments in different parts of the country under dryland conditions. Here summaries of four of them are given.

A long-term soil management practices experiment was conducted for the first time at Makassa on a field (2% slope) that has been under continuous cropping with rice for the past three years with the objective of studying the changes in soil productivity due to various management practices. It involved the methods of land preparation and use of various soil management practices such as mulching and burning of straw and use of pesticide against soil borne insects.

The plowing treatments consisted of tractor and traditional hand hoe at 20 and 10 days before sowing and just before seeding. The tractor plowing was done with a chisel plow 20 cm deep while the hand hoe was only able to scratch the soil surface to a depth of 3-5 cm. Straw was applied at 4 t/ha for full mulch or burning treatments. All the plots received fertilizer at $N_{60}P_{40}K_{40}$/ha.

The yield data presented in Table 33 show that all the soil management practices gave increased yields ranging from 75 to 90 percent over the control.

Table 33. Effect of soil management practices on upland rice (LAC 23) (Mean grain yield kg/ha).
Center: Makassa

Soil management practices	Tractor plowing	Hand hoe	Mean
Bare field	706	586	646
Dieldrex (2 kg a.i./ha)	1241	1126	1183
½ Straw burned + ½ Straw mulched	1235	1013	1124
Full straw mulched	1288	1163	1225
Full straw burned	1289	1128	1208
Mean	1152	1003	

LSD (0.05) for soil management practices = *158*
LSD (0.05) for method of land preparation = *141*
CV = *25.5%*

The yield maximization experiment was conducted at Makassa on upland soil that had been under continuous cropping with rice for the past three years. The objective was to find the factors that limit rice yield. The factors included in the trial were: method of seeding (broadcast and line sowing), fertilization, weeding, plant protection with insecticide, straw burning and mulching, liming and soil and water conservation practices. Only one cultivar, LAC 23, was used in the experiment and the yield data obtained are presented in Table 34. The treatments were designed to develop an intermediate package of practices for the small farmers and a complete package to suit the modern farmers with access to all resources.

Table 34. Response of upland rice (LAC 23) to various production factors.
Center: Makassa

Treatments	Yield kg/ha	% over control
Traditional method (control)	370	–
Complete package (CP)	1329	259
CP – SWC	1206	226
CP – (SWC + SM)	1375	272
CP – (SWC + SM + SB)	1309	254
Intermediate package (IP)	1219	229
IP – Fertilizer	560	51
IP – Weed control	575	55
IP – Plant protection	1554	320
IP – Line sowing	1246	236

LSD (0.05) to compare treatment means = *423*
CV = *27%*
SWC = *Soil and water conservation methods*
SM = *Straw mulch*
SB = *Straw burned.*

The results presented in Table 35 show that the complete package (1329 kg/ha) was not significantly superior to intermediate package (1219 kg/ha). The traditional practice gave the least grain yield of 370 kg/ha. Weed control and fer-

Table 35. Response of upland rice (LAC 23) to various production factors.

Production factors	Yield in kg/ha	Reduction in yield Kg/ha	%
Intermediate package	1219	–	–
Minus fertilizer	560	659	54
Minus weeding	575	644	53
Traditional practice	370	849	70
Complete package	1329	–	–

LSD (0.05) to compare treatment means = 423
CV = 27%

Note: The intermediate package consisted of fertilizer application ($N_{60}P_{40}K_{40}$) + weed control (manual weeding) + plant protection (malathion at 2kg a.i./ha) and line sowing. The complete package involved not only "intermediate package" but various soil management factors such as bunding, mulching and burning of straw and liming.

tilizer application had maximum contribution to the grain yield of upland rice. This confirms the findings of last year.

A long-term yield maintenance experiment was laid out for the first year in a newly cleared flat land (after eight years of bush fallow) at Samu (about 5 miles from Rokupr) to study the effect of various soil management practices on the yield maintenance of upland rice over a long period under scientific farming. The main plot consisted of five treatments: bare (traditional practice), straw mulched, straw burned (both at the rate of 4 t/ha), half straw burned + half straw mulched, and live mulched. Each of the main plots was divided into three sub-plots, namely: no weed control + no fertilizers, weed (manual) control alone without fertilizers and weed control plus fertilizers ($N_{60}P_{40}K_{40}$). The yield data for the first year (1977) are presented in Table 36.

The factors studied had a positive effect on grain yield in the following order: fertilizer, weed control, burning of plant material.

A field experiment was conducted with 12 treatments to study the relative efficiency of straight, compound and slow release fertilizer materials on upland rice (grown for the fourth year in succession) during the wet season of 1977. The fertilizers tested were nitrophosphate, urea, sulfur coated urea and urea supergranules. All the fertilizer treatments were adjusted to $N_{60}P_{60}K_{60}$ (kg/ha) for comparison by addition of P_{60} and K_{60} alone or in combination as needed. The statistical analysis did not show any significant difference among various treatments. However, all the fertilizer treatments gave higher yields than the control.

Inland swamp

Cultural practices. Two rice cultivars were planted in an experiment in the Inland valley swamp at Magbolontor (associated swamp) with the objective of testing one iron toxicity resistant cultivar (Gissi 27) against a susceptible one (BD2) under four methods of seeding and three dates of planting. The planting methods were transplanting, line sowing, broadcasting and broadcasting + beushening (a shallow plowing operation in the standing crop at early tillering stage to uproot the weeds, followed by redistribution of seedlings). The nurseries were sown on 21 May, 14 June, and 8 July 1977, and transplanted on 11 June, 5 July and 29 July respectively. Direct seeding was done in the field on the same dates as sowing in the nursery.

The crop stand could not be established on the third date (both the direct seeded and transplanted crops) due to submergence by deep standing water in late July. The grain yield data for the first two dates are presented in Tables 37 and 38.

Table 37. Effects of planting dates on the performance of rice cultivars in inland swamp.

Mean grain yield (kg/ha)
Center: Magbolontor — Wet season 1977

Cultivar	Dates of nursery/direct seeding 21.5.77	14.6.77	Mean
Gissi 27	2263	2725	2494
BD 2	787	2145	1466
Mean	1525	2435	–

LSD (.05) for cell means = 265
LSD (.05) for cultivar means = 188
LSD (.05) for date of planting = 249
CV = 18.3%

Table 36. Effect of different soil management practices on upland rice (LAC 23).

Soil management practices	Mean grain yield (kg/ha) W_0F_0	W_1F_0	W_1F_1	AV.YD	Response over traditional practice W_1F_0	W_1F_1
Bare (traditional practice)	564	1129	1733	1141	565	1169
Straw mulched	443	997	1999	1146	553	1556
Straw burned	638	1279	2096	1337	641	1458
½ Straw burned + ½ Straw mulched	819	1127	2051	1332	308	1232
Live mulch *(Psophocarpus palustris)**	666	818	1486	990	152	820
Mean	626	1070	1873		444	1247

LSD (0.05) to compare soil management practices = 172 — *CV = 23.1%*
LSD (0.05) to compare cultural practices = 128 — *W = Weed control F = Fertilizer*

Note: The live mulch* ***Psophocarpus palustris* *did not germinate in all the 12 subplots. But since the live mulch was to be accommodated, the number of rows of rice was reduced from 25 to 15. The quantity of seeds used in this treatment was 360 g/plot as against 500 g in other plots. Hence the plant population was reduced resulting in lower yield.*

Table 38. Effects of dates and methods of planting on rice yields (kg/ha) in inland swamp, 1977.

Methods of planting	Date of nursery/direct seeding 21.5.77	14.6.77	Mean
Broadcast	1504	2492	1998
Broadcast + beushening	1431	2318	1875
Line sowing	1284	2440	1862
Transplanting	1882	2491	2187
Mean	1525	2435	

LSD (.05) for cell means = 265
LSD (.05) for methods = 188
LSD (.05) for dates of planting = 249
CV = 18.3%

Soil amendment for iron toxicity. The experiment on soil amendments and fertilizer treatments in Inland valley swamp was repeated for the second year in succession at Magbolontor in the wet season, 1977, on the same location.

It can be concluded that Gissi 27, the cultivar previously tested and found to be resistant to iron toxicity, could be recommended as a replacement for BD 2 in inland swamps. Transplanting of Gissi 27 produced a yield just as good as broadcasting. For good yields, nurseries should be sown by mid-June and transplanting done by the first week in July.

Different methods of direct seeding were tested against transplanting using the cultivar BD 2. The grain yield data and response of treatments over control are presented in Tables 39, 40 and 41. Beushening had varying effects on the two methods of direct sowing, but none of these differences was statistically significant. Line sowing was significantly superior to broadcasting (Table 40).

The effect of the age of seedlings on the yield of the transplanted crop is presented in Table 41. In conclusion, line

Table 39. Relative yield performance (kg/ha) of different methods of sowing rice in inland swamp at Magbolontor, 1977.

Treatment	Mean grain yield (kg/ha)	Response over control	% increase over control
Broadcast (Control)	1203	-	-
Broadcast and beushening	1152	- 51	4.2
Line sowing	1445	242	20.1
Line sowing and beushening	1658	455	37.8
Transplanting 20 Dos at random	1401	198	16.5
Transplanting 20 Dos 20 cm x 10 cm	2043	840	69.8
Transplanting 40 Dos at random	860	-343	28.5
Transplanting 40 Dos 20 cm x 10 cm	1407	204	17.0
Mean	1396	193	16.0

LSD (0.05) = 523
CV = 25,5%
DOS = Day old seedlings

Table 40. Effect of beushening on the yield (kg/ha) of rice in inland valley swamp at Magbolontor, 1977.

Treatment	With beushening	Without beushening	Mean grain yield (kg/ha)
Broadcast	1152	1203	1178
Line sown	1658	1445	1552
Mean	1405	1324	

LSD (.05) for marginal means = 371
CV = 25.5%

Table 41. Effect of age of seedlings on the yield of transplanted rice in inland valley swamp, Magbolontor, 1977.

Treatment	Age of seedlings 20	40	Mean
			kg/ha
Transplanted at random	1401	860	1131
Transplanting at 20 x 10 cm spacing	2043	1407	1725
Mean	1722	1134	

LSD (.05) for marginal means = 371
CV = 25.5%

sowing is better than broadcasting but transplanting is best. Transplanting twenty-day-old seedlings is better than transplanting at 40 days. Rectangular planting (20 × 10 cm) was distinctly superior to random planting.

The grain yield data presented in Tables 42, 43 and 44 show that the yield increased with increasing fertilizer levels up to N_{80} P_{40} K_{40}. The highest responses to fertilizer were obtained where straw was plowed or burned (Table 43).

These data indicate that liming increases the pH and reduces the toxic effect of iron and increases the yield significantly. In addition, the incorporation of straw by either burning or

Table 42. Effect of soil amendments on rice (Vijaya) in inland swamp. Mean grain yield (kg/ha), Magbolontor, 1977.

Treatment	Without Lime	With Lime	Mean
SR $N_0P_0K_0$	1283	1752	1518
N_{80}	1479	1912	1705
$N_{80}P_{40}$	1684	2167	1926
$N_{80}P_{40}K_{40}$	1977	2267	2122
Mean	1606	2025	1816
SP $N_0P_0K_0$	1797	2071	1934
N_{80}	1931	2141	2036
$N_{80}P_{40}$	2179	2391	2285
$N_{80}P_{40}K_{40}$	2363	2743	2553
Mean	2068	2337	2203
SB $N_0P_0K_0$	1635	1948	1792
N_{80}	2017	2097	2057
$N_{80}P_{40}$	2210	2372	2291
$N_{80}P_{40}K_{40}$	2330	2885	2608
Mean	2048	2326	2187

LSD (0.05) for cell mean = 312
CV = 9%
SR = Straw removed, SP = Straw plowed
SB = Straw burned.

Table 43. Effect of straw and lime on rice (Vijaya) yield (kg/ha) in inland swamp, Magbolontor, 1977.

Treatment	Without Lime	With Lime	Mean
SR	1606	2025	1816
SP	2068	2337	2203
SB	2048	2326	2187

LSD for cell means = 251
LSD for lime means = 325
CV = 9.1%

Table 44. Effect of different fertilizer levels on rice yield (kg/ha) in inland swamp, Magbolontor, 1977.

Fertilizer level	Yield
Control	1748
N_{30}	1933
N_{80} P_{40}	2167
N_{80} P_{40} K_{40}	2428
Mean	2069

LSD (0.05) = 127

plowing would increase the yield significantly. Finally, yields are increased by the addition of fertilizer up to a level of $N_{80}P_{40}K_{40}$.

Drainage and application of basic slag. The experiment involving surface drainage of the soil and the application of different levels of phosphorus in the form of basic slag was repeated in the inland valley swamp at Magbolontor. Two adjacent fields of the swamp were used for laying out two separate experiments. One was kept in the natural condition, completely water-logged. The other field was freely drained with channels dug around each of the treatments creating oxidized condition of the surface soil. The cultivar Mahsuri was used in this experiment.

The grain yield data and treatment response are presented in Table 45.

In conclusion, surface drainage resulted in 45 percent increase in yield. In poorly drained swamps, application of basic slag alone at 40kg P_2O_5 increased the yield by nearly 100 percent. For well drained soils, balanced application of NPK at $N_{40}P_{40}K_{40}$ increased yield by 72 percent.

Fertilizer requirement for iron toxic swamp. Fertilizer treatments involving nitrogen (urea), phosphorus (single superphosphate) and potassium (muriate of potash), applied at different levels singly and in combination were set in an experiment in the inland valley swamp at Magbolontor in the wet season of 1976. Treatments involving lime alone (4 t/ha), basic slag alone (P_{40}/ha) and control were also included. The experiment was repeated on the same location in the wet season 1977. The grain yield data and treatment responses are presented in Tables 46 and 47.

In iron toxic swamp, a high dose of phosphorus is necessary to counteract the effects of iron toxicity and to give good yields. The incorporation of low levels of nitrogen (N_{40}) and moderate level of potassium (K_{40} to K_{60}) respectively also increased the yield significantly.

Yield maximization. An experiment was designed using the cultivar ADNY 11 with treatments involving drainage, fertilizer ($N_{80}P_{40}K_{40}$), and soil amendments of straw (4 t/ha) and lime (2 t/ha). Basic slag was used as the source of phosphorus. The objective was to test the effects of individual components of an intermediate package of cultural practices on the grain yield of rice in inland swamp. Two adjacent fields of the swamp were used. The grain yield data and the relative contribution of each of the main cultural practices are presented in Tables 48 and 49.

Among the various production factors influencing rice yields in the inland valley swamp, the contribution of surface drainage is the highest, followed by soil amendments (straw burning plus liming) and fertilizer in that order.

Sources of phosphorus. The first international trial on sources of phosphorus in flooded rice was conducted during the wet season of 1977 in the inland swamp at Magbolontor, as a part

Table 45. Effect of drainage and application of basic slag on rice in inland valley swamp, Magbolontor, wet season, 1977.

	Well drained			Water-logged		
Treatment	Yield in kg/ha	Response over control (kg/ha)	% increase over control	Yield in kg/ha	Response over control	% increase over control
Control ($N_0P_0K_0$)	1742	-	-	880	-	-
Basic slag (P_{40})	1923	181	10.4	1730	830	96.6
Basic slag (P_{80})	2305	563	32.3	1765	885	100.6
Basic slag (P_{40}) + Urea (N_{40})	2188	446	25.6	1850	970	110.2
Basic slag (P_{40}) + Urea (N_{40}) + MOP (K_{40})	3000	1258	72.2	1481	601	68.3
Mean	2232	490	28.1	154	661	75.1

LSD (0.05) = 459
CV = 10.9%

Table 46. Effect of fertilizer application on rice (BD2) in inland valley swamp, Magbolontor, wet season, 1977.

Treatments	Mean grain yield (kg/ha)	Response over control	% increase over control
$N_0P_0K_0$ (Control)	1158	–	–
N_{40}	1227	69	6.0
N_{80}	1228	70	6.0
P_{40}	1807	655	56.6
P_{80}	2594	1436	124.0
K_{40}	1640	482	41.6
K_{80}	1216	58	5.0
$P_{40}K_{40}$	1842	684	59.1
$P_{40}K_{80}$	1815	657	56.7
$P_{80}K_{80}$	2087	929	80.2
$N_{40}P_{40}K_{40}$	1924	766	66.2
$N_{40}P_{80}K_{40}$	2142	984	85.0
$N_{40}P_{40}K_{80}$	2238	1080	93.3
$N_{40}P_{80}K_{80}$	2232	1074	92.8
Lime (4 t/ha)	1963	805	69.5
Basic slag (P_{40})	1891	733	63.3
Mean	1813	655	56.6

LSD (0.05) = 435 CV = 16.9%

Table 47. Effect of N, P and K application on rice (LD2) in inland valley swamp, Magbolontor, wet season, 1977.

Nutrient	Level (kg/ha) 40	80	Mean
N	1227	1228	1228
P	1807	2594	2201
K	1640	1216	1428

Table 48. Effect of different management practices on rice yield (kg/ha) in inland valley swamp, Magbolontor, wet season, 1977.

Treatments	Well-drained paddy	Water-logged paddy	Response due to drainage	% increase due to drainage
Control ($N_0P_0K_0$)	2554	783	1771	226.2
IP	4103	3495	608	17.4
IP-Fertilizer	3880	2883	997	34.6
IP-Soil amendment	3387	2950	437	14.8
IP-Drainage	3033	2394	639	26.7
Mean	3391	2501	–	–

LSD (0.05) = 344 569 CV = 7.0% 16.7%

IP = Intermediate package (Fertilizer — $N_{80}P_{40}K_{40}$, phosphorus as basic slag) + drainage + soil amendments (lime 2 t/ha + straw 4 t/ha).

Table 49. Effect of different management practices on rice yield (kg/ha) in inland valley swamp, Magbolontor, wet season, 1977.

Treatment	Intermediate package	Contribution due to Fertilizer	Soil amendments	Drainage
Well drained	4103	223	716	1070
Water logged	3495	612	545	1101
Mean	3799	418	631	1086

of the International Network on Fertilizer Efficiency in Rice (INFER) organized by the International Rice Research Institute, the Philippines.

The objective was to evaluate phosphate rocks for agronomic and economic effectiveness. The experiment is expected to be conducted for five cropping seasons on the same location. The treatments included three phosphate materials: a highly reactive rock phosphate (phosmak), a less reactive phosphate (Christmas island rock phosphate) and single superphosphate (water soluble phosphorus). The yield data are presented in Table 50.

Table 50. Effect of sources of phosphorus on flooded rice cultivar ADNY 11.

Treatment	Mean yield kg/ha	Response over control	% increase over control
$N_0P_0K_0$ + $N_{80}K_{40}$ (Control)	1440	–	–
SSP (P_{20}) + $N_{80}K_{40}$	1751	311	21.6
SSP (P_{40}) + $N_{80}K_{40}$	2075	635	44.1
SSP (P_{60}) + $N_{80}K_{40}$	2173	733	50.9
Phosmak (P_{20}) + $N_{80}K_{40}$	1679	239	16.6
Phosmak (P_{40}) + $N_{80}K_{40}$	2012	572	39.7
Phosmak (P_{60}) + $N_{80}K_{40}$	2151	711	49.4
Christmas Rock phosphate (P_{20}) + $N_{80}K_{40}$	1848	408	28.3
Christmas Rock phosphate (P_{40}) + $N_{80}K_{40}$	1942	502	34.9
Christmas Rock phosphate (P_{60}) + $N_{80}K_{40}$	2281	841	58.4
Mean	1935	495	34.3

LSD (0.05) = 414
CV = 14.7%

Seed rates and spacing. In an effort to determine the appropriate seed rate and spacing, an experiment was carried out at Mando, Sierra Leone. The treatments comprised three seed rates: 50, 75 and 100 kg/ha, and three methods of seeding: broadcasting, 20 cm row spacing and 30 cm row spacing. The grain yield data are presented in Table 51.

Table 51. Effect of seed rate and spacing on rice (CP4).

Treatment	Mean grain yield (kg/ha) Seed rate in (kg/ha) 50	75	100	Mean
Broadcast	998	1276	1014	1096
20 cm row spacing	2116	2011	2039	2055
30 cm row spacing	1044	1765	1726	1512
Mean	1386	1684	1593	1554

LSD (0.05) marginal means = 178
LSD (0.05) for cell means = 291
CV = 13.2%

Nitrogen × variety × spacing interaction in irrigated rice. In Sierra Leone, this experiment was designed with two row spacings (20 cm x 10 cm, 30 cm x 10 cm) as main plot, four levels of nitrogen (at 0, 40, 80 and 120 kg/ha) as subplot and five high-yielding rice cultivars, as sub-sub-plot, under irrigated conditions at Mange. Analysis of variance indicated no significant effect of plant spacing on grain yield of rice cultivars included in this study. Nitrogen showed significant interaction with plant spacing (Table 52).

Table 52. Effect of nitrogen and plant spacing on grain yield of rice (kg/ha) (averaged over 5 cultivars) under irrigated condition, Mange, wet season, 1977.

	Spacing	
Nitrogen levels	30 cm x 10 cm	20 cm x 10 cm
0 kg/ha	1975	2330
40 kg/ha	3104	3012
80 kg/ha	3985	3650
120 kg/ha	4451	3915

LSD (0.05) for nitrogen levels within the same spacing = 339
CV = 13.08%

Yield under application of N at 120 kg/ha was not significantly different from that obtained with N_{80}.

Table 53. Performance of rice cultivars averaged over nitrogen and spacing levels, under irrigated conditions at Mange, wet season, 1977.

Cultivar	Grain yield kg/ha
ADNY 2	3784
ADNY 11	3757
Mange 2	3494
DJ 684D	3241
IR 2070-464-1-3	2238

LSD (0.05) = 21C
CV = 13.08%

Grain yield of rice varied significantly among cultivars (Table 53), with ADNY 2 and ADNY 11 giving the highest grain yields.

Cultural practices. An experiment was initiated in the wet season of 1977 to evaluate various methods of seeding rice under irrigated conditions at Mange, Sierra Leone.

Table 54. Effect of seeding method on grain yield of rice (ADNY 11) under irrigated conditions, Mange, wet season, 1977.

Treatment	Mean yield kg/ha
Line sowing in dry seedbed	4647
Broadcasting in dry seedbed	4837
Broadcasting in dry seedbed + beushening	5553
Sprouted seeds line sown in puddled field	4746
Rectangular transplanting (20 cm × 10 cm) in the puddle	4230
Random transplanting in puddled field	4538
Broadcastable seedling in puddled field	4629

LSD (0.05) = 662
CV = 9.39%

Results in Table 54 indicate that highest yield (5553 kg/ha) was obtained by broadcasting the seeds in dry seedbed and beushening at 35 days after seeding. Yield from other treatments was not significantly different from each other.

Yield maximization. This experiment was initiated in the wet season of 1977 to identify the optimum combination of cultural practices (weeding, fertilizer application and methods of transplanting) for rice production under irrigated ecology. The results (Table 55) indicated that methods of transplanting did not significantly affect grain production.

Table 55. Effect of weeding and fertilizer application (averaged over transplanting methods) on grain yield of rice (ADNY 11) under irrigated conditions, Mange, wet season, 1977.

	Fertilizer treatment		Mean
Weeding	$N_0\ P_0\ K_0$	$N_{40}\ P_{40}\ K_{40}$	
No weeding	2299	3604	2952
Manual weeding	2380	3612	2996
Chemical weeding	2620	4177	3399
Mean (kg/ha)	2433	3798	

LSD (0.05) for fertilizer levels = 240
LSD (0.05) for weeding levels = 323
CV = 13.08%

Under the non-fertilizer treatment the difference between chemical weeding and manual weeding was not significant. With moderate fertilization, however, chemical weeding was superior to hand weeding.

The effect of sulfur. Chlorosis of rice on transitional soils (between hydromorphic and dry land) has been thought to be a result of nitrogen deficiency. Rice was planted in soil from a hydromorphic valley bottom and soil from dryland above the valley and subjected to the two moisture regimes of flooding and saturation. When nitrogen was the limiting factor, yield reduction was constant through the two moisture regimes. When sulfur was the limiting factor, yields varied greatly between the moisture treatments. Yield reduction was greatest when the dryland soil was flooded and when the hydromorphic soil was saturated. Yield reduction was slight when the valley soil was flooded or when the dryland soil was saturated. This will be studied further in 1978.

Availability of zinc. Incorporating straw into the soil at harvest time had no influence on the availability of zinc through four seasons at Ibadan, Nigeria. No significant differences were found in rice plots treated with NPK alone, NPK + straw, NPK + zinc, and NPK + straw + zinc.

Effect of spacing. Two spacing trials were carried out with two different irrigated cultivars at IITA. IET 1444 is less leafy and more erect than BG 90-2 which is quite leafy and produces more tillers. IET 1444 showed no significant difference between the five spacings but in the case of BG-90-2, the differences were highly significant. Highest yields were obtained with the closed spacing of 20 x 20 cm followed by the spacing of 30 x 15 cm (Table 56).

Iron toxicity. A total of 107 cultivars including those in the National Rice Observation Nursery as well as the national co-ordinated varietal trials were screened for tolerance to iron toxicity at Suakoko, Liberia. Under severe iron toxic conditions, Gissi 27, Suakoko 8 and IR2902-50-1-4 were resistant. IR5 showed intermediate to susceptible reaction 11 weeks after transplanting but had tendency to recover from the setback during the reproductive stage.

Observations made in WARDA initial evaluation trial (in moderate iron toxicity conditions at Suakoko) identified 126

Rice pathology staff checking a medium-duration dryland rice cultivar for pale yellow mottle virus. Only a few cultivars are resistant to it.

Table 56. Mean yields (kg/ha) from different spacings.

Treatment	IET 1444	BG 90-2
40 x 5 cm	5100	4800
30 x 10 cm	5290	5110
30 x 15 cm	5300	5600
25 x 15 cm	5590	5450
20 x 20 cm	5320	5940
Total average	5320	5380
LSD 5%	763 kg	142 kg
CV	9.31%	17.11%

cultivars as resistant. Prominent among these were IET 2911, KLG 6987-191-P, BR51-18-2, CICA 4, B 151 h-kn-19-3-1, No. 1281, Sri Malaysia, FARO 8, ROK 8, ROK 5, ROK 6, ROK 7, TOs 7102, AUS 8, RR2071-586-5-6-3 and BKN 6987-128-4. Several cultivars showed susceptible reaction in the early growth stage but tended to recover from the stress. These included BG35-2, RP 291-7, IR1750B-7, BR 3-12-B15-33, KLG 6987-146-3P, IET 2137, TOs 2300 and IR5.

Screening dryland rice in Sierra Leone. Twenty-three cultivars out of 35 were identified to possess good overall adaptability including good resistance to major diseases, particularly blast. The selected cultivars are: M-258, AZ-261, Merikan Larger, HL-58, 68 f/b/20/b, LAC 5544, 13az-lg 3/3/7/2, Cumba, D4-115, Gbondobai, A2-67 Gbengben, A2-263, 194/1/2, Ngovie, Fossa, M 50/2/2/2, Mutant de 217/1, DO KHAO/E10 x 10, 131M50/4/2/2, 42 x 104/1080/4/3/b, Mahadi kwee and M1069/1/2.

Irrigated rice. Many cultivars that are resistant to blast during the wet season often become susceptible in the dry season in Sierra Leone. Therefore, from many blast screenings carried out in 1977 those showing good resistance during the dry season are of practical importance. Some of these are 2501c, 24263, 2246, IR 269-26-3-3-3 (TOs 78) and IR1721-11-4-22-4. The earlier blast resistant selections (ADNY 6, ADNY 11, ADNY 4) appear to still retain their high level of resistance.

Pale yellow mottle virus. Of the 124 short- and medium-duration dryland cultivars screened for resistance, only six were neither resistant nor moderately resistant to the disease. The resistant cultivars are shown in Table 57.

The relationship of the virus causing pale yellow mottle in some countries in West Africa was determined by the agar serology test. It was found that the Nigerian and Ivory Coast viruses are identical or closely related to all the Sierra Leone collections.

Table 57. Screening dryland cultivars for resistance to yellow mottle virus in Sierra Leone, 1977.

Cultivar	Reaction	% Stunting
IB 99	R	0.2
TOs 3514-1	R	0.5
2117	R	0.4
E425	R	3.5
IB 97	R	4.3
IB 34	R	0.1
TOs 4031	R	4.9
TOs 4120	R	0.1
TOs 4152-B-2	R	0.0
IAC 25	R	0.4
Line 13d x R75 (no. 953)	R	4.7
TOs 4414	R	0.0
63-83	R	3.7
TOs 4076	R	0.1
TOx 95-LS2	R	9.8
Iguape Cateto	R	3.3

Brown spot. In Liberia a trial designed to evaluate 105 cultivars for tolerance to iron toxicity at Bong Mines Agricultural Project site was found to have severe incidence of brown spot disease. Scoring of cultivars for the disease indicated that Suakoko 8, Jaya, IR2071-588-1-6, IR2058-435-3-1, IR2071-105-2, IR2071-105-7, IR4422-6-2, B462b-Pn-31-2, IET 1996, Hong Sun, IR2071-586-5-3 and IR2071-286-5-6 showed resistance to the disease, while cultivars IR5, IR1416-131-5, CICA 4, Mahsuri and Improved Mahsuri were susceptible.

Common rice weevil in Liberia. During the past two years a few rice cultivars stored in the seed store at Suakoko showed severe damage by the rice weevil when the other cultivars stored side by side had strikingly less damage. Studies were initiated during 1977 in cooperation with Science Division of Cuttington University College, Suakoko, to identify the pest and to confirm if there were varietal differences for damage done by the weevil. The results obtained so far are discussed below:

1. The rice weevil causing the damage was identified as *Sitophilus oryzae*.
2. The insect takes 23-27 days to complete one life cycle. The weevil larvae were successfully reared outside the grain in petri dishes using powdered rice.
3. Differences for damage due to the weevil were confirmed when healthy grains of 14 cultivars were infested under controlled condition with 100 insects and damage recorded. The cultivars P14, IRAT 10, IR 937-55-3, TOs 4030 and Juma 1 showed 25-67 percent damage while M18 and M4 showed 10-15 percent damage. The damage in IR5, Suakoko 8, Gissi 27, LAC 23 and M55 was less than 5 percent. Also the insects which were infested on IR5 and LAC 23 (damage below 1 percent) were found dead within 2-3 weeks of infestation.
4. The cultivars showing heavier damage had smooth grain surface while those showing lesser damage (1-15 percent) had hairy surface; which indicated that hairy grain surface may be responsible for the reduced damage. The reason for death of the insect after feeding on IR5 and LAC 23 was not determined.
5. The infestation by the pest also occurred in the field before harvesting. The observations made on number of insects present on the panicles of nine cultivars just before harvesting indicated that cultivars with smooth grain surface attracted more weevils than the cultivars with hairy grain surface.
6. A Hymenopteran parasite and a Heteropteran predator were found to attack the rice weevil larvae during storage.

In the search for genetic resistance to *Diopsis thoracica*, 500 rice cultivars were screened in a screenhouse at IITA.

Screening for resistance to *Diopsis thoracica*. In the search for genetic resistance to *D. thoracia*, 500 rice cultivars were evaluated during 1977. The screening was conducted in a screenhouse (20 × 25 m) where a high population of this insect pest was first developed in a susceptible cultivar. Each cultivar was planted in one-row plot of 20 plants each. Their reaction was evaluated at 50 days after transplanting by recording the number of dead hearts per plant. The reaction of a few selected cultivars is presented in Table 58.

Table 58. Reaction of selected rice cultivars to D. thoracica, IITA, 1977.

Cultivars	Dead hearts %
Huang-Sengoo	0.0
Td 10^A	0.0
Magoti	2.8
C 5565	5.1
Saconodo Brasil TM 1377	14.0
Samba	43.0
IR 630	63.0

The cultivars Huang-Sengoo, Td 10^A, and Magoti exhibited a high level of resistance to *D. thoracica* and will be further evaluated under a replicated trial to confirm these preliminary results.

Transfer of technology

Dryland rice. The 1977 results on varietal trials of medium-duration cultivars again confirmed that none of the introduced cultivars (IR 2035-108-2, IR 1754-F5B-23, Juma 1 and OS6) was superior to LAC 23 or LAC 23 (white). IR 2035-108-2, a semi-dwarf cultivar had been found to outyield LAC 23 at Suakoko during 1976; it continued to show its yield superiority in the Suakoko trial but at other sites it yielded lower than LAC 23. The results indicate that this cultivar is not suited to on-farm conditions as such but it has been used in the breeding program in crosses with LAC 23.

In a WARDA co-ordinated varietal trial conducted at Suakoko with 14 medium-duration cultivars, 4418 — an introduction from Colombia — outyielded LAC 23 (white). However, the plant type of this cultivar is not suited to peasant farm dryland eondition in Liberia. It can, however, be used as a parent in the breeding program.

Although none of the short-duration cultivars (TOs 2583, TOs 2581, 63-83, M55, M18 and IRAT 13) was found superior at all locations, TOs 2581, TOs 2583 and IRAT 13 were found to be higher-yielding than others at Suakoko, Zleh Town and Voinjama. However, IRAT 13, 63-83, M55 and M18 were again observed to be highly susceptible to the sheath rot and sheath blotch diseases in Liberia, and their yield was reduced. Some of these lines have been crossed with LAC 23 to combine their high yield potential with disease resistance.

Irrigated rice. In Liberia during 1977, medium-duration elite cultivars were evaluated on multilocation basis in replicated yield trials under upland and lowland conditions. The seven sites of Suakoko, Foya, Kolahun, Voinjama, Bong Mines, Zleh Town and Cestos Agriculture Project were selected because of their importance in rice research and development activities.

Varietal trials under lowland conditions. Among the medium-duration cultivars (130-150 days) evaluated, none of the cultivars was superior at all the locations; however, cultivars IR 2071-586-5-3, Brengut, IR 2055-473-2-1, Improved Mahsuri, IR5 and Suakoko 8 were found promising enough to be tested in the on-farm trials (Table 59). Improved Mahsuri, Suakoko 8 and Brengut are semi-tall to tall, have moderate tillering and medium-long to long (26-28 cm) panicles, whereas the other cultivars have semi-dwarf to intermediate-height and medium to medium-long (24-26 cm) panicles. All of these cultivars showed resistanee to moderately susceptible reaction to the major stress factors of neck blast, sheath rot, sheath blight, glume discoloration, leaf scald and iron toxicity. Except at Suakoko during dry season, none of the cultivars was significantly higher-yielding than IR5.

In a WARDA co-ordinated varietal trial, Improved Mahsuri was promising among medinm-duration cultivars.

Among the short-duration cultivars (less than 130 days) none of those tested showed consistently superior performance at all the locations. However, some of the short-duration eultivars IR 2053-94-1-2, CR 12-178, IR 2053-407-2-1, IR 2035-120-3 and CS 5 yielded higher than others. In general, yields of short-duration cultivars were lower than the yields of medium-duration cultivars during the wet season. It appears that under the prevailing agro-ecological conditions in Liberia, the medium-duration cultivars are better suited in the wet season and short-duration cultivars may bc useful for the dry season where there is a possibility of water shortage during the latter part of the season.

Trials in Nigeria. The transfer of technology in Nigeria is handled by the Nigerian Federal Ministry of Agriculture and IITA cooperates. TOs 78 (IR 269-26-3-3-3) and TOs 42 (IR 665-79-2) are amoug IITA's nomination in the on-the-farm trials in 1977. These two lines have entered multilocation phases in some states in the country for large-scale farming under irrigated conditions. TOs 103 (IR 790-35-5-3) has been multiplied for large-scale planting in a project in Anambra State.

Trials in Sierra Leone. Under the All Sierra Leone Coordinated Agronomic Trials on farmers' fields, several experiments on rice were conducted in various ecologies to study the impact of new cultivars and production technology developed at the Rice Research Station, Rokupr, on rice yields under the four ecosystems: uplands, inland swamps, mangrove swamps and bolilands in Sierra Leone. The program was mostly confined to inland swamps during 1977. The summary and conelusions from these trials are highlighted below.

Under improved practices of cultivation which consisted of applieation of fertilizer ($N_{60}P_{40}K_{40}$ kg/ha), line sowing and weeding, there was an improvement in rice yields as eompared to traditional practice of cultivation, whether it was the farmers' cultivar or an improved one.

On uplands, nitrogen application between 20 and 100 kgN/ha gave a response of 20 to 15 kg per kg of N applied. Response

Table 59. Performance of some medium-duration rice cultivars evaluated under irrigated conditions in national co-ordinated varietal trials, Liberia, 1977.

	Yield (kg/ha)					
	Suakoko					
Cultivar	Dry season	Wet season	Voiniama	Kolahun	Zleh Town	Mean
IR 2071-586-5-3	4811	4816	5110	5776	5940	5291
IR 2071-588-1-6	4243	4570	5336	4776	–	4731
IR 2071-105-7	4107	3634	5150	4000	3394	4057
IR 2071-588-3	4089	4376	5464	4400	1122	3890
IR 1416-131-5	3950	3350	5904	3900	3813	4183
IR 2055-473-2-1	3765	–	6176	5252	4425	4904
Brengut	3783	3690	4600	6000	6586	4932
IR 2070-575-5	3557	4570	5670	4024	4029	4370
Improved Mashuri	3896	5998	–	–	4682	4725
Suakoko 8	4259	4936	5770	5040	3357	4672
IR5 check	3448	5086	5252	5824	4376	4837
Mean	*3992*	*4457*	*5463*	*4899*	*4172*	*4599*
LSD	*1074*	*1294*	*1188*	*978*	–	
CV (%)	*20*	*22*	*15*	*14*	–	

to nitrogen in the inland valley swamp was comparatively low. It may be due to high organic matter in the soils.

In the inland valley swamp the crop responds well to phosphorus and yields increase. Application of 1 kg of P_2O_5 gave a response as high as 20 kg of grain in Makeni and 40 kg of grain yield at Fanima. However, application of phosphorus in the presence of nitrogen did not help in increasing the rice yield. In boliland, application of 1 kg of P_2O_5 gave a response of about 20 kg of grain in Kono. Interaction of phosphorus and potassium was negative at many locations.

In the inland valley swamp application of potassium gave good responses. At Makeni in north-east and Batkanu in the north-western region, very high responses (1200 to 1400 kg/ha) were observed from the application of 40kg K_2O/ha. In bolilands of Kono District, high responses ranging between 800 and 1600 kg/ha were observed from different levels of potassium.

On uplands, it was observed that application of N and P together is more beneficial than applying nitrogen alone. The application of potassium along with nitrogen and phosphorus was not found beneficial in the bush-fallow rice system. In the inland swamps, responses to $N_{60}P_{40}K_{40}$ were higher than those obtained to $N_{60}P_{40}$ and N_{60} in the north-western and southern regions, the average response to $N_{60}P_{40}K_{40}$ being 1552 and 1403 kg/ha, respectively in the two regions. In the bolilands in Kono and Tonkolili districts, $N_{40}P_{40}K_{40}$ was found more beneficial as compared to $N_{80}P_{40}$.

It was also observed that potassium application in conjunction with higher levels of N and P enhanced the yields significantly in Kambia, Kenema, Kono and Tonkolili. In mangrove swamp a similar trend was observed.

IITA-NAFPP Sorghum, Millet and Wheat Program

The year 1977 was the third and the last year of the pilot phase of this project located at the National Center for Sorghum, Millet and Wheat at Agricultural Extension and Research Liaison Service of Ahmadu Bello University, Zaria, Nigeria. IITA staff handed over the charge of the project to the national staff after the completion of their assignment.

Sorghum and millet program. The work concentrated on variety and management minikit and production kit trials, training, field visits and finalization of cultivars recommended for various zones of the country.

Minikit and production kit trials. Average yields of sorghum and millet from minikit field trials in 100 locations in Kano State are summarized in Table 61. The minikits in the southern zone were interplanted, such as sorghum with millet (Ex-Borno) and millet with sorghum (Y.G. 5760).

Since yield data were obtained from the trials on the farmers' fields accurate records were not obtained. Sorghum cultivars H.P. 8 and Y.G. 5760 were recommended for the northern and southern zones respectively of Kano State based on their overall performance in these trials. Similarly, millet cv. Ex-Borno was recommended for Kano State.

Sorghum cultivars recommended for various states. Improved varieties of sorghum are being recommended for different agroclimatological zones of Nigeria based on the results of their performance in regional yield trials and NAFPP minikit trials.

Wheat program. The program covered field trials of promising cultivars and management practices through minikits and production kits, training programs and screening new wheat lines from CIMMYT, Mexico.

Seventy-two trials were conducted in three states (Kano-52, Borno-8, Sokoto-12). The summarized results of varietal and fertilizer minikits are given in Tables 60, 61 and 62.

Table 61. Yields of sorghum and millet cultivars from mini and production kits in Kano State, Nigeria.

	Sorghum cultivars	Yield (t/ha)	Millet cultivars	Yield (t/ha)
A. Northern Zone (Kano)				
Minikits	H.P.8	3.1	Ex. Borno	2.7
	H.P.3	2.7	Ex. Benue	2.5
	B.E.S	2.5	Nig. Comp.	2.1
	Local	2.3	Local	1.9
Production kits	H.P.8	4.1	Ex. Borno	4.2
B. Southern Zone (Kano)				
Minikits	Y.G. 5760	4.9	Ex. Borno	3.6
	Kano Bulkline	4.4	Ex. Benue	3.3
	R.Z.I.	4.2	Nig. Comp.	2.1
	Local	4.0	Local	2.9
Production kits	Y.G. 5760	2.9	Ex. Borno	2.5

Table 60. Variety Minikit (yield kg/ha).

State	Location	No. of kits	301 x Son-Pi	Anza	Cultivars Siette cerros	Inia 66	Indus 66
Kano	Hadejia	10	1084	444	626	992	692
	Kazaure	3	1305	752	1550	1169	598
	Dambatta	3	1515	1460	1613	1512	1164
	Kadawa	6	3870	3533	3827	2725	2928
Borno	Daya	3	1987	1840	–	2173	2147
	Gamboru	1	*	3750	–	3250	3625
Sokoto	3 sites	6	1867	–	–	2067	2098

_ doubtful figure
Siette cerros was not planned for Borno.
Both Siette cerros and Anza were not planned for Sokoto. A local wheat cultivar was included in Sokoto trials; its yield (average of 6 kits) was 1989 kg/ha.

For 1977-78, a field program of varietal and management minikits and production kits for the northern states was finalized.

Training. Six in-service training courses were conducted at different locations in the northern states and were attended by about 200 participants. Six members of the extension staff successfully completed a sorghum/millet production course at ICRISAT, Hyderabad, India.

The common practice of retaining excess water after irrigation was adopted in Kano. One of the treatments in Sokoto was $N_{100}P_0$ (split), which gave a yield of 1680 kg/ha.

The frequency and duration of harmattan during the growing season was more favorable than in the previous year, hence the farmers had a good harvest even in cases of delayed planting.

In general, the trials in Borno and Sokoto appeared better organized with better results. Shortage of water at critical stages of growth and poor management in general contributed to poor crops in Hadejia, Kazaure and Dambatta areas in Kano State.

Cultivar 301 x Son-Pi appears promising compared to the traditional Siette cerros, and it has been planned to further test it in trials in 1978. Its bread making quality is being checked at Oshodi in Lagos and if acceptable, the cultivar may become popular.

The response to fertilizer dose $N_{100}P_{50}$ (N in split application) does not seem to have improved over single basal application of the same dose at Kadawa, considering the high soil permeability and high frequency of irrigation, this appears to merit checking during the next season.

The farmers apparently drained all the plots after irrigation, hence the poor drainage plot did not suffer as expected.

Table 62. Fertilizer minikit (yield kg/ha).

State	Location	No. of kits	$N_{50}P_{25}$ split	$N_{100}P_{50}$ all at sowing	$N_{100}P_{50}$ split	$N_{150}P_{75}$ split	$N_{100}P_{50}$ (farmers' practice)
Kano	Hadejia	10	1215	1677	1815	1215	1846
	Kazaure	3	951	2100	1248	1186	1087
	Dambatta	3	1260	1569	1581	1260	1433
	Kadawa	6	2287	3468	3011	3104	2845
Borno	Daya	3	1454	1627	1600	1653	1320
Sokoto	3 sites	6	–	1950	1761	–	1389

P means P_2O_5.

GRAIN LEGUME IMPROVEMENT PROGRAM

Cowpea breeding

The objective of the cowpea breeding program is to incorporate disease and pest resistance into a range of plant types suited to different cropping systems in the tropics. Efforts were directed primarily at grain legume types for sole crop conditions, but recently the improvement of lines for intercropped conditions and green pod vegetable production has received some attention.

Breeding procedures range from backcross methods to incorporate specific characteristics into otherwise well adapted materials, to population improvement methods using genetic male sterility to develop recurrent selection systems. In all procedures, the short-maturity period of cowpea is exploited by the growing of three to four generations per year.

Backcross methods. Backcross methods are being utilized to modify seed characteristics and disease resistance. One series, involving the crossing of TVu 6203, a large, white-seeded line from Senegal, to TVu 1977-OD (VITA-4) and TVu 4557 (VITA-5), is being grown on the BC_3F_1 generations in the current dry season. Other crosses between ACC 70002 and several IITA breeding materials are at the BC_1F_2 stage. Crosses are also made with the aim of incorporating resistance to *Colletotrichum truncatum*, bacterial blight or bacterial pustule into otherwise superior IITA lines.

Pedigree methods. During the year, about 200 crosses were made between IITA breeding lines and cultivars which had been developed and proved superior elsewhere. The latter included Ife Brown, developed in Nigeria, Kwara ex-Kwoi which gives good yields in northern Nigeria; SVS 3, Tanzania; White Wonder Trailing Ethiopia and CPRMV-10R-61 from Puerto Rico. Nearly 8,000 lines from these and earlier crosses were screened for disease and insect resistance and other plant characteristics in non-replicated progeny rows at IITA and other locations, and single plants were selected for further testing in 1978.

At least part of the material is being handled in a recurrent selection system with crossing F_1 and F_2 generations at Ibadan from September through June, and F_3 breeding lines at locations on a north-south axis in West Africa utilizing the various ecological conditions represented. Single plants selected from promising lines are multiplied at Ibadan in the dry season for Preliminary trials, and the best of these progress to Advanced and Uniform trials in successive years. New cycles are initiated each year by recombining superior lines from all stages of the system and useful germplasm from other sources. F_1 lines of the second cycle were multiplied at Ibadan during the 1977/78 dry season.

Preliminary trials. Two-hundred-and-thirty lines were compared with VITA lines and Ife Brown in two simple lattice trials at Onne and Ibadan (two seasons), Mokwa, Funtua, Gusau, Maradi and Ouagadougou.

At IITA, cowpea breeding procedures range from backcross methods to incorporate specific characteristics into otherwise well-adapted materials to population improvement methods using genetic male sterility to develop recurrent selection systems.

The seed yields of the better lines, together with those of the control cultivars, are shown in Table 1.

Several lines combined improved yields, relative to the controls, with satisfactory levels of disease resistance and other characteristics, and 85 were multiplied during the dry season for possible entry in Advanced trials in 1978.

Advanced trials. Sixty-three lines were compared with VITA lines and Ife Brown at the same locations as the Preliminary trials, in Gombe in Nigeria and also in Jamaica. Data recorded included various plant characters, disease and insect scores, pod characteristics and pod and seed yields. The performances of the better lines compared with the controls are shown in Table 2.

Table 1. Cowpea Preliminary Yield Trials, 1977. (Seed yield kg/ha.)

	Ibadan (F)	Onne (F)	Ouagadougou	Gusau	Funtua	Mokwa	Ibadan (S)	Mean
Trial 1								
VITA-1	819	871	1137	924	346	411	628	734
VITA-4	1382	258	1198	762	348	396	672	717
VITA-5	746	17	1326	746	438	273	699	606
Ife Brown	890	254	1079	709	152	433	714	604
TVx 1839-02F	1535	1553	1230	949	725	705	1190	1127
TVx 199-02F	1970	1026	1655	1179	334	605	795	1081
TVx 1461-01F	2245	1064	1300	1047	670	250	940	1074
TVx 2248-01F	1560	1141	2035	1247	251	285	850	1053
TVx 2283-02F	1340	1151	1805	749	566	325	880	974
Trial Mean	1120	629	1246	773	358	369	671	
S.E.	219.0	155.8	284.2	238.6	162.7	140.9	141.2	
C.V.	27.7	32.3	32.3	43.7	64.3	54.0	29.8	
Trial 2								
VITA-1	685	524	920	857	579	622	973	742
VITA-4	1368	231	1495	822	274	692	490	767
VITA-5	760	32	1208	673	606	680	510	639
Ife Brown	833	305	1262	483	437	685	675	669
TVx 12-01F	376	515	735	385	479	268	375	445
TVx 3122-06D	1370	554	1875	781	1190	640	980	1044
TVx 2949-01D	1580	674	1500	1120	660	760	720	1002
TVx 2907-08D	1190	804	1500	884	624	545	1055	943
TVx 1905-01F	1500	708	1273	868	541	735	945	939
TVx 2719-03D	1045	1047	1290	1040	505	885	715	932
Trial Mean	401	496	1188	745	641	572	684	
S.E.	219.8	138.4	266.1	229.8	208.0	112.2	167.9	
C.V.	34.5	39.5	31.7	43.7	63.8	27.7	34.7	

Particular attention is drawn to the strap- or narrow-leaved lines (indicated by (s) in the table) which were among the highest yielders in both trials in which they were included, suggesting a real advantage over traditional broad-leaved types. In Trial 1 TVx 289-4G averaged 1400 kg seed/ha, 29 percent higher than the controls.

However, there were highly significant interactions between the lines and their environments. Much of the variation could be accounted for by the regression of individual cultivars on environment mean yields which indicated that VITA-1, for example, does not appear to respond to improved conditions while TVx 2713-2C and some other lines are relatively better than average in these situations.

Population improvement. Population improvement methods involving genetic male sterility are being used to develop recurrent selection methods in a naturally self-pollinated crop. The system involves sub-populations selected for specific characteristics such as disease and insect resistance, and seed protein, from which lines are incorporated into back-up or main popnlations to upgrade agronomic characters before entering the routine breeding and testing program. The generalized system is illustrated in Figure 1.

In 1977 the disease, insect and back-up populations underwent their fourth, second and fifth cycles respectively. The number of crosses achieved totalled more than 100,000. Single plants selected from the back-up population in 1976 were advanced to F_4 generation in non-replicated rows; single plants selected in 1974 were tested in yield trials in two seasons at Ibadan. One line, 4R-0267-01F, was the second highest yielder in the Advanced Yield Trials of erect lines and is being multiplied for Uniform trials in 1978.

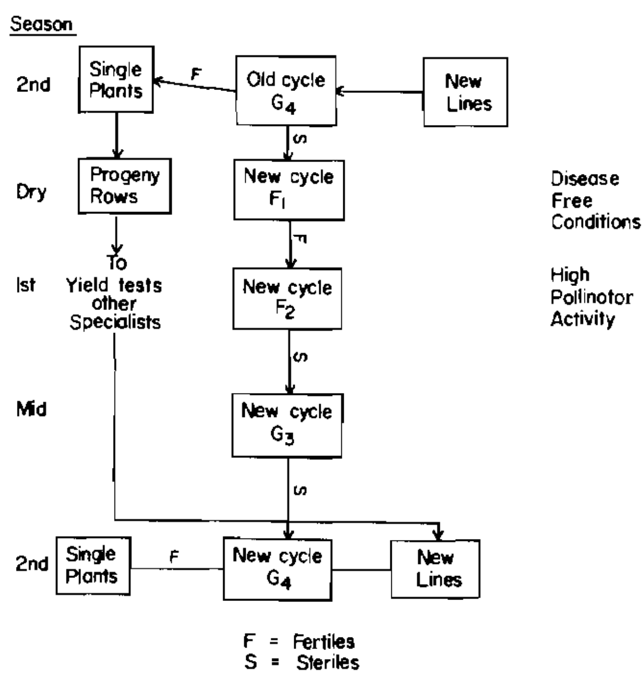


Fig. 1. Generalized population improvement system.

Intercropping. Thirty lines were grown as a sole crop and in association with cereals at IITA (second seasons) and Funtua in northern Nigeria and Ouagadougou (Upper Volta).

In the first season at Ibadan, sole crop cowpea was compared with cowpea and maize sown simultaneously. Owing to

Table 2. Cowpea Advanced Yield Trials, 1977. (Seed yield kg/ha.)

	Ibadan (F)	Onne (F)	Ouagadougou	Gusau	Funtua	Gombe	Mokwa	Ibadan (S)	Onne (S)	Mean	% Controls
Trial 1 (Spreading)											
VITA-1	978	1044	1167	578	464	1972	960	1272	1201	1071	
VITA-4	1140	443	1830	657	270	1713	1113	1438	1776	1153	
VITA-5	1448	112	1379	745	325	1485	1195	1400	1149	1026	
Ife Brown	1698	990	1762	445	154	1562	1038	1536	1120	1145	
TVx 289-4G (S)	1915	1394	2549	715	776	1415	893	1701	1148	1415	129
TVx 1948-01F	1985	1484	1631	712	269	1339	1245	1662	1455	1339	122
TVx 1997-3D	1993	727	1635	559	375	1296	1543	1751	1459	1296	118
TVx 33-1J (S)	1983	1281	1960	654	383	1256	931	1675	1192	1256	114
Trial Mean	1498	901	1781	601	329	1401	940	1438	1321		
S.E.	155.1	76.4	272.7	104.1	89.4	126.0	109.1	89.5	84.7		
C.V.	20.7	20.8	26.5	42.4	66.5	22.0	28.4	15.2	15.7		
Trial 2 (Semi erect)											
VITA-1	59	619	1428	1319	259	1473	991	1456	1324	994	
VITA-4	213	196	2083	1059	379	1213	1123	1746	1592	1067	
VITA-5	108	0	1637	1403	419	1212	1049	1441	1265	948	
Ife Brown	680	470	1738	830	194	908	759	1502	694	864	
TVx 1952-01E	30	700	1942	1396	376	1835	1036	1414	1429	1129	117
TVx 332-4G (S)	482	213	2382	1154	420	1228	863	1642	1064	1050	108
TVx 1850-01E (S)	982	895	1938	1124	443	1090	549	1358	644	1000	103
TVx 944-02E	776	599	1318	869	468	710	1072	1524	1285	959	99
Trial Mean	483	525	1501	862	256	960	860	1361			
S.E.	74.2	76.7	161.7	131.1	51.9	142.2	104.9	87.2			
C.V.	37.6	35.8	17.7	37.3	49.7	36.3	29.9	15.7			
Trial 3 (Erect)											
VITA-1	236	604	1093	417	1548	616	1314	971	910		
VITA-4	360	309	1250	276	1092	901	1161	1433	868		
VITA-5	426	1	1410	439	1062	917	1352	693	860		
Ife Brown	866	578	1467	210	940	1152	1582	1041	976		
TVx 7-4K	1276	1377	2070	300	1047	901	1115	925	1103	122	
4R-0267-01F	1575	1072	2007	454	925	710	1362	901	1080	119	
TVx 1576-01E	784	963	1600	319	1060	1088	1597	1219	1079	119	
TVx 1841-01E	1089	1153	1523	330	1093	953	1443	976	1042	115	
Trial Mean	846	694	1403	301	764	775	1300	832			
S.E.	104.7	79.5	138.8	54.9	143.9	82.7	108.8	108.2			
C.V.	30.4	28.1	17.1	44.7	46.1	26.2	20.5				

insect damage the data were variable and although significant differences in seed yields were recorded between cultivars there were no interactions between cultivars and cropping systems.

In the second season at Ibadan cowpea was sown on two dates; at the same time as maize and when maize reached anthesis. Significant differences in seed yield were recorded between cropping systems and cowpea cultivars and there were significant interactions between cultivars and sowing dates. The extremes of response to cropping systems are shown in Table 3.

Vegetable cowpea. Six green-pod vegetable, climbing cowpeas were tested in yield trials at Ibadan (second seasons), Onne (first season), Umudike and locations in the Gambia, Liberia and Trinidad.

In Onne (Port Harcourt) five of the lines were affected by a whitefly-borne golden mosaic; only TVu 3654 exhibited

Table 3. Cowpea maize intercropping trial, Ibadan, 1977.

	(Cowpea seed yield kg/ha)			
	System		Time of sowing cowpea	
Accession	Intercrop	Sole crop	With maize	At anthesis
TVu 1460	1525	1206	1342	1388
TVu 1593	1087	1207	925	1368
TVu 1258	1044	1152	1143	1052
TVu 1552	1041	1153	832	1362
TVu 420-1B	1029	1119	1111	1037
TVu 6433	534	1049	688	896
TVu 3518	723	1690	1135	1278
TVu 1630	531	1438	1055	913
S.E. ±	131.5			

any tolerance to the disease. The data from the first season trial at Ibadan are summarized in Table 4.

Table 4. Yields of vegetable type cowpea. (Ibadan, first season, 1977.)

	Yield green pods t/ha	Taste ranking	Sugars
TVu 1209	27.73	5.0	4.8
TVu 2176	25.81	3.0	4.4
TVu 3398	24.17	2.3	4.8
TVu 6493	23.77	2.6	4.3
FARV 13	23.67	1.0	6.8
TVu 3654	19.55	2.8	5.9
S.E.	1.31		.39

Green pod yields of nearly 30 t/ha were obtained from TVu 1209 with TVu 3654 producing the lowest yields. Taste tests indicated, however, that TVu 1209 was least preferred while FARV-13 was the most acceptable to consumers. The lines differed significantly in total sugar percentage and there were indications of a correlation between taste ranking and total sugars. Data from the other locations are yet to come.

Disease and pest management—Pathology

During 1977, emphasis continued to be placed on the identification of multiple virus resistance in cowpea, and on early-generation screening of cowpea breeding material.

Work was begun on the etiology and epidemiology of whitefly-borne virus diseases in legumes. Results from cooperative work at CIAT have provided evidence that a golden mosaic in lima bean in Nigeria is closely related serologically to the bean golden mosaic virus which has been purified and shown to possess doublet particles. A golden mosaic of cowpea in southeastern Nigeria has been shown to be transmitted by whiteflies; similar symptoms have been observed in cowpeas in Kenya, Tanzania and Niger. Cowpea (yellow) mosaic virus was serologically identified from cowpeas in a farmer's field in Togo and southern bean mosaic virus was similarly found in the Guinea Savanna of Ghana.

Reeent cooperative work with the University of Ife has concentrated on the greenhouse screening of elite multiple disease resistant lines in the International Cowpea Disease Nursery (ICDN) for resistance to southern bean mosaic virus (SBMV), cowpea aphid-borne mosaie virus (CAMV) and cowpea mottle virus (CMeV). Twelve lines combine resistance to cowpea (yellow) mosaic virus (identified previously) with SBMV and CAMV resistance, while five lines possess resistance to all four viruses. Field screening during 1977 first season at IITA's high-rainfall station at Onne, Port Harcourt, has identified numerous sources of resistance to the whitefly-borne golden mosaic which is epidemic at Onne. Three lines have been found to possess resistance to all five viruses which, together, are amongst the most important in African cowpeas. These results are summarized in Table 5.

The eooperative work in the University of Ife on resistance to SBMV is reported fully elsewhere, and a report of results from the ICDN for 1975–77 is being compiled.

Table 5. Multiple virus resistance in cowpea.

Resistance	No. of lines	Source (TVu)
CYMV	93	
CYMV + SBMV	26	
CYMV + CAMV	16	
CYMV + CMeV	17	
CYMV + SBMV + CAMV	12	
CYMV + SBMV + CAMV + CMeV	5	393, 493, 1888, 1948, 2755
CYMV + SBMV + CAMV + CMeV + GM	3	393, 493, 2755

CYMV = Cowpea (Yellow) Mosaic Virus
SBMV = Southern Bean Mosaic Virus
CMeV = Cowpea Mottle Virus
CAMV = Cowpea Aphid-borne Mosaic Virus
GM = Golden Mosaic (a whitefly-borne disease)

The ICDN, grown in 20 countries to date, is in its fourth year. It was established to identify broad-spectrum, stable resistance by exposing lines found to possess multiple disease resistance under Ibadan conditions to various environments and pathogen populations. Essential reports received so far are summarized here.

Locations have been found which favor the development of natural epidemics of certain diseases not present at Ibadan; testing at these sites has permitted the identification of resistance which is additional to those already reported. Thus, trials in Malawi and Zambia have demonstrated the widespread susceptibility of the current ICDN lines to *Ascochyta* blight which is a locally devastating disease in parts of eastern Africa. Three entries appear to possess low susceptibility to *Ascochyta*. The identity of these lines, and of others found to be resistant to other locally important diseases including *Fusarium* wilt, root knot nematode and *Synchytrium* are shown in Table 6. The number of lines which combine some of these additional resistances with resistance to six major diseases is summarized in Table 7. Thus, lines have been identified possessing combined resistance to at least eight fungal and bacterial pathogens, some of them additionally beiug resistant to viruses.

Table 6. Newly identified sources of resistance to disease in cowpea.

Disease	Location	Source (TVu No.)
*Ascochyta**	Zambia	4536, 4569, VITA-5
Fusarium Wilt	Nigeria	109-2, 347, 984, 1000, 1016-1
Fusarium Root Rot	Puerto Rico	202, 231-2, 243, 266-1, 274, 310, 316, 393, 408-2, 1563
Phakopsora Rust	Nigeria and Uganda	612, 1258-1, 1962, 2455-2, 4540
Root Knot	Nigeria	264-2, 401, 857, 1560
Synchytrium	Uganda	43, 222, 612, 647, 984, 1081, 1330, 2331, 2480, 2897, 3433, 4535, 4537, 4544, 4545, 4546, 4569, 6666, TVx 157-1E

**Low susceptibility.*

Differential reactions have been obtained with several major diseases including anthracnose, rust, powdery mildew and bacterial blight. Similar differential responses have been

Table 7. Multiple disease resistance in cowpea.

Resistance	No. of lines
ANTH + CCr + CCa + CORY + RUST + BP	100
ANTH + CCr + CCa + CORY + RUST + BP + PM	50
ANTH + CCr + CCa + CORY + RUST + BP + SYNCH	15
ANTH + CCr + CCa + CORY + RUST + BP + FUS	5
ANTH + CCr + CCa + CORY + RUST + BP + SYNCH + FUS	1
ANTH + CCr + CCa + CORY + RUST + BP + ROOT KNOT	4
ANTH + CCr + CCa + CORY + RUST + BP + WB	2

ANTH = *Anthracnose*
CCr = *Cercospora cruenta*
CCa = *Cercospora canescens*
CORY = *Corynespora target spot*
BP = *Bacterial pustule*
BB = *Bacterial blight*
PM = *Powdery mildew*
SYNCH = *Synchytrium false rust*
FUS = *Fusarium wilt*
WB = *Rhizoctonia web blight*

Table 8. ICDN entries with differential reactions to anthracnose, rust, powdery mildew (PM) and bacterial blight (BB) at six locations.

TVu No.	Locality	Disease ANTH	RUST	BB	PM
317	Lilongwe, Malawi	O			
	Kampala, Uganda	S			
	Ibadan, Nigeria	R			
2331	Kampala		R		
	Ibadan		S		
1185	Lilongwe	O			
	Ibadan	HS			
1851	Lilongwe	O			
	Ibadan	HS			
1190	Samaru, Nigeria			R	
	Ibadan			R	
	Monteria, Colombia			S	
4539	Mayaguez, Puerto Rico				R
	Ibadan				HS
1962	Mayaguez				HS
	Ibadan				R

Where: O= free, R = resistant, S = susceptible, M = moderately and H = highly.

reported for Cercospora leaf spot. Though the cause of such differential responses (examples of which are shown in Table 8) may be attributable to environmental effects and to genetic variation within pathogen species, it emphasizes the importance of multilocational testing for disease resistance, particularly in environments representative of distinct pathosystems.

Entomology

The cowpea leafhopper in Nigeria was thought to be *Empoasca dolichi*. Recent surveys have now indicated that two predominant species, *E. christiani* and *E. dolichi,* are found together as a mixed population in the ratio of about 60 percent and 40 percent respectively. Greenhouse studies indicate that *E. christiani* is the more prolific. Cowpea cultivars TVu 59, TVu 123, TVu 1509 and VITA-3 have been found resistant to *E. christiani*.

The cowpea aphid, *Aphis craccivora* is a major pest of cowpea in Asia, but as yet, it is unimportant on cowpea in Africa; though recent surveys show that large colonies are found in East and West Africa. It is known as the vector of cowpea aphid-borne mosaic virus.

Host plant resistance. A large number of lines were screened in a variety of observation nurseries and replicated field trials to identify sources of resistance to major insect pests. A brief description of this work is given here, and a summary of the sources of resistance found is shown in Table 9.

Leafhopper. Four cowpea cultivars were tested for leafhopper damage in field trials conducted during the second season at IITA. The leafhopper population at 30 DAP varied from 25-60 per plant with an average of 35 per plant (adults and nymphs). The results confirm earlier evidence of the resistance of VITA-3, TVu 123 and TVu 1509 (Table 9).

Aphids. A method of screening for resistance to *Aphis craccivora* in the greenhouse was developed. One-hundred-eighty-five lines from the ICDN were examined; several lines were identified as resistant to aphids (Table 9).

Pod borer. Five cowpea cultivars were tested for resistance to *Maruca testulalis* damage to stem and pods in a field trial in the second season. Each plant was infested by two second instar *M. testulalis* larvae at 40 DAP. VITA-5, Ife Brown and TVu 7274 were free from borer damage to stems.

Flower thrips. The germplasm collection of 4,800 cultivars was screened for resistance to flower thrips, *Megalurothrips sjostedti* during the first and second seasons at IITA. A heavy population in thrips was built up by planting dwarf pigeon peas along the borders of the field about one month before sowing cowpeas. The resistant cultivars showed lower than average damage (Table 9). Several crosses involving TVu 946 appear to have resistance to flower thrips in the breeding nursery.

Cowpea cultivars which, from a preliminary observation, appeared resistant to *Megalurothrips sjostedti* damage to flower buds, were tested in a replicated trial. By spraying Thiodan at 300 g a.i./ha per application at 15, 35 and 45 DAP practically all the other cowpea pests besides flower thrips were kept under control. The thrips population per plant was very high and varied between 120-350 with an average of about 250 thrips at 40 DAP. Several of them and ER-1 showed resistance to thrips damage (Table 9).

Table 9. Cowpea cultivars identified as resistant to insect pests in Nigeria, IITA, 1977.

Insect pests	Resistant to plant part	Cultivars: Resistant	Moderately resistant	Early maturity escape mechanism
Leafhoppers, *Empoasca* sp.	Foliage	TVu 37, TVu 59, TVu 123 TVu 662, TVu 1509, VITA-3	VITA-1, VITA-4, VITA-5, ER-1,	
Aphids, *Aphids craccivora*	Foliage	TVu 57, TVu 134, TVu 157 TVu 191, TVu 200, TVu $266P_1$, TVu 310, TVu $408P_2$, TVu 410, TVu 801, TVu 2000, TVu 2657, TVu 2755, TVu 2845, TVu 2896, TVu 3273, TVu 3346, TVu 3433, TVx 337-3F, TVx 418-1F	TVu 2740, TVu 3509 VITA-1	
Thrips *Megalurothrips sjostedti*	Flower buds	TVu 1509, TVu 2870	TVu 503, TVu 2870, TVu 3346, TVu 3903, TVu 7133, TVu 7134, TVu 7138, TVu 7274	TVu 946, TVu 6863, ER-1, ER-5, ER-7
Pod borer, *Maruca testulalis*	Stem	TVu 946, VITA-5	TVu 1509, ER-7	
Pod borer, *Cydia ptychora*	Seed		TVu 2994, TVu 3709, TVu 3799, TVu 4328, TVu 4579	TVu 946
Pod sucking bug, *Acanthomyia* sp.			TVu 4049, TVu 4052, TVu 4546, TVu 4596, TVu 4601, TVu 4621, TVu 7274, VITA-4	
Cowpea weevil, *Callosobruchus maculatus*	Seed in storage	TVu 2027		

Pod sucking bugs. The germplasm collection was also screened in the field for resistance to a complex of pod sucking bugs. Eight cowpea cultivars showed resistance to damage (Table 9). These cultivars along with a local check were subsequently tested for resistance in replicated field trials in which plants were protected up to 40 DAP by spraying Nuvacron at 400 g a.i./ha per application at 15, 30 and 40 DAP. Maize and tall pigeon pea plants were planted in the field for attracting *A. curvipes* and *R. dentipes* for egg laying. The results confirmed that the eight cultivars identified in the initial screening were moderately resistant.

Insecticides—high-volume application. Nine insecticides were compared for control of cowpea pests (Table 10). All were applied at 500 g a.i./ha except for the synthetic pyrethroids—Decis, Ambush and Sumicidin which were applied at the rate of 25.0, 50.0 and 100 g a.i./ha respectively. Insecticides were applied at 25, 35, and 45 DAP on Prima cowpeas. The number of leafhoppers, and the damage caused by flower thrips and pod borers were significantly lower in all the

Table 10. Efficiency of different insecticides applied as high-volume spray against cowpea pests. Second season, 1977, IITA.

Insecticide	g. a.i./ha per application	No. of leafhoppers per plant	% Damage by thrips on flower buds	% Damage of pod borer on pods	Yield kg/ha
Sumicidin	100	21.7	15.0	4.7	577
Ambush	50	15.0	10.0	15.7	518
Decis	25	16.0	8.7	25.0	412
Nuvacron	500	15.0	7.7	43.7	403
Actellis	500	14.3	8.7	38.3	374
Versuchs	500	18.3	10.0	56.3	298
Miral	500	11.7	7.0	28.3	269
Baygon	500	21.7	15.0	42.0	139
Viydate	500	10.0	9.7	51.0	116
Control		66.6	32.7	100.0	0
S.E.		1.3	1.0	1.6	15.8
C.V.		33.9	47.2	28.8	23.8

Sources of resistance to aphids *(Aphis craccivora)* and other major pests are identified in field and screenhouse tests.

insecticide treatments than in the controls. Yields were low, but plots sprayed with the three synthetic pyrethroids and Nuvacron gave better yields than those treated with other insecticides. Sumicidin was particularly effective for control of pod borers. Decis, Nuvacron, Actellic, Miral and Viydate were effective for control of flower thrips.

Ultra-low Volume (ULV) application: Because synthetic pyrethroids are of low mammalian toxicity, four which are commercially available as ULV formulations (Decis, Ambush, Ripcord and Sumicidin) were tested against the standard insecticides recommended for cowpea pests in a replicated field trial on a farmer's field on Odo-Ogun, a village northwest of IITA.

The insecticides were applied at 33, 44, and 55 DAP. Treatments with synthetic pyrethroids and Nuvacron gave good results; Thiodan was the least effective (Table 11).

Table 11. Yield of VITA-5 under different ULV insecticide applications on a farmer's plot. Second season, 1977.

Insecticide	g a.i./ha per application	Yield kg/ha
Ripcord	70	960
Nuvacron	500	793
Decis	25	690
Sumicidin	250	683
Ambush	50	525
Thiodan	500	423
Control		175
C.V.		33.6

Yield losses. Yield losses caused by leafhoppers, *Empoasca* sp. and flower thrips, *Megalurothrips sjostedti* were estimated in two field trials in which the insecticide used, the time of application and dosage were manipulated to selectively control insect pests other than the one being studied. The losses attributable to the two pests are indicated in Tables 12 and 13.

Integrated control. The yields of five cowpea cultivars selected for their differential reactions to cowpea pests were compared, under minimum insecticide protection in the second season at IITA and at Odo-Ogun village. Nuvacron at 500 g a.i./ha was applied at 40 and 50 DAP. VITA-5 and ER-7 gave

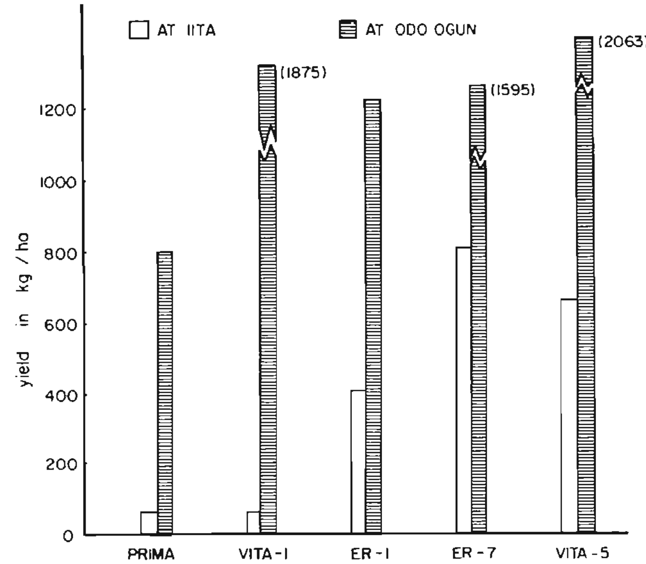


Fig. 2. Performance of insect resistant and susceptible cowpea cultivars under minimum insecticide application.

comparatively higher yields at both locations. The results are shown in Figure 2. The yields at Odo-Ogun were higher than at IITA because there were fewer pests at Odo-Ogun.

Table 12. Yield losses in cowpea as a result of leafhopper damage. Second season, 1977, IITA.

Cultivar	Complete insect protection		No protection against leafhoppers		% Loss in yield
	% Leafhopper damage	Yield kg/ha	% Leafhopper damage	Yield kg/ha	
TVu 1509	3.0	1286	6.1	1210	6.6
VITA-3	4.3	1200	5.0	1100	8.3
TVu 123	4.3	986	13.3	900	8.7
VITA-5	3.7	1250	15.0	1100	12.0
TVu 662	6.7	1124	25.0	800	21.8
Prima	21.7	875	56.7	560	36.0
VITA-1	6.7	1500	31.7	950	36.6
TVu 2045	8.7	850	36.7	500	41.1
S.E.	0.1	0.2	0.2	0.1	
C.V.	19.3	21.7	42.1	67.9	

Table 13. Yield losses in cowpea as a result of flower thrip damage. Second season, 1977, IITA.

Cultivar	Complete insect protection		No protection against thrips		% Loss in yield
	% Damage to flower buds	Yield kg/ha	% Damage to flower buds	Yield kg/ha	
TVu 1509	6.7	772	21.0	560	27.4
ER-1	5.7	548	27.8	375	31.5
VITA-5	4.7	850	68.6	186	78.1
TVu 2045	6.3	700	86.0	111	84.1
Prima	9.0	520	91.0	37	92.8
VITA-3	6.3	460	95.0	12	97.3
S.E.	13.2	6.8	13.2	6.8	
C.V.	27.1	33.0	27.1	33.0	

Storage pests. From the entire germplasm and several hundred breeding lines screened for resistance to cowpea weevil, *Callosobruchus maculatus* infestation in storage, one cowpea cultivar, TVu 2027 was identified as resistant. Insect infecundity and growth on TVu 2027 and other cowpea cultivars are indicated in Table 14. The resistant cultivar TVu 2027 had about 20 percent infestation while the other cultivars had 66 to 91 percent infestation. Its loss in weight during storage was only one-fifth of that suffered by seed of other cultivars. Studies conducted at the University of Durham indicate that seed of TVu 2027 contains about three times as much trypsin inhibitor as seed of other cultivars. Trypsin inhibitor is destroyed when the seed is cooked and therefore does not detract from the value of the seed as human food.

Table 14. Resistance to cowpea weevil, Callosobruchus maculatus storage. 1977, IITA.

Cultivar	Mean number of eggs laid per female	% Larval survival	% Loss in seed weight 45 days after infestation
TVu 2027	50.0	21	14
VITA-1	44.8	72	54
VITA-3	63.3	65	50
VITA-4	48.3	76	62
VITA-5	46.5	92	62
Ife Brown	49.5	68	53
Prima	56.8	76	61
S.E.	4.9	3.9	0.45

Table 15. Days to first flower of 29 cowpea lines sown on three dates at IITA (70°N Latitude) and exposed to artificially extended photoperiod (13½ hrs.) on one of these dates (January 1977).

	Number of lines	Date sown: Photoperiod 40 days after sowing:	January 12:16	January 13:30†	April 30 12:53	Aug. 12:19
Very sensitive	10		45	>60	>100	61**
Moderately sensitive	9		40	>60	>100*	49
Sensitive	4		40	>60	39	45
Slightly sensitive	3		46	50	44	49
Insensitive	3		39	37	38	45

†artificially extended photoperiod
**natural daylength increasing. Some plants flowered, and became vegetative again.*
***vegetative until late October.*

Growth and management

Phenology of cowpeas. Flowering of Nigerian cowpea had been demonstrated to be cultivars controlled by their response to photoperiod, local cultivars flowering at the end of the rains at their latitude of origin. Because in West Africa the rains begin later and finish earlier with distance north and inland from the coast local cultivars of cowpea exhibit different degrees of photosensitivity depending on their origin.

To examine the response more closely, 29 lines collected from latitudes 5°N to 15°N in Nigeria and Niger, were sown on six dates during the year at IITA (7°N latitude) and on two dates at three locations further north. From observations on these lines and on five standard cultivars at IITA, five categories of photoperiod response can be distinguished (Table 15). The most sensitive lines failed to flower when sown in April; when sown in August they did not flower until late October. Moderately sensitive lines began to flower when sown in April, but as the daylength increased they became vegetative again. Sensitive lines flowered and set fruit in natural daylengths whenever they were sown, but did not flower in the artificially extended photoperiod (13½ hrs.). A 13½-hr. photoperiod delayed flower development of slightly sensitive lines by 4–10 days but had no effect on flowering date of insensitive cultivars.

Data from these studies at IITA and at one other site have been used to estimate the date and hence the photoperiod at which induction of reproductive growth occurs. For this it was assumed from other observations that the interval from initiation to anthesis is 31 days. No correction for temperature has been made since night temperatures at the two sites differed by only 2°C. The calculation showed that very sensitive lines initiated flowers at a photoperiod of 12 hrs. 31 mins., or shorter; moderately sensitive lines at photoperiods of 12 hrs. 50 mins., or less.

Cultivars from northern latitudes were usually the least sensitive to photoperiod, but included a few very sensitive and moderately sensitive lines. These would yield well only in seasons of abnormally prolonged rain or if sown on soils with a large water storage capacity that would allow them to continue growth beyond the end of the rainy season.

Yield physiology. To investigate whether light limits the yield of cowpea in the field at Ibadan, the broad-leaved erect cowpea cultivar TVx 1193-10F was grown in rows 1 m apart with white aluminum reflectors placed to direct radiation into the base of the canopy. Light from the reflectors amounted to 25 percent of incident radiation during the middle of the day, compared with 6 percent from bare soil. Although there was no significant effect on plant dry weight or leaf area, the reflectors produced a 10-percent yield increase when placed in the crop from flowering to maturity or from mid-podfill to maturity (Table 16). When the experiment was repeated with a narrow-leaved cultivar (TVx 332-4G), the reflectors had no effect on yield. The difference between these two results suggests that the narrow-leaved plants allowed better distribution of light within the canopy and to the lower leaves. A further experiment will be conducted in 1978 to verify the results.

Table 16. The effect of supplementary light on seed yield of an erect, broad-leaved cowpea (TVx 1193-10 F); IITA, first season, 1977.

Supplementary light	Yield kg/ha
None	1273
Flowering to mid podfill	1344
Mid podfill to maturity	1405
Flowering to maturity	1414
S.E.	33
C.V. %	4.8

Tolerance to acid soils. The role of legumes in cropping systems in the lowland tropics depends partly on legume tolerance to acid soils. Studies begun in 1975 to determine the reaction of different cowpea lines to isolated factors of the soil acidity complex were continued.

In addition to developing cowpeas that are resistant to pests and diseases, IITA grain legume scientists are making progress in adding high-yielding capability to the crop.

Aluminum toxicity. Ten lines that represent a range of tolerances to acid soils were chosen as standards. The effect of Al on the fresh weight of shoot and root of seedlings grown in nutrient solution and in pots in an Al-treated Ultisol, was used as a measure of varietal differences in tolerance to Al. The two methods gave a similar ranking of cultivars but the soil method proved to be cheaper and more reliable for screening. Shoot growth seven days after sowing is now being used to differentiate tolerant and susceptible cultivars.

Calcium deficiency. The same 10 lines showed large differences in tolerance to Ca deficiency; TVu 354 appeared to be very tolerant but Solojo was extremely sensitive.

Manganese toxicity. Thirty cultivars were tested for tolerance to Mn in cooperation with the University of Berlin, using a sand culture technique. With seedling growth as the criterion for measuring tolerance, four cultivars were found to be highly tolerant and four extremely sensitive. However, with the possible exception of TVu 91, grain production appeared to be more sensitive than vegetative growth to excess Mn.

The responses of the 10 cowpea cultivars to excess Al and Mn and to deficiency of Ca, are summarized in Table 17. It seems that the reactions are genetically independent since none of the cultivars shows a high level of tolerance to all three factors. VITA-3 (TVu 1190) is perhaps the best adapted to acid soils; VITA-5 (TVu 4557) and Solojo are the most sensitive. Even so, field trials at Onne indicate that cowpea has a comparatively high tolerance to acid soils and grows well in the first two seasons after clearing (not burning) the bush fallow, provided no nitrogen fertilizer is applied.

Table 17. Reaction of 10 cowpea cultivars to three isolated factors of the soil acidity complex.

TVu No.	Excess Al	Excess Mn: Vegetative growth	Excess Mn: Grain yield	Ca deficiency
91	T	S	T	M
1190	T	M	-	T
3629	M	M	S	M
1283	M	S	M	M
201	M	M	-	M
3231	S	T	T	M
1977	S	M	S	M
354	S	T	S	M
4557	S	S	-	S
Solojo	S	S	-	S

T = Tolerant; M = Moderately tolerant; S = Susceptible.

Management of sole crop cowpea. Experiments at several sites have shown that for sole crop and intercrop cowpea, the most important input is two to four effective applications of insecticide. The advantage of improved cultivars over local ones becomes obvious when they are adopted together with improved management practices. This was well illustrated in a number of farmers' field trials conducted in western Nigeria. The local cultivar, when fertilized but not protected against insect damage, gave no yield at all, but the improved cultivars (particularly ER-1) gave 500 kg/ha of seed. TVx 930-01B gave twice the yield of the local cultivars when protected against insects. By far the best yields were obtained when ER-1 and TVx 930-01B were fertilized and protected — at this level of management they produced four times the yield of the local cultivar (Table 18).

Table 18. Effect of insecticide and fertilizer on yields of cowpea on farmers' fields at Shaki, Western Nigeria, 1977 (33 farmer trials).

	Management level*				
Cultivar	I_0P_0	I_0P_1	I_1P_0	I_1P_1	Mean
ER-1	689	495	866	1200	813
TVx 930-01B	444	140	1001	1108	673
VITA-5	313	169	557	838	468
Local	126	0	433	252	203

I_0 = No insect control — I_1 = 3 applications of Gammalin
P_0 = No fertilizer — P_1 = 30 kg P_2O_5/ha

Soybean improvement

Breeding

The principal objectives of soybean breeding are to combine the good seed storability and germinability, and capacity to fix nitrogen, in association with native rhizobia of Asiatic lines with the resistance to lodging and shattering and heavy yield potential of materials from the U.S.A. Disease and insect resistance are also being incorporated.

Recombination and selection. The numbers of lines screened in the breeding nursery in 1977 are shown in Table 19.

Table 19. The numbers of lines in breeding nurseries 1977.

	Season	
Cross Series	First	Second
1	143(F_8)	45(F_9)
2	73(F_7)	1(F_8)
3	278(F_6)	54(F_7)
4	1439(F_4)	591(F_5)
5	45(F_2)	42(F_3)
6	16(X's)	16(F_1)

Cross series 1 to 4 comprise exclusively US/US combinations from which about 300 lines have been selected for possible inclusion in preliminary trials during 1978. Cross series 5 are US/US and US/Asiatic combinations. Bulk seed of each of the crosses is being subjected to accelerated aging and screening for ability to fix nitrogen with native rhizobia at several sites in West Africa where soybean was never grown before.

Cross series 6 comprises a set of diallele combinations involving US and Asiatic lines differing in seed size and color to study the inheritance of seed storability in relation to the type (ambient v. cold store) and duration (3, 6 or 9 months) of storage.

Yield trials. The numbers of lines tested in yield trials during first and second seasons were the same in 1977 as shown in Table 20.

Table 20. The numbers of lines included in yield trials at Ibadan, 1977.

Type of trial	
Observation nursery[1]	121
Preliminary	42
Advanced	24
Intsoy/IITA Uniform[2]	26

1 Also sown at Mokwa, Onne, Kumasi, in Ivory Coast and Yandev.
2 Also sown at Mokwa and Onne.

Observation nursery. At Ibadan, Onne, Mokwa and Kumasi (Ghana) the nurseries were simple lattice designs with two replicates. At Yandev, Nigeria and Abidjan in Ivory Coast 78 and 81 lines were sown in a single replication. The mean yields of the best lines in Ibadan, Abidjan and Yandev are shown in Table 21.

Table 21. Yields of the best lines in the observation nursery, 1977.

Line	Ibadan	Yandev	Ivory Coast	Mean
TGx 46-3C	1,643	2,083	1567	1,764
TGx 26-33D	2,337	1,500	1217	1,685
TGx 47-5C	2,268	1,083	1555	1,635
TGx 12-4E	2,593	1,361	950	1,634
TGx 68-8C	1,920	1,472	1375	1,589
TGx 26-23E	1,785	1,667	1117	1,523
TGx 11-13E	1,773	1,805	950	1,509
TGx 12-6E	1,480	1,805	1208	1,498
Mean	1280	995	858	

Although common checks were not included, several lines produced very satisfactory mean yields across the three locations and will be tested further in 1978.

Preliminary trials. Forty-two lines were compared in three randomized block trials with three replications in the first and second seasons at Ibadan. The performances of the better lines compared with Bossier or Jupiter are summarized in Table 22.

Despite reduced plant stand due to inherently poor seed storability, Bossier produced high yields in all trials. Nevertheless, some lines were significantly higher-yielding combined with satisfactory levels of resistance to bacterial blight and lodging. Notable were the performances of TGx 11-3E (Trial 3), the former producing a mean seed yield over 2 t/ha.

Advanced trials. Twenty-four advanced lines were compared in two randomized block trials with four replications in the first and second seasons at Ibadan. The performances of the best lines and controls are shown in Table 23.

In Trial 1, Bossier was the highest yielder, despite reduced stand; and several lines were resistant to bacterial pustule. In Trial 2, several lines yielded significantly better than Jupiter and showed resistance to bacterial pustule.

Uniform Trial. Twenty-six lines were compared in two randomized block trials with four replications at Ibadan in the first and second seasons. The yield performances of the better-yielding lines are summarized in Table 24.

Table 22. The performance of lines in preliminary trials at Ibadan, 1977.

Line	Seed yield kg/ha 1st season	2nd season	Mean	No. of plants	Bacterial pustule	Lodging*
Trial No. 1						
TGx 25-1D	1214	1285	1250	143	2.7	2.3
TGx 25-5D	1381	844	1113	94	3.0	2.3
TGx 68-2C	901	1151	1026	120	2.0	2.3
TGx 32-11D	903	1065	984	118	1.3	2.7
Bossier	1069	974	1022	68	1.7	1.3
Mean	961	949	955	102	2.7	2.3
S.E.	200	142			0.33	0.26
C.V.	36.0	25.9			24.9	19.9
Trial No. 2						
TGx 11-3E	2324	1850	2087	102	2.0	1.7
TGx 32-4D	1950	1570	1760	125	1.7	1.7
TGx 27-10D	1666	1659	1663	151	1.3	1.7
TGx 27-6D	1727	1268	1498	111	1.3	1.3
TGx 2-23E	1827	1088	1458	125	1.0	1.0
TGx 68-3C	1558	1179	1369	107	2.0	1.0
Bossier	1503	1548	1525	62	1.7	1.3
Mean	1412	1487	1448	105	1.7	2.1
S.E.	175	216			0.25	0.27
C.V.	21.4	25.2			29.9	23.5
Trial No. 3						
TGx 47-5C	1906	1759	1832	141	1.3	1.7
TGx 12-4E	2275	1147	1711	151	1.0	2.3
TGx 12-28E	1106	1551	1328	167	1.0	4.0
TGx 11-14E	1188	1394	1291	101	1.0	3.0
TGx 9-14E	1054	1191	1122	105	1.0	2.7
Jupiter	1031	1399	1215	110	3.0	2.3
Mean	1152	1339	1246	109	1.38	2.71
S.E.	302	168			0.13	0.32
C.V.	45.0	20.9			18.3	20.9

**Scored on a 1-5 scale (1 = absence of symptoms. 5 = Severe disease incidence.)*

Table 23. Performance of lines in advanced yield trials at Ibadan, 1977.

Lines	Seed yield kg/ha 1st season	2nd season	Mean	No. of plants	Bacterial[1] pustule	Lodging
Trial No. 1						
TGx 21-2	1182	2225	1704	100	3.0	2.0
Amsoy 5002	1357	1932	1644	122	3.5	1.5
TGm 225-3	1103	2202	1652	116	4.3	1.8
Kent 2070	815	2417	1616	96	1.0	1.3
Bossier	1293	2495	1894	79	1.8	1.0
Mean	1068	1921		107	2.5	1.7
S.E.	156	183			0.21	0.20
C.V.	29.2	19.0			17.2	24.5
Trial No. 2						
TGx 26-23D	1120	2015	1568	147	2.0	3.5
TGm 242-4-4241	877	2024	1451	118	1.8	1.3
TGx 26-34D	583	2030	1307	127	1.0	2.3
TGx 46-3C	565	2042	1304	134	1.3	2.8
TGx 57-12C	341	2207	1274	139	1.0	1.8
Jupiter	244	1745	994	115	3.0	2.5
Mean	478	1790		111	1.7	2.1
S.E.	130	164			0.21	0.26
C.V.	54.4	18.3			25.6	24.2

[1] *Scored on 1-5 scale (1 = absence of symptoms. 5 = severe disease incidence.)*

Table 24. Seed yield (kg/ha) of lines in Uniform Trials, Ibadan, first and second seasons, 1977.

Lines	Season First	Season Second	Mean
Trial No. 1			
TGm 210-1-2363	2310	2265	2288
TGm 220-1-2205	2324	1830	2077
TGm 255-2-4341	1718	2038	1878
TGm 249-5-5078	1619	2093	1856
TGx 16-2E	1705	1989	1847
TGm 249-4-b	1802	1853	1828
TGx 66-5100	1531	1809	1670
TGx 13-3-2644	1293	1577	1435
Bossier	1937	1990	1964
Jupiter	1189	1708	1449
Mean	1483	1735	1609
S.E.	113.0	196.2	
C.V.	20.2	18.1	
Trial No. 2			
TGm 260-2-4293	2352	2319	2336
TGm 249-3	2302	2035	2169
Amsoy 4192	1781	2409	2095
TGm 210-1-2317	1721	2055	1888
TGm 187-3-2	1335	2245	1790
Bossier	1593	1890	1742
Mean	1698	2009	1854
S.E.			
C.V.	19.9	17.2	

In Trial 1, TGm 210-1-2363 and TGm 220-1-2205, both from crosses involving Lee 68 and Hill x PI 454, have given consistently improved yields relative to Bossier. In Trial 2, several lines showed improved yield levels over Bossier. A significant positive correlation ($r = 0.59$, $P < 0.05$) was recorded between grain yield and nodule number per plant after flowering. A similar relationship was recorded in the observation nursery at Abidjan.

Yield component analysis. Studies of yield components in three agronomic or breeding trials indicate that yield is inversely correlated with variation in seeds per pod at successive nodes. In two cases inereased variation was associated with a decline in seed number per pod from nodes 6 and 7 upward. Seed number per pod was also shown to be less affected by plant density than other yield parameters and may therefore enable more effective selection for yield in segregating populations.

Biochemical studies. Studies conducted in collaboration with the Tropical Products Institute indicated that oil content is positively correlated with seed size but not with age of seed, although old seeds showed higher free fatty acid content. Polyacrylamide gel electrophoresis gave no indication of changes in metabolism of protein components in storage.

Soybean seed viability

Deterioration of seed viability during storage is a problem in the lowland tropics where ambient temperature and humidity are high. Varietal differences in storability exist, but a method is needed to identify them quickly. To develop such a method, eight soybean cultivars that differed in keeping quality were stored at ambient temperature (Ca. 27°C), 35°C or 40°C, and at a relative humidity of about 70 percent. Disused refrigerators into which heaters and thermostats had been installed were used as storage cabinets. A pan of water in the bottom of each cabinet maintained the desired humidity.

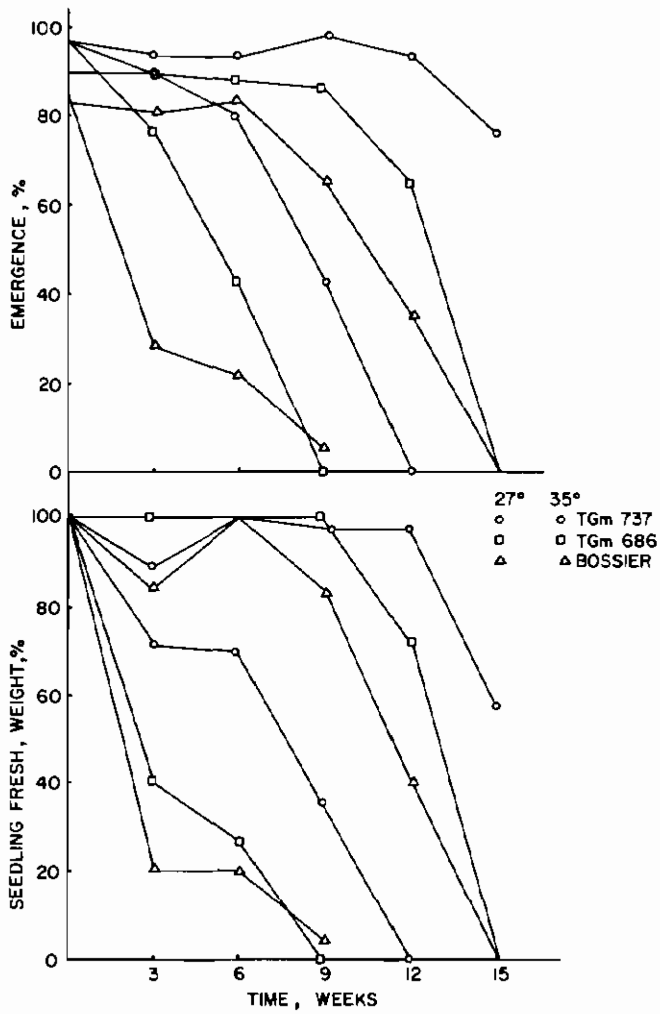


Fig. 3. Decline in seedling emergence and seedling vigor (as measured by fresh weight of the emerged seedlings) of three soybean cultivars.

Samples of seed were removed at intervals and sown in trays of soil to determine changes in the viability of seed. High temperature hastened the decline in seed viability, and the decline was more rapid with seed of Bossier and TGm 686 than of TGm 737, which is consistent with earlier results (Figure 3). The viability of seed of cultivars having poor keeping quality fell sharply after three weeks at 40°C, after 6 weeks at 35°C, and after 12 weeks at ambient temperature. Therefore, rapid aging of seed at high temperature and high humidity can be used to distinguish between lines of good and poor seed-keeping quality.

Lima bean improvement-breeding

The main objectives continue to be the incorporation of golden mottle mosaic and green mottle mosaic resistance into high-yielding viny and bush lima beans.

Germplasm evaluation. In the first season the agronomic and disease resistance characteristics of 335 viny and 91 bush lines were evaluated in non-replicated rows at Ibadan and 47 were also grown at Onne. The best of the new lines will be evaluated again in 1978.

Recombination and selection. The numbers of lines examined in breeding nurseries in 1977 are shown in Table 25.

Table 25. Numbers of lima bean lines in nurseries, 1977.

Cross series	Season Dry	First	Second
1 (v)	21 (F_2)	39 (F_2)	47 (F_2)
	–	231 (F_2)	479 (F_3)*
	–	–	69 (F_4)
1 (b)	–	–	3 (F_3)
2 (v)	–	4 (F_2)	6 (F_2)
	–	34 (F_3)	413 (F_3)*
	–	–	72 (F_4-F_6)
2 (b)	–	–	112 (F_3)
3 (v)	16 (F_2)	13 (F_2)	63 (F_3)*
	–	58 (F_3)	13 (F_4)
	–	–	17 (F_2)
4 (v)	17 (X's)	17 (F_1)	17 (F_2)

Some lines also grown at Onne and Ikenne.

Cross series 1 and 2 include artificial and natural crosses, respectively between viny (v) and bush (b) germplasm lines exhibiting good yield and agronomic characteristics or resistance to golden yellow mosaic. Cross series 3 are intraspecific crosses between wild and cultivated forms of *P. lunatus* and cross series 4 are more recent crosses specifically to incorporate resistance to golden mottle mosaic or green mottle mosaic into high-yielding lines.

In all the nurseries, plants showing symptoms of golden mosaic were removed and single plants were selected on the basis of freedom from Cercospora leaf spot and general appearance. Flowering notes and seed types were also recorded. Some single plants will be screened further in non-replicated plots at Ibadan in 1978.

Yield Trials. The numbers of entries in yield trials in 1977 are shown in Table 26.

Table 26. Numbers of entries in lima bean yield trials, 1977.

Type of trial	Season First	Second
Preliminary	–	44
Advanced	14*	14
Uniform	10*	10

Also sown at Onne.

Preliminary Trials. Eighteen F_4 lines from cross series 1, and 20 from series 2 were compared with TPI 60E and TPI 111A in two randomized block trials at Ibadan in the second season. The lines were still highly variable and single plants were selected on the basis of appearance and resistance to golden mosaic and Cercospora leaf spot for further evaluation in the breeding nursery in 1978.

Advanced and Uniform Trials. Twenty-four previously tested germplasm accessions were compared in two randomized block trials with four replications, sown in the first season at Ibadan and Onne and in the second at Ibadan. At Onne, there was a very heavy infestation of whiteflies associated with a previously unrecorded severe leaf distortion and stunting of growth which occurred in all lines except TPI 111A and the trial was abandoned. The performances of some lines in the Ibadan trial are summarized in Table 27.

Seed yields and root knot scores were higher and days to flowering longer in the first than in the second season. In the Advanced trial, TPI 174 yielded highest in both seasons to give a mean yield of 1600 kg of dry seed per hectare. In the Uniform trial, TPI 250B gave the highest yield for the second successive year. TPI 111A in the Advanced trial maintained its high level of resistance to golden mosaic but had the lowest seed yield.

In contrast to previous years, TPI 10 showed only a low level of resistance to golden mosaic. All other entries in the trials were highly susceptible. Significant differences were recorded

Table 27. Performance of lines in viny lima bean Advanced and Uniform trials at Ibadan, 1977.

Line	Seed yield kg/ha First	Second	Mean	DFF	Weight of 100 seeds	Golden mosaic	Cercospora leaf spot	Root knot score
Advanced trial								
TPI 174	1972	1227	1600	44.2	326	3.7	3.2	1.3
TPI 61A	1479	1156	1318	47.2	346	4.2	1.7	3.0
TPI 178-26	1638	962	1300	46.3	315	3.8	3.5	1.7
TPI 60-E	1669	809	1239	43.2	359	3.9	3.4	3.6
TPI 323A	1334	1007	1171	43.3	340	3.4	4.4	1.4
TPI 111A	848	653	751	48.5	821	1.3	1.5	2.7
Mean	1381	851	1116	45.2	396	3.5	3.2	3.1
S.E.	160	130						
C.V.	23.3	30.5						
Uniform trial								
TPI 250B	2101	837	1469	45.7	344	4.6	4.6	1.5
TPI 183-6	1936	878	1407	45.0	355	4.3	5.4	1.0
TPI 247	1705	1016	1361	42.7	305	4.7	5.6	1.3
TPI 170-33	1488	810	1149	41.4	425	5.2	5.7	1.9
TPI 10	971	438	705	40.8	481	3.7	2.6	3.9
Mean	1299	767	1020	45.8	380	5.1	4.9	2.7
S.E.	288	133						
C.V.	45.5	34.7						

for Cercospora leaf spot and root knot, with several lines exhibiting relatively low scores for these conditions. An important observation was the occurrence in both trials of significant negative correlations between seed yield and root knot score ($r = -0.60$, $P > .05$; $r = 0.92$, $P > .01$) suggesting that root knot nematode may be a major limiting factor to lima bean yields at Ibadan. The best lines from the trials will be tested further in 1978.

Interspecific crosses. Studies of interspecific hybrids of *Phaseolus lunatus* with *P. ritensis* and *P. polystachyus* continued in collaboration with the University of Gembloux in Belgium. Field plantings of early generations of both crosses were screened for diseases and pest incidence, yield and other agronomic characteristics and single plants have been selected for further observations in 1978. In addition, seed of intersown parental materials will be grown to check for natural hybrids.

Cooperative Program

In Tanzania, USAID and IITA scientists have identified high-yielding and multiple disease resistant lines of cowpea (SVS-3, VITA-4, Ife Brown and TVx 966-OID). Good progress has been made in incorporating the disease resistance with high yielding capability.

Studies conducted involving surveys and management trials in farmers' fields have indicated insect pests as major constraints in cowpea production. Meantime, pest management studies are underway for the control of cowpea pests.

In Kenya, an aggressive research and management program has been initiated with national scientists at the University of Nairobi and the ministry of agriculture. This program is supplemented by basic research on insect resistant lines from the International Center of Insect Physiology and Ecology (ICIPE) in Nairobi, Kenya.

Cowpea cultivars identified as resistant to leafhoppers (*Empoasca* sp.) and to stem damage by *Maruca testulalis* at IITA will be further evaluated for resistance to these two pests in Kenya.

Breeding nurseries and on-farm trials were successfully completed at several locations in Upper Volta as part of a special food legume project made possible through a grant from the International Development Research Center (IDRC). The best selections from these trials consistently outyielded the best check cultivars by about 40 percent.

ROOT AND TUBER IMPROVEMENT PROGRAM

The ultimate goal of the Root and Tuber Improvement Program (TRIP) is to develop a package of improved technology in terms of cultivars and improved cultural methods for high stable yields, high economic returns and high consumer acceptance of cassava, yams, sweet potato and cocoyams, and to transfer the package of technology to farmers by training scientists of national root and tuber improvement programs and by close cooperation with these programs in the tropics.

To achieve this goal effectively, the Program has adopted an interdisciplinary team approach. The Program also interacts with the Farming Systems Program in improving cultural methods and it receives assistance from the Genetic Resources Unit in introducing new germplasm sources. The Program is involved in training researchers from the national root and tuber improvement programs. It also cooperates with the International Center for Tropical Agriculture (CIAT) in cassava improvement and with the Asian Vegetable Research and Development Center (ARVDC) in sweet potato improvement through staff visits and exchanging materials and information.

Special projects. The core program is involved in several special projects to facilitate its research in different environments in the tropics and to test research results in cooperation with national root and tuber improvement programs. The Nigerian National Accelerated Food Production Project (NAFPP) emphasizes evaluation, multiplication and distribution of improved cassava lines and demonstration of improved technology, all at the farm level. Zaire's Programme National Manioc (PRONAM) has focused on research to develop lines of resistance to cassava bacterial blight (CBB) and cassava mosaic disease (CMD).

The Cameroon National Root Crop Improvement Program is charged with the improvement of cassava, yams, sweet potato and cocoyams, with emphasis on cassava.

Research highlights

Cassava

In Nigeria, significant progress was made toward stimulating many small-scale farmers to increase their cassava production, through the use of an improved technology package consisting of improved cultivars, improved cultural practices and a highly motivated extension network.

High-yielding clones with resistance to disease, especially cassava mosaic disease (CMD) and cassava bacterial blight (CBB), and with acceptable *gari* quality were selected after four years of testing in Nigeria. The clones with high overall value for important agronomic traits were found to be TMS 30572, TMS 30337 and TMS 30555. Among other promising clones was TMS 30395.

Of the low HCN cassava clones produced, A/40705 was the most promising.

A rapid method for tissue analysis has been developed and used to evaluate a large number of clones for quality. The relationship between carbohydrate spectra and texture profile in cassava roots and its effect on qualities has been determined.

A genetic relationship between resistance to CMD and CBB was confirmed. The rate of CMD development on seedlings under field conditions was found to be highly dependent on the *Bemisia* vector population which is dependent upon rainfall.

Nitrogen fertilizer application to low-fertility Apomu soil induced a severe symptom expression of CMD in a highly susceptible cultivar, but had only a mild effect on the severity of the disease in a moderately susceptible cultivar.

To regulate CMD symptom expression as a screening mechanism, detopping test materials in August induced a strong, immediate and persistent response compared to detopping during other periods which was characterized by mild responses and definite recovery phases.

In a positive screening test for evaluation of resistance to CBB by artificial inoculation, 12 out of 47 IITA improved clones ranked as resistant compared with five standards which ranked in the same order when artificially inoculated under field conditions.

CBB developed earlier in inoculated plants growing in a sandy low-fertility acid soil fertilized with 200 ppm NPK. Unfertilized plants, however, were more severely affected five weeks after inoculation and exhibited a higher mortality rate.

In Zaire, a pilot scheme was initiated to test the best 15 clones in the fields of some 30 selected farmers in the M'vuazi area. In Sierra Leone, Liberia, Cameroon, Zanzibar, Tanzania, Burundi, Uganda and India several thousand seeds from IITA's segregating populations were evaluated by national programs for disease resistance, root characteristics and other important agronomic characteristics.

Yams

True seed of white yam *(Dioscorea rotundata)* containing large genetic diversity were distributed for evaluation to collaborators in 16 countries during 1977.

Clonal selection from segregating breeding populations was continued with the evaluation of 17,000 seedlings as well as material in hill and preliminary yield trials located at IITA and two offsite locations.

Sixteen of the highest-yielding accessions from IITA's germplasm collection of water yam *(D. alata)* were further evaluated. Those clones which performed well were multiplied and distributed to farmers and research institutions in Nigeria.

Analyses of heat treated yam tissues revealed that there is a diversity of texture among yam genotypes.

Through chemical and biochemical analyses of *D. rotundata* and *D. alata* total phenolic compounds and their enzymic browning activities were found to differ widely among genotypes.

The yield reduction in *D. alata* due to 100 percent mechanical defoliation was significantly higher at 40 and 120 days after planting (DAP) than that of 60 DAP. Field rating of disease severity with respect to the effect of defoliating pathogens in the yield of *D. alata* may be more accurately carried out 40 DAP for early or vegetatively borne disease or at 120 DAP for late-developing diseases.

Sweet potato

Large numbers of improved seeds of sweet potato *(Ipomoea batatas)* were produced and distributed to national programs for their selection during 1977.

An improved clone, TIS 2498, was distributed to local farmers. This clone showed a yield potential of more than 30 t/ha in four months without the use of fertilizers.

TMS 2534 continues to show promise with a yield potential of about 25 t/ha in four months and high resistance to virus and field resistance to weevil. In this clone there appeared to be no difference in oviposition of sweet potato weevil *(Cylas puncticollis)* but a significant difference in field infestation compared with susceptible cultivars.

A leaf-screening method was developed, enabling the evaluation of sweet potato for resistance to weevil in the seedling stage.

In a positive screening test for evaluation of resistance to sweet potato virus disease (SPVD) by the rapid tuber-graft screening method, five out of 57 IITA improved clones were ranked as highly resistant.

In Cameroon, TIb 1 outyielded other introductions. In Sierra Leone and Liberia TIb 2 yielded highest.

Seed from families which had been improved for yield and resistance to viruses and weevil were distributed to collaborators in Nigeria, Zaire, Sierra Leone, Cameroon, Liberia, Argentina and Swaziland.

Cocoyam

In the permanent cocoyam plot, five accessions of *Colocasia* and three of *Xanthosoma* flowered and hand pollinations were made.

Gibberellic acid was successfully used to promote flowering.

Tissue culture

The use of meristem culture techniques enabled the rapid propagation of cultivars in a "disease- and insect-free form to meet demands of national programs. IITA established a tissue culture laboratory in 1977.

Several media have been identified for meristem culture of yam, sweet potato and cocoyam.

Cassava breeding

The major constraints to cassava production in Africa are disease and insects. Cassava breeding programs seek to produce cultivars with increased disease and insect resistance and desirable physiological characteristics.

Recombination. Extensive hand pollinations were made among selected clones which showed both resistance to Cassava Mosaic Disease (CMD) at an early growth stage, and low cyanide content. Five isolation plots were planted for out-crossing within composite A and B, among half-sib families and among selected parents (two groups) with known high-breeding values. Out-crossed seed among the clones put in the uniform and advanced trials was also collected.

Germplasm introduction. Several thousand seeds from 802 sources were received from CIAT and several thousand seedlings were raised and screened for resistance to CMD and Cassava Bacterial Blight (CBB) and for root characteristics.

Seedling nursery. More than 200,000 seedlings, raised from 2,715 families resulting from crosses and introductions, were screened for resistance to CMD and CBB and for good root characteristics. The cyanide (HCN) content of seedlings from the cross between low HCN clones was tested.

Several thousand seedlings were also raised from 90 families in Warri (high-rainfall, acid poor soil) and screened for resistance to diseases.

Yield trials. The Uniform trials consisting of the 50 most promising clones were conducted in both rainy and dry seasons. The data of yields and other agronomic characters for the best 25 clones including two local check cultivars are shown in Table 1.

The clones TMS 40081 and TMS 30572 have shown the highest overall value for all important agronomic traits observed, followed by TMS 4 (2) 0027, 30786, 30211 and 30555. TMS 40081 gave an average yield of 48.3 t/ha over the past three years; TMS 30572 gave 46.7 t/ha over the past four years; TMS 4(2) 0027 gave 29.6 t/ha over the three years; TMS 30786 gave 40 t/ha over the past four years; TMS 30211 gave 33 tons over the past four years and TMS 30555 gave 41.5 tons over the past four years. TMS 30572 has performed consistently well and had had good consumer acceptance quality and has shown resistance to CMD and CBB.

A total of 3,327 clones were planted for preliminary yield trials. The 221 selections from the 1976 preliminary trial were entered in the intermediate trial, and the 50 selections from the 1976 intermediate trial were entered into the Advanced trial. The most promising 41 clones from the 1976 Intermediate trial were entered into the Advanced Yield trial

Cooperative off-site trials. In cooperation with the Nigerian National Root Crops Research Institute (NRCRI), cooperative off-site trials for 50 clones were conducted in nine locations in Nigeria, 25 clones being from IITA and 25 other clones from NRCRI. The environments of the testing locations ranged from high rainfall (2,400 mm per annum) to derived savanna (1,000 mm per annum). These trials were conducted in both rainy and dry seasons. In the trials, half of the block was treated with fertilizer (15:15:15 – 400 kg/hectare) at three months after planting.

Trials were conducted in Warri (high annual rainfall, 2,771 mm, low-fertility sandy soil); in Mokwa (annual rainfall, 1,097 mm, derived savanna) and at Onne station (annual rainfall, 2,421 mm).

An expansion in the rapid multiplication of cassava is facilitating the availability of improved planting material to many large-scale farmers.

Table 1. Yield, dry matter percent, resistance to diseases, lodging and quality of IITA cassava clones.

Clones	Fresh yield t/ha	Dry matter %	Dry yield t/ha	CMD score	CBB score	Lodging %	Gari grade
TMS 40081	32.6	30.4	9.9	2.0	1.3	0.0	3.1
TMS 4(2)0027	32.2	31.8	10.2	2.4	2.0	0.0	3.2
TMS 30572	30.9	33.0	10.2	2.0	1.8	0.0	3.9
TMS 30337	30.6	29.1	8.9	2.9	1.8	7.5	3.3
TMS 30040	30.5	34.8	10.6	2.4	2.0	10.0	3.6
TMS 30786	30.0	32.8	9.8	2.6	1.8	3.8	3.5
TMS 4(2)1425	29.8	35.8	10.7	2.4	1.8	0.0	3.4
TMS 30211	28.5	30.4	8.7	1.8	1.5	1.2	3.2
TMS 4(2)0599	28.4	26.0	7.4	2.9	2.0	0.0	3.0
TMS 4(2)1031	28.4	34.1	9.7	2.3	2.5	1.8	3.2
TMS 30555	27.8	32.4	9.0	2.0	1.8	1.3	3.2
TMS 40378	27.8	22.9	6.4	3.1	2.0	7.5	3.4
TMS 41589	27.7	26.0	7.2	3.7	2.0	18.3	3.3
TMS 4(2)0267	27.5	34.8	9.6	2.6	1.5	0.0	3.3
TMS 41699	27.4	32.6	8.9	2.3	1.5	3.8	3.4
TMS 30395	26.9	29.6	8.0	1.7	1.8	0.0	3.5
TMS 4(2)1329	26.3	35.0	9.2	2.2	2.0	6.7	3.6
TMS 40160	26.2	32.9	8.6	3.8	2.0	10.0	3.7
TMS 4(2)0850	26.2	33.7	8.8	1.6	1.8	0.0	4.0
TMS 30157	26.1	31.1	8.1	2.3	1.8	1.3	2.9
TMS 40780	26.1	33.5	8.7	2.5	2.0	0.0	3.6
TMS 30158	25.9	32.0	8.3	1.8	1.8	0.0	3.7
TMS 4(2)1445	25.5	31.9	8.1	2.1	1.5	20.0	3.6
60506	23.4	32.8	7.7	3.0	1.8	5.0	3.8
60444	22.0	28.2	6.2	3.9	3.5	2.5	3.7
Yardstick	28.0	30.0	9.0	2.0	2.0	5.0	3.0

60444 and 60506 are local cultivars and the former is the standard cultivar used. Gari grades over 3 are acceptable.
Yardstick represents an estimate of the practical optimum attainable.

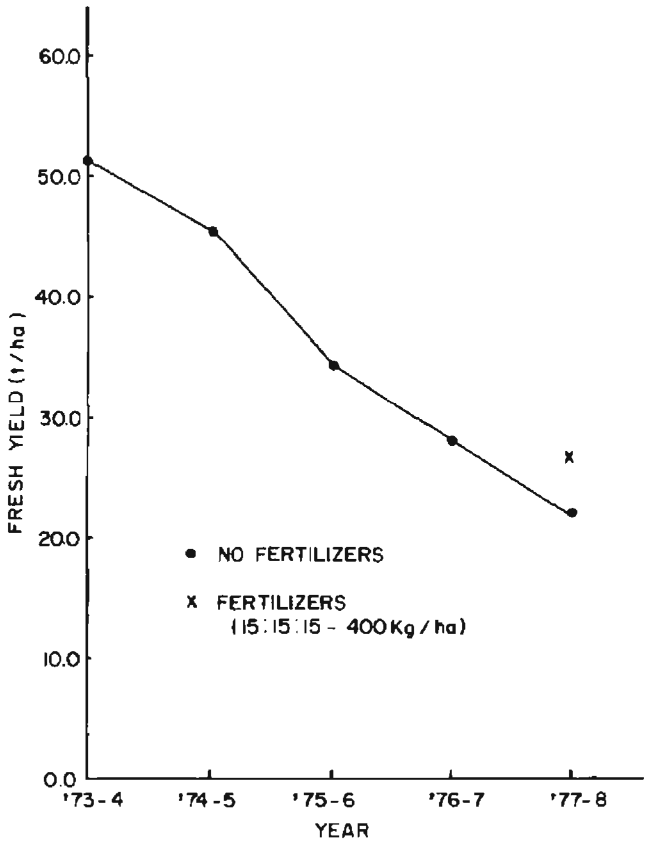


Fig. 1. Average cassava yields at IITA with years.

Yields over years at IITA. The average yields of the 10 most promising clones tested at IITA during 1973 to 1977 were plotted as shown in Figure 1. The average yields have been drastically reduced. The yield in 1977 was reduced by 57 percent when compared with the yields of 1973. The causes of this yield reduction need to be investigated. Application of 400 kg, 15:15:15 fertilizer per hectare at three months after planting resulted in yield increase by 23 percent. This increase, however, did not make the yield levels of previous years.

International cooperation. In Nigeria, in cooperation with NRCRI, off-site trials were conducted for the 50 clones in nine locations.

In Zaire, seedling nurseries were established with IITA-improved seeds at four locations and advanced yield trials were conducted in five locations.

Improvement for quality. The biochemist tested the clones from Uniform and Advanced trials for quality characters. Results showed that the *gari* grades above 3 are regarded as acceptable. TMS 30572 was rated best in *gari* grade.

The clones shown to be low in cyanide content by the picrate leaf test were screened for low cyanide quantitatively using an enzymatic assay in cooperation with Tropical Product Institute, and 31 low cyanide clones were selected.

Seed introduction and dissemination in Zaire. Many thousands of cassava seeds were received from IITA in 1977 – both improved seeds from the Root and Tuber Improvement Program and introductions from Latin America. Recombined seeds from Programme National Manioc (PRONAM) breeding clones were also produced. These seeds were established at M'vuazi (alluvial river valley soils) and Kimpese (savanna) in Bas-Zaire where anthracnose and mealybug are very serious; Gandajika, Kasai region, where CBB and anthracnose are the major problems; and at high altitude (about 1800 m) in Mulungu, Kivu region. Seeds of wide genetic base have also been supplied for establishment at Iberizi within the Ruzizi plains in Kivu, Eastern Zaire. This area borders Burundi and Rwanda and the green spider mite is a very serious dry-season pest.

Root yields – Advanced Trials. Since 1972 there has been a declining trend in manioc root yield at the M'vuazi river valley.

During the 1972/73 season, about 9 percent of these clones yielded up to 32 t/ha fresh root per year and the highest frequency was in the 16 t/ha range. Between 1974 and 1976, the highest-yielding clones (1 percent and 5 percent, respectively) were in the 20 to 24 t/ha range. High disease (CMD, CBB and Anthracnose) and pest (mainly mealybug) incidence are considered major factors in this trend although drastic weather changes such as the severe seven-month drought of 1975/76, which favored mealybug attack in Bas-Zaire, could be a contributing factor.

CMD and anthracnose severity in relation to vigor. Severe anthracnose infection (Classes IV and V) significantly reduced the elongation of cassava branches and leaf retention of some 105 clones at six months (Table 2).

Table 2. Anthracnose and CMD severity in relation to cassava vigor.

Vigor Parameter	Rating parameter	Entries	Mean	t 0.05	% Class II Class IV & V
	Anthracnose				
Plant height (cm)	II	47	230	0.38	93.5
	IV + V	58	246		
Length tertiary branch (cm)	II	47	1118	3.58	130
	IV + V	58	806		
Length 4° and other branches (cm)	II	47	472	4.93	254
	IV + V	58	186		
Leaf no.	II	47	295	3.15	166
	IN + V	58	178		
	CMD				
Plant height (cm)	II	50	239	0.72	103
	IV + V	21	231		
Length tertiary branch	IV + V	50	941	1.48	112
	IV + V	21	837		
Length 4° and other	II	50	272	2.36	145
	IV + V	21	187		
Leaf no.	II	50	182	0.87	93
	IV + V	21	195		

While primary branch growth was unaffected by severe anthracnose incidence, leaf number was reduced by 66 percent. The effect of CMD was to retard elongation of young branches (those above tertiary) by 45 percent. A small increase in leaf number (7 percent) was associated with CMD infection (Classes IV and V). Many leaves were small and poorly developed compared with those on plants in Class 2 rating.

Among segregating breeding populations of yam at IITA were 17,000 seedlings including 241 families of outcrossed seed from local cultivars, IITA breeding populations, and seed from other controlled hand pollinations.

Pre-plant treatment of cuttings with malathion. Owing to rapid re-infestation of new foliages, pre-plant treatment of cassava cuttings (cv. Mpelolongi) with malathion against mealybug attack resulted in no differences in mealybug incidence, severity and root yield.

Yield loss due to mealybug, was demonstrated with 122 pairs of tagged plants. Some of the plants were moderately infested: about Class 3 and some others severely infested, approx. Class 5.

Mealybug severity and plant vigor. A close association was observed between mealybug severity and cassava vigor ratings at a pre-artificial-infestation stage, indicating that plant vigor may be a factor in selecting for tolerance to mealybug infestation.

Leaf retention and duration in dry season. Cassava leaf is a staple vegetable in Zaire and variations in leaf retention under moisture stress have been observed at M'vuazi. Leaf loss for 02864, and INERA improved clone, was about 80 percent. A popular local clone, Mpelolongi, lost only 36 percent of its leaf during the dry season, explaining, in part, its popularity in spite of low root yields (about 12 t/ha). The PRONAM clones lost between 25 and 61 percent of their leaves, with 30083/18 losing the least, which suggests some tolerance to moisture stress.

In rating tests on 15 manioc clones over a three-year period, eight of the clones maintained fairly stable yields. Three clones showed yield increases and four showed yield decreases. The one constant high yielder was 05746Yb. The clone 02715Yb 39/40 showed a decreasing yield, but ended the tests near the top in yield as did 02864S. The clone 02715SYb had an increase over the three years and was among the top yielders.

Yam breeding

White yam *(Dioscorea rotundata).* Clonal selection from segregating breeding populations continued at IITA and at two off-site locations, one high-rainfall site in Bendel State, one derived-savanna site in Niger State. These populations contained 2,350 seedling-derived clones grown in hill trials and preliminary yield trials, and 17,000 seedlings composed of 241 breeding families including outcrossed seed from local cultivars and from IITA breeding populations as well as seed from controlled hand pollinations. At IITA, selection was carried out under both staked and unstaked conditions.

Quality evaluation. One first harvest tuber from each clone in the preliminary yield trials was evaluated for quality characteristics which determine consumer acceptance and processing quality. These tubers were also analyzed for total reduced nitrogen. Clones with greater than 0.89 percent total reduced nitrogen and having desirable agronomic characters and good quality were selected for further testing.

Controlled hand pollinations. A total of 1,855 controlled sib and cross pollinations of *D. rotundata, D. dumetorum,* and *D. cayenensis* were made between selected parents for recombination of desired characteristics. These were made with and without the application of benzyl adenine (BA) to the base of the ovaries at the time of pollination. In all species BA, at the concentration of 0.8 percent, suspended in lanolin increased seed set, whereas the same concentration of BA suspended in vaseline reduced seed set. In *D. rotundata* BA reduced the number of seeds in each fruit, but in the case of BA in lanolin this was outweighed by the increase in percent fruit set. In *D. rotundata* sib pollinations within breeding families were more successful than cross pollinations between breeding families.

Water yam *(Dioscorea alata).* At IITA 16 accessions of the water yam germplasm were compared in a staked trial at 1×1 m spacing. All accessions were noted for plant and tuber characteristics and scored for scorch and nematode severity. Yields ranged from 17.4 t/ha to 35.0 t/ha with a mean of 27.8 t/ha. A significant difference for cultivar was found. The highest-yielding accessions are being distributed within Nigeria.

At Mokwa (Niger State), four accessions were compared with a local clone in an unstaked trial at 1×1 m spacing. Yields were low, ranging from 6.6 t/ha to 11.4 t/ha and there were no significant differences between yields of clones. At Mbiri (Bendel State) five accessions were compared with a local clone in a staked trial using 1×1 m spacing. Before 1 August, all clones were destroyed by a severe infestation of scorch and no marketable tubers were produced.

Cluster yam *(Dioscorea dumetorum).* One-hundred-and-sixty clones of *D. dumetorum* representing six breeding families originating from seed in 1976 were grown in hill trials and evaluated for flowering, disease resistance and tuber characteristics. Sixty-four percent flowered. Most showed wild characters and only a few were selected for further testing.

Cocoyam breeding

In a preliminary experiment flowering of *Colocasia* and *Xanthosoma* was promoted by the foliar application of 1,000 ppm Gibberellic acid applied with spreader sticker to plants in the 3-5-leaf stage.

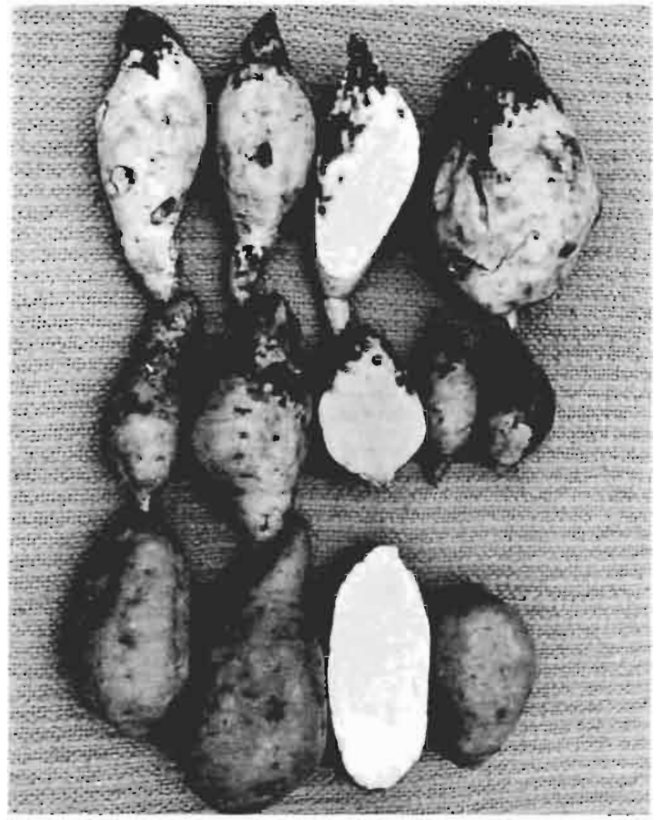
Treated plants of five accessions of *Colocasia* and three accessions of *Xanthosoma* flowered. Self, sib and cross pollinations were made but no seed developed.

Sweet potato breeding

Large-scale crossing plots (two hectares) were established in isolation for out-crossing among 25 selected parents. Extensive hand crossings were also made between clones which did not flower under field conditions but were induced to flower by grafting onto morning glory under short-day treatment. About 10,000 seedlings were raised in seedbeds, and about 1,000 clones were planted out for field evaluation for resistance to weevil, viruses and for root characteristics. Several thousand seedlings were raised from the seed from Solomon Islands and Taiwan.

Yield trials. The 25 most promising clones from the uniform trial were tested at IITA, Mokwa (dry savanna with 1,097 mm annual rainfall) and Mbiri (high rainfall, about 2,000 mm per annum) without fertilizers and harvested four months after planting. The results are shown in Table 3.

TIS 2489 gave the highest average yield with 23 t/ha and showed the highest overall value. This clone also rated highest in texture and eating quality and in resistance to virus. It also stored well. TIS 2534 stored best of all the clones tested and also had high resistance to sweet potato virus. This clone was also high in quality and had the least damage by weevil under field conditions. TIS 2544 rated consistently high in quality, showed good storability and had a high level of resistance to virus and weevil.



IITA works toward resistance to sweet potato weevil *(Cylas puncticollis).*

Cassava biochemistry

Preliminary and Intermediate trials (PT-77, IT-77). Screening for quality was applied to Preliminary and Intermediate trials of the 1976/77 growing season. Breeder's selections of 277 clones from preliminary trials and 154 clones from intermediate trials were evaluated for quality. Particular attention was given to development of vascular woodiness and root deterioration.

For PT-77 only 26 percent were acceptable, while only 8 percent of IT-77 were acceptable on the basis of excessive woodiness and root deterioration.

Starch content. The UT-1 (Uniform trial) cassava showed 5 percent of clones in the 10-15 percent range of starch content. Test showed no clones with high starch content in the range of 30-35 percent. On the other hand, UT-2 grown on a second plot showed no clones in the low starch-content range, but showed 20 percent of clones with high starch content. The shift in the distribution of starch content showed that UT-2 series contained higher starch generally than UT-1.

Distributable accessions. A special attention was given to the quality status of selected materials for farm-level trials and distribution. Two sets of accessions, TMX — Warri series and TMX — Ibadan series were examined for quality.

A summary of quality performance against four major categories of food utilization is shown in Table 4.

Tissue characteristics and quality. The Uniform and Advanced trials were subjected to detailed tissue analysis with

Table 3. Yield, dry matter percent, resistance to weevil and virus, storability and quality of IITA sweet potato clones.

Clones	Fresh yield (t/ha)	Dry matter %	Dry yield (t/ha)	Weevil score	Virus score	Stor-ability	Quality grade
TIS 2498	23.0	30.2	6.9	1.65	0.69	G	4.9
TIS 2534	20.8	26.8	5.6	0.80	0.70	VG	4.8
TIS 3030	20.2	30.5	6.2	1.00	1.10	G	2.8
TIS 3277	19.3	22.5	4.3	3.00	2.66	M	3.1
TIS 2544	19.3	27.2	5.2	0.90	0.96	G	4.8
TIS 2330	19.0	21.2	4.0	2.30	1.28	M	3.3
TIS 1487	18.3	30.4	5.6	2.30	2.77	M	4.8
TIS 2532	17.4	29.8	5.2	1.25	1.45	G	3.0
TIS 1499	17.0	27.0	4.6	2.50	2.85	M	4.7
TIS 3017	16.8	29.4	4.9	1.65	1.60	G	4.7
TIS 3247	16.4	28.4	4.7	2.65	2.44	VG	3.7
TIB 9	15.6	34.1	5.3	1.75	2.05	G	4.7
TIB 11	15.5	24.2	3.8	1.65	1.40	VG	4.4
TIS 3270	15.5	28.0	4.3	2.80	2.03	M	2.8
TIS 2153	14.1	35.1	4.9	1.05	1.09	VG	4.8
TIS 3228	12.7	25.0	3.2	2.40	1.71	M	2.8
TIS 1145	12.7	27.9	3.5	3.00	3.38	VP	4.6
TIS 3290	11.8	34.7	4.1	1.75	2.25	G	4.6
TIS 3053	11.2	27.8	3.1	1.30	1.05	G	4.8
TIB 2	11.0	25.0	2.8	2.25	3.29	M	4.3
TIS 2154	10.6	36.8	3.9	1.75	1.05	G	4.7
TIB 10	10.4	29.5	3.1	2.50	2.80	G	4.6
TIB 8	8.0	30.4	2.4	2.25	2.61	M	4.7
TIB 4	7.9	25.0	2.0	2.30	2.20	G	2.8
TIS 2328	4.7			1.25	2.66	G	4.5
Yardstick	18.0	27.0	5.0	1.70	1.50	G	3.0

TIB 4 is the standard cultivar.
Yardstick stands for an estimate of the practical optimum attainable.

Table 4. Quality performance of farm-tested materials.

Food utilization	TMX – Warri % acceptable (n = 14)	TMX – Ibadan % acceptable (n = 58)
1. Basic vegetable	35.7	8.6
2. Poundable material	57.1	20.7
3. Flour and products	85.7	82.8
4. *Gari*	92.9	84.5

particular reference to vascularity, vasculature and stele deterioration. Tissue quality in UT clones varied greatly in both vascularity and vasculature. Quality as reflected in stele deterioration was more constant through the clones. Quality as reflected in all three aspects was consistently higher through the AT series than through the UT series.

One of the very important quality indices is the deterioration of the stele; that is, evidence that starch storage in the root falls progressively to the point of a total loss in the central part of the root enclosed by the pericycle. It can be shown (Fig. 2) that product loss can range from 5 percent –90 percent among genotypes.

Vascularity as a screening index was applied to the two Uniform trials. Materials from the first trial demonstrated a high development of vascular tissue (negative quality factor). Screening on the basis of this criterion alone permits only 24 percent of the UT-1 and 86 percent of the UT-2 to be regarded acceptable (Fig. 3).

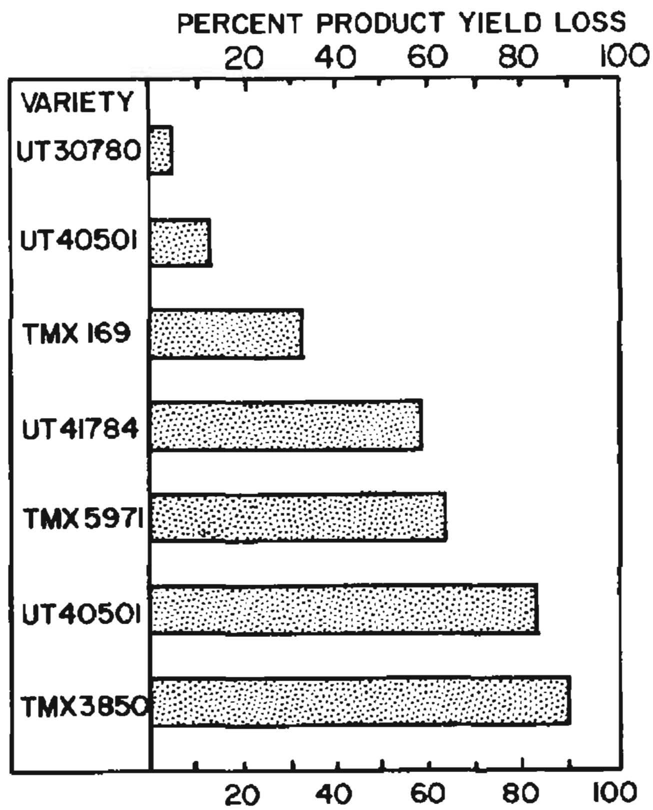


Fig. 2. Range of starch storage depletion in some cassava roots.

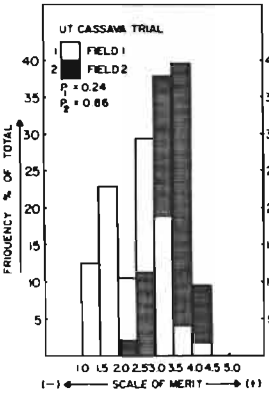


Fig. 3. Distribution of cassava tissue quality W.R.T. vascularity.

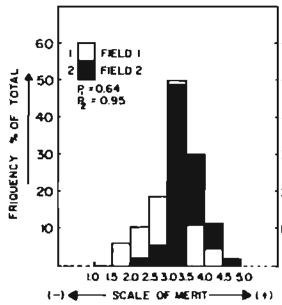
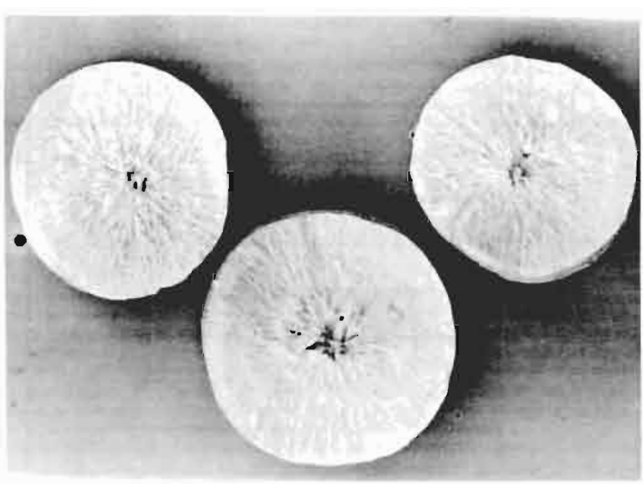


Fig. 4. Distribution of gari quality of cassava Uniform trial.

On the basis of *gari* quality, which is the least sensitive index 64 percent of UT-1 clones were acceptable; while 95 percent were acceptable in UT-2 (Fig. 4).

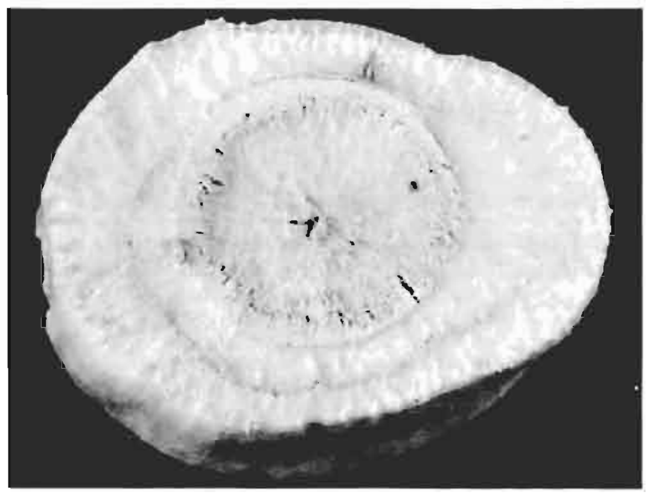
Vasculature. The patterns of distribution of woody vascular tissue in roots of 131 cassava clones were examined at stem-end, central and root-end sections. Observations showed that definite patterns of arrangement of vascular tissue in the forms of a series of concentric or eccentric rings, existed among genotypes. The prominence of vascular tissue also varied widely among clones. Only 20 percent of the 131 clones examined had the central primary xylem alone running through the length of the roots. About 55 percent of the genotypes showed a prominent second concentric vascular ring or cylinder (endodermis) through the whole length of roots. However, only 6 percent of clones demonstrated a third woody vascular cylinder along the whole length of roots; while 3 percent of clones showed a fourth vascular ring or cylinder through the central section of roots.

Differences in vasculature (cross-sectionally, the number of rings, including the primary xylem) among genotypes, and sections of roots, were highly significant ($p = 0.05$); and more so in sectional differences. Examples of vasculature are illustrated in photo plates on this page.

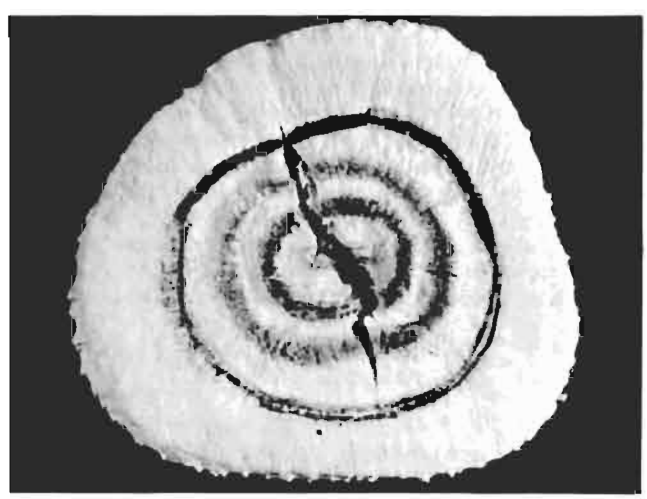


Dried cassava root section showing only the central primary xylem as a woody-vascular tissue.

Fresh cassava root section showing, in addition to the primary xylem, a woody second ring.



Fresh cassava root section showing two other woody vascular rings in addition to the central primary xylem.



Dried cassava root section showing three marked concentric woody vascular rings in addition to the central primary xylem.

In screening for root quality, the most recommendable is the root that shows the central primary xylem as the only prominent woody vascular tissue.

Texture profile and amylose content of cassava. Cassava is generally classified into sweet and bitter cultivars, based on the cyanide content and the eating qualities. This basis of classification can be misleading especially when there appears to be an overlapping in cyanide content in sweet and bitter eultivars.

Under optimal conditions, clearly defined textural characteristics do exist among certain categories or tissue types. Previous studies (1976) had established the major and minor textural characters in heat-treated cassava tissues. In general, almost all cassava cultivars that are regarded as "sweet" show a "mealy" or floury texture. The "bitter" types are predominantly of a "waxy" texture.

Intermediate or "mixed" texture also exists. A mealy tissue which contains a higher moisture can give rise to a "soggy" or wet texture. A "gummy" texture is the intermediate of mealy and waxy textural types. The major textural types of mealy, waxy and mixed or heterogeneous were evaluated for dry matter, starch and amylose contents.

Mealy cassava cultivars have an average amylose content of 21 percent. This level of amylose is similar to those of yams *(D. rotundata)* and potato *(Solanum tuberosa)*. Isunikankiyan, a popular mealy cassava cultivar has 21 percent amylose. The waxy types show amylose contents of about 15 percent. On the other hand, those clones which demonstrated heterogeneous textural eharacteristics have about 17 percent amylose.

Gari as quality index. *Gari* is a grit derived from fresh cassava by grating, fermenting, de-watering and roasting. It is one of the prineipal forms in which cassava is utilized as human food in West Africa. The cassava root has to undergo a series of processing operations to produce the pre-cooked grits, and several quality factors are affected or introduced by the *gari* process. One example is the partial removal of fiber during processing.

High vascular woodiness in a fresh cassava root not only affects the quality of the end product, but also affects the yield in processes where the excess fiber has to be removed. Processing factors must be taken into consideration when relating *gari* quality to the raw material.

However, development of woodiness in the cassava is used as one of the screening indices. Table 5 shows how degrees of vascular woodiness can affect the quality of *gari*. Although sifting off fibrous material is done in the *gari* process, higher fiber levels persist in *gari* manufactured from very fibrous roots than from the least vascularly woody raw materials.

Particle – water relationships. Some water-related quality factors of *gari*, as a product, are:

1. Ability to swell in water.
2. Water holding capacity.
3. Water vapor sorption characteristics.

Studies show that particle size in *gari* is related to the swelling capacity and the water holding capacity of the product. These results provide a guideline for sample preparation in a quality control program. Water sorption by *gari* also varies in relation to particle size. This information is relevant to the problems of packaging and storage as environments with relative humidity above 75 percent can adversely affect *gari* quality.

Table 5. Fibrousness of cassava roots and effect on gari quality.

Woodiness of roots	Gari Crude fiber content % Range	Average
Very fibrous	3.0–5.0	3.5
Moderately fibrous	2.0–3.0	2.3
Least fibrous	0.4–2.0	1.2

Yam biochemistry

Breeding lines of 82 *D. alata* and 98 *D. rotundata* were evaluated and screened for quality. Figure 5 illustrates the distribution of total dry matter among clones of both *D. alata* and *D. rotundata*. Both species *(D. alata* and *D. rotundata)* show dry matter 10-35 percent and above. The majority of *D. alata* clones had dry matter in the 20-30 percent range; while the majority of the *D. rotundata* lines showed dry matter content between 25 and 35 percent.

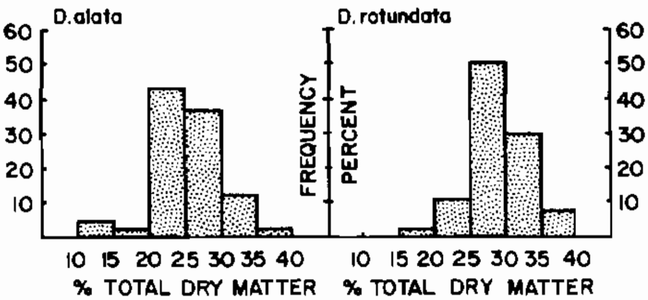


***Fig. 5. Distribution of total dry matter in yams.** (D. alata **and** D. rotundata.)*

Texture profile of yam. In tests on heat treated yam tissues, *D. alata* species show prominently the two textural characteristics of mealiness and sogginess which appear to be complementary. This explains why most cultivars are both soft and floury. Only 3 percent of *D. alata* had demonstrated full mealiness; while only 15 percent had shown complete sogginess. Waxy and gummy textures were not encountered in the *D. alata* series.

Relatively, all *D. rotundata* lines showed higher degrees of mealiness. The undesirable textural characteristics of waxiness, gumminess and jelliness were found in some *D. rotundata* clones.

Enzymic browning and taste score. Phenolic activity, with respect to enzymic browning, was also applied to screening for quality in two major breeding families of *D. rotundata* (FL and MFS series). Most of the clones demonstrated minimal enzymic browning. Those which showed phenolic activity index beyond the value 13 were rejected. On the basis of taste score, 24 clones of *D. rotundata* (24.5 percent of total) could be rejected for astringent taste. In overall quality performance of the *D. rotundata* lines 91 percent of FL series and 94 percent of the MFS series were acceptable.

Sweet potato biochemistry

About 60 clones of the Advanced, Uniform and Intermediate trials were evaluated for quality. In Table 6 are those cultivars which, on the basis of their superior qualities, are recommended highly for distributable accessions.

Table 6. Recommended cultivars of sweet potato.

1. TIS 1499	6. TIS 2544	10. TIB 9
2. TIS 2498	7. TIS 2153	11. TIS 3053
3. TIS 1487	8. TIS 2154	12. TIS 2534
4. TIS 32	9. TIB 8	13. TIS 3017
5. TIB 11		

Texture profile of sweet potato. There is more diversity in the texture of heat-treated sweet potatoes than in any other root crops under study. Texture profiles of the TIX and TIB series show that only 3 percent TIX and 17 percent of TIV clones showed a completely mealy texture. The TIB series were mealier than those of TIX.

The negative textural eharacters of pithiness, graininess and lumpiness appeared to be more pronounced in the TIX clones than in those of TIB.

Pigmentation and carotene content. A quantitative determination of total carotene content in sweet potato was carried out on typical cultivars. With the results as a guide, it is possible to estimate the carotene content of a clone according to its exodermal and flesh eolor.

Phenotypic categories and quality characteristics. Representatives of five major phenotypic categories were evaluated for texture profile, sensory sweetness and total sugar content. Most of those with a creamy flesh (e.g. TIS 3247) have a mealy-lumpy texture, and are mildly sweet with total sugar content of about 5 percent (Table 7).

Entomology

Cassava

In Nigeria, the main insect problems of cassava were variegated grasshopper *(Zonocerus variegatus)*, whitefly *(Bemisia tabaci)* and red spidermites *(Oligonychus gossipii)*, while outside the country green mite *(Mononychellus tanajoa)* and mealybug *(Phenacoccus manihoti)* remained the main problems.

Mealybug. The main emphasis of the mealybug program in Zaire is to identify sources for resistance in the IITA and local germplasm. At the same time a biological control program is under way and first releases will be made in 1978.

Green spidermite. The green spidermite has now reached the coast of Tanzania, Zanzibar and the east of Zaire. In Zanzibar, local and IITA germplasm collections were evaluated by local scientists for resistance. Several clones showed levels of resistance.

Red spidermite. Spidermite infestation at Ibadan during 1977 was very high due to high temperatures and early starting dry season. This provided ideal field screening conditions. The Latin American seedling nursery was screened for sources of resistance, and about 10 individual plants were identified as less attacked.

Whiteflies. The joint experiment with the pathologist to study the relationship of whitefly population development in relation to CMD incidence was repeated on a smaller scale. Symptom development of CMD again followed whitefly population density. Highest incidence of the disease was observed during May-June planting as that was the peak of the whitefly population.

Variegated grasshopper. Of the 1976/77 cassava planting, 104 clones could be identified where no barkfeeding or even shootfeeding took place. These clones were replanted in two replications and at three different planting times: April, June and August. The three planting times were included to study defoliation by *Zonocerus* on younger and older cassava. This should give an indication whether age and defoliation have any influence on yield.

Sweet potato

The major insect problem observed in sweet potatoes during 1977 was the weevil *Cylas puncticollis*. During September – October a hawkmoth caterpillar made considerable leaf damage.

Screening for resistance in the germplasm over the past two years indicates that there are yet no major sources of tuber resistance. Minor differences could be found and the clones are now included in the breeding program.

Apart from tuber screening, a leaf screening method has been developed for the field. The major idea of the method is to expose only a certain area of the leaf for feeding. The area fed is then measured by a leaf-area meter.

The first results show that there are differences in the area consumed by the weevils on different clones. This indieates that leaves might be a good indicator also for measuring the level of tuber resistance. For stem screening, a field cage method is under testing. So far only one clone, TIS 1419, has shown a high degree of stem resistance.

Cassava pests in Zaire include the cassava mealybug, *Phenacoccus manihoti*, Mat-Ferr., the cassava green mite, *Mononychelus tanajoa;* these two being the major pests of economic importance. The black scale *Saissetia miranda;* white scales, *Pinaspis strachani* and *Aonidomytilis albus*, and an unidentified subterranean scale whieh occurs occasionally in parts of Zaire have no significant damage to the crop.

Crop damage and yield reduction. Infestation by *P. manihoti* usually occurs during the dry season (May – September). With the onset of rains in October, pest populations drop considerably and plant regrowth commences. Changes in soil moisture and consequent changes in plant sap and avail-

Table 7. Sweet potato phenotypes and sugar content.

	Category		Texture profile						Dry weight
No. Cultivars	Skin color	Flesh color	Mealy	Soggy	Pithy	Grainy	Lumpy	Sensory sweetness	% basis total sugars
1. TIB 11	Orange	Deep orange	–	+ + +	–	–	–	Very sweet	14.55 ± 0.983
2. TIB 4	Orange	Orange	+	–	–	–	+ +	Mildly sweet	7.05 ± 0.849
3. TIS 2498	Purple	White	+ +	+	–	–	–	Sweet	8.60 ± 0.895
4. TIS 1499	Light purple	White	+	+ +	–	–	–	Sweet	8.40 ± 0.771
5. TIS 3247	White	Creamy	+	–	–	–	+ +	Mildly sweet	5.80 ± 0.895

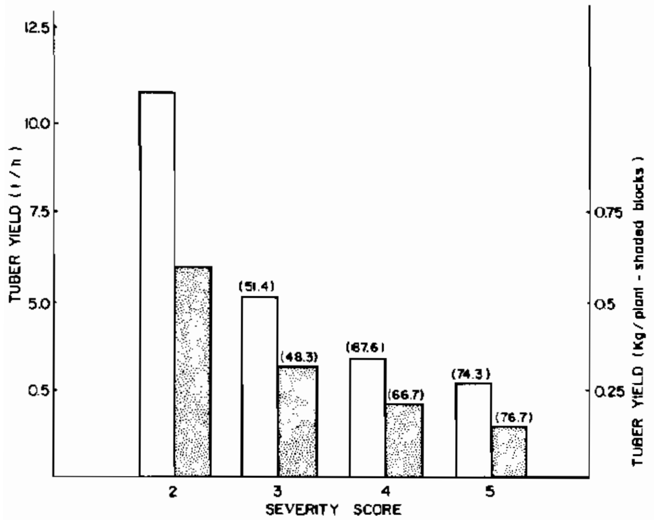


Fig. 6. Severity of mealybug attack on tuber yield of cassava (Var. Mpelo-longi) on farmers' fields. (Figures in brackets represent percentage yield reduction with severity score of 2 as control.)

able soluble nutrients during the dry season, may have a positive effect on mealybug development. Field trials at M'vuazi show that tuber yield reduction due to mealybug infestation can be as high as 54 percent. Information collected from farmers' fields (Fig. 6) show that yield reduction could go as high as 75 percent at a damage severity score of 5 for October planting. Comparative studies for later plantings are in progress.

Population dynamics. Annual population fluctuation of *P. manihoti* was investigated using three sampling procedures: trapping of airborne crawlers, direct examination of 100 randomly selected plants and direct monitoring of all plants of two plots at M'vuazi and Kimpese.

Crawler activity corresponds with dry conditions, low humidity, moderate temperatures and light radiance and an increased wind speed. Similarly increased pest infestation may be explained by changes in cell sap composition and concentration imposed by drought stress and their effect on pest population development.

Control strategy. Research in 1977 was geared toward developing a sound integrated pest management program for the control of the pest. Several natural enemies of *P. manihoti* were reported in Congo Brazzaville by D. Matile-Ferrero. In Bas Zaire, several predators have been observed in association with the pest.

Unfortunately, the predators are only attracted to the high densities of *P. manihoti* and seem not to be particularly adapted to it as control agents. It becomes imperative that exotic predators be introduced from South Africa with priority being given to parasites, as they are totally lacking in Zaire.

By screening over 1,000 families of cassava introduced as seeds from CIAT, IITA and PRONAM selections, where individual plants were artificially infested, it was shown that there is scope for the selection of resistant cultivars.

The use of insecticides as foliar sprays is discouraged because cassava leaves form a major part of the daily diet in Zaire. However as a component of an integrated pest management program, it may serve to limit the spread of the pest by the use of clean planting materials. In a preliminary trial, by dipping cuttings in dimethoate solution, infested planting materials were adequately protected for eight weeks. Other insecticides are being screened for their efficacy.

In a preliminary mulching experiment with a grass base of *Imperata cylindrica*, mulch plots were less attacked in percentage, number of plants and severity of attack. Other suggested cultural practices include early planting, mixed cropping with three legumes to serve as windbreaks against airborne crawlers and laying down of vegetation twice during the dry season and turning under before first rains in October.

Cassava pathology

CMD host plant resistance screening. Reaction of new improved cassava cultivars to the cassava mosaic agent varies considerably with locations. The following investigations were carried out to identify some environmental factors which modify cassava plant reactions to CMD to further improve the methodologies for host plant resistance screening.

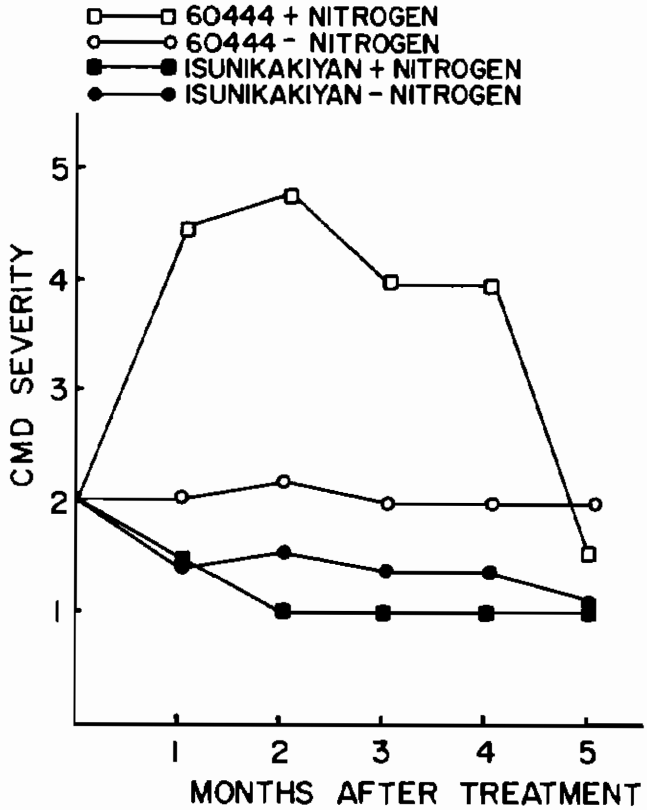


Fig. 7. Effect of soil nitrogen levels on CMD symptoms expression in 2 cassava varieties. IITA, Ibadan, 1977.

Effect of high soil nitrogen. To test the effect of high soil nitrogen on CMD expression and plant vigor, cultivars 60444 and Isunikankiyan (highly and moderately susceptible respectively) were used as indicators. The results summarized in Figures 7 and 8 show that for 60444, high soil nitrogen induced a high CMD severity and vigor response over a three-month period for the former, and throughout the whole five-month period for the latter, compared to the reaction of the

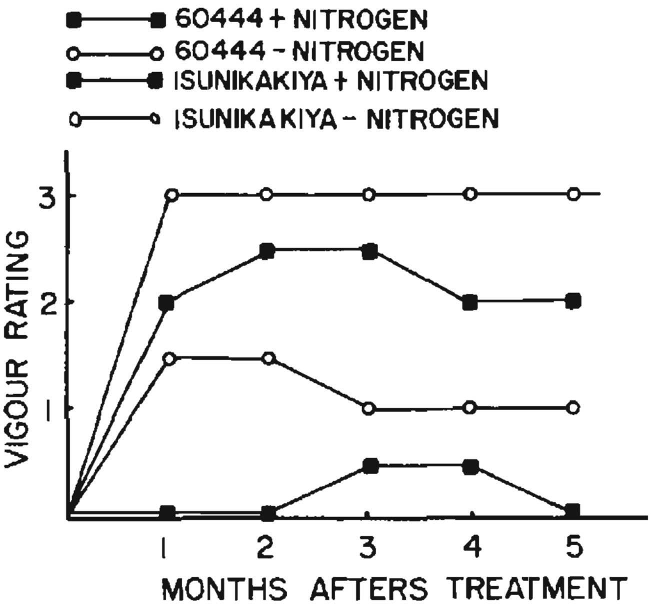


Fig. 8. Effect of soil nitrogen levels on vigor of 2 cassava. IITA, Ibadan, 1977.

untreated plants. High nitrogen application drastically modifies CMD severity in some cassava cultivars while exerting minimal effect on others. The results indicate the need to test the reaction of improved cultivars under high soil nitrogen conditions.

Effect of **soil moisture.** Cultivars 30211 and Isunikankiyan (improved and local respectively) were used as indicators in testing the effect of soil moisture on CMD expression.

The data indicate the following:

1. That on a 1-5 increasing scale of CMD severity (where 1 represents symptomlessness and 5 represents the highest degree of CMD severity) cultivar Isunikankiyan expressed a higher level of severe mosaic under normal moisture and moisture stress regimes respectively compared to 30211.
2. For both cultivars CMD expression was more severe under normal soil moisture regime and was reduced under moisture stress. However, Isunikankiyan was more sensitive to these differences and 30211 only moderately so.
3. Cultivar 30211 was less sensitive to changes in CMD severity expression with time than was Isunikankiyan. After indicator plants had made three-month uninterrupted growth under their respective treatments, the moisture regimes were reversed in selected boxes. Both cultivars were highly sensitive to a change from moisture stress to normal moisture regime and new growth expressed a high severity response on plants that were hitherto symptomless within two weeks. The reverse treatment, however, did not produce a change from high severity to symptomlessness in Isunikankiyan, while for 30211 the response only appeared after 12 weeks.

Effect of seasonal and biological factors. To determine the effect of seasonal and biological factors on the incidence, rate of development and severity of CMD on disease-free cassava seedlings, open-pollinated seeds of three cassava families were germinated in the greenhouse and transplanted at monthly intervals in 1976 and at bimonthly intervals in 1977. Results are summarized in Figure 9. The implications

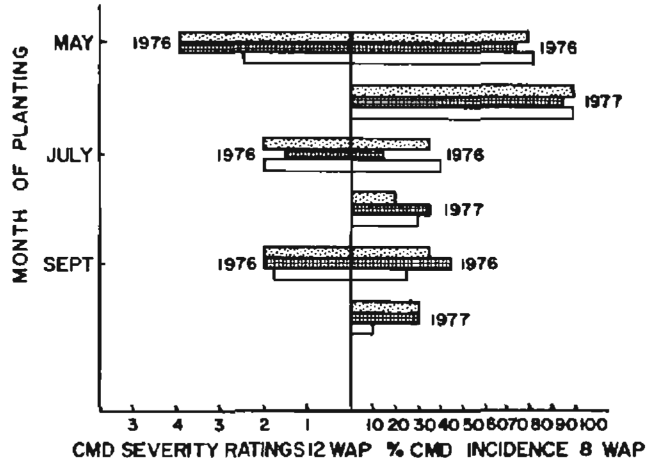


Fig. 9. Effect of month of planting on rate of development and severity of CMD. IITA, Ibadan, 1976, 1977.

here are that seasonal factors and whitefly population levels drastically modify rate of development and symptom expression of CMD and therefore constitute significant factors in screening for host plant resistance to CMD.

The effect of detopping as a regulating mechanism for CMD expression. Cuttings of cultivar 58308 were established in a randomized complete block design with three replicates in April 1977 and subjected to detopping treatments in June, July, August and September. An untreated check was included among the treatments. Data on symptom intensity response after detopping were recorded over a five-month period and are summarized in Figure 10.

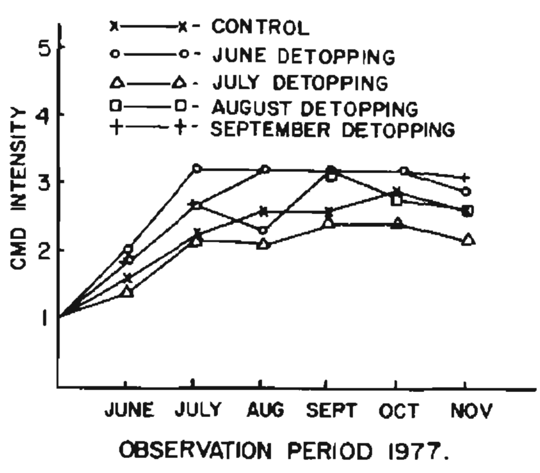


Fig. 10. Effect of detopping on CMD symptom intensity response of variety 58308. IITA, Ibadan, 1977.

The 1977 data confirm observations reported in 1976 that the August detopping induced the strongest and most persistent symptom intensity response. The data also confirm observations made in 1975 that June detopping also induces a strong response and that there was, however, a tendency for plants so treated to recover and express milder symptoms later. This recovery tendency underlines the necessity for selecting the appropriate period for evaluation of resistance to CMD.

Brown leaf spot disease *(Cercospora henningsii)* host plant resistance screening. Twenty-eight improved cassava cultivars were artificially inoculated 90 days after establishment with a suspension of 50,000 spores/ml of *Cercospora henningsii* to test the applicability of this method for host plant resistance screening to brown leaf spot disease. Twenty-six of the cultivars tested scored a higher severity rating than the uninoculated controls. The highest severity ratings were recorded for seven of the improved cultivars included among which was cultivar 30395 (highly rated for field resistance to CMD and CBB).

Cassava Bacterial Blight. CBB was newly recorded from Rwanda, Kenya and Tanzania. In East Africa, it was observed on local farms and experiment stations around Lake Victoria. It was not observed on the East African coast.

Seed transmission. A previously unreported potential for seed transmission was demonstrated by the recovery of *X. manihotis* from seed which had been stored at 5°C and 6 percent relative humidity for 15 months. In addition, CBB was observed in two-month-old seedlings in a situation where infection from outside sources was unlikely. These findings indicate that given the appropriate environmental conditions, seed transmission of the disease can occur. Treatment of seed in hot water at 60°C for 20 minutes eliminated the pathogen without appreciably reducing germination.

Ecology. CBB survived the dry season at Ibadan in dry angular leaf spots, green stems and dead branches on infected plants and in plant debris on the soil surface. The numbers present in the debris decreased sharply with increasing moisture and temperature. Evidence that it survived in soil was all negative.

During the 1976 growing season and in January, during the dry season, an epiphytic population was found on leaf surfaces. In June 1977 the pathogen was detected on the surface of apparently healthy leaves, before new angular leaf spots were formed, suggesting that a low population of the pathogen survived the dry season as an epiphyte. The magnitude of the epiphytic population fluctuated during the season depending on the prevailing weather conditions, especially rainfall.

Resistant screening. Forty-seven experimental cultivars were compared with five others of known field reaction after inoculation in the greenhouse. The five standards ranked in the same order as they behave in the field. Stem and leaf infiltration methods of inoculation were compared, with the former giving more consistent results. However, further studies are necessary to see if resistance screening in the greenhouse is feasible, since field performance depends on more complex epidemiological factors than can be measured in the greenhouse.

Effects of soil fertility on disease development. The addition of 200 ppm NPK to Warri soil (sandy, acidic) and Egbeda subsoil (clayey, alkaline) reduced the severity of CBB symptoms in plants subsequently grown in the soil and inoculated with *Xanthomonas manihotis.* Although disease symptoms developed earlier in plants supplied with fertilizer, the unfertilized plants became more severely affected after five weeks and showed a higher mortality rate. This suggests that there is a correlation between plant vigor and resistance to bacterial blight.

A severe disease-like condition considered a potential threat to cassava production. This is the first report of the incidence of a disease-like condition on cassava, the agent of which has not been identified, but for which the effect of intercropping on its development and almost total recovery during the growing season has been documented.

Characteristics. The condition clearly bears striking resemblance to cassava mosaic disease, but other characteristics hitherto unassociated with CMD suggest the involvement of other agent(s).

In Figure 11 the incidence of this unknown condition was highest on cassava as a monocrop for the first four months after it was first observed. It is also evident that there was a sharp increase in incidence on cassava intercropped with maize and cowpeas when these crops had matured and were harvested. The data also show that two months after the maize and cowpea were harvested, the incidence on cassava which was intercropped with these two crops was higher than on that which was monocropped.

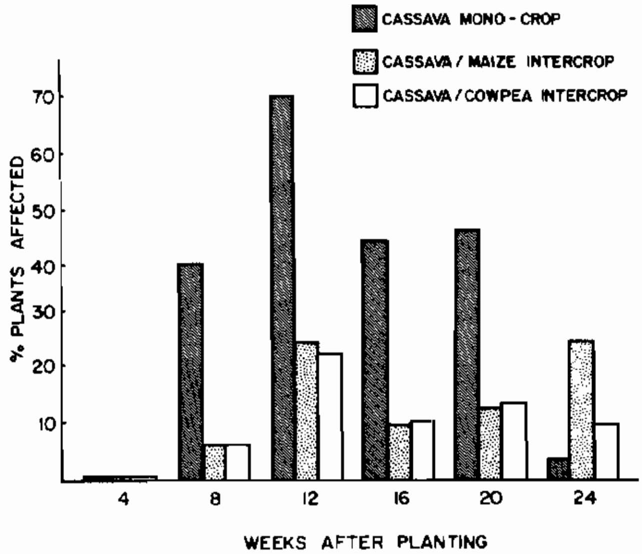


Fig. 11. Effect of intercropping on the incidence and recovery of a severe unidentified disease-like condition on cassava. IITA, Ibadan, 1977.

Yams – *Dioscorea alata*

Control of *Dioscorea alata* diseases by cultural practices. The effect of three staking systems and the canopy orientation resulting from these systems on the incidence and severity of foliar and tuber diseases of *D. alata* was investigated.
The three staking treatments were as follows:

1. Each plant attached to a 3-m stake and each vine trained only on individual stakes.
2. Each plant attached to a 1.5-m stake and all vines exceeding the height of the stakes were trained on cross wires to form a dense low canopy above the soil.
3. None of the plants was staked, and vines were allowed to cover soil randomly.

There were only very small differences in incidence and severity of leaf spot and anthracnose or scorch at 60 and 120 DAP, and at harvest for the three staking treatments. At harvest, leaf spot severity averaged just below 3 (on an increasing severity scale of 1-5) and scorch severity averaged just above 3.

There was a marked difference, however, at harvest in the percentage of tubers among the different treatments that had penetrated the soil surface, with the highest percent of exposed tubers in the 3-m staking treatment. The highest percentage of rotted tubers also occurred in the 3-m staking, and is likely associated with the high percentage of exposed tubers.

Ground cover by yam foliage was best in the zero staking treatment and least in the 3-m staking. There was an attendant high degree of erosion control because of the ground cover in the zero staking which also drastically reduced tuber exposure and possibly tuber rot.

The yield obtained from the 3-m staking was significantly higher than those of the other treatments. However, with the reduction in cost of planting if zero staking is practiced, coupled with the reduction in soil erosion and tuber rot, and the absence of any significant effect on disease severity, the potential yields obtainable from unstaked *D. alata* recommends the practice as a viable one.

Development of a model for assessing yield reduction due to defoliation by *Dioscorea alata* diseases. Defoliation of *D. alata* due to diseases was simulated by mechanically detaching leaves when plants were 40, 60, 120 and 180 days old. The four levels of defoliation were 0 percent, 40 percent, 60 percent and 100 percent of the total number of leaves at the time of defoliation. Percentage natural refoliation when plants were 40, 60 and 120 days old respectively, and actual leaf area reduction per plant due to defoliation of 120- and 180-day-old plant respectively were assessed.

The data, summarized in Table 8, show that there was a highly significant interaction between age of plant at defoliation and level of defoliation. Figure 12 shows the differences in yield reduction when defoliation occurred at the various stages of growth.

Figure 13 shows that for 51 percent and 66 percent actual defoliation there was a 20 percent and 30 percent differential respectively in the actual yield loss recorded when compared to the predicted loss from the model.

The results indicate therefore that field rating for defoliating diseases of *D. alata* may be more accurately carried out 40 DAP for early or vegetatively borne diseases, or at 120 DAP for late developing diseases, the model can be utilized for prediction of yield reductions with minor adjustments for differential values between actual and predicted yield reductions.

Sweet potato virus disease (SPVD)

Resistance screening. Fifty-seven sweet potato lines from the breeding program were screened for resistance to the sweet potato virus by the tuber graft transmission method. Vines from symptom-free seedlings were grafted on to viruliferous tubers of the high susceptible cultivar TIS 1499. Each of the 57 grafted test lines was replicated four times. Vines of *Ipomoea setosa* (a sensitive indicator for SPVD) were randomly grafted to representative batches of the virus source (1499) tubers to confirm their viruliferousness. The characteristic SPVD symptom developed on the indicator plants within 14 days of grafting.

Resistance to SPVD was categorized on the basis of rate of symptom development and severity of disease expression. Five lines were categorized as highly resistant to SPVD. Eight lines were moderately resistant while the remaining 44 lines were highly susceptible.

***Table 8. Effect of mechanical defoliation on yield (kg/plant) of* D. alata.**

	Defoliation percentages (A)				
B	0	40	60	100	Mean
40	4.81	3.90	4.14	1.50	3.59
60	3.51	3.93	3.28	2.25	3.24
120	4.06	3.95	3.69	1.43	3.28
180	4.28	4.29	3.50	3.99	4.02
Mean	4.16	4.02	3.65	2.29	

LSD .05 (AB) 0.36 *B = Age of plants in days at defoliation.*

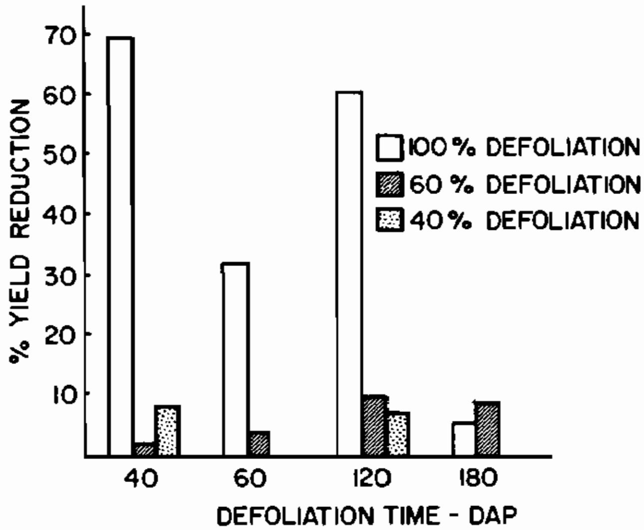


Fig. 12. Percent yield reduction due to defoliation of* Dioscorea alata. *IITA, Ibadan, 1977.

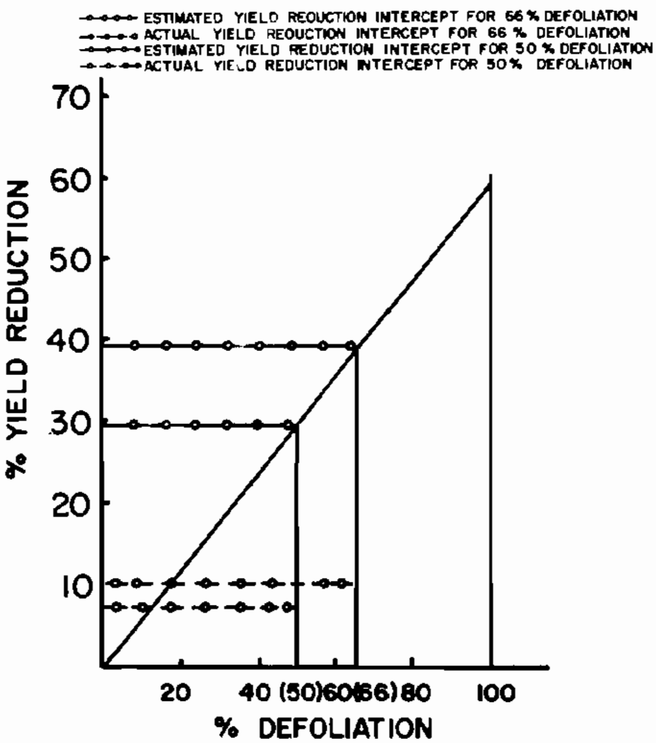


Fig. 13. Effect of defoliation on yield of* D. alata *120 days. IITA, Ibadan, 1977.

Cassava pathology, Zaire

The major objectives of the PRONAM plant pathology for 1976-77 were to obtain new knowledge on the epidemiology, cultural control measures and efficient screening methods of the major diseases of cassava.

Cassava planted in December, February and April in relatively rich soils (Manekwa) showed a greater incidence of CBB and CMD than did cassava planted in relatively poor soil (M'palukidi). Similar observations of anthracnose were noted for the December and February plantings, but there was no difference in this disease incidence between the two locations on the cassava planted in April.

Data from studies at both locations lead to the recommendation that planting of cassava should be in March or April to escape CBB and CA diseases, but for escape from CMD alone, planting should be done in November and December.

In an experiment to find efficient ways of screening and selecting cassava for resistance to diseases, plants were detopped at one month after shoots emerged and continued at one month intervals up to three months. Three local cassava cultivars were either highly resistant or moderately resistant to CBB and CA organisms.

Preliminary screening of 1,614 cultivars indicates that 270 clones have resistance to the three major diseases of cassava.

Tissue culture

Yam. Murashige and Skoog medium (MS) supplemented with 6-benzylamino purine (BAP) and α-naphthaleneacetic (NAA) was used for callus induction, root formation and shoot differentiation from nodes and shoot meristems of yam, *Dioscorea rotundata*. Numerous shoots were initiated from nodal material cultures in MS medium supplemented with 0.5 and 0.1 mg/l BAP and NAA respectively, while 0.25 and 0.05 mg/l BAP and NAA produced plantlets with shoots from apical or lateral meristems. Media high in NAA and low in BAP induced callus and root formation on tuber slices, nodal and shoot meristems, but not on petiole slices or leaf discs. Attempts to differentiate shoots from callus have not been successful. When excised shoots were transferred to culture media containing 0.1 mg/l NAA, they readily developed into well rooted plantlets within two weeks. The plantlets grew successfully in the greenhouse.

Yam embryos dissected from green fruits germinated in two weeks on MS medium containing three percent sucrose and without growth regulators. However, more shoots were initiated from each embryo when 0.125 mg/l BAP and 0.05 mg/l NAA were added to the medium.

Cassava. The medium developed by Gamborg and Kartha for culturing cassava from apical meristems was tested with seven of our improved lines. The medium was found unsuitable because it induces profuse callus formation.

Sweet potato. Plantlets ready for transplanting were initiated in about six weeks from apical or lateral meristems on MS medium supplemented with three percent sucrose, 0.5 mg/l BAP and 0.5 mg/l indoleacetic acid.

Cocoyam. Plantlets were initiated from axillary corm buds on MS medium supplemented with three percent sucrose, 0.2 percent activated charcoal, 1 mg/l BAP and 0.1 mg/l NAA. It was possible to obtain 20 to 30 buds, suitable for culturing, from one corm.

Yam pollen germination. Pollen grains from four cultivated and four wild yam species were germinated in a modified Brewbaker and Kwack's medium. Pollen germination began in 30 minutes after incubation and maximum germination and pollen tube growth occurred 24 hours after. Optimum pollen germination and tube growth were obtained by using the following medium: 8 percent sucrose, 100 ppm H_3BO_3, 200 ppm Ca $(NO_3)_2 \cdot 4H_2O$, 100 ppm $MgSO_4$, $7H_2O$ and 50 ppm KNO_3.

The medium is adjusted to pH 6.8 and semi-solidified with 0.7 percent agar and dispensed in petri dishes.

Yam pollen storage. Yam pollen was stored for three months at $-20°C$ in a medium containing the above salts and 16 percent sucrose. During the first month of storage the pollen viability was reduced only slightly; however, only about 20 percent of the pollen remained viable after three-month storage.

National Cassava Center, Umudike, Nigeria.

On-farm minikit trials were expanded by small-holders from the original pilot in Anambra and Imo States to sites in Rivers, Bendel and Ondo States. Also an effort was made to involve large farms, special cassava projects, institutions, schools and companies in the NAFPP minikit trials. Farmer-conducted demonstrations were used to train other farmers on the package of improved practices, and production with improved technology was increased. Multiplication of elite cassava clones was stepped up to provide planting materials for 1978 planting season.

Cassava variety minikit trials. These trials contain four improved cultivars which are compared with the best local cultivar so that participants can select which they consider the most acceptable. All five cultivars were compared under fertilizer and no fertilizer conditions. Results from Abakaliki Zone are summarized in Table 9.

Table 9. Fresh tuber yield (t/ha) from Anambra NAFPP cassava minikit trial, 1977.

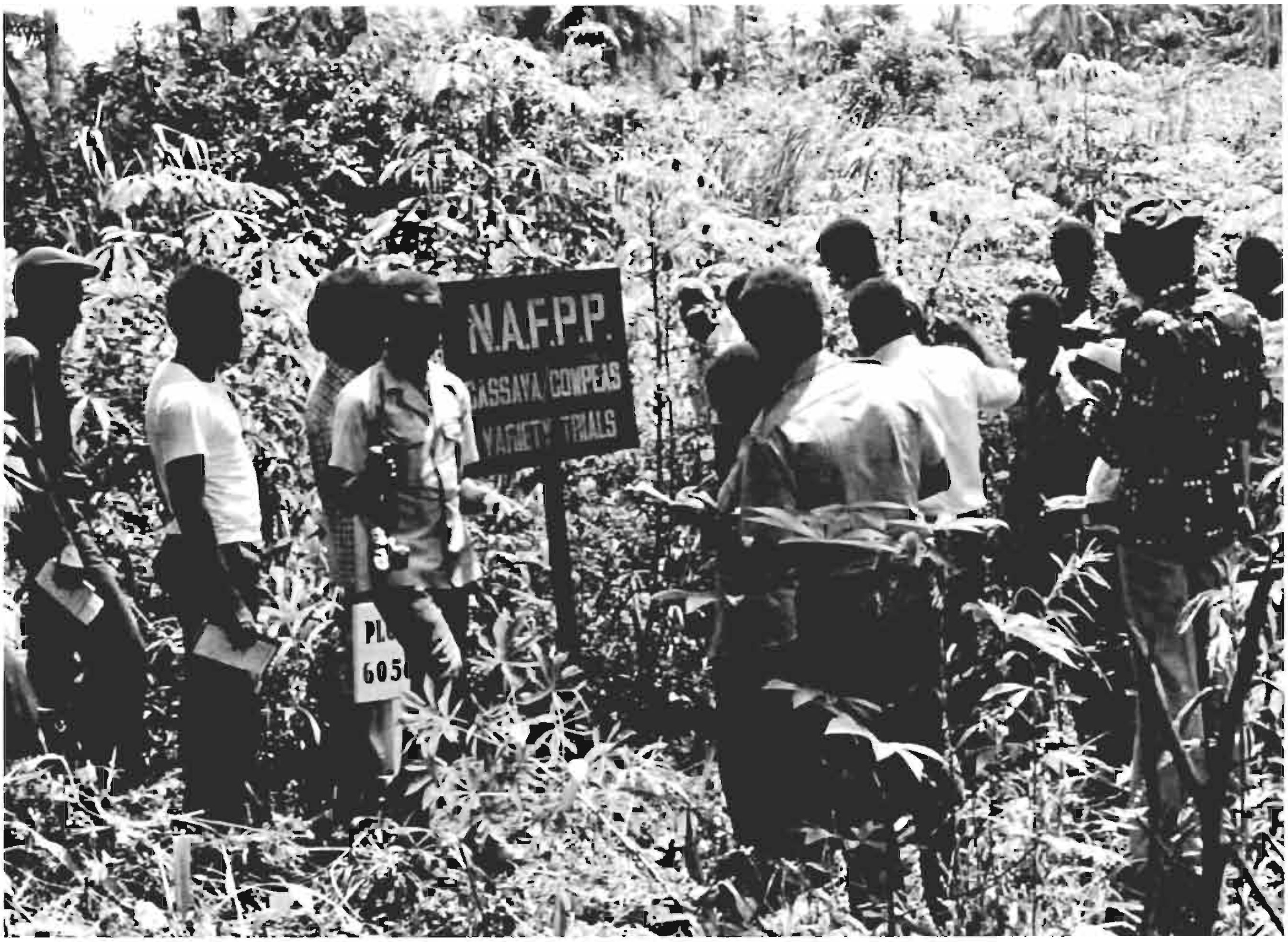
Cultivar	TMS 465	60506	TMX 1087	TMX 1756	Local (Nwagbogho)
With fertilizer*	30.0	15.0	14.0	10.0	10.0
Without fertilizer	16.0	8.0	8.0	6.0	6.0

**Fertilizer N-P_2O_5-K_2O: 60:30:90*

Results of a trial at Umudike (on highly cropped acid soil, rainfall 2,199 mm) are summarized in Table 10.

Table 10. Average fresh tuber yield of replicate I & II of K treatment only.

Rate (kg/ha)	Fresh tuber yield t/ha		
K20	Rep	60506	TMX30211
	I	19.9	23.4
0	II	21.5	18.1
	$\bar{X}$	20.2	20.8
	I	21.3	33.2
75	II	22.0	28.6
	$\bar{X}$	21.7	30.9



In Nigeria, IITA improved cassava is distributed for multiplication mainly through the National Accelerated Food Production Project.

The conclusion from this experiment is that under the same fertilizer regime, TMX 30211 out-yields 60506; and also, TMX 30211 is particularly more responsive to higher levels of K than 60506.

Demonstrations. Cassava (interplanted with maize) demonstrations were carried out so that farmers could learn the skill and convince themselves of the superiority of the improved package (consisting of improved cultivars, fertilizer application, and better cultural practices. Maize yields from the 1977 demonstrations again showed that the improved practice outyielded the local practice. The cassava will be harvested in 1978. In all 1,117 demonstrations were carried out in Anambra State, 726 in Imo State, 300 in Rivers State and 23 in Bendel State.

Multiplication. Farmer-to-farmer spread of improved planting materials from the 1977 production kit cultivar and fertilizer trials and demonstrations will be enough to plant about 14,000 hectares in 1978.

Distribution of elite clones to the state ministries of agriculture "Operation Feed the Nation" program, Federal Department of Agriculture and other institutions was stepped up in 1977 to provide planting materials for 1978 planting.

THE FARMING SYSTEMS PROGRAM

The Farming Systems Program (FSP) has the task of developing methods of crop management and land use suited to the hnmid and subhumid tropics which will enable more efficient and sustained prodnction of foodcrops 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 eomponents 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 international and national agricultural institutions.

The farming systems in the lowland humid and subhumid 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), the major agricultural regions are characterized for research purposes on this basis.

A broad diversion of the humid and subhumid tropics of Africa and Latin America in terms of land types, cropping systems and dominant bio-technical limitations is shown in Figure 1; a further subdivision, not shown, is based on population densities. The distribution of the major soil types within the tropics (Table 1) shows that the highly weathered low- and high-base statns soils occupy the majority of the region within which IITA operates. 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 tropics – 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. Therefore, 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 of resourees committed to food crop production.

Geographic/ ecological region	Humid tropics (1,500 mm rainfall)			Subhumid tropics (1,000 to 1,500 mm rainfall)	
Soil characteristics	Low base status[a]		Derived from basic rocks[b]	High-base status[c]	
Moisture regime	Hydromorphic	Pluvial		Hydromorphic	Pluvial
Principal components of cropping systems	rice yams	tree crops plantain yam/cocoyam rice vegetable-legumes	perennials and annuals depending on climate	rice off season crops (plantain)	maize cassava yams seed legumes sole and intercrop
Major constraints to production	water management weeds fertility management Al,Fe) pests/diseases	+ + + Al toxicity nutrient ratios weeds pests/diseases	fertility management (P) weeds soil physical management pests & diseases	water management weeds fertility management pests/diseases	soil physical management moisture regimes weeds nutrient deficiencies pests/diseases

a. Oxisols, Ultisols and associated Entisols, Inceptisols.
b. Soils derived from basic rocks important locally but of limited distribution in tropical Africa.
c. Alfisols and associated inceptisols.

Fig. 1. Each of the primary soil/climatic zones in tropical Africa has different dominant cropping systems and problems involved in increasing crop production.

Table 1. Percentage distribution of soils in the rainy tropics.[1]

Soils	Rainy (9.5 to 12)[2]	Seasonal (4.5 to 9.5)[2]	Total
	..............%		
1. Highly weathered, low base status (Oxisols, Ultisols)	70	\37	50
2. Highly weathered, high base status (mainly Alfisols)	8	30	20
3. Sandy and shallow soils (Psamments, lithic taxa)	12	8	10
4. Dark colored, high base status (Vertisols, Molisols)	2	8	6
5. Moderately weathered (mainly Inceptisols)	1	5	4
6. Hydromorphic (Allevial soils) (Aquepts, Aquents, etc.)	12	8	10

1. After Moorman, unpublished.
2. Number of months with average rainfall higher than 100 mm.

Objectives

On this basis, the objectives of the Farming Systems Program are to:

1. Develop systems of crop production which will enable good yields on a sustained basis with aeceptable input levels;
2. Develop methods of land management which will enable intensified systems of food crop production to replace shifting cultivation where environmentally feasible;
3. Disseminate food erop technologies to national agencies for adaptation to specific areas;
4. Provide training in farming systems research and its application for researehers and extension workers associated with tropical food crop production.

Criteria regarded as important in the design of technology appropriate for farmers of the tropics require that it will:

1. Generate substantial, sustained, stable, and acceptable levels of incomes for farm families by increasing the productivity of labor, land and other agricultural inputs.
2. Make optimal use of renewable natural resources while protecting the farmer's non-renewable resourees (particularly soil).
3. Be within the financial and managerial capacity of target farmer groups.
4. From a national viewpoint, be aceeptable and feasible in terms of input requirements and distributional consequences.

Organization of program

In 1977 the Farming Systems Program was reviewed as part of the Technical Advisory Committee's Quinquennial Review Mission of IITA and the "Stripe" Review Mission by TAC of farming systems programs in the international institutes. As part of this review the structure of IITA Farming Systems Program was examined. It was resolved to retain the structure on which the Program has been focusing its aetivities.

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 produetion and processing, and reduce post-harvest 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.

Regional analysis

Regional analysis is involved in three major project areas:

1. Studies of Farming Systems.
2. Benchmark Soils Project.
3. Agro-climatological Analysis.

Agro-economic studies of farming systems

Three intensive interdisciplinary studies of indigenous farming systems were in progress in 1977. The three sites (in Nigeria) are as characterized in Table 2. Analysis of the first study (the majority of field work being undertaken in 1976) is nearing completion, while data collection in the latter two investigations will finish at the end of the 1977-78 dry season.

Table 2. Intensive agro-economic studies currently in progress at IITA.

Location (area)	Land type	Farming system	Field work From	Field work To
Ilora/Oyo	Alifisol/Savanna	Maize based	Feb. 76	April 77
Lokoja	Alifisol/Savanna	Yam/Guinea eorn	Feb. 77	April 78
Onitsha	Alifisol/High rainfall	Yam/oil palm	Feb. 77	April 78

Rice production systems in north-west Cameroon. Five systems of rice production were studied among a sample of 118 farms in northwestern Cameroon. In this region, rice is grown under both pluvial and irrigated conditions, under improved and unimproved cultivars and systems of management. The area is high altitude — 1,500 to 2,000 metres.

A eonstant product price for paddy and average factor prices were used for all inputs including hired labor. The major findings resulting from this study are:

1. While four of the five rice production systems had

positive gross margins, only the irrigated paddy systems approached positive net returns after taking account of capital depreciation and valuing family labor at the prevailing farm-level casual wage rate.

2. The irrigated paddy system which is based upon improved seed, a low level of fertilizer use and "medium" water control had the lowest opportunity cost of production (i.e., after valuing family labor).
3. On-farm yields are directly related to the ecosystem in which rice is produced. The ecosystem with the highest yield is irrigated paddy (2.2 to 3.0 t/ha) followed by seasonally shallow flooded rice (1.6); the lowest yields were realized in the rainfed dryland systems (0.8 to 1.0 t/ha).
4. "Improved" systems of rice production require more labor per hectare than the prevailing traditional system. Using a base of 100 to represent the total labor requirement of the traditional system, the index of labor use for the dryland semi-mechanized system is 110, for the seasonally shallow flooded system 200, and irrigated paddy 250 or 2½ times the labor of the traditional system.
5. The utilization of both hired and family labor increases when improved systems of rice cultivation are adopted. In addition, with the improved production systems, the role of women relative to men as a source of labor declines, particularly in pre-harvest activities. Women remain dominant for threshing, winnowing and bagging.

In addition to private profitability, an economic analysis of each system was undertaken. In this case the factor subsidies were reduced to zero and paddy was valued at the import parity price. The following conclusions resulted:

1. If the subsidies on factor inputs (i.e., fertilizer and mechanization services) were reduced to zero and farmers were charged full economic cost for the currently subsidized inputs, with the present inputs/output relationships, the cash income per hectare would be greater than the present incomes.
2. The dryland, semi-mechanized system of rice production is clearly unattractive financially and the economic cost of production per unit of output is more than three and one-half that of the traditional and improved irrigated paddy systems.
3. The most profitable system of rice production from both the financial and economic points of view is the irrigated paddy system, followed by the seasonally shallow flooded system.
4. Under the alternative (economic) factor/product pricing system, rice farmers would receive an attractive return on their family labor which would be above the prevailing wage rate. The cash income is estimated to be about $500 per hectare compared to about $330 per hectare under present cost-price relationships or compared to $90 per hectare under the prevailing pricing policy for the traditional method of rice production.

From a production function analysis of the field data it was found that:

1. Farm size and the quantity of family labor available to work on the rice farm are the most significant factors influencing total farm output in the study area.
2. Among the most important factors affecting yield are seed rate, rate of nitrogen application and the intensity of labor involved in birdscaring. Timing of the first weeding is more critical in determining yield than the intensity of weeding.
3. In general, the marginal value products (MVP) of labor are low but positive; however, the MVP of land for all systems is high. For all systems investigated the study clearly shows that the efficiency of resources presently committed to rice could be improved.

Cost and returns among smallholders producing irrigated rice in the Gagnoa Region of the Ivory Coast. The rice production system of 35 rice farmers producing irrigated rice under the supervision of the SODERIZ (the rice development agency in the Ivory Coast) was surveyed in 1977. The agency provides compound fertilizer, urea, IR-5 seed, pesticide (Furadan), jute bags and a cash loan for hiring labor and credit-in-kind at the beginning of the crop season all at fixed rates per hectare. Participating farmers are supervised by extension agents provided by the SODERIZ.

The major findings and conclusions resulting from this survey are:

1. The SODERIZ supervised system of smallholder irrigated rice production based upon improved seed, fertilizer, pesticide and manual field operations generates relatively high on-farm yields.
2. Based upon the data generated by this survey, the level of utilization of both hired and family labor is the principal factor determining the costs and returns of participating farmers. The smaller rice farmers are using excessive labor given the yields and net returns of the larger-area farmers. The marginal value product (MVP) of both family and hired labor on the smaller farms, above the rate of utilization of the larger farms, is either very low or negative. The reasons for this surplus/redundant labor on the smaller farms were not determined.
3. The SODERIZ purchases paddy at a rate above the prevailing market price ($0.20/kg vs. $0.18/kg) and provides all inputs as credit-in-kind to be repaid at harvest.
4. Farmers repay their loans at harvest time by selling their output to the SODERIZ at the agency's output subsidy price. However, farmers receive deductions based upon the amount of paddy produced per hectare.
5. In this study, an alternative pricing policy was proposed which is simple, and far less complicated from the producer's point of view. The proposed pricing policy maintains current income levels for a given level of output, but directly debits the account of participating farmers for the market value of all inputs and the value of the cash loan supplied at the beginning of the crop season. Farmers would then sell their paddy to the SODERIZ at a calculated "effective output subsidy price," or $0.24 per kg. for paddy sold within the acceptable range of humidity and impurities.

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. This project is a collaborative one among IITA, the universities of Reading and Louvain, Rothamsted Experimental Station and the International Soil Museum. Phase I of the Project concentrated on developing appropriate methodology and focused on toposequences located in Nigeria.

Characterization of benchmark soils in the humid tropics. Studies of the chemical and mineralogical characteristics and nutrient status of benchmark soils extended to soils in the several countries of West Africa and tropical America. Special attention was given to two aspects of basic soil research that bear important implications to the management and agricultural land classification of soils in the tropics.

Physico-chemical properties of soil oxides. The surface and charge properties of Fe and Al oxides and hydrous oxides and their interactions with silicate clay minerals play an important role in influencing the physical and chemical properties of highly weathered soils. The heavy-textured Ultisols and Oxisols with stable structure and low bulk density, generally contain large amounts of very fine, clay-size Fe oxides having an average diameter around 0.1 micron. These oxides have large specific area (200 m^2/g of Fe_2O_3), higher point of zero charge (PZC), and high surface reactivity with respect to soluble phosphate and silica. Soils dominating in "high specific surface oxides" are mostly derived from basic parent rocks such as basalts and amphibolites.

Alfisols, Ultisols and Oxisols having poorer physical conditions, such as low permeability, unstable structure, high bulk density, are generally dominating in kaolinitic clays. A predominant portion of Fe oxides present in these soils normally have very low specific surface area as a result of strong associations with layer silicate minerals. In most cases, they form massive surface coatings around the clay particles. Such Fe oxide-layer silicate interactions result in a net reduction of specific surface area of the soil particles. Soils with "low specific surface oxides" generally have low PZC (below pH-4 and low pH-dependant CEC and AEC.

As shown in Table 3, the contrasting differences in the "derived" specific surface area of Fe oxides (SFe) clearly separate the soils into two groups which, to some extent, relate to parent materials and clay mineralogy and the chemical environments when the formation of Fe oxides took place.

Silica solubility. Silica solubility is among the most sensitive soil properties reflecting the stage of soil weathering, clay mineralogy, as well as the reactivity of the oxidie surfaces in tropical soils. Data presented in Figure 2 depict these relationships.

Table 3. Specific surface area of selected soils from Africa and South America before and after dithionite (DCB) treatment and calculated surface area of soil Fe oxides.

Soil	Parent rock	Clay %	Specific surface area # So	SR	SFe
Paleudult, $B_{21}t$	Diabase	65	59	33	263
Paleudult, $B_{21}t$	Basalt	70	73	55	257
Paleudult, $B_{21}t$	Amphibolite	65	47	30	169
Paleudult, $B_{21}t$	Acidic gneiss	54	30	28	58
Haplorthox, B_2	Coastal sediments	64	34	30	63
Acrustox, B_{21}	Acidic gneiss	55	30	26	66

 # So = m^2/g of untreated soil, SR = m^2/g of dithionite treated soil, SFe = m^2/g of Fe_2O_3.

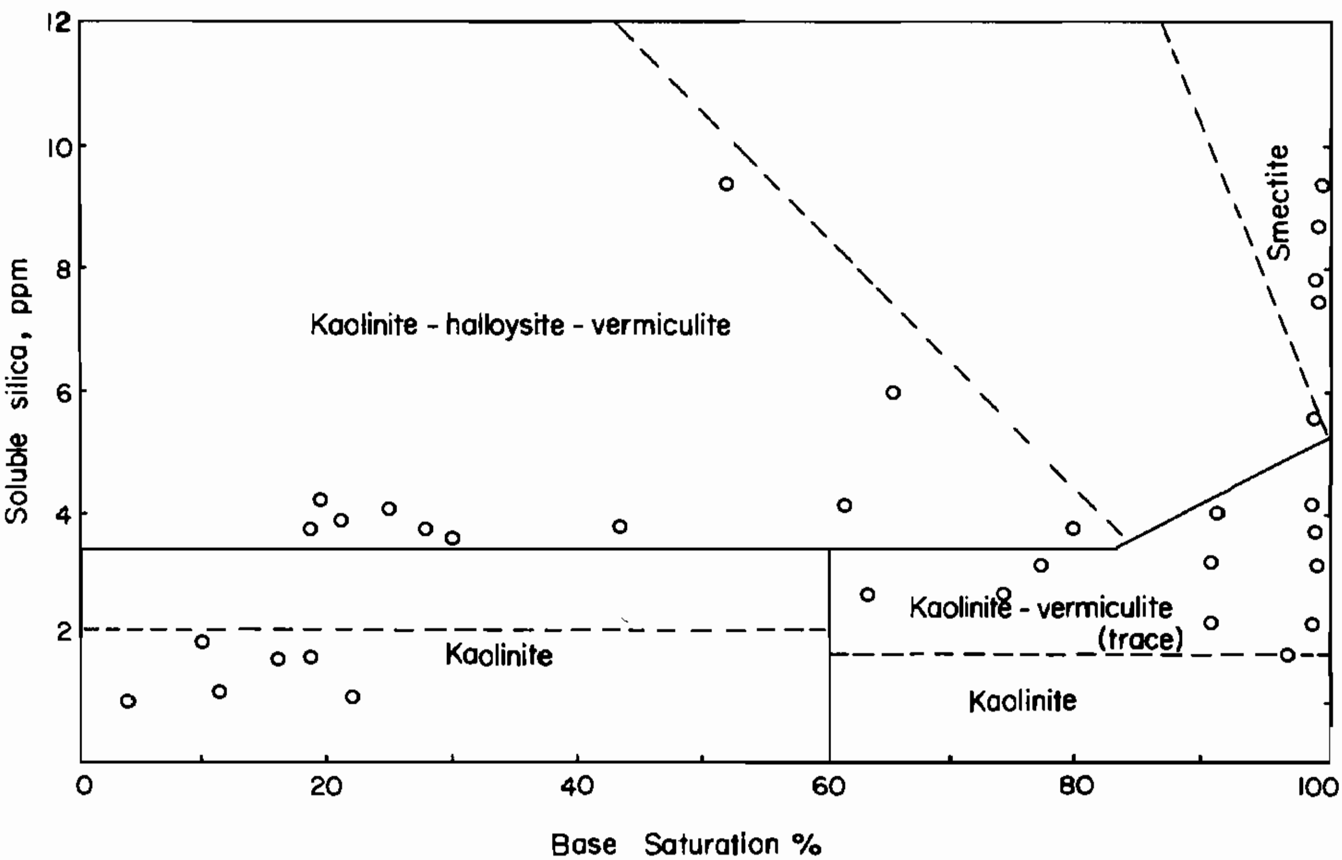


Fig. 2. Silica solubility as related to base saturation and clay mineralogy of selected Alfisols, Ultisols and hydromorphic soils in the humid tropics.

The strongly acidic and low-base saturated Ultisols and Oxisols derived from sedimentary formations occupy the lower left-hand corner of Figure 2. The only silicate clay mineral present in these soils is Kaolinite and the concentration of soluble silica (dilute NaCl extractable) in the textural B horizons is normally below 2 ppm.

The Ultisols derived from acidic and intermediate crystalline rocks support higher concentration of soluble silica in the soil solution (3.5 to 9 ppm). This is apparently associated with their distinct mixed clay mineralogy (kaolinite-halloysite-vermiculite). These soils contain predominately kaolinite but with small to trace amount of vermiculite and halloysite. Soluble silica in these Alfisols ranged from 2.3 to 4.3 in dilute NaCl extraction. On the other hand the high-base saturated Aquolls, Aqualfs, and Vertisols occupy the upper right-hand corner of the silica-PBS diagram showing high silica solubility. The low soluble silica content in the well-weathered kaolinitic Ultisols and Oxisols may become an important limiting factor in upland rice cultivation as rice plants normally have higher Si requirement than other cereal crops.

Ultisols which contain substantial amounts of vermiculite and other 2:1 mixed layer minerals did not exhibit the expected specific affinity for potassium. This seems to suggest that these 2:1 clay minerals may not possess the usual high negative charge. Surface coating of Fe oxides or interlayer Al hydroxides may be responsible for the reduction of surface charges.

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 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 area.[1]

Interdisciplinary studies of traditional intercropping. The lack of information on the basic principles underlying the functioning of indigenous cropping systems is a major constraint to the development of research strategies aimed at identifying ways of increasing the productivity of these systems. Available information is often superficial and devoid of hard facts. Therefore, a series of experiments and field observations were initiated in 1977 with the aim of gathering precise information on the dynamics of indigenous cropping systems.

The first study is of a bush-fallow, slash-and-burn, mixed cropping system in which maize and cassava are the major crop components. Twelve scientists representing nine disciplines are collecting information from this experiment. The major features of the trial include comparison of mixed cropping and traditional practices versus pure cropping and recommended, improved practices. As cassava is a component of these systems, complete first cycle results are not yet available.

Maize/cassava/cowpea intercropping. Under simulated peasant farm conditions, a maize/cassava combination with cowpea as an extra component was compared with the recommended "modern" pure stand practices. The results in Table 4 show that the crops in pure stand generally gave higher yield than in intercropping. These higher yields however, were not proportional to population densities, and lower crop yields in intercropping were partly attributed to lower population. Results from other trials substantiate the conclusion that spacing in indigenous systems may be reduced with a substantial yield increase attainable due to increased population densities, providing plant nutrients are maintained at adequate levels.

The land equivalent ratios show that the production of maize, cowpea and cassava obtained from one hectare of intercropping would require 1.84 ha. and 2.1 ha. of pure cropping in the forest and savanna zones respectively. The low cowpea yield obtained in intercropping was attributed to shading and other forms of competition from the earlier planted cassava.

Weed control in intercropping. Various methods of weed management were evaluated in maize, cassava and yam based cropping patterns on the IITA site. Results showed that mixed cropping patterns generally had less weeds at crop harvest (64 percent) than the sole crops. Weed control methods included mechanical, biocontrol (low growing field crops), chemical control, and a series of integrated weed control measures involving mechanical plus biocontrol or chemical plus biocontrol methods. An integrated weed control method involving use of melon followed by sweet potato, both of which are low-growing crops, was not effective in keeping weed infestation to a minimum in all cropping patterns tested (Table 5). Primextra applied preemergence controlled weeds the best and was second best to a permanent ground cover provided by the melon-sweet potato treatment.

Table 4. Yields of maize, cowpea, and cassava in intercropping and pure cropping.

Cropping	Maize	Cowpea	Cassava	LER
		kg/ha		
(a) Forest Zone				
Intercropping	2536 a*	85 a	6870 a	1.84
Pure Cropping	3688 b	423 b	7210 a	–
(b) Savanna Zone				
Intercropping	1726 a*	88 a	3432 a	2.1
Pure Cropping	1356 a	426 b	5538 b	–

**Numbers followed by the same letter in each environment in a column are not significantly different at the 5 percent level.*

Intercropping yam with maize or with maize relay-cropped with cassava caused up to 25 percent reduction in yam relative to yield of the sole crop yam. Keeping yams weed free for the first three months was necessary to minimize yield reduction caused by weeds (Table 6). Hoe weeding three times, growing melon and sweet potato, or using a herbicide were equally effective in minimizing yield loss caused by weeds. Irrespective of cropping patterns, yam yield in weed control treatments that failed to control weeds effectively for the first 12-16 WAP yam was significantly lower than in the weed-free treatment.

1. *Vegetable and yam based cropping systems are also important in specific locations and are included in Program activities at a lower level.*

Table 5. Effect of cropping pattern on weed weight at crop harvest.[1]

Treatment		D.W. of weeds (kg/ha)		Yam/ Maize/	
		Sole Yam	Yam/Maize	Cassava	Mean
1.	Weeding at 3+5 WAP	4,688	1,100	1,823	2,537
2.	Weeding at 3+8 WAP	1,163	1,455	1,437	1,352
3.	Weeding at 3+12 WAP	2,057	1,228	1,163	1,483
4.	Weeding at 5+12 WAP	2,662	1,515	1,738	1,972
5.	Weeding at 3+5+12 WAP	1,150	1,908	1,643	1,567
6.	Melon + Weeding at 3 WAP	1,810	1,823	1,925	1,853
7.	Melon fb sweet potato	983	347	395	575
8.	Melon + Herbicide[2]	1,412	1,385	1,362	1,386
9.	Sweet potato + Weeding 3 WAP	1,162	975	435	1,237
10.	Primextra 2.5 kg/ha PE	1,225	1,272	1,215	1,237
11.	Weedy check	4,745	2,265	1,585	2,865
	Mean	2,096	1,388	1,338	
	LSD 0.05				792

1. *Weed weight at yam harvest.*
2. *Diuron + alachlor at 1.0+1.8 kg/ha PE.*

Table 6. Effect of weed control method and cropping pattern on tuber yield in white yam.

Treatment		Tuber F.W. t/ha		Maize/ Yam/	
		Sole Yam*	Maize/Yam	Cassava	Mean
1.	Weeding at 3+5 WAP	21.0	16.3	17.0	18.1
2.	Weeding at 3+8 WAP	20.3	15.0	17.4	17.5
3.	Weeding at 3+12 WAP	26.0	17.8	18.7	20.8
4.	Weeding at 5+12 WAP	21.7	17.9	18.1	19.2
5.	Weeding at 3+5+12 WAP	26.3	18.0	17.1	20.5
6.	Melon + Weeding at 3 WAP	18.9	18.4	13.7	17.0
7.	Melon fb sweet potato	23.4	16.7	17.4	19.2
8.	Melon + Herbicide	22.2	18.8	17.9	19.7
9.	Sweet potato + Weeding 3 WAP	18.9	13.8	16.5	16.4
10.	Primextra	24.4	17.4	15.7	19.2
11.	Weed free check	28.6	17.7	20.9	22.4
12.	Weedy check	22.5	17.0	17.3	
	Mean	22.5	17.0	17.3	
	LSD 0.05				3.5

**Yam population 10,000 plants/ha.*

The effect of weed control methods and cropping pattern on maize yield is shown in Table 6. In each of the cropping patterns, maize population was three-quarters that in the sole cropped maize (40,000 plants/ha). Maize yield was depressed in the maize/yam mixture but not in the maize/cassava and maize/yam cassava mixtures. Unlike in the longer-season yam, all cover crop treatments effeetively covered the ground throughout the period of maize growth. The sweet potato treatment significantly reduced maize yield. Similar yield depression was noted in yam when sweet potato was planted at the same time as yam but not when the sweet potato followed melon. As in yam, Primextra stood out as a superior weed control tool for both sole cropped and mixed cropped maize.

Nematode dynamics in intercropping. The intercropping experiment was sampled for nematodes at preburn, postburn, and at crop maturity at the end of the first and second growing seasons. Nineteen kinds of plant-parasitic ncmatodes were found on the plots during the four sampling periods. The root-knot nematode juveniles (*Meloidogyne* spp.) were the most abundant of the plant-parasitic nematodes. The root lesion nematodes (*Pratylenchus* spp.), spiral nematodes (*Helicotylenchus* spp.) and pin nematodes (*Paratylenchus* spp.) occurred at low-population densities. The other 15 kinds of plant-parasitic nematodes were also recorded to enable their population trends under the conditions of the experiment to be monitored and effects on plant-parasitic nematode populations evaluated (Table 7).

After nine years of bush fallow, the mean of 352 plant parasitic nematodes per liter of soil was below levels expected to cause damage to the following crop. A significant decline in the numbers of all kinds of nematodes occurred after burning. At planting (29 April), 40 days after bush burning, the numbers of plant-parasitic nematodes had doubled compared to the preburn situation. The increase in plant-parasitic nematodes suggests a heat stimulation in the hatch rate of eggs of plant-parasitic nematodes. The numbers of predacious and saprozoic nematodes had returned to their approximate preburn population levels at planting time. The root-knot nematodes and the spiral nematodes followed the general population trend at planting. The numbers of root-knot nematode juveniles ended the crop growing season at about

Table 7. Summary of plant-parasitic, predacious and saprozoic nematodes from the interdisciplinary study of traditional intercropping systems. *

Nematode	Pre-burn	Post-burn	At planting	August harvest	December harvest
Saprozoic	9,520	1,880	10,006	15,259	9,733
Mononchoid	95	16	74	54	31
Total parasites	352	76	705	323	210
Meloidogyne sp. juveniles	225	53	575	280	203
Helicotylenchus spp.	31	2	75	23	3
Paratylenchus spp.	79	14	41	9	1
Pratylenchus spp.	0.8	3	0.2	4	0.2
Trichodorus spp.	6	0	0.4	1	0.1
Criconemoides sp.	6	0.6	1	1	0
Hoplolaimus pararobustus	1	2	3	2	2
Scutellonema bradys	0.8	0	2	1	0
Xiphinema bergeri	0.6	0.5	2	0	0
Xiphinema ebriense	0.6	0	0	0	0
Xiphinema ifacolum	0	0	2	0	0
Xiphinema nigeriense	0.9	0.8	1	0.7	0
Xiphinema setarae	0	0	0	0	0.3
Xiphinema yapoense	0	0	0.09	0	0
Heterodera sp. juveniles	0	2	0	0	0
Trophurus imperialis	0	0	0.2	0	0
Hemicycliophora sp.	0	0	3	0.06	0
Tylenchorhynchus sp.	0	0	0	0	0.06
Radopholus sp.	0	0	0	0	0.06

**Numbers of nematodes per liter of soil based on 108 samples of 294 cm^3 of soil each.*

the preburn population level. The spiral nematodes and the pin nematodes declined below preburn population levels by the end of the growing seasons. In this first year after clearing all other plant-parasitic nematodes occurred in low or trace numbers. Nematode collection data separated on the basis of traditional and recommended farming practices are given in Table 8.

***Table 8.* *Numbers of plant-parasitic, predacious and saprozoic nematodes recovered from soil farmed in traditional and recommended intercropping systems. First year.* ***

Nematodes	August harvest		December harvest	
	Traditional	Recommended	Traditional	Recommended
Saprozoic	15,806	14,717	9,825	9,641
Predacious	54	55	33	30
Total parasites	266	375	91	329
Meloiodogyne spp.	217	343	86	321
Helicotylenchus spp.	30	12	1	5
Pratylenchus spp.	8	0.4	0.3	0.1
Paratylenchus spp.	4	14	0.4	1.7
Trichodorus spp.	1.4	0.5	0.1	0.1
Hoplolaimus pararobustus	1.2	3	3	1.6

**Numbers of nematodes per liter of soil based on 54 samples of 294 cm^3 of soil each.*

Saprozoic nematode populations were unaffected by cultural methods as were the predacious nematodes. The mean numbers of all plant-parasitic nematodes were lower under traditional methods of farming than under the recommended methods used.

Insect incidence in maize/cowpea intercropping. Trials in 1976 showed no influence of intercropping cowpea on the pest complex of maize. Research in 1977 was thus concentrated on the insect fauna associated with cowpea as the crop of interest in the intercrop. To enable realistic comparisons to be made on the insect fauna associated with the cowpea, the first season trial in 1977 involved monocrop and intercropped cowpea grown under insecticide protection to determine the extent of yield depression due to these factors, and control plots where no insecticide was applied.

Effects of the crop mixture on insect populations. In work conducted during 1976 the numbers of thrips, *Megalurothrips sjostedti,* in cowpea flowers from mixed plots were less than those from sole plots. Fewer thrips were also recovered from water traps at cowpea canopy height in mixed plots. This phenomenon was felt to be potentially important as a means of conferring protection on cowpea through a mixed cropping situation and was further investigated in 1977. Flower samples were taken four times from untreated plots and twice from plots treated with insecticide. No *Megalurothrips* were recorded from the latter.

As in the previous season, consistently more thrips were found in flowers from sole plots, the differences being highly significant on two occasions (Table 9). Toward peak flowering, which occurred about 70 DAP, thrips populations were also higher in sole plots. Suction trap catches summed over the growing season are shown in Table 10. Numbers of

Table 9.* *Catches of* Megalurothrips sjostedti *at two heights in three cropping situations. Totals from 10 sampling occasions.

Trap height	Sole crop maize	Maize/cowpea intercrop	Sole crop cowpea
0.5 m	92 a	620 b	345 c
2.0 m	99 a	214 b	88 c
			P 0.005

thrips remained low until flowering commenced at 40 DAP, when a marked increase occurred for both sole and mixed plots.

Table 10. Megalurothrips sjostedti ***from DVac samples in two cropping systems. Mean number per 100 plants ± SE.***

DAP	Maize/cowpea intercrop	Sole crop cowpea
24	12.2 ± 3.2	5.6 ± 1.0
38	31.7 ± 6.1	26.1 ± 6.1
55	660.6 ± 136.5	753.4 ± 129.0
66	462.2 ± 107.1	747.2 ± 74.6

Catches were substantially higher at both heights in the intercrop. This is somewhat at variance with other data and the difference may be associated with the indirect nature of the sampling technique, the size of the catch depending on the numbers of insects active within the effective radius of the trap. Thus, if activity is favored by the intercrop situation, perhaps in association with microclimatic effects, a higher proportion of the population may be susceptible to trapping despite a lower absolute population density. Alternatively the presence of the cereal may limit dispersal of adults and thereby increase aerial population density over the cowpea canopy. DVac sampling showed that populations of the foliage thrips, *Sericothrips occipitalis*, were unaffected by the cropping system though higher numbers were recovered from sole than intercropped cowpea on three out of four sampling occasions. A similar effect to that observed for *Megalurothrips* occurred in suction trap catches where a greater than fourfold increase in the number of *Sericothrips* was recorded in mixed plots compared to sole cowpea between 40 and 50 DAP. A range of other thrips including *Galiothrips impurus*, *Scirtothrips* sp., *Frankliniella schultzei*, and *Haplothrips* sp. were abundant in suction trap samples though their pest status in the present context is uncertain.

Throughout the flowering period there were no differences in the incidence of *Maruca* larvae attributable to the cropping mixture in either pesticide treated or untreated situations, though there was a suggestion that the pesticide was more effective in the intercrop (Table 11).

Table 11. Maruca testulalis ***larvae from flower samples. Mean no. per 25 flowers.***

DAP	Untreated cowpea		Treated cowpea	
	Intercropped with maize	Sole crop	Intercropped with maize	Sole crop
49	16.2 ± 2.3	13.7 ± 2.0	8.3 ± 1.2	11.0 ± 3.5
58	8.0 ± 0.8	8.3 ± 2.0	10.3 ± 2.7	13.7 ± 1.3
73	10.8 ± 2.3	11.3 ± 1.2	*	*
86	2.7 ± 1.0	3.5 ± 1.0	*	*

**No flowers available for sampling.*

Data from 1976 showed that for *Acanthomyia tomentosicollis* at 61 DAP, when maximum number occurred, population density in sole cowpea was significantly higher at 13.9 ± 3.1 per 100 plants than in the intercrop, where 5.5 ± 1.8 were recorded. The intercrop figure is based on all types of plants. However, though incidence on cowpea only in this situation was also lower at 8.3 ± 2.8 per 100 plants the higher incidence on maize in the intercrop than sole maize made potential invasion or pest pressure per host plant virtually the same. A similar picture emerged for *Acanthomyia horrida*, where incidence on sole cowpea was significantly greater than on mixed cowpea at 57 DAP although when the total plot population is considered in relation to food resources there is no difference between the two situations. These data underline the importance of considering the context of the crop, because observations on cowpea alone would have been misleading. In the first season of 1977 *Riptortus dentipes* was the dominant pod-sucking bug with maximum numbers recorded at 50 DAP. Populations in mixed and sole plots were very similar at 9.3 ± 2.3 and 10.3 ± 2.2 per 100 plants respectively producing a correspondingly higher pest pressure on the cowpea in the mixture. This in turn, can be demonstrated by relating numbers recorded to specific feeding sites, probably the most meaningful measure of pest incidence, at 64 DAP. For mixed cowpea the infestation level was 5.6 ± 1.4 insects per 100 pods compared to 3.0 ± 0.6 in sole plots.

Populations of *Ootheca mutabilis* showed a response to cropping situation with lower numbers (p. 0.05) on mixed cowpea than on sole crop cowpea at 37 DAP, although populations were low, being only 2.6 ± 0.8 per 100 plants even in the latter treatment.

Empoasca can be an important pest of cowpea and DVac data from the second growing season of 1976 suggested that populations were reduced by intercropping. Corresponding data for the first season of 1977 are given in Table 12 and show that from 55 DAP sole cowpea again supported higher leafhopper populations, the difference being significant at 66 DAP.

Table 12. *Empoasca* ***populations estimated from DVac sampling. Mean no. per cowpea plant ± SE.***

DAP	Maize/cowpea intercrop	Sole crop cowpea
24	0.30 ± 0.08 a	0.35 ± 0.07 a
38	1.28 ± 0.16 a	0.95 ± 0.24 a
55	2.56 ± 0.65 a	3.90 ± 0.27 a
66	2.78 ± 0.44 a	5.17 ± 0.84 b
		P 0.05

Relative yields of monocrop and intercrop with and without pesticide protection. The insecticide regime employed[1] was highly effective against the majority of insect pests, all groups being virtually absent from treated plots with the notable exception of *Maruca*. Despite early evening applications of Gammalin, reported as being effective against the larvae during migration to new feeding sites on the plant, there were no significant differences between treated and untreated plots. The major effect of the pesticide was thus the elimination of *Megalurothrips* and *Riptortus*, the two other major pests in this season. Yields from the different treatments are shown in Table 13. Comparison of yields from treated sole and intercrop shows that cowpea yield is reduced by approximately 45 percent due to competition from the cereal under conditions of minimal insect damage. Without pesticide, cowpea yields are negligible in both situations though mixed plots yield 18 times more seed than sole plots.

1. Carbofuran at planting (10 mg a.i. per plant) followed by alternate spraying of cowpea at four-day intervals after flowering with Nuvacron and Gammalin at 0.5 kg. a.i./ha and a further application of Carbofuran to the maize at 40 DAP.

This is not a viable agronomic practice, particularly with the significant reduction in maize yield, but the principle of protection of the legume by its presence in a cereal intercrop is clearly demonstrated, and the potential exists for exploitation of this phenomenon, using low pesticide input for maize/cowpea intercrops.

Table 13. Effect of pesticide on sole and intercropped maize and cowpea. Grain yield kg/ha.

Plant type	Sole crop	
	Untreated	Treated
Maize (TZB)	2580 ± 180 a	2740 ± 240 a
Cowpea (Ife Brown)	0.06 ± 0.05 a	760 ± 28 b
	Intercrop	
	Untreated	Treated
Maize (TZB)	1710 ± 170 b	1410 ± 120 b
Cowpea (Ife Brown)	1.11 ± 0.41 a'	442 ± 91 c

Different letters denote difference significant at p 0.01.

Hymenoptera are important as agents of biological control and attempts have been made to monitor the effects of intercropping on parasite populations. This work has been hampered by the extreme diversity of the fauna and taxonomic difficulties encountered. Approximately 150 species of Hymenoptera have so far been identified, many of which occur sporadically and in low numbers and little is known of their host associations or other functions within the crop ecosystem. The only data presently available are from suction trapping, summarized for the more important and abundant superfamilies of parasites in Table 14.

Table 14. Catches of parasitic Hymenoptera at two heights in three cropping situations. Totals from seven sampling occasions.

Superfamily	Trap height	Sole crop maize	Maize/cowpea intercrop	Sole crop cowpea
Bethyloidea	0.5 m	59 a	89 b	54 a
	2.0 m	25 a	32 a	12 a
Ichneumonoidea	0.5 m	35 a	67 b	69 b
	2.0 m	25 a	35 a	34 a
Proctotrupoidea	0.5 m	1092 a	1365 b	1024 a
	2.0 m	408 b	516 a	148 a
Cynipoidea	0.5 m	35 a	74 b	56 ab
	2.0 m	13 a	19 a	8 a
Chalcidoidea	0.5 m	975 a	1757 b	1118 a
	2.0 m	406 a	458 a	276 a
Total	0.5 m	2196 a	3352 b	2321 a
	2.0 m	842 a	452 a	276 a
				P 0.05

The most abundant species were those belonging to the Proctotrupoidea and Chalcidoidea, both predominantly parasitic on immature stages of other insects. There were no significant differences between the two sole crops at either height when overall activity of parasitic Hymenoptera is considered, though catches from both were significantly lower than from the mixed crop at 0.5 m. Thus conditions within the intercrop favor the activity of the major parasitic groups. Although no differences between the sole crops are apparent when broad groupings are considered it is likely that as more detailed data are generated species composition will be shown to vary considerably since many hymenopterans have high host specificity.

The effect of cropping pattern on pest incidence. To test whether reduced thrips invasion of cowpea flowers in the intercrop was directly related to a shielding effect from the maize, a second-season trial was established to compare populations in inter- and intra-row mixtures of the two crops. In the latter situation the cowpea is more shielded and any concealment effect maximized. A third treatment in which the inter-row mixture was surrounded by sole maize guard rows was added to examine effects on lateral invasion. Data for flower invasion are shown in Table 15.

Table 15. Megalurothrips sjostedti from cowpea flowers in two intercropping patterns. Mean numbers per flower ± SE.

DAP	Inter-row mixture	Inter-row with maize border	Inter$_a$-row mixture
58	34.5 ± 14.9 a	14.9 ± 3.4 a	27.2 ± 3.8 a
65	29.9 ± 3.8 a	21.5 ± 2.2 a	51.9 ± 16.2 b
75	33.6 ± 6.6 a	30.6 ± 5.8 a	63.4 ± 4.7 b
			P 0.01

Significantly higher numbers of *Megalurothrips* were found in flowers from the intra-row mixture at 65 and 75 DAP. Flower production in these plots was also greater, though no significant correlation between level of invasion and flower density exists. A similar trend was apparent in suction trap catches with larger numbers recovered from the intra-row situation, though the difference was not statistically significant. DVac samples at 64 DAP also influence higher numbers of *Megalurothrips* in intra-row plots (0.05); it is therefore concluded that the more extreme cover situation favors the build up of populations of this insect. No treatment effect on *Sericothrips* was observed. No sole crop cowpea was cultivated on the site and comparisons with a situation in which a maize canopy is absent are not possible. Another pest apparently favored by the intra-row mixture was *O. mutabilis* with populations in this treatment of 12.9 ± 1.5 per 100 plants compared to 5.8 ± 1.0 in inter-row plots. This significantly higher population is difficult to explain since the data were obtained at 19 DAP, when horizontal rather than vertical structure of the cropping system is likely to be more important.

The response of Homoptera to different cropping patterns was variable. *Empoasca* populations rose to 10.7 ± 0.8 insects per plant at 64 DAP in the intra-row planting, significantly more than in either of the other treatments. Total cicadelids followed the same trend though at 50 DAP there were significantly more *Cicadulina* on cowpea in the inter-row mixture and the same was true for derbids and delphacids.

Yields from both crops in all treatments were low, partly due to the shortness of the growing season, and no significant treatment differences were demonstrated.

Effects of pre- and post-flowering insecticide protection. An experiment was conducted in the second season to determine at which stage of growth the protective effect of the crop mixture was expressed. This was accomplished using three insecticide regimes to give pre-flowering protection only using Carbofuran, post-flowering protection with Nuvacron and Gammalin sprayed alternately after flowering and full protection using the combined regimes. The principal pre-flowering damage was caused by thrips and the treatment in which no protection was given during this period had a significantly higher (p. 0.05) damage rating than those in which Carbofuran was applied. This was associated with increased populations of *Sericothrips occipitalis.*

Numbers of *Megalurothrips* were low and unaffected by the treatment at this stage though after flowering they increased markedly in unsprayed plots to 23.6±6.0 per plant compared to 1.2±0.5 in those sprayed with Nuvacron and Gammalin. A similar situation was apparent in flowers. At 65 DAP those from the preflowering treatment contained 63.8±10.4 thrips per flower compared to sprayed treatments with 0.6±0.2. Observations were made on Maruca populations from the same sampling which took place at peak flowering. Significantly more larvae were recovered from flowers on plants which had been sprayed than those which had received only Carbofuran at planting. A higher flower production, resulting in increased attractiveness of the crop for oviposition, may provide an explanation for this phenomenon. The flower density at 65 DAP was significantly higher in the pre- and post-flowering protection treatment than in either of the others which were similar at this stage and both had about the same flower production over the flowering period. However, the pattern of production was different, with plants receiving post-flowering protection showing peak flowering at 62 DAP while those which received only preflowering protection did so at 72 DAP.

Carbofuran had relatively little effect on most Homoptera though populations were significantly reduced at 50 and 64 DAP in plots treated with Gammalin and Nuvacron, there being no significant difference between post-flowering and total protection treatments. An exception to this generalization was provided by *Cicadulina* (Table 16). In this case Carbofuran appears to suppress early population development and even at 64 DAP numbers remain lower than in plots sprayed only with Gammalin and Nuvacron, whieh seem to have no significant effect. This information is of interest beeause *Cicadu lina* is a vetor of maize streak virus. The maize was untreated and because population development was affected by Carbofuran, cowpea therefore, apparently serves an alternative food source for the insect; this observation may have important implications for maize/cowpea intercropping.

Table 16. Populations of Cicadulina mbila and C. triangula on intercropped cowpea under three insecticide regimes. Mean no. per 100 plants.

DAP	Pre-flowering protection	Post-flowering protection	Pre- and post-flowering protection
26	2.2 ± 1.1 a	3.3 ± 1.9 a	3.3 ±1.9 a
50	24.4 ± 4.8 a	51.1 ±10.6 b	16.7 ±6.9 a
64	26.6 ±10.7 a	63.3 ±13.9 b	14.4 ±4.0 a

P 0.05

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. When fallow periods are reduced to two or three years, natural regeneration seldom produces the types of shrub or tree growth capable of providing desirable stakes. *Leucaena leucocephala* (a tree-type legume) is a species which produces stakes and may be either cut or used *in situ*. It is suitable for supporting yam in 9 to 12 months in climates similar to that of IITA. An 18-month-old plantation of *Leucaena* (150 cm x 50 cm) was used to evaluate six methods (Table 17) of using its stem as support for yam vines. Method F gave highest yields; however, its superiority to B was due to the higher plant population. Method B was significantly better than A, C, D, or E. This superiority was ascribed to taller vine height and better leaf area distribution. The similarity in yield of A, D and E suggests that the conventional method of staking yam can be substituted by placing smaller untrimmed branches on the soil surface. *In situ* support with live trees was as good as conventional staking when the trees were kept pruned (E) but unpruned live trees (C) significantly reduced yield by competing for light, nutrients and moisture. Shading appeared the most significant cause of the low yield of C but no direct relationship between light penetration and yield was established.

Weed control in yams. The growth habit of yam (*Dioscorea* spp.) and its inability to completely shade the ground makes it very susceptible to weed competition. Uncontrolled weed growth caused above 65 percent reduction in yield of white yam (D. *rotundata* L. cv. Nwaipoko) in experiments conducted at IITA in 1977.

Table 17. Effect of method of supporting yam vine on light penetrations, vine height and yield.

Method of support	Light penetration	Vine height	Yield
	%	cm	ton/ha
A Conventional staking	98	214	20.7
B Killed *in situ* stems of *Leucaena*	87	346	30.5
C Live unpruned *in situ* stems of *Leucaena*	30	363	2.8
D Horizontally placed untrimmed branches of *Leucaena*	99	–	19.5
E Live pruned stems of *Leucaena*	96	216	20.6
F Same as B with doubled yam population	78	425	39.7

Handweeding three times or a pre-emergence application of a mixture of fluometuron plus metolachlor at 2.0+2.0 kg a.i./ha gave similar yields to weed-free plots.

Diuron which is used in some parts of the tropics as a standard herbicide for weed control in yam was inferior to fluometuron and metolachlor mixture in both total weed control and yam tuber yield. A weed eompetition study designed to identify the critical time of weed removal and frequency of hoe weeding in white yam showed that when weeds were not removed during the first three months of growth, they resulted in about 30 percent reduction in yield when compared to the weed-free control. When yam plots were not weeded for the first four months yield loss was identical to those that were not weeded at all (Table 18). Similarly, keeping yam weed free for the first four months was identical to the weed-free treatments. At least four weedings at one monthly interval during the first four months of yam establishment were found to be necessary to minimize yield loss due to weeds.

Yam seedling susceptibility and damage by root-knot nematode. In a cooperative project with the Institute's Root and Tuber Improvement Program, true yam seed from four breeding families (*Dioscorea dumetorum* (W512), *D. praehensilis* (W513) and two of *D. rotundata* (W501, W511) were evaluated

Table 18. Effect of time of weed removal and frequency of weeding on yam tuber yield (IITA, 1977).

Treatments	Average weed dry weight kg/ha	Average tuber yield t/ha	Yield as % of weed free
Weed free 0 WAP then weedy	1690	15.86	55.9
Weed free 4 WAP then weedy	1457	19.22	67.8
Weed free 8 WAP then weedy	1830	21.34	75.2
Weed free 12 WAP then weedy	1277	22.19	78.2
Weed free 16 WAP then weedy	1145	26.21	92.4
Weedy for 0 WAP then weed free	0	28.36	100.0
Weedy for 4 WAP then weed free	0	29.65	104.5
Weedy for 8 WAP then weed free	0	25.00	88.2
Weedy for 12 WAP then weed free	0	20.34	71.7
Weedy for 16 WAP then weed free	0	16.99	59.9
Weed at 3+8 WAP	1553	21.27	75.0
Weed at 3+8+12 WAP	1233	22.74	80.2
Weed at 3+8+16 WAP	1294	22.52	79.4
Weed at 3+8+12+16 WAP	1262	27.83	98.1

to determine the degree of genetic variability within seed families in relation to susceptibility or resistance to root-knot nematode and to estimate damage to yam plants due to root-knot nematode attack.

D. dumetorum was found to be resistant to root-knot nematode attack. Two plants showed light infections on the roots, and eggs were recovered from one plant only. No gall development was seen on the tubers. The mean weights of roots and tubers between treatments were not significantly different.

D. praehensilis, in general, was highly susceptible in both roots and tubers. Mean root weight tended to increase with higher inoculum levels. Mean tuber weight was not significantly different from the control mean weight. The two breeding families of *D. rotundata* were susceptible in both roots and tubers. In the breeding family W501 there was a mean increase in root and tuber weight over the noninoculated control treatment. Breeding family W511 had a mean root weight less than the control and a mean tuber weight increase over the control (Table 19).

Plantain as an intercrop. In most indigenous cropping systems in which plantain is grown, intercropping is practiced with such food crops as cocoyam, cassava, maize and sweet potato. However, despite the popularity of intercropping plantain, efforts to increase plantain productivity have been confined largely to pure cropping systems. In order to determine the effects of intercrops on plantain yield and their contribution to the total food production an experiment was conducted with plantain sole and intercropped with cocoyam, maize and cassava.

Out of IITA's 149 plantain accessions, 33 cultivars have been identified from which three seem to have higher yield potential than the popular Agbagba.

Table 19. Dioscorea rotundata seedling attack by the root-knot nematode, Meloidogyne incognita, in a 131-day greenhouse trial. Family W501.*

Inoculum eggs/plant	Root wt. g	Tuber wt. g	R-K index roots**	R-K index tubers**	Egg count
0	2.02	25.57	1.00	1.00	0
500	3.48	36.17	1.58	1.83	0
1,000	6.80	36.32	2.35	1.73	0
2,000	5.70	29.18	2.82	1.67	0
4,000	4.43	37.43	2.17	2.83	0
8,000	3.75	23.83	4.20	2.62	7
16,000	3.10	32.55	3.53	3.40	533
32,000	5.50	24.70	4.40	4.45	95
Grand mean	3.35	30.72	3.01	2.50	91

**Means of six replicates of one plant each in a 12-cm pot.*
***Root-knot index: 1 — no galling, 5 — maximum galling.*

Table 20. Yields of plantain and other food crops (t/ha) in four intercropping systems.

	Treatment			
	1	2	3	4
Plantain spacing (m)	2.5 x 2.5	3 x 2	3 x 2	6 x 2
Plantain	15.6	15.7	16.8	8.8
Cocoyam	–	2.96	–	–
Maize	–	–	2.94	3.35
Cassava	–	–	2.58	10.24

Intercropping did not significantly affect plantain yields (Table 20) at the high-population densities, the lower plantain yield in treatment 4 is attributed to the low population density.

There were marked differences in labor requirement for weed control within the four treatments. The use of herbicides in sole plantain kept the man days per hectare relatively low; intercropping with cocoyam also effectively suppressed most

Table 21. Plantain intercropping: input-output balance US ($/ha)

	Treatments 1	2	3	4
a. Outputs				
Plantain @ $93/t	$3770	$3780	$4060	$2125
Cocoyam @ $93/t	–	715	–	–
Maize @ $200/t	–	–	588	670
Cassava @ $40/t	–	–	105	410
Vegetable propagating materials	100	160	170	120
Total cash revenue	$3870	$4655	$4923	$3325
b. Inputs				
Labor @ $4/day	$765	$1065	$1540	$1390
Seeds, sucker, etc.	100	160	180	130
Tools	65	40	65	65
Fertilizer and pesticides	440	340	510	340
Supporting stake @ $0.15 each	150	150	150	80
Irrigation	670	670	670	670
Total cash costs	$2190	$2325	$3115	$2675
Gross margin	$1680	$2330	$1808	$ 750

Table 22. Main features of three promising accessions and the popular cultivar.

Features	Cultivar and accession # Ogoni 76–13	Ishiokpo 76–11	Orishele 75–56	Agbagba (local check)
Pseudostem color	red	red	red	green
Pseudostem size	large	medium	medium	medium
Months to harvest	13	11	11	11
Number of fruits	61–72	49–59	50–59	30–45
Bunch weight/kg	22	19	22	16

weeds. The other intercrops were not good weed suppressors and weeding accounted for the dominant labor use.

Aggregate production of food crops was generally higher with intercropping than with pure cropping, and plantain/cocoyam and plantain/maize/cassava at close spacing intercropping had higher cash return than the pure stand plantain (Table 21). Reducing the plantain density resulted in reduction of income as increased yield from the lower-priced maize and cassava did not compensate for the reduction in plantain yields. Thus, where cash income is the goal, the feasible plantain intercrops are cocoyam and maize/cassava with high plantain density.

Collection and selection

During the year the number of plantain accessions reached 149. Thirty-three cultivars were identified, 19 were horn type and 14 French type plantain. Data from horn type cultivars indicate that at least three new accessions may have higher potential than the popular Agbagba (Table 22).

Pest management, sole cropping

Studies in weed management

Maize. A formulated mixture of atrazine plus metolachlor (Primextra) identified in previous years' studies as an effective preemergence herbicide for weed control in maize at 2.5 kg a.i./ha continued to give good weed control and maize yield (Table 23). Weeds not controlled by this mixture were *Commelina benghalensis* L. and *Talinum triangulare* Willd. from old root stock. A formulated mixture of atrazine plus alachlor at a comparable rate was as good as the standard herbicide in the first-season maize trial. Penoxalin at 2.0 kg/ha was the only herbicide that controlled *Rottboellia exaltata,* a serious weed in tropical crops.

An unexpectedly prolonged dry spell after application of preemergence herbicides in maize often results in poor subsequent weed control. It is thus appropriate to identify suitable postemergence herbicides for use in maize for situations where the preemergence herbicide has failed. Herbicides evaluated for postemergence weed control in both first and second season trials gave fair to poor weed control (Table 23). The most prevalent weeds in the weedy plots were *Rottboellia exaltata, Brachiaria lata, Talinum triangulare, Euphorbia heterophylla,* and *Commelina benghalensis.*

Rice. Herbicides that gave promising weed control under poor water management conditions in 1976 direct-seeded lowland rice trials were again evaluated in 1977. Several herbicides including thiobencarb and propanil (3.6 kg/ha) and monilate (3 kg/ha) were less effective in controlling weeds when water control was poor. Yields in plots treated with these herbicides were significantly lower than weed-free plots and were not included in results reported in Table 24. Weed was controlled best in plots treated preemergence with oxadiazon at 1.5 kg/ha. Other herbicides that were as effective, when used singly as standard formulated mixtures, including preemergence application of bifenox at 2.0 kg/ha and postemergence applications of bentazon and cyperquat. Inclusion of silvex as a tank mix in a mixture of thiobencarb and propanil improved the control of sedges. Similarly, the inclusion of 2, 4-D aimine as a tank mix with cyperquat improved control of broad-leaved weeds.

Without good water control, a condition characteristic of most farmers' rice fields, uncontrolled weed growth caused more than 60 percent reduction in yield of direct seeded lowland rice. Weeds present in the untreated plots include *Cyperus difformis L., Pycreus* spp., *Kyllinga* spp., *Sphenoclea zeylancia* Gaertn., *Echinochloa colonum* (L) Link, *Commelina* spp. and *Monochoria vaginalis. Sphenocloa zeylanica* was not well controlled by most of the herbicides evaluated. An exception to this was tank mixture of fluorodifen plus propanil.

Cowpea. Fluorodifen at 3.5 kg/ha or metolachlor at 2.5 kg/ha applied preemergence gave good control of a wide range of annual weeds in both first- and second-season trials in cowpea. These herbicides were also well tolerated by the crop (Table 25). Although none of the herbicides tested was effective against wild poinsettia *(Euphorbia heterophylla)* a tank mix of metolachlor plus metribuzin suppressed the infestation of this weed long enough to minimize yield reduction in cowpea.

Wild poinsettia is a rapidly growing annual broad-leaved weed which if not controlled, completely shades cowpea within six weeks of planting. Stand densities of 150 wild poinsettia plants/m^2 have been observed under normal field conditions.

A pure stand of only 10 wild poinsettia plants/m^2 has been found to reduce yield of semi-prostrate and erect cowpea cultivars by 25 percent and 53 percent respectively. When

Table 23. Weed control in maize (cv. TZB). First season, 1977.

Treatment	Rate (kg/ha)	Time	Weed control broadleaves 1st	broadleaves 2nd	grasses 1st	grasses 2nd	Grain yield (kg/ha)
1. Primextra	2.5	PE	87	76	76	56	4437
2. Pendimethalin	2.0	PE	61	16	100	100	4660
3. Metholachlor	2.0	PE	83	67	92	73	4578
4. Atrazine/alachlor G	3.0	PE	86	79	84	65	4304
5. Atrazine/alachlor (flowable)	2.4	PE	81	53	65	35	5297
6. Atrazine/alachlor (flowable)	3.0	PE	82	63	79	65	4120
7. Bentazon	2.0	Post E	65	43	2	0	2858
8. Candex	1.5	Post E	63	50	74	47	3844
9. Weed free check	–	Weekly	100	100	100	100	4448
10. Weedy check	–	–	0	0	0	0	3572
LSD 0.05							1085
CV							20.4%

Weed rating at 44 and 72 DAT.
Post emergence treatments applied 17 DAP.

Table 24. Weed control in direct seeded lowland rice (cv. BG 90-2) under poor water management conditions. (IITA, 1977.)

Treatment		Rate (kg/ha)	Time[2]	D.W. weeds (kg/ha)	Paddy yield (kg/ha)
1.	Thiobencarb + propanil	1.2+2.2	7 DAP	86.3	4787
2.	Tamarice — T[1]	10.0 L	14 DAP	114.3	4957
3.	Propanil + MCPA	10.0 L	14 DAP	283.6	4877
4.	Molinate 10 G	3.0	14 DAP	397.6	4576
5.	Avirosan	2.5	PE	55.6	4148
6.	Oxadiazon	1.5	PE	37.3	4582
7.	Bifenox	2.0	PE	84.3	4419
8.	2, 4-D Granular	1.0	21 DAP	132.3	4406
9.	Bentazon	3.0	14 DAP	158.0	4312
10.	Cyperquat	2.5	28 DAP	98.3	4476
11.	Cyperquat + 2, 4-D amine	1.5+0.5	28 DAP	67.0	4382
12.	Fluorodifen + propanil	1.5+2.0	21 DAP	292.3	3855
13.	Hand weeding	–	7+35 DAP	325.3	3706
14.	Weed free	–	–	0	4749
15.	Weedy check	–	–	747.6	1827
	LSD 0.05	–	–		1458

1. Trade name for formulated mixture of Thiobencarb + Propanil + Silvex.
2. DAP = days after planting. PE = preemergence.

Table 25. Effect of herbicides on weed control and crop yield in cowpea (cv. VITA-5) second season, 1977.

Treatment	Rate	Time	Weed control Broad leaves 1st	Broad leaves 2nd	Grasses 1st	Grasses 2nd	Grain yield
1. Metolachlor	3.0	PE	83	73	93	89	683
2. Metolachlor + metribuzin	1.5 − 0.25	PE	83	76	87	74	709
3. Pendimethalin	2.0	PE	66	80	92	63	619
4. Pendimethalin + metribuzin	2.0 + 0.25	PE	81	68	83	77	660
5. CDEC	8.0		34	17	19	19	455
6. DCPA	10.0		26	8	87	88	685
7. Fluorodifen	3.0		78	51	91	90	619
8. Hoe weeding	–	14 + 28 DAE	98	94	95	96	844
9. Weed free	–	Weekly	100	100	100	100	883
10. Weedy	–	–	0	0	0	0	336
LSD 0.05							169
CV							20.4%

Weed rating at 27 and 60 days after treatment.

the population was increased to 80 plants/m^2 cowpea yield reduction of 68 percent and 75 percent respectively were noted in the semi-prostrate and erect cowpea cultivars. Only the wild poinsettia seedlings that established within 20 days of planting eowpea significantly redueed cowpea yield relative to weed-free plots. This implies that effective control measures will require keeping cowpea free of wild poinsettia within the first 30 days of establishment to minimize eompetition with the crop.

The tolerance of cowpea eultivars to selected herbicides was also evaluated in 1977. The cowpea cultivars tested were more tolerant of metolachlor and pendimethalin than of alachlor. VITA-5 was more susceptible to alachlor than other cultivars tested. Pendimethalin at 2.5 kg a.i./ha caused stand reduction in VITA-4.

Soybean. Fluorodifen at 3.5 kg/ha or metolachlor at 2.5 kg/ha applied preemergence gave good weed control and high grain yield in soybean. Preemergence herbieide mixtures which also combined exeellent weed control with good crop yield were metolachlor plus metribuzin, metolachlor plus metobromuron and metolachlor plus chlorbromuron. These mixtures were superior in crop yield and weed control to mixtures involving alachlor or pendimethalin. The latter herbicide was toxic to soybean.

Cassava. A weed control study was carried out in cassava in a field fallowed for one year prior to the study. Weeds when not controlled caused a yield reduction of 64 percent relative to cassava plots that were kept weed free until harvest. Two or three properly timed weedings were as effective in controlling weeds as when the cassava was kept weed free throughout the growing season. Preemergence applications of fluometuron at 2.0 and 3.0 kg/ha, diuron at 2.0 kg/ha and a formulated mixture of atrazine and metolachlor at 2.5 kg/ha gave cassava yields that were similar to the weed-free treatments.

Cover and conservation crops

Fallow legumes. 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.

Four legumes, *Stylosanthes guianensis, Pueraria phoseoloides, Centrosema pubescens* and *Psophocarpus palustris,* are being evaluated as fallow species in areas where *I. cylindrica* is a dominant weed. At the end of the first year, legumes planted through established *Imperata* were rated in a descending order of establishment: *Stylosanthes, Pueraria, Psophocarpus* and last, *Centrosema.* Absence of appropriate strains of *rhizobium* bacteria appeared to be responsible for poor establishment of the latter two legumes. Suppressing *Imperata* with paraquat was not necessary for good establishment of *S. guianensis* and *P. phaseoloides.*

Fallow shrubs and trees. In addition to *Leucaena leucocephala,* certain species are being evaluated for use in specialized fallow e.g., providing *in-situ* support for climbing crops. Those being evaluated in replicated plots include *Acioa bateri, Glyricidia sepium, Tephrosia* sp. and *Cajanus cajan.*

Mulches as modifiers to populations of plant-parasitic nematodes. A long-term trial is being conducted at IITA to evaluate the effect of selected plant residues on soil microflora and micro-fauna as sources of plant nutrient and the yields of maize, cassava, cowpea and soybean.

After the third year of the trial the spread of plant-parasitic nematodes above and below the mean of the unmulched control plots was within the range of the previous two years. Changes in nematode populations under the various mulch treatments were mixed. Soil populations of plant-parasitic nematodes were generally consistent under soybean tops, rice straw, maize cobs, cassava stems and pigeon pea stems in relation to the control plots (Table 26). In plots mulched with mixed twigs, *Pennisetum* straw, pigeon pea tops, rice husks, oil palm leaves, black plastic and fine gravel, the previously observed decline in nematode numbers continued. Sawdust, typha straw, Panicum straw, elephant grass straw, Andropogon straw, bean husks, maize stover, Eupatorium tops and clear plastic mulches showed a mixed response in nematode numbers.

The mean numbers of all plant-parasitic nematodes were greater than the previous two years and higher than the preplant mean. Maize had the highest numbers of nematodes followed by soybean, cowpea and cassava in that order. The numbers of nonplant-parasitic nematodes remained under the preplant mean for all crops. Populations under soybean, maize and cowpea were similar to the first year of crops while population under cassava declined to one-third. The root lesion nematodes *(Pratylenchus selfaensis, P. brachyurus)* continued to be the most abundant of the plant-parasitic nematodes with the greatest buildup on maize. The spiral nematodes *(Helicotylenchus pseudorobustus, H. cavenessi)* were most abundant on soybean, cassava and maize with small numbers being associated with cowpea. Cowpea had the greatest number of root-knot nematode juveniles *(Meloidogyne incognita)* in the rhizosphere with population numbers being maintained under maize and cassava and none being recovered from soils associated with soybean. The pin nematodes (*Paratylenchus* spp.) were occasionally found associated with soybean roots with an overall mean for all treatments of 197 nematodes per liter of soil. Trace numbers of the ring nematode (*Criconemoides* sp.) and the false spiral nematode *(Scutellonema clathricaudatum)* were found.

Light profile in maize canopies. In a follow-up study on light transmission in maize canopy at two different populations (100 x 20 cm and 100 x 40 cm spacings) in 1976, investigations were carried out to determine the changes in light climate, again within maize canopies, by changes in planting pattern or geometry, keeping plant population constant. The results (Table 27) show that about a 10 percent gain in transmitted light can be achieved at the recommended spacing (80 x 25 cm) by orienting the crop rows east-west (in the first season) as compared to a north-south orientation. This compares favorably with the 10-20 percent gain obtained in the previous study by changing plant density from 50,000 to 25,000 plants/ha depending on fertility level, keeping inter-row spacing at 1m, (see IITA Annual Report 1976). A quadrilateral planting pattern proved to be most efficient in intercepting light.

Light transmission in crop mixtures was also studied as part of an experiment on weed competition in different cropping systems. The results given in Table 28, indicate a substantial reduction in light received by the maize at cob level because of the inclusion of yam in the mixture. This probably constitutes a significant yield reduction factor because of the important contribution of photosynthates by the leaves around the ear during its filling period. Spacing arrangements in maize-yam crop mixtures would therefore need to be carefully considered to minimize the possible adverse effect on maize yield, resulting from insufficient incident light on the crop.

Table 27. Influence of cropping pattern on light transmission through maize canopies.

Cropping pattern	Mean relative light transmitted (%) Period 1*	Period 2*
E-W, 80 x 25 cm	100 (306.4)**	100 (226.6)**
N-S, 80 x 25 cm	94	90
WNW-ESE, 80 x 25 cm	93	–
Quadrilateral; E-W/N-S: 44.5 x 44.5	–	72

**Period 1=21-27 DAP, 34-44 DAP; Period 2=31-37 DAP, 45–53 DAP.*

***Figures in brackets are the actual mean values of light measured in gcal-cm² day-1.*

Table 28. Percent light transmitted through different crop mixtures*

Height of measurement	Percent global radiation transmitted (%) M	MC	MY	MYC	Y
Mean cob height (= 140 cm)	64	50	37	37	35
Ground level	30	29	21	21	19

**M = Sole maize; MC = Maize-Cassava; MY = Maize-Yam; MYC = Maize-Yam-Cassava; Y = Yam.*

Table 26. Ranking of all plant-parasitic nematodes with mulch treatments on all crops for both growing seasons for the years 1975, 1976 and 1977.*

Nematode percentage of control 1975	1976	1977	Treatment	Plant-parasitic nematodes 1975	1976	1977
80	80	102	Sawdust	1,613	913	3,596
86	63	96	Soybean tops	1,736	716	3,387
87	77	82	Rice straw	1,761	876	2,902
88	128	76	Elephant grass	1,778	1,463	2,666
93	87	88	Maize cobs	1,883	995	3,087
95	59	79	Cassava stems	1,918	669	2,781
100	100	100	Control (bare)	2,027	1,142	3,519
106	107	58	*Andropogon* straw	2,139	1,217	2,027
108	55	78	*Panicum* straw	2,190	623	2,743
108	71	82	*Typha* straw	2,193	813	2,891
117	86	133	Bean husks	2,365	985	4,663
123	74	51	*Pennisetum* straw	2,488	844	1,795
126	153	82	Maize stover	2,545	1,745	2,896
130	76	74	Pigeon pea tops	2,631	863	2,606
136	112	215	Clear plastic	2,750	1,282	7,558
148	129	131	Pigeon pea stems	2,996	1,473	4,612
169	66	63	Mixed twigs	3,428	754	2,231
174	87	122	*Eupatorium* tops	3,520	989	4,298
201	111	58	Rice husks	4,074	1,262	2,030
222	191	141	Black plastic	4,501	2,178	4,948
242	115	74	Oil palm leaves	4,904	1,313	2,601
264	126	107	Fine gravel	5,353	1,441	3,755
184	136	164	Spread	3,740	1,555	5,763

**Mean numbers of nematodes per liter of soil based on 36 samples. Sample size was 294 cm³ of soil.*

Table 29. Sweet potato yields at different levels of insolation, Rg.

Season	Variety	Actual yield at 100% Rg t/ha	Relative mean yield/plot (%) at: 100% Rg	77% Rg	66% Rg	Relative mean yield/plant (hill) at: 100% Rg	77% Rg	66% Rg
1st, 1977	TIS 1499	25.000	100	81	64	100	82	72
1st, 1977	TIS 2534	14.000	100	54	35	100	50	33
2nd, 1977	TIS 1499	21.200	100	43	41	100	58	55
2nd, 1977	TIS 2534	18.960	100	57	29	100	66	37

Crop response to simulated light climate. Studies on the implication of the seasonal and areal changes in global radiation on crop production were continued using two cultivars of sweet potato, TIS 1499 and TIS 2543. As was the case with the cereal (maize) and grain legumes (cowpea, soybean) reported earlier, moderate reduction in insolation decreased yields in both cultivars. Unlike the other crops however, the yield reduction, particularly in the case of TIS 1499 appears to level off substantially (for the 23 percent and 34 percent light reduction studied) as evident from the relative yield per hill (Table 29). This suggests a fair degree of tolerance for low light within certain limits; it should lend the crop well to production in mixture, i.e., as an intercrop, as well during seasons with relatively poor isolation. TIS 2534 proved far more sensitive to reduced incident light.

Crop water requirement. Maximum water requirements were determined for two cultivars of cowpea (TVu 3629 and VITA-5) using the drainage lysimeter set-up previously described (IITA Annual Report, 1975).

Total water consumption[1] by TVu 3629 during the dry season 1976/77 amounted to 321 mm with a mean daily requirement of 4.28 mm over the season. These eompare with values of 276 mm and 3.58 mm respectively for the cultivar TVu 6204 (IITA Annual Report, 1976) during the corresponding season of 1975/76. The extremes in weekly mean values, 2.95-5.69 mm/day, are also higher than in the previous case. This appears to be mainly due to the higher evaporative demand during the latter season. The mean daily water use DP VITA-5, grown during the second season of 1977 ranged from 2.87 to 4.79 mm, averaging 3.78 mm/day over the season. As noted in previous studies, consumption by the same crop on the Iwo soil lysimeter was slightly higher (+9 percent) because of the better growth of the crop. The ratio of evapotranspiration to pan water evaporation ranged from 0.72 to 1.11 and from 0.79 to 1.22 on the Alagba and the Iwo soils respectively.

The preceding results together with those previously reported indicate a mean water requirement of 3.5-4.5 mm/day for the area.

Land management

Early research in land management at IITA was focused on nutritional and physical aspects of soil management, using as a starting point the land after clearing. However, methods of forest or bush clearing and subsequent land development will have a major impact on the subsequent productivity and problems of managing the soil. The Farming Systems Program has initiated a research program to investigate methods of land clearing and soil management as a continuum which will ensure that the productivity of tropical soils is not depleted during clearing and thereafter. Following extensive work in project design, a watershed under secondary forest is being developed at IITA to enable the integrated evaluation of the impact of alternative methods of land clearing and subsequent soil management on crop production, hydrological, chemical, physical and biotic properties of the soil. It is proposed that this site will be the first of a network to evaluate methods of land development as influenced by the preclearing vegetation, soil types and climates of the humid and subhumid tropics.

Nutrition: Biological nitrogen fixation

Diurnal changes in nodule efficiency and carbohydrate content in cowpeas. Previous studies have shown a decline in nodule efficieney in cowpeas between 1200-1600 hrs. and reference was made to the relationship between changes in carbohydrate metabolism and nitrogen fixation. Two field experiments were conducted to examine the relationship. Cowpea cultivars TVu 3629 and TVx 715 were inoculated with *Rhizobium* sp. sown in a completely randomized block, with five replications. At flowering and pod fill, data were taken daily at 0900, 1200, 1500 and 1600 for three consecutive days.

In general, total activity (C_2H_4 produced/pl/hr), total reducible carbohydrate per plant and amino acids per plant were low in the morning, increased between 1200-1500 and then decreased. Figure 3 shows changes in specifie activity, the concentration of amino acids in bleeding sap and the amount of total reducible carbohydrates. The increases in nitrogen content of sap lagged by about three hours behind carbohydrate content. Specific activity was not related to amino acid content until 1500 hours when both increased. The fall in the quantity of amino acids in bleeding sap as a result of the decreased rate of nodule fixation, is in part a consequence of the low amounts of carbohydrates available for fixation.

Soybean cropping history on the survival and function of *Rhizobium*. When inoculated legume seed is planted it is desirable to know how many inoculations are necessary to establish adequate numbers of efficient rhizobia and to remove the need for subsequent inoculations. Soils were collected from various locations in Nigeria (Table 30) and estimates of nodulation and rhizobial numbers madc. In 15 soils from Mokwa, Samaru, Yandev, Onne and IITA, rhizobia infecting soybean cultivar TGm 294 were absent or few (0-12/g soil) in soil not previously cropped to soybean. In soils with one or more inoculations there were many rhizobia (up to 3,600) – more than adequate to give effective nodulation. Nodulation, nodule efficiency and total nitrogen followed a similar pattern. A similar study was made of soils from locations with a known history from the IITA site.

Nodulation, nodule efficieney and total nitrogen fixed again were significantly higher in soils with one or more inocu-

1. Values in all cases from Alagba soil lysimeter unless otherwise indicated.

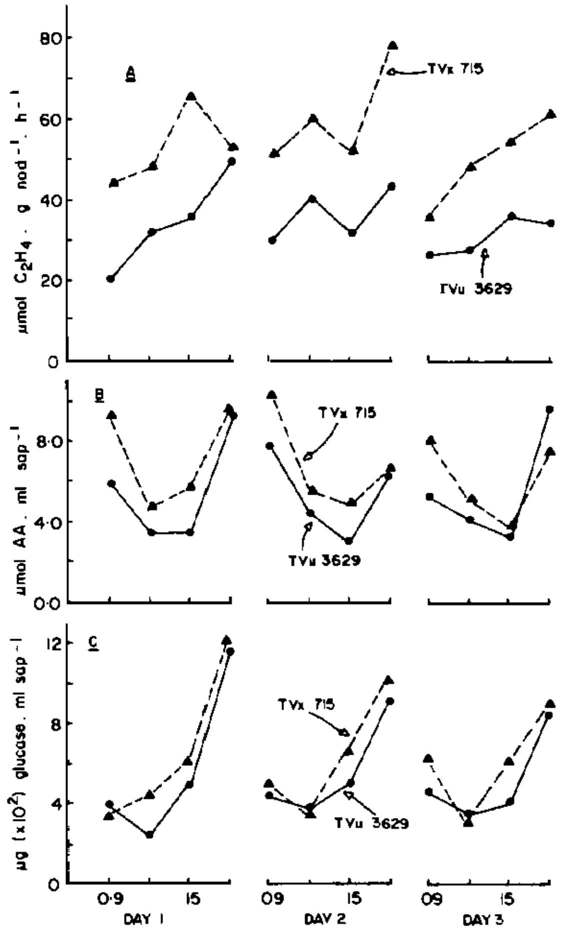


Fig. 3. Daily variation in nodule efficiency (A) and in concentrations of amino acids (B) and reducible carbohydrates in the bleeding sap of two cowpea cultivars at flowering.

lations within the past four years. The differences in efficiencies in Egbeda soils suggest selection and adaptation of different strains since it is known that the inoculant which was used contained different strains.

Collection and typing of indigenous rhizobia strains. In improving the nitrogen contribution from legume rhizobia to crops and soil fertility in the lowland humid tropics, nodules were collected from 16 legumes from various locations in Nigeria. Rhizobia insolated from nodules of several of these hosts were added to the IITA collection of cultures of *Rhizobium* after they were typed and authenticated.

Authenticated strains of rhizobia already in the culture collection were utilized in laboratory and screenhouse studies to identify highly superior legume – *Rhizobium* combinations. The isolates were screened in Leonard jars for their ability to infect and form effective nodules on four hosts: cowpea, lima bean, soybean and *Centrosema*. The results from this preliminary screen are shown in Table 31. Most of the 60 strains tested (65 percent) were effective on cowpea. The low percentage of isolates effectively nodulating soybean was a reflection of the few *R. japonicum* used in the test. Out of the seven *R. japonicum* strains included in the test, two were highly effective.

Cross-infectivity among members of the cowpea group is little studied and consequently little is understood precisely why, for example, rhizobia isolated from certain members

Table 31. Summary of results of the preliminary plant testing of Rhizobium spp.

Legume host	Effective	Not effective
Cowpea (VITA-3)	65.0	3.3
Centrosema	11.7	–
Lima bean (TPI 80)	6.7	–
Soybean (TGm 80)	5.0	8.3

Table 30. Description of soils used in experiments on soybean cropping history, with mycorrhiza and with paraquat.

Source of soil	Series	Classification	Texture	Clay %	pH $CaCl_2$	C %	C/N
Savanna zone soils							
Mokwa	–	Oxic paleudult	Loamy sand	9	5.3	0.62	13
Samaru	Funtua	Haplustalf	Loam	16	4.9	0.40	7
Yandev	–	Psamment	Sand	5	4.7	0.48	16
Abomey-Davougon	–	Ustalf	Sand	4	5.4	0.73	18
Dassa-Zoume	–	Ustalf	Loamy sand	5	6.0	0.86	17
Sub-humid forest zone soils							
Ibadan	Adio	Aerie tropaquent	Sandy loam	10	4.7	1.42	7
	Apomu	Psammeutic ustorthent	Loamy sand	8	5.8	0.78	13
	Egbeda	Oxic paleustalf	Sandy clay loam	25	5.4	1.50	11
Ikenne	Kolo	Udic rhodustalf	Sandy clay loam	21	5.5	2.61	3
	Alagba	Oxic paleustalf	Sandy loam	13	6.3	1.21	8
Isoya	Okpannam	Ustipsamment	Loamy sand	6	4.2	0.94	19
Agonkanme	–	Paleustalf	Sandy loam	10	6.0	1.35	13
Sehoue	–	Ustert	Clay	45	6.2	2.98	15
Zinvie	–	Aquent	Sandy clay loam	35	4.0	12.32	30
Humid forest zone soil							
Onne	–	Oxic paleudult	Sandy loam	18	3.7	1.35	22

of the cowpea cross-inoculation group do not nodulate other members of the group.

As part of the initial phase of a broader study, an experiment was initiated to examine cross-infectivity and the identity of rhizobia, using seven *Rhizobium* strains and five legume hosts. The results (Table 32) indicated that not all the cowpea isolates nodulated other members of the cowpea cross-inoculation group. Moreover, an isolate from one cowpea cultivar (strain 89) failed to nodulate the cowpea under test.

Table 32. Screenhouse trials on cross-inoculation using seven** Rhizobium **spp. and five hosts. Egbeda soil (Alfisol) was sterilized and plants were harvested after 4-5 weeks.

	Relative effectiveness on**				
Rhizobium strain*	Cowpea	Pigeon pea	Winged bean	Lima bean	Centrosema
16	+	–	–	+ +	–
22	– +	–	–	+ +	–
28	+	–	–	+ +	–
59	+ + –	–	–	–	–
69	+ +	–	–	+ +	–
89	–	–	–	–	–
90	+ +	–	–	+ + +	–

**All are cowpea isolates except 16, from bambarra groundnut.*
***Effectiveness (nodulation, dry matter production) rating:*
– *Not effective*
+ *Slightly effective*
+ + *Moderately effective*
+ + + *Highly effective*

Mycorrhiza and phosphorus nutrition

Previous work (IITA Annual Report, 1976) suggested that field inoculation with Vesticular-arbuscular mycorrhizae did not increase grain yield of plants. Follow-up experiments were conducted in 1977.

Phosphate fertilization and mycorrhizal inoculation of cassava. The effects of inoculating cassava with *Glomus mosseae* on the availability of rock phosphates in an Egbeda soil series were investigated in a screenhouse experiment. Inoculation failed to increase root infection in nonsterile soil because the soil contained abundant spores of *Glomus* and *Gigaspora* spp. Phosphorus uptake and concentration in plants were increased by inoculation of sterile and nonsterile soils. Plants supplied with Morocco rock absorbed more P than those supplied Togo rock. Dry matter production followed a similar trend. The benefit of inoculating cassava with *G. mosseae* was limited to the sterile soil, reflecting the abundance of efficient indigenous mycorrhiza in soil.

Endogone spore type on cowpea yield. The yields of TVx 1836-44G when inoculated with four mycorrhizal spore types were compared iu a pot experiment (Table 33). *G. mosseae* was found to be superior to the other spore types.

Methods of field inoculation. Efficient methods for large-scale field inoculation of mycorrhyzal spores are not known. In two field experiments two ways of inoculating VITA-4 and TVx-44G were compared: seeds were either pre-infested and the seedlings transplanted, or inoculum was plaeed directly below seeds at planting time. The method of inoculation had little or no effeet on the parameters examined (Table 34). Inoculation was the more efficient; it increased all parameters examined, including grain yield. Direct placement of inoculum with seed will be adopted in all future work as it is less laborious and less time-consuming than pre-infecting and transplanting.

Table 33. Inoculation of cowpea (**Vigna unguiculata* ***TVx 1836-44G) with four mycorrhizal fungi under pot conditions.

Fungal inoculum	No. of pods/ plant	No. of seeds/ pod	Seed weight g/plant	100 seed wt. (g)	Increase in seed wt. (%)
Uninoculated	8.0	6.5	7.6	14.6	–
Glomus fasiculatus	12.7	7.0	12.9	14.5	70
G. macrocarpus	10.3	8.3	12.4	13.9	63
G. mosseae	12.7	8.3	14.4	15.5	90
Acaulospora leaves	11.7	7.6	12.9	14.5	70

Table 34. Effects of method of seed inoculation with** Glomus mosseae **on yield of nodules, nitrogen and grain in cowpea (**Vigna unguiculata**) under field conditions. Nodule yield and total nitrogen at 48 days after sowing/transplanting.

Method of planting	Inoculation*	Nodule dry wt. (mg/plant)	Total N (mg/plant)	Grain yield (kg/ha)	Increase in yield (%)
Seeds sown	–	33.2 ± 2.9	1989	712 ± 59	–
	+	81.7 ± 7.5	2699	1065 ± 115	49.5
Seedlings transplanted	–	49.1 ± 2.6	1948	810 ± 100	–
	+	118.2 ± 10.9	2595	1015 ± 88	25.4

**Seeds were inoculated (+) or not (–) at time of sowing in screenhouse or field.*

Field sterilization and mycorrhizal inoculation on cowpca and maize yield. The effects of indigenous mycorrhiza and an introduced strain, *G. mosseae,* on phosphate nutrition and yield of cowpea and maize were examined. Root infection, P uptake and dry matter production in both crops were increased by inoculation, whether the soil was sterilized or not. Maize grain yield was increased more in non-sterile than sterile soil by inoculation. These results show that under low soil fertility, inoculation of highly effective strains will increase crop yield although indigenous strains already influence such yield. On-going research is designed to establish the relationship between soil fertility and the role of mycorrhiza on crop yields.

Effects of paraquat

The effects of different rates (0, 0.25, 2.5 and 250 ug/g a.i.) of Paraquat on soil respiration, nitrification and dehydrogenase activity were examined in the laboratory using 13 soils and in the field on Apomu soil series.

Respiration of incubated soils treated with cowpea residue and paraquat was significantly lowered by treatment with paraquat. The clay content of the soils was significantly correlated with respiration. At the highest rate, paraquat significantly depressed oxidation of added ammonium, especially, in Abomey and Kolo soils. Increasing clay content or CEC of soils decreased the inhibitory effect of paraquat, reflecting paraquat inactivation by the soil. Dehydrogenase activity was little affected by paraquat, but this was probably due to loss of enzymatic activity during handling and storage.

The Apomu field soil treated with 0, 0.50 and 50 kg/ha a.i. paraquat, was sampled for incubations initially and after one and seven days. Respired CO_2 was unaffected by paraquat, but dehydrogenase activity was significantly depressed (Table 35). Though paraquat reduced nitrifieation and dehydrogenase activity its use is acceptable because a high rate of these two processes is undesirable.

Table 35. Effect of field application of paraquat to Apomu soil on dehydrogenase activity in soil sampled initially and one and seven days later.

Paraquat rate (kg/ha)	Microliters H evolved/g oven-dry soil			
	Initially	Day 1	Day 7	Mean
0.0	27.34	31.33	26.68	28.45
0.50	19.48**	23.11**	20.70**	21.10**
50	26.27	21.27**	22.24**	23.26**
Mean	24.36	25.24	23.21	24.27

***Different from the "no paraquat" treatment at $P = 0.01$.*

Soil acidity and nutrient imbalances

Long-term liming experiment. Field experiments were established at the Institute's substation at Onne to investigate the requirement and residual effects of lime in a Paleudult (pH 4.3) under high-rainfall conditions (2600 mm). Maize, cowpea and cassava were used as testing crops. Downward movement of applied Ca and reoccurrence of exchangeable Al were monitored periodically. In the maize-cowpea rotation trial, grain and stover yield in maize of the second year are given in Table 36.

Table 36. Response of maize (Cv. TZPB) to lime in a Ul at Onne during the second year.

Initial lime rate t/ha	Soil pH (H_2O) at planting	Grain t/ha	Stover (dry matter) t/ha	Root depth cm
0	4.3	1.92a #	1.67a	12.7a
½	4.6	3.57b	2.69a	14.0ab
1	4.7	2.68ab	2.35ab	16.3ab
2	4.9	3.47b	3.25b	18.0b
4	5.3	3.40	3.09b	21.3b

#Duncan's multiple range test, figures followed by different letters are significantly different at 5% level.

Initial rates of lime above 0.5 t/ha did not increase maize grain yield although higher lime rates slightly increased stover yield and root growth. Surface soil pH of the 0.5 t/ha plot measured at planting time during the second year was 4.6. The same maize cultivar yielded 70 percent more (6 t/ha) on an Alfisol without liming at IITA (rainfall 1400 mm). The large differenees in growth and yield between the two locations are apparently due to factors other than soil nutrient supply because macro, secondary and micro nutrients were maintained at adequate levels throughout the growing season. Varietal adaptability and low radiation in the high-rainfall region may be important growth limiting factors.

Data in Figure 4 show considerable loss of Ca from the surface soil two years after liming, indicating substantial downward movement and leaching of Ca in this coarse-textured

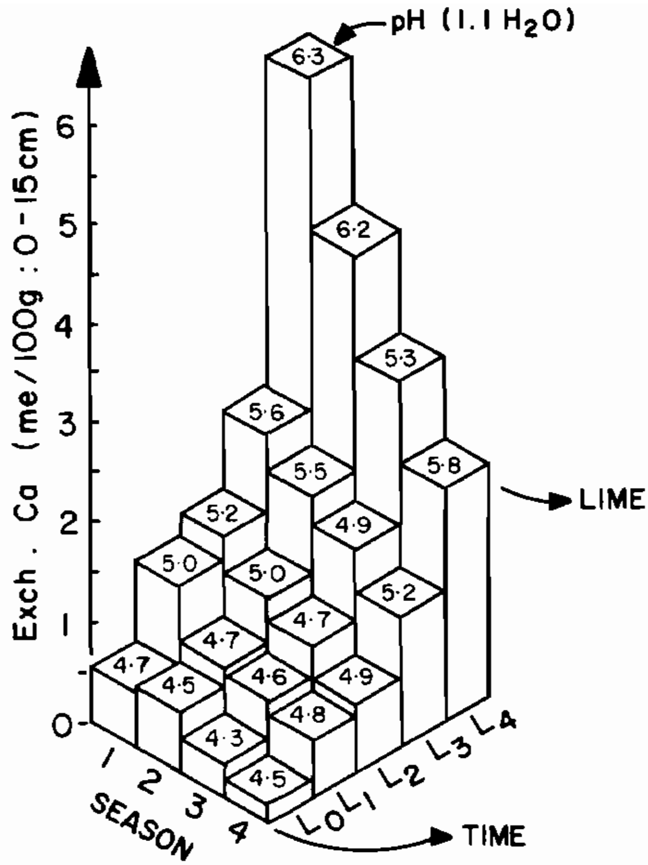


Fig. 4. Changes in exchangeable Ca and pH in a Paleudult after 2 years of cropping. Lime rates are 0, ½, 1, 2, 4 t/ha, for treatments L_0, L_1, L_2, L_3, L_4, respectively.

Ultisol. Judging from the field data accumulated to date, it seems that a sum of exchangeable Ca and Mg of approximately one meg per 100 g of soil which, corresponding to about 40 percent of exchangeable Al saturation and pH 4.7 (in water), would provide adequate conditions for the TZB maize to correct Al toxicity and supply Ca and Mg to the plant in this coarse-textured, kaolinitic Ultisol.

Lime-phosphorus-zinc interactions. An extensive factorial greenhouse experiment to investigate the lime-P-Zn interactions was concluded during the year. Two Ultisols representing different mineralogy and degree of weathering were used. A Paleustult (Nkpologu series) was collected from the savanna, and the Paleudult (Onne series) was collected from a high-rainfall region.

Strong, highly significant nutrient interactions were observed, indicating that nutrient imbalance is an important growth-limiting factor in the Kaolinitic Ultisols. When P was optimal, relatively small lime rates produced maximum dry matter yield of three-week-old maize and were sufficient to reduce exchangeable Al to less than 30 percent and soil solution Al to less than 2 ppm.

Growth responses to liming also depend upon the levels of native and applied P in the soil. In the low P status Nkpologu soil (Bray P_1, 5 ppm), there was no response to lime without P, while liming doubled dry matter yield of maize on the Onne soil (Bray P_1, 90 ppm) without additional P application. The most pronounced effect of balanced lime and P supply was on root development.

Liming soil to neutrality depressed dry matter yields on both soils only when no zinc was supplied. Overliming did not effect P availability as indicated by P uptake by plant when other nutrient elements were maintained at adequate levels.

The response to Zn was most striking in the older and well-weathered Nkpologu soil (Paleustult) from the savanna region. When no Zn was applied, dry matter yields were depressed significantly by high lime rates, which corresponded to a soil solution Zn level of 35 ppb (parts per billion) or lower (Fig. 5).

Calcium deficiency appears to be a major growth-limiting factor in both soils, although experimental data do not permit a definitive discrimination between the effects of lime as a soil acidity ameliorant and as a source of Ca for the plant.

Total nutrient accumulation in plants is controlled by factors both within the plant and in the soil. Under well balanced conditions of lime (or Ca), zinc and other nutrients, maize dry matter yield correlates significantly with P concentrations in plant tissue, depicting a critical concentration of about 0.18 percent for the three-week-old maize. However, under conditions where Ca or Mg or Zn is growth-limiting, this relationship is not obeyed.

Soil analysis (Table 37) indicated that the increased surface charge due to liming was balanced by increased exchangeable Ca. But high concentrations of Ca were also found in the soil solution of the limed soils which would be subject to leaching loss under field conditions. Soils incubated with soluble salts, such as KCl, $MgSO_4$ and NH_4NO3 used in the pot experiments, resulted in a 10-fold increase in solution Al and a big drop in soil pH in both soils; while the amount of exchangeable Al and the percentage exchange Al saturation was slightly reduced. Such phenomena indicate the limitations of using exchangeable Al alone as a criterion for predicting Al toxicity without referring to the concentration of Al in the soil solution phase.

Increased lime rates did not affect the distribution of exchangeable K and soil solution K, whereas the soluble and

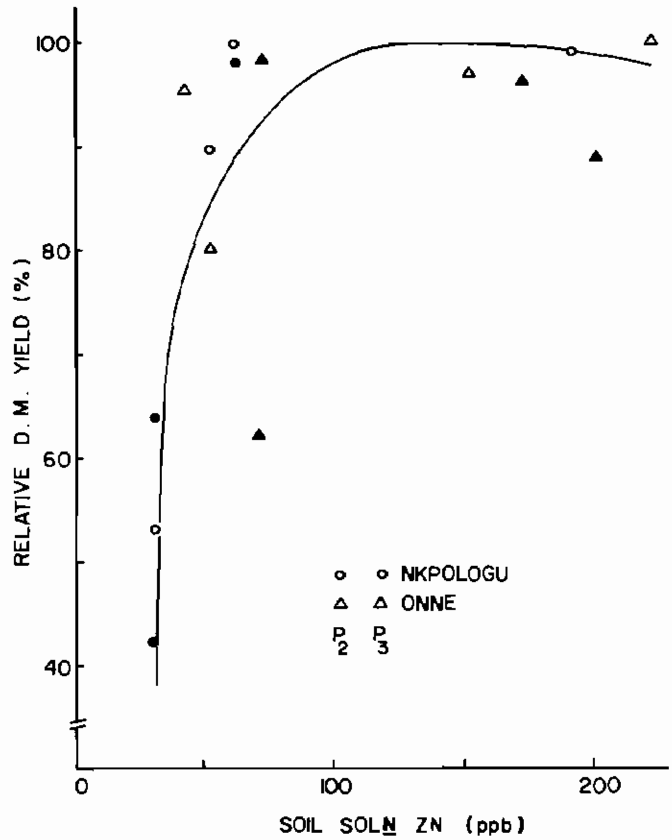


Fig. 5. Effect of soil solution zinc on dry matter yield of maize (Cv TZPB) grown in two Ultisols when P, Ca and other nutrients are maintained at optimum.

exchangeable Mg were somewhat reduced when soils were limed to neutrality. Concentrations of Mn and Zn in soil solution however, were reduced drastically with increasing rates of lime.

*Table 37. Effects of lime on soil solution (saturation extract) and exchangeable Ca and Al in two Ultisols in the presence of fertilizer salts.***

Lime rate g/kg	Soil pH (H_2O)	Solution Al	Solution Ca	Exch. Al	Exch. Ca	ECEC
		ppm		meg/100g		
		Paleudult, Onne (15–40 cm)				
Check #	4.3	2.7	–	1.79	0.21	3.00
0	3.7	17.0	60	1.46	0.30	3.35
0.25	3.9	7.8	224	1.15	0.43	3.11
0.5	4.2	3.3	276	0.82	0.67	2.90
1	4.8	0.5	432	0.21	1.05	2.56
2	5.8	0	685	0.01	1.98	3.17
4	7.2	0	1000	0	4.02	5.05
		Paleustult, Nkpologu (15–40 cm)				
Check #	4.7	0.6	–	1.88	0.21	2.94
0	3.9	10.0	77	1.44	0.40	3.44
0.25	4.1	3.8	140	1.13	0.66	3.35
0.5	4.2	2.3	268	0.86	0.74	3.03
1	4.8	0.3	412	0.25	1.18	2.73
2	5.8	0	733	0.01	2.03	3.20
3	6.7	0	921	0	3.08	4.15

***KCL, $MgSO_4$ and NH_4NO_3 were added at rates (K-Mg-N) of 150, 80 and 150 mg/kg, respectively.*
#No fertilizer salts, no lime added in check treatment.

Leaching losses of nutrients under high-rainfall conditions. Lysimeter studies were initiated during 1977 to evaluate leaching of nutrients in selected Ultisols. Selectivity coefficients (Kc) of K-Al and Ca-Al systems at actual exchangeable Al saturation in a Paleudult profile (pH 4.3) are given in Table 38.

Table 38. Selectivity coefficients (lnKc) of K-Al and Ca-Al in the Onne profile (Paleudult) at actual Al saturation of each horizon. Temperature 25°C and 0.01 total normality.

Profile depth	ln Kc (Al/K)	ln Kc (Al/Ca)
0.20	−3.2	2.9
20–40	−1.2	3.2
40–60	−1.1	2.5
60–80	−0.7	5.1
80–100	−1.6	3.9

The negative Kc values in the K-Al system indicate that the soil exchange complex has stronger affinity for K. While in the Al-Ca system, the positive Kc values indicate the preferenee of Al to Ca. The same horizon which has the maximum affinity for Al ion in the K-Al system also depicts the maximum affinity for Al in the Ca-Al system. Mineralogical data of the soil show more amorphous materials in this particular horizon of the profile.

Attempts are being made to use the ion-exchange data to prediet the effect of Al saturation on potential K and Ca leaching. At given soil physical conditions (e.g., porosity, hydraulic conductivity and diffusion factor), it may be possible to determine optimum levels of Al saturation (or rates of lime) at which leaching could be minimized.

Fertility management of Alfisols and Entisols

Long-term fertilizer trials. Two experiments were initiated in 1972 at the IITA site in Ibadan on Egbeda (Oxic Paleustalf) and Apomu (Alfic Ustipsamment) soil series, to stndy the long-term fertility mauagement problems of Alfisols and Entisols. A maize-sweet potato annual cropping cyele was used from 1972 till 1975. Starting from 1976 the second-season potato crop was replaced by cowpea to evaluate its N- eontribution to the system.

N and P responses on both soils were observed during the first three years of cropping after land clearing. Despite six years of intensive cropping, no response to K application is seen on the Egbeda soil (Table 39) indicating the high productivity of this soil.

However, responses to K application on the Apomu soil were observed since 1976 on the maize grain yield. Yield increases due to K application were also observed on the cowpea crop in 1977. The response on the Apomu soil was expected, eonsidering the low K status of the surface soil even with annual K application.

The inelusion of cowpeas in the cropping cycle, already showed some beneficial effect on the maize even after only one cowpea crop. There were marked inereases in the 1977 grain yield on both soils in the control treatment and also in the no N treatment on the Apomu soil.

On the Egbeda soil annual removal of the maize crop residue from the plots since 1972 had no effect on maize yield. Ou the less productive Apomu soil, on the contrary, removal of crop residue tends to decrease maize yield.

Table 39. First season grain yield of IITA maize TZB and second season grain yield of cowpea in 1977 as affected by fertilizer applications and crop residue treatment.

Soil type treatment	Egbeda soil		Apomu soil	
	Maize	Cowpea*	Maize	Cowpea**
	kg/ha			
No Po Ko So	2899	585	1895	746
No P_2 K_1 S_1	4364	884	2942	1195
N_1 P_2 K_1 S_1	4916	969	4890	847
N_2 P_2 K_1 S_1	4907	918	5768	1161
N_2 Po K_1 S_1	3065	542	3648	884
N_2 P_1 K_1 S_1	5217	848	5193	795
N_2 P_2 Ko S_1	4924	1020	4860	788
N_2 P_2 K_2 S_1	4512	951	5606	1107
N_2 P_2 K_1 So	4551	815	5315	968
No Po Ko So***	2747	535	1837	793
N_2 P_2 K_1 S_1***	5296	979	5386	1169
LSD .05	1222	205	1256	230

**VITA-4; **VITA-1; ***Maize crop residue removed*
Fertilizer rate: $N_1 = 80$ kg N/ha; $N_2 = 160$ kg N/ha for Egbeda soil; $N_1 = 100$ kg N/ha; $N_2 = 200$ kg N/ha for Apomu soil; $P_1 = 30$ kg P/ha; $P_2 = 60$ kg P/ha; $K_1 = 40$ kg K/ha; $K_2 = 80$ kg K/ha; $S_1 = 15$ kg S/ha.

No significant responses to S and micronutrients were observed on either soil during the six years of intensive cropping.

N contribution from grain legume. The N contribution from grain legumes grown in rotation with maize has been investigated on an Iregun soil. (Oxic Haplustalf) at the IITA site in Ibadan since 1975. Four rotation patterns: maize-maize; maize-cowpea; maize-pigeon pea and maize-soybean were tested. Maize was grown as the first season crop, except for the maize-maize rotation where maize was also grown in the second season. The grain legumes were all grown in the second season following maize. Four N rates respectively 0, 45, 90, and 135 Kg N/ha were applied only to the first-season maize crop.

In this trial maize grain yield in the no N treatment showed significant increases after one crop of the grain legumes. The effect of two years rotation with the grain legumes on maize yield is marked at the 0 and 45 kg N/ha as evaluated from the maize grain yield (Fig. 6). No distinct differences were observed in the effects of the three legume species. It thus appears that inclusion of cowpea, pigeon pea and soybeans in crop rotations has a significant effect and can reduce the need for applied nitrogen.

Cassava response to phosphorus. A field trial was eonducted on Egbeda soil series (Oxic Paleustalf) at the IITA site in Ibadan to determine the external and internal P requiremeut of cassava cultivar Isunikankiyan. The cassava was harvested 15 months after planting. Tuber yield responded significantly to P application. Tuber yields are correlated with P concentration at low levels in the soil, but not so at higher P values. Thus, to obtaiu 95% of the maximum yield, the required P concentration in the soil solution established at planting is estimated to be about 0.04 ug P/ml. This value corresponds to a Bray no. 1 extractable P concentration of about 8 ppm P.

The degree of myeorrhizal infeetion of the cassava roots was also determined. During early growth the pereent root infection declined with increasing P concentration in the soil so-

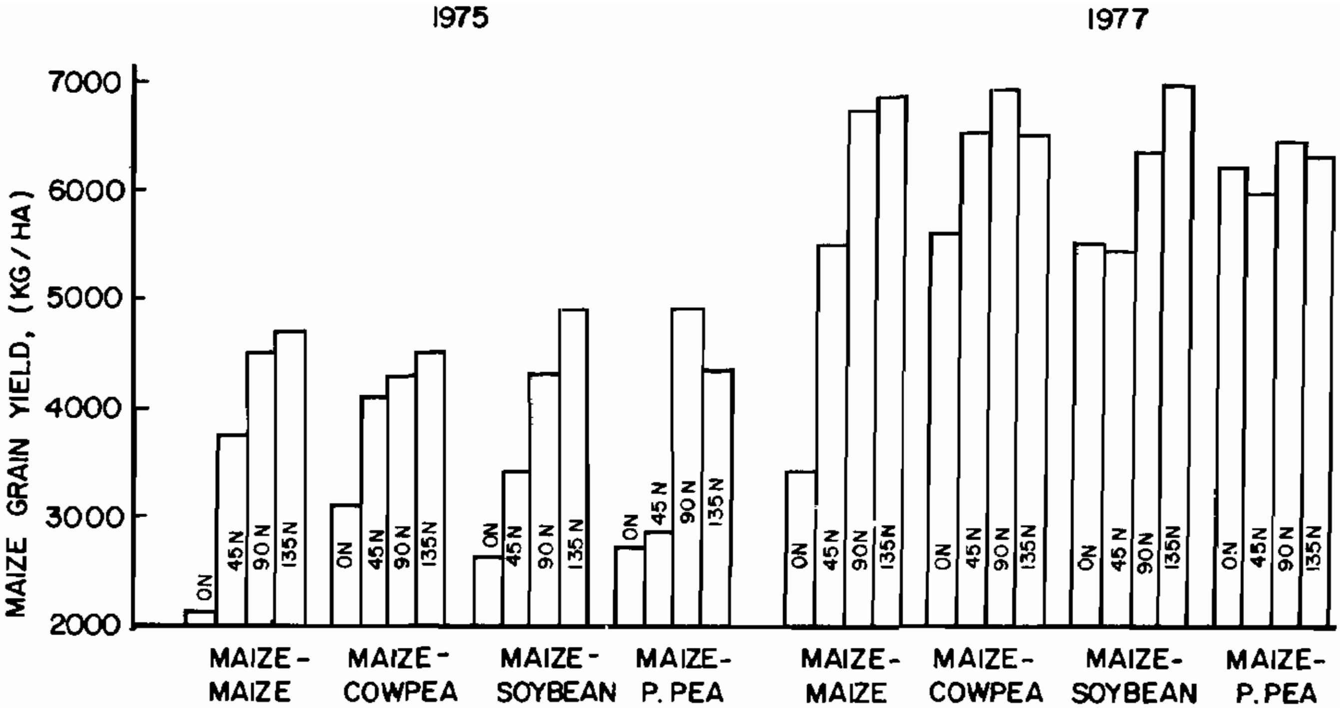


Fig. 6. Effect of crop rotation and nitrogen rates on maize grain yield on Iregun soil.

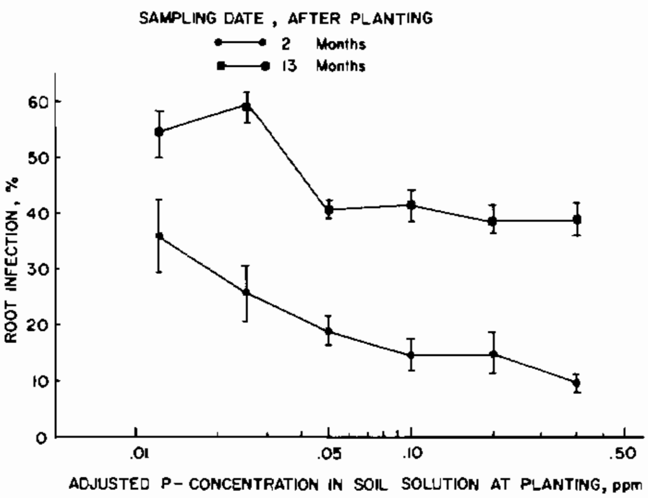


Fig. 7. Effect of adjusted P concentrations in soil solution at planting on % mycorrhizal root infection.

lution (Fig. 7). There is an increase in percent root infection with age. At 13 months after planting the effect of initial P concentration on the percent root infection is less pronounced, which may be related to the decrease in P concentration with time.

It appears that the low P response of the cassava crop in the field and also ability to do well in soils with low P status, may in part be attributed to the high degree of mycorrhizal root infection, which enable the plant to forage more P, particularly at low soil P levels.

P concentrations in the blades and petioles of the uppermost fully mature leaves determined at 3 and 13 months after planting increased with increasing P rates. At 3 MAP, the critical P concentrations in blades and petioles are estimated at respectively 0.50 and 0.38 percent P. Increased P rates also significanrly increased N content of the leaf blades.

Effect of soil heating on soil properties and plant growth. Burning of plant residue as a method of land preparation is widely practiced under traditional farming systems in tropical Africa. However, very little information is available on the direct effect of soil heating during burning on properties of tropical soils and also on plant growth. Surface soil temperatures and duration of heating observed under field conditions vary widely depending mainly on the nature and quantity of plant residue burned. Laboratory investigations were conducted to simulate the effect of burning. The effect of heating of Egbeda (Oxic Paleustalf) surface soil for six-hour periods at various temperatures is shown in Table 40. Heating the

Table 40. Effect of heating on some chemical properties of Egbeda surface soil.

Heating temperature (°C)	pH-H_2O	Organic C (%)	NH_4OAC Extractable K	Ca	Mg	Bray P-1	DTPA-Extr. Fe	Zn
			ppm				ppm	
Control	6.1	1.75	90	690	224	7.2	27.3	2.9
70	6.2	1.75	90	690	239	8.4	–	–
100	6.1	1.70	90	705	240	9.6	35.9	4.1
200	6.2	1.48	90	603	195	39.6	54.5	4.5
500	6.9	0.10	20	465	60	18.3	39.7	0.9

soil at 200 C decreased the Organic C content and the extractable P, K, Ca, Mg, Fe and Zn were also decreased. Soil heating appeared to have a significant effect on crop growth. Heating the soil at low temperatures, which has little effect on the chemical soil properties, significantly improved the growth of rice (Table 41), while heating at 200°C and 500°C had an adverse effect on dry matter yield and growth of rice.

Table 41. Effect of heating treatment of Egbeda soil and fertilizer application on plant height and dry matter yield of rice cultivar IR-20.

Heating temperature (°C)	Plant height (cm) 0	Plant height (cm) NPK	Dry matter weight (mg/pot) 0	Dry matter weight (mg/pot) NPK
Control	29.8	31.4	974	1482
70	32.5	31.8	1065	1445
100	34.4	32.9	1197	1470
200	29.5	28.3	1080	1169
500	9.9	13.4	53	107
LSD .05	2.4		133	

Fertility management of Ultisols

Effect of liming and nitrogen application on cowpeas. In previous studies to identify the tolerance of various grain legume species and cultivars to soil acidity using an Ultisol from Onne (Typic Paleudult), it was observed that cowpea shows higher degree of tolerance to factors associated with soil acidity than soybean, lima bean or pigeon pea. However, some of the cowpea cultivars grown in unlimed Onne soil showed poor early growth and chlorosis. Greenhouse studies were therefore conducted to determine the causal factors. Nitrogen and Ca deficiencies associated with poor nodulation and N- fixation appear to be limiting factors for good cowpea growth on the Onne soil. Application of mineral N in the absence of liming increased Ca content of plant tops and partially corrected Ca deficiency in cowpea TVu 1977-OD. Without liming and at low lime rate, N application increased plant dry weight (Figure 8). Application of mineral N had little or no effect on plant dry weight at higher lime rates. Nodulation was improved with application of low and moderate lime rates (250-1000 kg $CaCO_3$/ha), which also corrected N deficiency. High lime rates (5000 kg $CaCO_3$/ha) suppressed nodulation, plant dry matter yield and the Mg, Zn and Mn concentrations of plant tops. Application of low lime rates and small amount of starter mineral N appears to be important for growing cowpeas on the Onne soil.

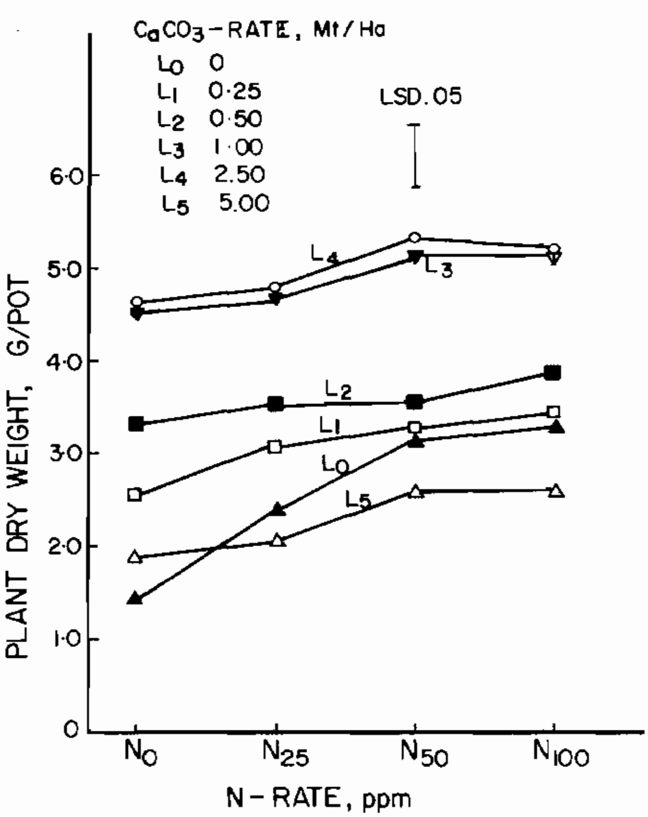


Fig. 8. Effect of application of N under various rates of liming soils low in Ca.

Effect of crop residue management

Field trials were established at Onne to provide a better understanding of the importance of the local practice of burning the plant residues during land preparation particularly on the acid soils. In this trial, burning and retaining the plant residue as mulch after land clearing and fertilizer combinations are compared. Preliminary data from this trial showed that burning plant residue from 6 to 7 years of fallow (predominantly Anthonata) added about 560 kg ash/ha. This amount of ash increased the pH-H_2O of the 0-7-5 cm surface soil from 4.29 to 5.03. Addition of the ash also increased the amounts of extractable P, cations and micronutrients and also significantly decreased the amount of extractable Al. The trial is still in progress.

Soil management – Physics of soil erosion

Climatic erosivity. Experiments were continued on the characterization of climatic erosivity. Previous observations on drop size measurements have indicated the following relationship between median drop diameter (D_{50}) in mm, and peak rainfall intensity (I, mm/hr., sustain over a 7.5 minute period):

$$D_{50} = 2.59\ I^{0.40} \qquad (r = 0.97)$$

The limitation of this equation lies in the fact that only the maximum intensity was taken into consideration, which may account for the large exponent. Sand splash, measured by Ellison's splash cup, was correlated with various erosivity indices (Table 42). Whereas the amount of sand splashed was related exponentially to indices AI_m and EI_{30}, it was linearly related to D_{50} and KE>1.

Table 42. Comparison of erosivity indices with sand splash (A) using Ellison's splash cup (number of rainfall evens 24).

Erosivity index	Regression equation	Correlation coefficient (r)
D_{50} (mm)	$A = -0.-0 + 0.91\ D_{50}$	0.99
AI_m (cm^2/hr.)	$A = -0.67\ (AI_m)\ 0.39$	0.94
EI_{30} (foot-ton/acre)	$A = -0.18\ (EI_{30})\ 0.32$	0.95
KE > 1 (foot-ton/acre)	$A = 0.77 + 0.0014(E)$	0.89

The measurements of drop size distribution by "Distromet" has shown D_{50} ranging between 2.5 and 3 mm for the majority of rains received between August and October 1977. Seventy percent of the rains fell with a drop size ranging from 2.25 to 5.50 mm. This particular storm was highly erosive with an energy load of 69 Joules/mm of rain. Research will continue to characterize climatic erosivity of tropical rains in relating sand splash with energy load, drop size distribution, intensity and wind velocity, for different agroecological regions of the tropics.

Slope length and degree effect. Experiments were conducted in field runoff plots of 1, 5, 10, and 15 percent slopes to investigate the effect of 5, 10, 15, 20, and 25-m slope length on runoff and erosion for bare fallow plowed soil surface. Runoff and soil loss per unit area is exponentially related to slope length as shown in Table 43. For gentle slopes of 1 and 5 percent, erosion is proportional to the reciprocal of slope length. However, for steeper slopes the erosion increases as a square root of slope length. The validity of these results will be further assessed.

Effect of cumulative soil loss on maize yield. Maize grain yield, grown on land eroded to various degrees and with recommended levels of chemical fertilizers, declined exponentially with successive increase in soil erosion:

$$\text{Yield} = 30.5\ E^{-0.5}$$

where yield and erosion are both expressed in t/ha. This type of cause-effect relationship has limitations that may be due to the crop, cultivar, and the soil conditions of the experiment. More basic research, relating crop productivity to degradation of soil physical and chemical characteristics (infiltration, porosity, organic matter, CEC, etc.) is needed to develop empirical models to assess the quantitative effects of soil degradation on crop yield.

Crusting and seedling emergence. The effect of matric potential, aggregate size, and soil temperature on germination of maize, cowpea, soybean and rice was investigated in the laboratory. Both soil moisture potential and aggregate size had a significant effect on seed germination. Whereas rice germination at zero suction was between 50 and 100 percent, it was 0.30 percent for cowpea, 0 to 40 percent for soybean and only 0 to 7 percent for maize.

There was no germination of any of the crops at 15 bar suction. At 10 bar suction, germination ranged from 40 to 60 percent for cowpeas, 20 to 30 percent for soybean, 13 to 30 percent for maize, and merely 7 to 13 percent for rice (Table 44).

Effect of soil conditioners and mulching on runoff and soil loss. The comparative effects of soil conditioners (PAM, Bitumen, Soil Penetrant) on runoff and erosion were evaluated on field runoff plots and compared with that of control, mulch, and no-tillage system (Table 45). The treatments mulch, no-tillage, PAM, and bitumen provided good erosion control for the gentle rains received during the 1977 second season. Soil penetrant was not effective in controlling erosion. Soil chemical properties and crop performance were also compared. Straw mulch was the most effective conditioner for growing crops on this fragile tropical Alfisol.

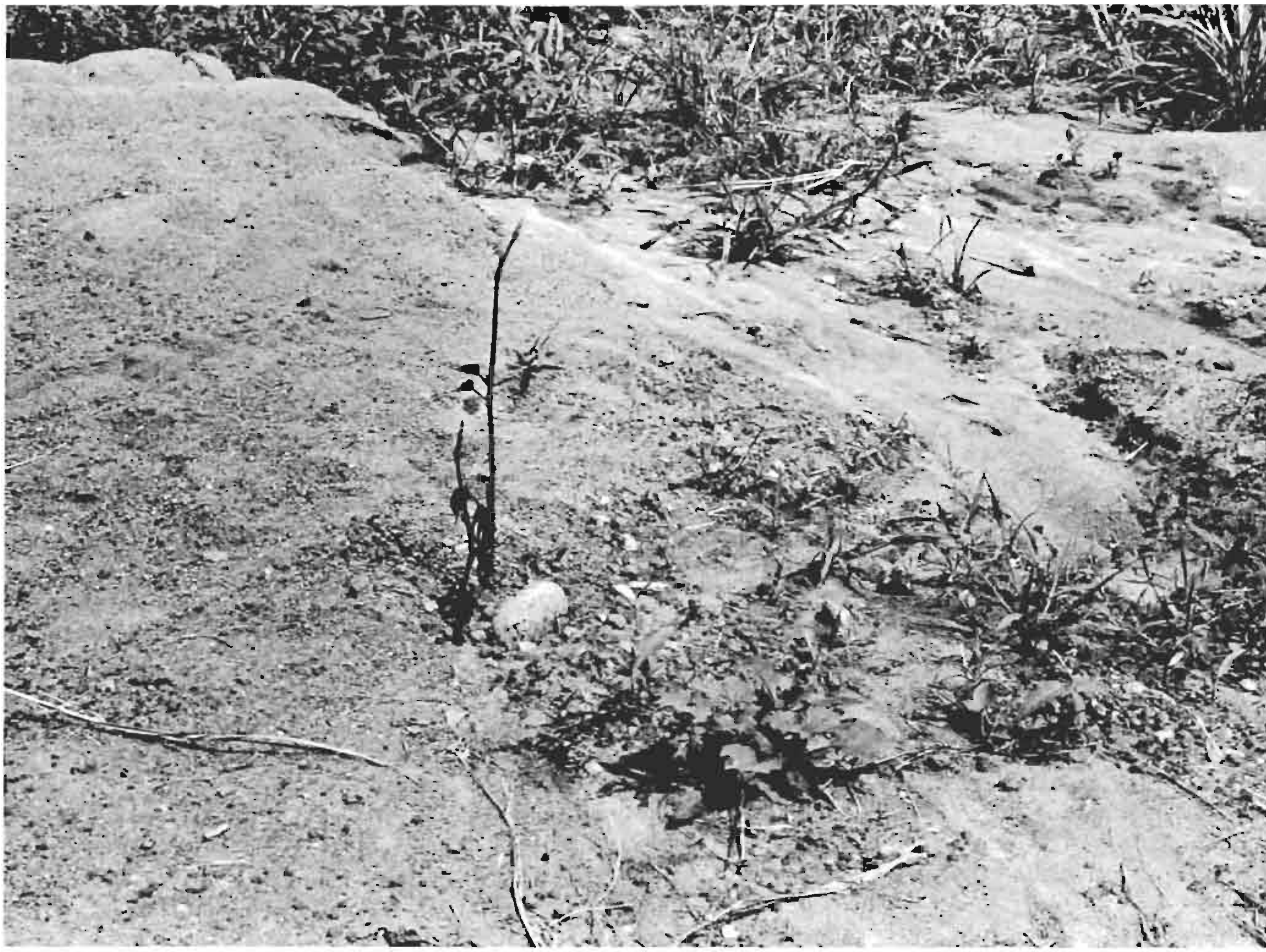
Effect of mulch rate on runoff and soil loss. Runoff and erosion decrease exponentially with increase in surface cover provided by straw mulch (Table 46). Increase in the infiltration with high mulch rate was attributed to high mean-

Table 43. Effect of slope length (m) and degree on soil erosion E (t/ha).

Slope %	Soil loss on different slope lengths (m): 5	10	15	20	Regression equation	
1	0.4	0.05	0.7	0.07		
5	10.4	6.7	5.4	2.4	$E = 58.22m^{-1}$	r = –.93
10	7.4	14.6	16.4	11.3	E = 4.72m 0.4	r = 0.67
15	9.1	17.2	19.2	17.8	E = 4.22m 0.5	r = 0.90

Table 44. Effect of aggregate size and soil moisture potential (bars) on seed germination (%).

Aggregate size (mm)	Moisture potential (bars): 0	0.005	0.01	0.03	0.05	0.1	0.3	1.0	3.0	5.0	10.0	15.0
Maize												
2	0	67	80	93	100	93	100	100	100	73	27	0
2–10	7	93	93	100	100	93	100	93	100	73	27	0
10–50	7	93	87	100	100	100	93	100	100	67	33	0
Rice												
2	50	73	87	97	97	100	100	100	100	87	7	0
2–10	77	90	100	100	90	100	93	100	97	70	13	0
10–50	97	90	100	100	100	97	93	100	100	77	7	0
Cowpea												
2	0	27	53	100	100	100	100	100	100	93	47	0
2-10	27	47	67	100	93	100	100	100	100	93	60	0
10-50	20	67	60	100	100	93	93	100	100	93	40	0
Soybean												
2	0	20	40	93	80	100	100	100	93	100	33	0
2–10	7	67	80	100	87	100	100	93	87	93	33	0
10–50	40	53	47	93	100	100	100	100	100	80	20	0



Tropical soils are, generally, highly erodible. A lot of top soil is therefore lost every year where the erosion is unchecked, rendering the soil progressively unproductive.

Table 45. Effect of soil conditioners on runoff and erosion (total rain = 432 mm)

Treatment	Runoff mm	Erosion (t/ha)
Control	35.0	4.8
PAM	0.0	0.0
Bitumen	1.4	0.0
Soil penetrant	26.1	1.9
Mulch	0.0	0.0
No-tillage	0.0	0.0

Table 46. Effect of mulch rate on runoff and soil erosion. (Total rain = 432 mm.)

Mulch rate t/ha	Runoff mm	Erosion (t/ha)
0	75.4	9.6
2	43.4	2.3
4	15.2	0.5
6	5.4	0.1
12	0.0	0.0

weight diameter of structural aggregate, more porosity, bigger pores due to more earthworm activity, and absence of crust formation. This experiment has now been conducted for two years, and there have been significant changes in soil chemical properties attributable to mulch rate treatments.

Mulches and soil management

Mulching and seedbed preparation. The influence of black and white polythene sheets on soil temperature, soil moisture, and on root growth of maize was compared with maize grown on ridges, straw mulch, and bare ground surface for the third and fourth crops on the same location. The root density of maize at 2 WAP was the highest under straw mulch and the least on ridges (Table 47). The stress was highest on ridges due to high soil temperature and low soil moisture. Maize yields were 5.97, 5.53, 4.74, 3.14, and 2.39 t/ha for black polythene, straw mulch, bare ground, ridges, and clear polythene respectively.

Effect of mulch material on crop yields without fertilizer. Mulch material, whether cereal or leguminous, had a significant effect on maize yield. The highest maize grain yield was obtained with a mulch material of cowpea and soybean husk applied at 6 t/ha (Table 48). The choice of an appro-

Table 47. Mean root dry weight (g/plant) as affected by mulch and seedbed preparation at 2 WAP.

Depth (cm)	Black polythene	White polythene	Straw mulch	Ridges	Bare ground
0.05	0.161	0.142	0.240	1.125	1.145
5–10	0.079	0.080	0.090	0.038	0.088
10–15	0.020	0.027	0.028	0.020	0.044
15–20	0.012	0.012	0.024	0.007	0.020
20–25	0.012	0.009	0.007	0.004	0.017

Table 48. Mulch response to maize yield without fertilizer.

Mulch material	Seedbed	Maize yield t/ha
None	without mounds	0.52
None	with ridges	1.43
None	on the flat	2.19
Maize stover	on the flat	3.12
Rice stover	on the flat	3.27
Pigeon pea	on the flat	3.27
Soybean	on the flat	3.77
Water lettuce	on the flat	3.93
Cowpea-soybean husk	on the flat	4.30
S.E.		1.00

priate mulch material, grown particularly for this purpose in suitably designed cropping systems, can reduce the dependence on commercial fertilizers.

In-situ mulch material of various grasses and leguminous crops. *Stylosanthes*, killed by chemical or mechanical means, produced excellent mulch material for sod seeding of maize, cowpea, soybean, pigeon pea or cassava. Crop yields were similar to those reported in 1976. Mulch produced by *Pueraria* and *Centrosema* produced yields similar to that of *Stylosanthes* only when these covers were effectively suppressed by herbicides.

No-tillage and maize yield at various fertility levels. At both low and high fertility levels, permanent no-tillage plots outyielded the plowed treatments for a maize-maize rotation. Low maize yields in the plowed plots are attributed to high weed competition, and a gradual degradation of inherent fertility by preferential nutrient removal due to soil erosion.

No-tillage trials on an Ultisol. In general maize on tillage plots outyielded the no-tillage treatments by 15 to 20 percent. Mean maize grain yield was 1.30 t/ha for no-tillage compared with 1.55 t/ha for the plowed plots. Cowpea yield was extremely low and was only 160 and 150 kg/ha for the no-tillage and plowed plots respectively. Cassava performed the best of all crops and yielded satisfactorily regardless of tillage system.

A convincing demonstration that minimum tillage techniques (with mulches) can substantially boost production, reduce labor and increase farm income. Some farmers are now trying out minimum tillage systems in comparison with traditional methods.

Table 49. Nutrient level in worm casts from no-tillage and plowed plots receiving no fertilizer.

Tillage system	pH		CEC meg/100g		Organic carbon %		Total nitrogen %		Calcium meg/100g		Magnesium meg/100g	
	a	b	a	b	a	b	a	b	a	b	a	b
No-tillage	5.9	6.2	17.32	10.64	1.58	1.00	0.20	1.19	14.85	9.15	1.28	0.61
Plowed	6.8	7.1	13.41	4.79	1.43	0.48	0.18	0.07	10.40	3.68	1.55	0.39

a = Cast *b = Soil*

No-tillage experiments with paddy rice. The influcnce of four levels of N and P combinations, with direct sowing and transplanting, on rice yield was compared for no-tillage and puddling systems of seedbed preparation. In the first year of this experiment, no significant differenccs in rice yield were observed between tillage treatments.

Earthworm activity and soil characteristics. Crop yields on no-tillagc and mulch treatments are generally high, whereas runoff and erosion are low compared with plowed treatments. Good soil structure and high infiltration rate in the no-tillage plots are partly attributed to earthworm activity. The chemical characteristics of worm casts are more favorable for plant nutrients than the soil from which casts are derived. The organic carbon, nitrogen, and phosphorus can be two to three times more in casts than the soil (Table 49). This is a natural recycling mechanism, and can have an important effect on fertility management of tropical soils.

Energy Management – Crop Engineering

The primary objective of the agricultural engineering component of the FSP is to develop and adapt tools and machines which will complement improvcd methods of crop production and land management being developed elsewhere in the institute. The focus of crop engineering in 1977 was on developing equipment suitable for zero and minimum-tillage farming practices adapted to the low-resource farmer's situation.

CDA application of pesticides

The logistical difficulties of transporting 400 to 500 l/ha of liquid for the conventional (knapsack) application of insecticides and herbicides suggest that the use of controlled droplet applicators (CDA), which takc 5-15 l/ha would be a realistic, low-energy alternative. The "Micron" CDA system has been evaluated against conventional applicators and shows an enormous saving in labor requirements for crop production (Table 50).

Table 50. Comparison of man-power requirements, using no-till versus conventional crop establishment systems, for maize and cowpea on savannah (Imperata) grass covered land.*

Operation	Man-hour/ha no-till	Man-hour/ha conventional
A. Field preparation:		
a. Slash, burn and till manually		180
b. CDA spraying with contact herbicide	4	
B. Seeding:		
a. Manual planting into tilled soil with machete (low plant population)		20
b. Auto-jab planting (maize-cowpea 75 x 25)	35	
C. Weed control:		
a. Manual weeding twice		280
b. CDA spraying with pre-emergent herbicide	4	
D. Fertilizer application:		
a. Banding by hand along rows		25
b. Using hand propelled band applicator	6	
E. Plant protection:		
a. Knapsack spraying of insecticide, twice (on cowpea)	2	10
Total man-hour spent to establish the crops each on 1 ha.	51	515
Comparison of yields	2400	1255

**No-till tools used were CDA sprayers (herbicide and insecticide) and IITA automatic "jab" planter.*

A problem encountered with the CDA involved patches within adequate and uneven spray coverage. The cause was due to blockage of the venting system, especially noticeable when using "flowables" which formed a cake inside the vent tube. This was relieved by increasing the diameter of the vent pipe, and has now been incorporated in production models of the applicator. Other faults emerging during field use are faulty or severed connections in the electrical system, the poor dependability of the motor spinning the disc, and inadequate sealing of the motor against ingress of chemicals and water. Many of the defects have now been resolved in cooperation with the manufacturer. The motors of CDAs are powered by a set of flashlight batteries, the herbicide sprayers consuming about 1.5 watts and the insecticide sprayer, 5-6 watts.

As the cost of photo-voltaic cells (now about $18 per watt) is expected to drop within some years, the potential for operation of the CDA's using solar power was investigated. A photo-voltaic panel containing 38 semi-circular silicon cells was assembled onto a light shoulder-supported frame to provide over 6 watts at 1 watt to 14 volts; Ni-Cad cells were used in the application to absorb surplus electrical energy for use during dull periods and to act as a voltage stabilizer. Subsequently the Ni-Cad cells were replaced with regular flashlight cells maintained at peak voltage by the panel. Despite the low humid tropical solar intensity of about 350 g.cal/cm^2/day, continuous (6 hrs/day) daily use was possible without change of batteries. The potential for solar energizing of such low-powered agricultural equipment will improve with the anticipated industry improvement in conversion efficiency (10-15 percent) and reduction in cost. The expected figure of $0.50 per watt is less than the cost for thermally generated electrical power sources.

The ability to apply herbicides easily and quickly with the CDA enables the technique to be used in rice culture to achieve a ratoon crop of reasonable yield with minimal increases in labor inputs. The second rice (ratoon) crop yielded 70 percent of the yield of the first crop, in 60 percent of the time to maturity, and with only 12 percent of the man hours for crop establishment.

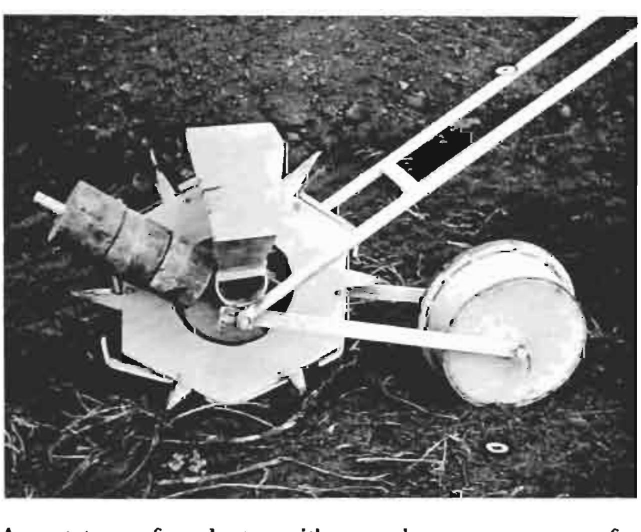
Planters

Three levels of planters (seeders) which will facilitate seeding into a herbicide desiccated or mulch covered field are being developed. The first "level" of planter must be suitable for the operator to plant selectively in a field where stumps, trees and roots exist (such a field out of bush fallow); the second level is hand operated on cleared fields and the third level is suitable for operation with a low horsepower tractor.

Automatic feed "jab" planter. The IITA Annual Report 1976 described an automatic feed "jab" planter, developed after the lines of the (late 1800s) US corn planter. Field testing revealed inconsistent metering of seed, particularly when planting maize with its wide variability in size, length, breadth and depth. Efforts to develop a simple, cheap and effective seed grader were unsuccessful. A compromise was reached by changing the seed-metering plate from 7 mm thickness to 3.5 mm, and a change in the design of the cut-off mechanism from foam to brush (old toothbrushes were satisfactory). Plans for this planter are available on request.

Several other types of hand operated injection planters were evaluated against the automatic feed jab planter. As a result, a prototype, of much simpler construction and equal effectiveness has been built. Drawings of this planter will be available in 1978.

Rolling injection planter. With the assistance of a VITA (Volunteers for International Technical Assistance) cooperator, the concept of a rolling injection planter has been developed at IITA. This machine uses the principle of the hand operated "jab" planter but is mounted on the periphery of a wheel to provide consistent in-row spacing, and the speed of the rolling motion to inject the planter through the trash covered soil and insert the separately metered seed at the required depth. (Fig. 9.) Initial evaluation showed the necessity (e.g., when planting maize) for a seed cover-compactor.



A prototype of a planter with a seed cover-compactor for planting maize.

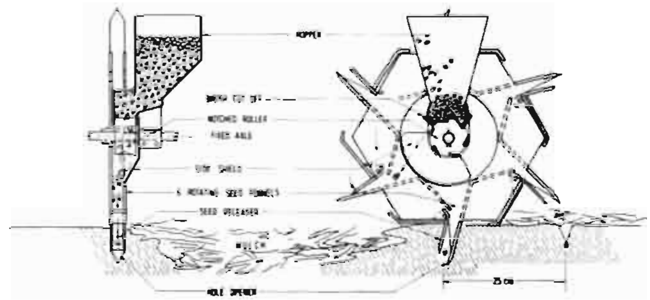


Fig. 9. Schematic drawing of a rolling injection planter.

The prototype machine is illustrated in the photograph. Several versions of this planter have been developed, both for pushing and for pulling, for single- and double-row operation. At least for maize and cowpea one version appears a satisfactory compromise of simplicity and ease of operation. The hand-pushed model shows potential for a planting rate of 3½ hr/ha (at 1 m row spacings) as against nearly four times this when using the automatic feed "jab" planter.

A model of the rolling injection planter was developed for mounting behind a 5-hp tractor, with facility for driving out to the field, manual raising and lowering of the planters from the driving seat, and the ability to go through the stalks of harvested maize, still standing, pushing them down while simultaneously planting directly into this trash. The possibility here, of spraying both contact and pre-emergence herbicide just after planting would further help reduce "dead" time between harvest of the first crop and planting of the next one.

Fertilizer applicator for zero tillage. Mulch farming trials in 1976 (see IITA Annual Report 1976) identified fertilizer application as an area of constraint earlier eclipsed by higher field-preparation and weed-control times in traditional farming practices. A simple hand-pushed fertilizer band applicator was therefore developed to dibble fertilizer in a band along the side of the plants emerging through a mulch.

Figure 10 provides a schematic design of the applicator and of the spiral used for metering fertilizer into the feed slot for deposit alongside the planted row. Rates of application are achieved from 5 to 20 g/m, corresponding to about 200 kg/ha when applied to rows 1 m apart. The speed of application was about 4 hr/ha. The narrow configuration of the applicator enables it to operate easily even between rows of rice planted 25 mm apart.

Establishing rice in poorly drained soils. While rice can be easily drilled into well drained soils, the crop does not emerge satisfactorily when drilled into wet, poorly drained soils which are typical of most rice grown under poor water management in West Africa. Thus, three alternative systems of establishing rice in poorly drained fields were compared with the practice usually adopted of hiring a tractor for initial tillage, followed by manual tillage, seeding and manual weed control (Table 51).

System 2, using a 5-hp rotary tiller to till the soil roughly, so that seed broadcast onto it will be in contact with the moist soil for germination, followed by chemical weed control applied using the CDA applicator suggests this as the most appropriate technique on small farms if tillage services and post-emergence herbicides are available. System 3, direct seedling into the soil, was not satisfactory given the laborious task of planting up to 160,000 hills/ha. System 2 may be considered a "minimum-tillage" system as it involves the least tillage required for broadcast seed to be in contact with the soil, although not inserted into it. Herbicide application techniques are relied on for subsequent weed control.

System 3, direct seedling into the soil, was not satisfactory given the laborious task of planting up to 160,000 hills/ha. System 2 may be considered a "minimum-tillage" system as

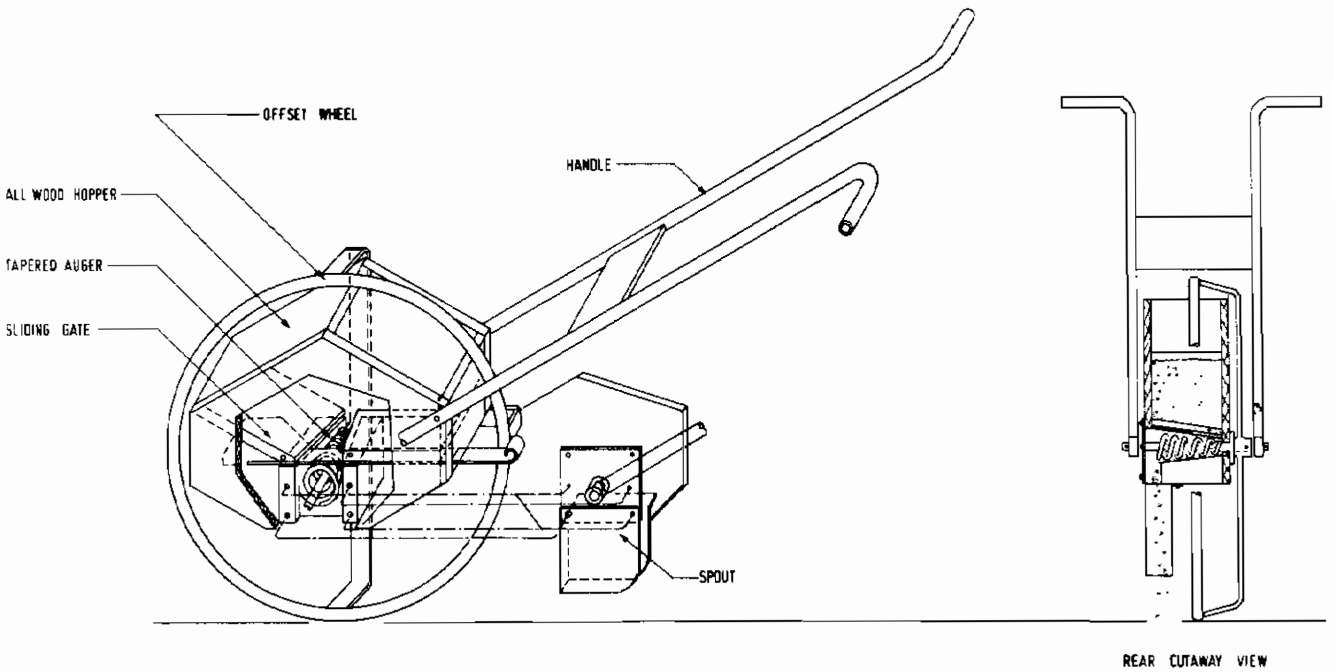


Fig. 10. Schematic drawing showing internal parts of the IITA fertilizer band applicator.

Table 51. Rice establishment on hydromorphic midland (phreatic) soils. Machine and man-hour requirements of alternative systems.

System 1 (machine and manual, only)	Machine ha/hr.	Man ha/hr.
Plowing (hand-tractors)	16	32
Comb harrowing (hand-tractors)	8	16
Seeding (2 row push seeder, rows 25^{cm} apart)		42
Weeding (inter-row push-pull type)		76
Insecticide spraying (CDA, twice)		1
Totals:	24	167
System 2 (machine plus Ag. Chem.)		
Rotary tilling (hand-tractor)	13	28
Fertilizer application (broadcast)		3
Seeding (broadcast)		3
Comb harrowing – lightly (hand-tractor)	4	8
Herbicide spraying (CDA, twice)		8
Totals	17	48
System 3 (hand plus Ag. Chem.)		
Herbicide spraying (CDA)		4
Seeding (Auto-Jab-Plant, 25^{cm} x 25^{cm}, 160,000 hills/ha)		140
Herbicide spraying (CDA)		4
Totals:		148
Conventional – for comparison		
Field preparation (using contract tractor for initial tillage)	4	120
Seedling (hand dibbling in rows 25^{cm} apart)		300
Manual weeding by hand and hoe (twice)		500
Totals:	4	920

Notes: 1. (Ag. Chem.) herbicide used was propanil + 245 TP.
2. In system 3, stand was poor due to inadequate drainage.
3. "Conventional" data from N.A.F.P.P. surveys.

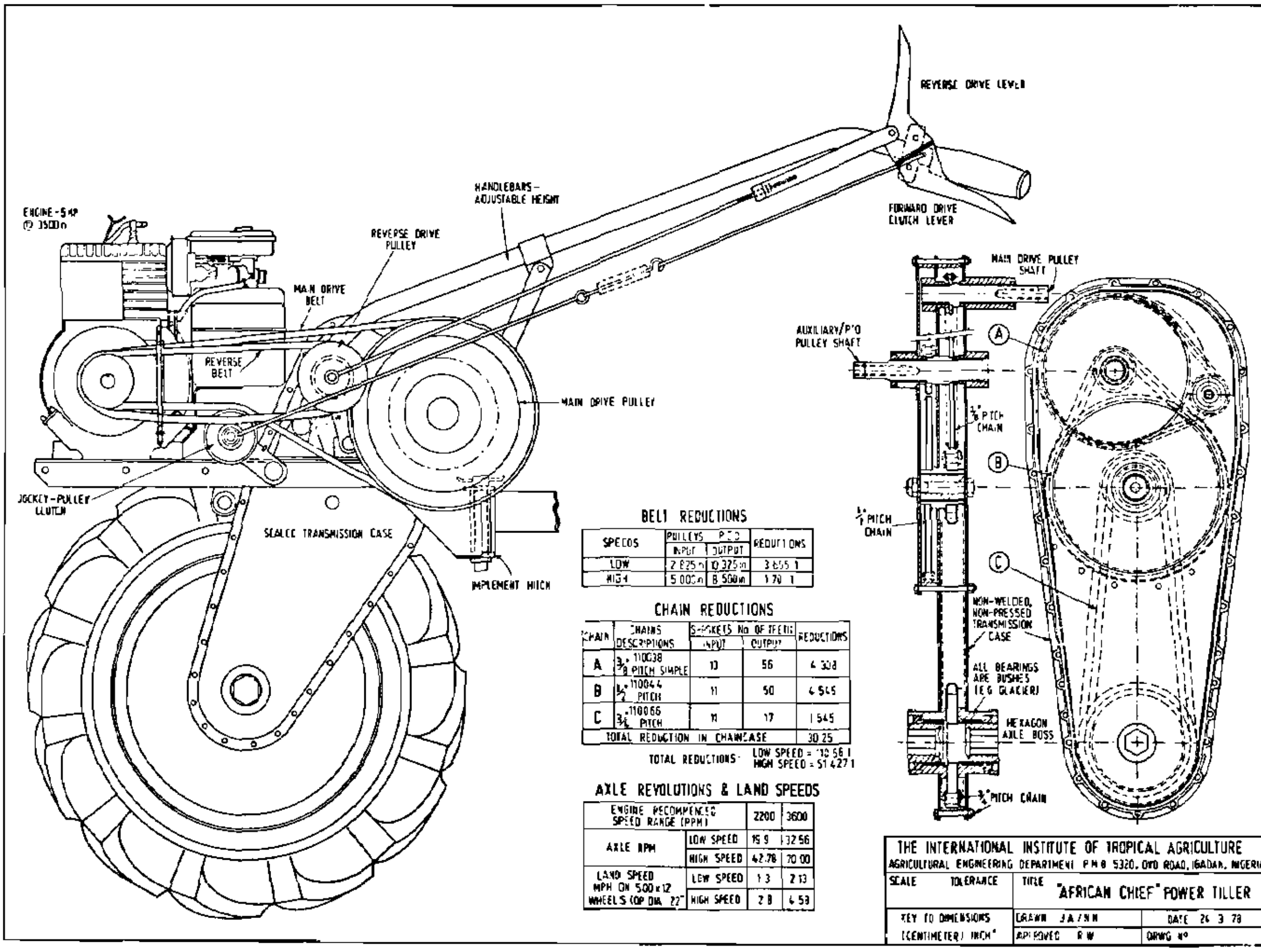


Fig. 11. Schematic drawing of the "African Chief" Power Tiller's features which will enable its manufacture and maintenance in Africa with minimum fabricating facilities.

it involves the least tillage required for broadcast seed to be in contact with the soil, although not inserted into it. Herbicide application techniques are relied on for subsequent weed control.

Development of the "African Chief," 5-hp tractor

A compact 5-hp tractor based on the proven and popular (in Asia) "Landmaster Lion" tractor, but incorporating features which will enable its manufacture and maintenance in Africa with minimal fabricating facilities, has been designed and constructed at IITA. All bearings are bushes, to eliminate the cost and complexity of roller or ball bearings. The internal transmission gears have been replaced by sprockets and chains (Fig. 11). A non-press-found and non-welded fabrication transmission case is a major contribution toward simplicity in manufacture. With a 5-hp engine the "Chief" achieves the operating performance of the 7-hp "Lion," due to more economical selection of transmission reductions. Through most of 1977 the "Chief" as continued in steady and consistent field test and evaluation, with no repairs apart from a change in design of the forward-reverse clutch levers to avoid chance of misuse.

The tractor was developed specifically for the "intermediate-level" and to have the following capabilities:

1. As a sitting, (4-wheel) tractor for:
   (a) Transporting farmer and produce with 0.4-ton capability.
   (b) Propelling a two-row, mounted, "no-till" planter appropriate to a 20-ha farm.
   (c) Carrying a 6-m swath herbicide/insecticide CDA spray rig appropriate to a 20-ha farm.
   (d) Powering a 60-cm front mounted rotary brush cutter.
2. As a pedestrian (2-wheel) tractor for operation in the difficult soil conditions of a rice farm up to 5-ha and for:
   (a) Plowing.
   (b) Rotary tilling up to 150 mm wide.
   (c) Puddling.

Development work on the system, which has been specifically directed toward the small power needs of the intermediate farmer in the humid tropics, will be completed in 1978 for the basic range, and extension of the project commenced.

Non-ferrous casting techniques

A furnace and appropriate boxes for casting up to 14-cm diameter and 0.5-kg weight have been developed. This

A simplified casting technology suited to rural-level casting of components of agricultural tools has been developed at IITA.

simplified casting technology is suited to rural-level casting of components for agricultural tools. A booklet on rural-level casting techniques is being developed.

Post-harvest engineering

During 1977 Phase I of the African Rural Storage Project funded by FAO was completed. The emphasis in this phase was on maize drying and storage under humid conditions.

Planning and initiation of Phase II of the project were completed in 1977. The main emphasis during Phase II, scheduled to be in operation to October 1980, will be on the more important post-harvest processes of the major food crops of the humid tropics, with special reference to West Africa.

The principal research effort in 1977 centered on continued monitoring of insect control methods in maize cribs, observations on crib performance as part of the evaluation of farming technologies, and the initiation of observations on yam storage under freely ventilated conditions.

Five insecticides, available as liquid formulations, were compared on crib-stored maize. Table 52 summarizes their relative performance over the storage period to December 1977.

A reasonable degree of insect control was achieved other than when Decis and Nuvan were used. On the "FSP units," where the application of the insecticides was undertaken with minimum supervision of the farmers, the comparatively effective control by the insecticide suggests the technique could be within the grasp of relatively unskilled operators.

The trials on yam storage are aimed at assessing the possible effect on suppression of sprouting and rotting by dehydrating yams under freely ventilated conditions. Two levels of shading/ventilation are being studied. Results to date indicate that while dehydration does take place at approximately 6 percent per month and rotting seems thus far to be arrested, sprouting does not appear to have been inhibited in the levels of ventilation imposed.

Technology evaluation

FSP in 1977 placed greater emphasis on the integrated evaluation of research findings emerging from its activities, and initiated studies of the diffusion of IITA-generated technology.

"Commercial" evaluation of zero tillage. The application of zero tillage for a simulated commercial maize production system continued in 1977 on an area which had been similarly grown to four crops of maize during the previous two years.

Table 52. Control of insects with alternative insecticides in maize cribs.

Treatment		% Control (Ratio of dead [dead + live insects])			
		Sept.	Oct.	Nov.	Dec.
Actellic	15 ppm admixed + monthly outside*	82	84	89	88
Actellic	– monthly outside	64	91	83	79
Actellic	monthly outside (FSP units*)		77	85	90
Permethrin	– 10 ppm admixed + monthly outside	96	89	94	96
Permethrin	– 10 ppm admixed	75	76	84	67
Permethrin	– 5 ppm admixed	62	61	70	79
Permethrin	– monthly outside	49	81	97	70
Ripcord	– 10 ppm admixed	73	91	91	84
Ripcord	– monthly outside	56	98	92	86
Decis	– monthly outside	21	75	41	40
Nuvan	– monthly outside	25	53	53	73
Control	– – –	32	53	47	26

*"*Monthly outside" is a monthly spraying of the outside of cribs with a 7½ percent a.i. solution of insecticide at a rate of 15 cc a.i. per 3 t of cobs.*

Maize yields in 1977 on the zero tillage plots continued to be superior to yields obtained from the conventionally tilled lands. The low second season yields of the portion of the conventionally tilled plots were due to massive invasion of stem borers where carbofuran was not applied to the area at planting. Unobserved blockages in the pesticide applicator tubes of the planter occurred when planting on wet, tilled soil. This problem further demonstrated the ease of managing equipment on zero as opposed to conventionally tilled plots.

Table 53. Maize yields on an Alfisol, IITA site, 1977.

Tillage practice/ field	Yield (tons/ha) First season	Second season
Zero tillage		
D1/D2	3.44	1.87
D14	2.70	1.43
Conventional tillage		
D3 to D13	2.23	1.80
D3 to D10*	NA	.59

**Contours with no carbofuran applied, second season.*

The zero tillage technique has proven superior to conventional tillage on economic grounds for a wide range of crop and input prices. The cost advantages of zero tillage include:

1. Elimination of the costs of soil conservation structures and their maintenance.
2. No loss of land from production due to soil conservation structures.
3. Speedier operations.
4. Saving on tractor fuel.
5. Minimized soil erosion.
6. Improvement in levels of organic matter and soil structure.
7. Reduced soil damage and compaction.
8. Increased water retention and reduced runoff.

A negative aspect of zero tillage is its dependence on herbicides for weed control. However, with labor costs generally increasing more rapidly than the cost of agro-chemicals, the availability as opposed to cost of herbicides is the critical constraint.

The zero-tillage technique is now being evaluated at five sites outside IITA to determine its performance over a range of soil types and climates.

Technology evaluation through "unit" farms

Five "unit" farms were developed to provide a focus for integrating and evaluating the potential and constraints of crop production methods and land management developed by the Institute. This on-station evaluation of research within a whole-farm framework is designed to serve as a filter or bridge between research plot experimentation and on-farm evaluation of the most promising technology. As the availability of inputs (credit, implements, improved cultivars, agro-chemicals) and land base per unit of labor force vary within tropical Africa, the five unit farms were designed to represent different resource combinations and as a result, different levels of appropriate technology and farm management (Table 54).

The crop combinations, planting sequences and placement of crops on various aspects of the landscape were chosen to make the most effective use of the farmer manager's resource base — his land, labor and capital. From earlier toposequence based studies of crops in relation to soil type and moisture regimes, cropping patterns based on cassava, maize and cowpea were established on the upland (pluvial) soils; yams, plantain and cocoyam on the lower (fluxial) slopes; and rice and off-season vegetables on the hydromorphic (phreatic) valley bottoms.

Table 54. Management levels of five unit farms established at IITA in 1977.*

	M1	M2	M3	M4	M5
Varieties	V_0	V_1	V_1	V_1	V_1
Crop Systems	C_0	C_0	C_0	C_1	C_1
Land Management	L_0	L_0	L_1	L_2	L_2
Fertilizer	F_0	F_0	F_1	F_2	F_2
Weed Control	W_0	W_0	W_1	W_2	W_2
Mechanization	M_0	M_0	M_1	M_2	M_3
Paddy Development	l_1	l_1	l_2	l_2	l_2
Ha./unit of labor	.3	.3	.3	.6	1.2

**The subscripts in increasing order, represent higher, improved levels of technology. For example for "varieties," V_0 are local lines while W_1 and W_2 are alternative levels of chemical weed control.*

As 1977 was the first year of the unit farms operation, a considerable amount of energy was devoted to site development (particularly the paddies) and the farms were not stabilized. Nonetheless, the following points were verified:

1. The integrated management of hydromorphic valley bottoms and associated uplands in this environment is attractive. The diversification over crops and landscape increases the efficiency of labor use and provides a more stable flow of output over the farming year.
2. Improved cultivars of maize (TZB, TZPB) were profitable under local and improved management levels in the first season and performed well as a sole crop and when intercropped with cassava.
3. 110 to 120-day maize as a second-season crop in the derived savanna remains a risky proposition; the development of a shorter-season cultivar (e.g., TZE) for this zone is appropriate.
4. The improved cassava cultivar 30211 grown is clearly superior (in yield and disease resistance) when compared to the local material.
5. Yams and plantain are profitable on the lower slopes and integrate well within the overall management of the farm units.
6. Important components of the management of hydromorphic valley bottoms are water and weed control.
7. With the CDA herbicide applicator for weed control and a minimum tillage planter, a farmer has the potential to handle several times the previous area cropped with a higher level of output, compared to currently used systems of hoe cultivation.
8. Under the crop management system mentioned in (7), harvesting and post-harvest handling and processing of crops may well become effective constraints on farm production.

The evaluation of research results in an integrated, though simulated, farm environment by a multi-disciplinary team of IITA scientists has identified some limitations in components of proposed technologies. These findings have contributed to the focus of collective research within the Institute to the modification of proposed management practices to reduce these constraints.

Implementation of NAFPP plan

June 30, 1977 concluded Phase I – the pilot operations and planning stage of the Nigerian National Accelerated Food Production Project (NAFPP). The plan was published under the title *A New Dimension for Nigerian Agriculture* and presented to the Federal Ministry of Agriculture and Rural Development who accepted and agreed to implementing the plan and issued guidelines for its implementation.

During Phase I, the research and extension components were tested in five plot states. These components will continue as the basic plans of action. Modifications and improvements are being incorporated to include fewer and better mini-kit trials, better selection of participating farmers, more fertilizer and herbicide trials, more demonstration plots, organization of farmer groups, and personnel development through intensive training courses. Whereas the research and extension components have been field tested in the pilot operations, the third component, the Agro-Service system was not field tested before implementation. Flexibility exists for the guidelines that were established by the government for the implementation of the Agro-Service system to be redefined and modified with accumulated experience in their operation.

Essential ingredients for operational success as identified in the NAFPP Plan and endorsed at a planning workshop for the Agro-Service Centers were a uniform plan of aetion, an autonomous organization with accountability and strong management emanating from a manpower development program. The implementation committees set up for developing the Agro-Service Centers in each state are interpreting the guidelines to meet local government requirements.

Diffusion and adoption of cassava technology. One of the major thrusts of IITA's involvement in the NAFPP has been the introduction of a cassava production package in southeastern Nigeria. Although cassava is the dominant food crop in the region, the practice recommended was to intercrop with maize (TZPB). This has proved to be more profitable than sole crop cassava, is in line with farmers' customary practices and also reduces the spread of bacterial blight disease in cassava.

The yield of improved cassava intercropped with maize (over 14 t/ha) was three times that of the local cultivars, while maize yields (2 t/ha) were at least doubled. After allowing for the increased cost of the new technology (principally labor for ridging and agro-chemicals), profits were doubled, compared to local cultivars and practices. This technology is clearly profitable, and justifies the considerable effort that went into its extension.

Demonstration plots were used to encourage adoption of the new methods of cassava production. Among the groups examined, the best included those whose members were most closely related. The performance of the group was also related to the capability of the extension officer; the major constraint to adoption of the new technology was unavailability of inputs. The adoption of components of the package by farmers not in the groups was dependent more on the success of neighboring groups and a farmer's personal contact with group members than on the demonstration plots.

In all 12 loeations, farmers within and outside the target groups considered that high yields and early maturity were the most important attributes of the improved cassava. However, mass adoption of the total package (cultivars, spacing, ridging, fertilizer, plant protection) appears unlikely at present because inputs are not always available, and the costs (partieularly labor costs for ridging) and complexity of the package is high compared with current practices.

Outside the supervised group plots, the new cultivars of cassava were usually planted according to traditional practices. Almost all farmers who grew the improved cassava had experienced difficulty in obtaining inputs and planting material. This is one of the problems that Agro-Service Centers hope to solve.

It is too early to specify the effects on farmer income of the program. Where maize marketing had been successful, farmers were aware that their income had increased; but the extra was largely used to repay the loans for the maize/cassava package.

The NAFPP cannot also dispose of the extra maize at prices attractive to the farmers. Gari is the most profitable form in which to sell cassava, but farmers feel that the capacity to process cassava in the villages is a factor that limits potential sales.

VIROLOGY UNIT

A new disease, discovered in maize at IITA was proved to be caused by maize dwarf mosaic virus. The virus is mechanically transmissible, belongs to the Poty-virus group of aphid transmitted viruses and is closely related to or identical with sugarcane mosaic virus and sorghum red stripe virus. Only a few plants out of populations of most cultivars, developed or used in the maize breeding program at IITA, were found to develop characteristic symptoms after artificial inoculation. This partly explains the low infection incidence observed in the field.

Maize streak virus was proved to be efficiently transmitted by *Cicadulina triangula*, not earlier reported as a vector of this virus. Streak disease symptoms commonly observed in rice at IITA, but, to our knowledge, not earlier reported for rice, proved to be caused by a virus which was found to belong to the streak virus complex of maize and several grass weed species. Investigations into the etiology of other virus-like diseases of maize and rice are in progress.

A useful extension of the *Dioscorea rotundata*-virus indexing method was found in a local lesion assay on *Chenopodium amaranticolor* (or *C. quinoa*); inoculated from *Nicotiana benthamiana*, earlier identified as a sensitive alternate host for this virus. It is necessary that yam seedling is included as a control, since *N. benthamiana* is a host for many different viruses, inducing similar symptoms.

The sweet potato virus might have a reservoir in a wild sweet potato-like plaut, fouud in the Port Harcourt area of eastern Nigeria. It showed the same type of symptoms and also contained fimamentous virus particles, similar to the aphid-transmitted component of the sweet potato virus disease. However, aphid transmission to the sweet potato virus test plants, *Ipomoea setosa*, could not be achieved.

Cassava mosaic disease (CMD) could not be transmitted to *Nicotiana glutinosa* and *N. benthamiana* in whitefly transmission experiments. A cassava colleetion from a farmer's field near Iseyin (Oyo State), Nigeria, found to be remarkably free from CMD symptoms, persisteutly developed only minor disease symptoms on cuttings further propagated at IITA.

A virus isolated from bambara groundnut *(Voandzeia subterranea)* in the Zaria region (northern Nigeria), was thought to be a manifestation of cowpea mottle virus, once described as an apparently distinct virus of cowpea and bambara groundnut in southern Nigeria (Robertson, 1967).

Unfortunately neither an original antiserum nor a stored isolate of the once tentatively identified cowpea mottle virus was available.

An antiserum prepared for our bambara groundnut isolate later revealed the occurrence of a serologically identical virus in cowpea at Mokwa in central Nigeria which is additional evidence for the cowpea mottle virus earlier described to be involved.

Its persistent occurrence in southern Nigeria was subsequently confirmed at the Institute of Agricultural Research and Training, Moor Plantation, Ibadan, when using this same antiserum to the bambara groundnut isolate.

Extensive characterization work at Boyce Thompson Institute in New York also revealed that most likely a distinet virus of cowpea and bambara groundnut is involved.

An aphid transmissible *(Myzus persicae)* filamentous virus (Poty-virus group) from cowpea at IITA was found to be serologically related to cowpea aphid-borne mosaic virus in East Africa. Of 30 promising, multiple virus resistant cowpea introductions tested with this virus, only three remained symptomless, the multiple virus resistant introduction TVu 410 being among these.

A randomly collected locally grown cowpea selection from Kano State (northern Nigeria) proved to be highly resistant too, which is good evidence for a high level of natural resistance to this virus in the main cowpea growing area, where virus disease incidence was found to be very low. Aphid infestation of the young crop, however, is a common feature.

A very severe and conspicuous golden mosaic disease of cowpea at IITA's high-rainfall substation at Onne near Port Harcourt, however, predominantly occurring in vegetable cowpea types (*V. unguiculata* var. sesquipedalis) was proved to be whitefly transmitted. Sap transmission, like that receutly found for similar golden mosaic of *Phaseolus vulgaris* in Central and South America could not be achieved, however.

Resistance screening conditions for this virus in the field are esseutially adequate since generally the whole infection occurs at early stages of growth. Soybean, besides showing symptoms due to infection with a sap and aphid-transmissible filamentous virus soybean mosaic virus, widely found wherever soybean is grown in the world was found to show symptoms of a disease which was found to be graft-transmissible only. Strong indications were obtained that the whitefly transmitted lima beau golden mosaic virus is involved in this case.

Electron microscopic and host range studies at IITA revealed that in lima bean, often a latent virus occurs in addition to lima bean golden mosaic virus (whitefly transmitted) and lima bean green mottle virus (aphid-transmitted, Poty-virus). The identity and ecology of this virus and viruses of the same type, electro microscopically, isolated from cowpea and soybean, is presently being investigated. Mosaic, ring spot and sometimes vein necrosis symptoms often leading to die-back of plants were commonly observed in wing bean *(Psophocarpus tetragonolobus)*. Host range and electron microscopic investigations with two isolates, one representing mosaic and the second vein necrosis symptoms, revealed that in both cases probably the same virus, poty-virus, is involved.

Of several introductions tested generally only a low number of plants out of each population proved to be suseeptible to each of the two isolates.

Vein necrosis and mosaic symptoms could both be induced with the necrosis and the mosaic isolate, indicating that host plant geuetics play a predominant role in the type of symptom expression by this virus, whereas its epidemiology is apparently governed by the same genetic heterogeneity.

A comparison of the symptoms in a series of test plant/species evoked by viruses isolated from severely virus diseased African yam beau *(Sphenostylis stenocarpa)* and jackbean *(Canavalia ensiformis)* and electron microscopic studies revealed that the viruses are probably closely related or identical, and belong to the Poty-virus group. Also, symptoms induced in lima bean were reminiscent of lima bean green mottle virus. To prove their identity and relationship, purification and serology are anticipated.

GENETIC RESOURCES UNIT

Exploration. The first priority of the Genetic Resources Unit (GRU) is to collect the germplasm of African rice, food legumes, root crops and aroids from sub-Saharan Africa. During 1977 the unit was involved in nine germplasm collection missions within West Africa, and received seeds from important collections already held at the International Rice Research Institute and the University of Ghana. From all these sources 2,736 new accessions were gathered (Table 1), and by the end of the year the unit held a total stock of 17,945 items of germplasm (Table 2). This total excludes the year's 1,417 collections from outside Nigeria which had not been released from Nigerian post-entry quarantine screening by the end of the year.

Grants of money to assist germplasm collection for IITA were made to collaborators in Ghana, Sierra Leone, Liberia and Niger. Germplasm from these collaborators will begin to reach the Institute during 1978. A grant was also made to IRAT to support their exploration for rice in Africa during 1977.

Evaluation, maintenance, documentation. During the year 6,585 food legumes, 594 rice accessions, 2,032 cassava clones and 615 yam clones (*Dioscorea* spp.) were grown for maintenance or evaluation. Arrangements were made with the crop improvement programs of IITA to share the work of germplasm evaluation. The GRU will observe and record stable (mostly qualitative) characters at IITA whereas specialists in the crop programs will evaluate new germplasm for less stable characters of agronomic importance in more than one environment.

For every accession at least 20 "passport" descriptors defining provenance are recorded at the time of collection. Progress was made to define minimum sets of descriptors for the subsequent evaluation of collections. Data from these two sources have been accumulated, but no use was made of the computer to store genetic resources data or to publish catalog pending the installation of a new machine and a suitable program for it.

Seed production, storage and distribution. The GRU managed all the Institute's seed stores and completed their reorganization in 1977. An order was placed for a -20°C long-term store big enough to contain about 25,000 seed samples of 0.5 kg each (store volume 88 m^3). This facility will be used primarily to preserve base collections of cowpeas and African rice, but about 20 m^3 will be available to other genetic resource centers to duplicate their collections. The unit multiplied legume breeders' seed on 6 ha and helped to pack and distribute it for off-site uniform trials. In addition, legume germplasm was distributed to 66 countries in response to 215 requests and within Nigeria in response to 384 requests.

Table 1. Germplasm yields from 1977 collections.

Source	Food legumes	Rice	Roots and aroids	Total
S.E. Nigeria			110	110
N. Nigeria (Prof. Oka)	16	126		142
Benue River Valley, Nigeria	221	282	41	544
N. Nigeria (CIAT)	23	1		24
Mali	247	12	3	262
Upper Volta	19			19
Ivory Coast	185	17	12	214
Liberia	47	243	83	373
Sierra Leone	89	327	133	549
From IRRI (*Oryza glaberrima*)		428		428
From University of Ghana	71			71
Totals:	918	1,436	382	2,736

*Table 2. IITA's Germplasm stocks – December, 1977. *(Collected in Nigeria.)*

Rice:			
Oryza glaberrima		874	
O. sativa		923	
Other *Oryza* species		86	
	Total:		1,883
Legumes:			
Vigna unguiculata		6,250	
V. radiata		103	
V. mungo		10	
Wild *Vigna* spp.		70	
Phaseolus lunatus		911	
Voandzeia subterranea		168	
Glycine max		148	
Cajanus cajan		5,531	
Sphenostylis stenocarpa		57	
Psophocarpus tetragonolobus		15	
Lablab purpureus		19	
Other legumes		123	
	Total:		13,405
Roots:			
Manihot esculenta		2,032	
Dioscorea rotundata		291	
D. cayenensis		37	
D. alata		226	
D. dumetorum		33	
D. bulbifera		13	
D. esculenta		4	
Wild *Dioscorea* spp.		30	
	Total:		2,657
	Grand Total:		17,945

**Includes only material at IITA 31 December.*

TRAINING

The Training Program continued to pursue its goals of assisting in the transfer of knowledge generated by the research programs of the Institute and in responding to requests for training in research, production, laboratory, library and administrative skills.

Research training. During 1977, IITA scientists supervised thesis research for 13 doctoral candidates (Research Fellows), 28 M.Sc.-level candidates and 40 employees of departments and ministries of agriculture, international organizations and private and public agencies for whom non degree-related research training was requested. In addition, the Institute received 24 vacation student research scholars from Rwanda, Togo, Ghana, Benin, Sierra Leone and Nigeria. By the end of the year, IITA had extended its collaborative arrangements with universities to include 42 universities in 20 countries on four continents. Twelve of these universities are in Africa.

Group courses. The schedule included the following courses:

	Language	Participants
–Crop Production and Seed Multiplication Technology and Extension. (1 Dec. 1976–25 March 1977.)	French	22
–Soil and Water Conservation and Management Research. (14 March–1 April.)	English	27
–Rice Production Training for Research Workers and Extension Supervisors in Tropical Africa. (28 March–15 July.)	Eng./French	33
–Root & Tuber Crop Production Training for Research Workers and Extension Supervisors in the Tropics. (9 May–8 July.)	Eng./French	23
–Grain Legume Production Training for Research Workers in the Tropics. (22 August–18 November.)	Eng./French	28
–Training Course on Rhizobium Isolation and Utilization. (10–28 October.)	English	15

Totals for 1977 and cumulative from 1971 through 1977 were:

	1977	Cumulative
Research Fellows	13	32
Research Scholars	28	47
Vacation Student Research Scholars	24	121
Research Training Associates (non degree-related training)	40	86
Group Course Participants	148	409
Total		695

Postdoctoral fellowships. The postdoctoral fellowship program seeks applicants with newly acquired degrees of the level of the Doctor of Philosophy in a broad range of agricultural disciplines. In 1977, 23 fellows conducted research in such disciplines as agricultural economics, agronomy, biochemistry, entomology, phytopathology, physiology, plant breeding, soil microbiology, soil physics, soil chemistry, and virology. The fellows participated actively in the research activity of the Institute and contributed significantly to it. At the same time, they gained experience in research oriented to solving problems of small farmers of the humid and subhumid tropics.

LIBRARY AND DOCUMENTATION CENTER

About 2,000 volumes of books and 1,500 volumes of periodicals were added to the collection during 1977. As of December 1977, the collection of the Library and Documentation Center consisted of 12,000 books, 16,500 volumes of periodicals, 2,500 pamphlets and some microfiches, microfilms and slide sets.

Mealybugs are pests of many tropical and subtropical crops. To assist research on mealybug initiated by IITA staff and collaborators, the library staff compiled, during 1977, abstracts of literature on the pest, and distributed copies to scientists and institutions throughout the world known to have research projects on mealybugs.

Research and development on plantains at IITA have increased during the last two years. To support this work at IITA and elsewhere, the library staff compiled a world bibliography on plantains and other cooking bananas during 1977. This bibliography was published as a special issue of *Paradisiaca*, newsletter of the International Association for Research on Plantain and other Cooking Bananas.

The first draft of the bibliography on farming systems in Africa was completed and distributed to staff of the IITA Farming Systems in 1977. A revised version is being prepared and will be published in 1978 by G. K. Hall, Inc., a commercial publisher in Boston, Massachusetts, USA.

The International Grain Legume Information Center published three issues of the *Tropical Grain Legume Bulletin* in 1977. The Center completed work on abstracts of cowpea literature published during 1950-1973. Printed copies will be available for distribution in 1978. The Center continued work on the literature of winged beans *(Psophocarpus tetragonolobus)* and of bambara groundnuts *(Voandzeia subterranea)*.

During 1977 the Library provided opportunities for practical experience to 14 training participants.

COMMUNICATIONS AND INFORMATION

During 1977, the Communications and Information office provided all editorial, print, photographic, translation, and graphic art supports for IITA research, training, administration, and special projects.

The synchronized tape/slide presentation on IITA was put into effective use and efforts made to update this periodically. More presentations were made for certain individual research programs for use during training sessions or with special visitors.

A special publication in both English and French, marking the 10th Anniversary of the institute, was produced by the department. More than 5000 copies have been distributed worldwide.

A new type composing machine and a "total copying system" were purchased to help solve the delay problems in the printing unit.

RESEARCH STATION OPERATIONS

In addition to providing routine field support for scientific staff, Research Station Operation had a year of consolidation in 1977 following many years of research land expansion.

Hydromorphic valleys have been developed into productive areas mainly for rice research, and access roads, drainage systems and soil conservation installations have all been improved. A full quota of tractors and drivers has resulted in improved timeliness of farm operations and increased scope for informal staff training.

Active involvement in the more practical aspects of the zero-tillage research program has continued.

Research expansion continued at the high-rainfall substation at Onne and progress has been made on the construction of the main station building whieh includes offices, laboratory, stores and workshop.

PERSONNEL

ADMINISTRATION

W.K. Gamble, *Ph.D., director general*
M.A. Akintomide, *B.S., director for administration*
D.C.L. Pritchard, *assistant director and treasurer*
C.E. Barringer, *B.A., planning and budget officer*
D.C. Goodman, Jr., *M.B.A., assistant to the director general (Special Projects)*
R. Jacob, *assistant to the director general*
A.R. Rinde, *assistant to the director general**
K.A. Aderogba, *principal administrative officer*
S.J. Udoh, *accountant*
F.O. Ogunyemi, *accountant*
C.A. Enahoro, *assistant to the director for administration*
J.E. Brinkworth, *manager data processing*
D.J. Sewell, *dormitory and food service manager*
R.O. Shoyinka, *B.S., personnel manager*
O. Adebiyi, *personnel officer*
J.D. Abidogun, *B.S.. supplies & purchasing officer*
E.A. Onifade, *security superintendent*
J.T. Okediran, *purchasing superintendent*
M.G. Etuk, *administrative assistant, Ikeja*
D.A. Kasumu, *assistant accountant*
C.A.O. Nylander, *nursing sister**
S.B. Okiti, *assistant accountant*
Oye Olatawura, *housing superintendent*
E.O. Omole, *conference coordinator*

RESEARCH

J.C. Flinn, *Ph.D., acting director of research*
S.V.S. Shastry, *director of research*

GENETIC RESOURCES UNIT

W.M. Steele, *Ph.D., coordinator*
S.D. Sharma, *Ph.D., plant explorer*
A. Perez, *Ph.D., plant explorer*

POSTDOCTORAL FELLOW

R.B. Eastwood, *Ph.D., plant explorer**

FARMING SYSTEMS PROGRAM

I.O. Akobundu, *Ph.D., weed scientist*
A. Ayanaba, *Ph.D., microbiologist*
F.E. Caveness, *Ph.D., nematologist*
A. Cook, *B.S., insect ecologist*
B.R. Critchley, *Ph.D., entomologist*
D. Devleeschauwer, *Ir., soil scientist – physics (FAO associate expert)*
P. Devos, *Ir., agronomist, plantain (FAO associate expert)*
J.C. Flinn, *Ph.D., assistant director and agricultural economist*
J.M. Hoyoux, *Ir., agricultural economist (FAO associate expert)*
A.S.R. Juo, *Ph.D., soil scientist – chemistry*
B.T. Kang, *Ph.D., soil scientist – fertility*
R. Lal, *Ph.D., soil scientist – physics*
T.L. Lawson, *Ph.D., agroclimatologist*
F.R. Moorman, *Ph.D., pedologist*
N.C. Navasero, *agricultural engineer, assistant*
C.L. Padolina, *agricultural engineer, assistant*
S.J. Pandey, *farm input technology advisor*
J. Perfect, *M.S., insect ecologist (COPR visiting scientist)*
P.R. Wijewardene, *M.S., agricultural engineer*
L.B. Williams, *M.S., agricultural economist, NAFPP*
G.F. Wilson, *Ph.D., agronomist*
F.E. Winch, *Ph.D., agricultural economist*
R. Yeadon, *B.S., pesticide analyst*

VISITING SCIENTISTS

G. Burnbury, *agricultural engineer*
A.J. Herbillon, *soil chemist*
P.J. Le Mare, *soil chemist*

POSTDOCTORAL FELLOWS

J. Braide, *Ph.D., agronomy, plantain*
E.S. Bromfield, *Ph.D., soil microbiology*
R. Maurya, *Ph.D., soil physics*
C. Okali, *Ph.D., rural sociologist*
J.L. Pleysier, *Ph.D., soil chemist*
M. Rodriguez, *Ph.D., soil physics*

CEREAL IMPROVEMENT PROGRAM

A.O. Abifarin, *Ph.D., rice breeder*
V.L. Asnani, *Ph.D., maize breeder*
M.N. Harrison, *B.Sc., maize breeder*
P.E.J. Soto, *Ph.D., entomologist*
J. ter Vrugt, *B.Sc., agronomist*
F.M. Quin, *Ph.D., physiologist*
I.W. Buddenhagen, *Ph.D., pathologist*
S.S. Virmani, *Ph.D., rice breeder, Liberia*
I.C. Mahapatra, *Ph.D., rice agronomist, Sierra Leone*
S.A. Raymundo, *Ph.D., rice pathologist, Sierra Leone*
S.J. Pandey, *Ph.D., sorghum/millet coordinator, NAFPP*
R.B. Thakare, *Ph.D., sorghum/millet specialist, NAFPP*

POSTDOCTORAL FELLOWS

Z. Siddiqi, *Ph.D., entomologist*
M.D. Thomas, *Ph.D., pathologist, maize*
Y. Tanaka, *Ph.D., pathologist, rice*
K. Alluri, *Ph.D., physiologist/agronomist*
H.C. Bittenbender, *Ph.D., physiologist*
R.A. Coker, *Ph.D., entomologist**

GRAIN LEGUME IMPROVEMENT PROGRAM

P.R. Goldsworthy, *Ph.D., assistant director*
D.J. Allen, *Ph.D., plant pathologist*
D. Nangju, *Ph.D., agronomist*
E. Pulver, *Ph.D., microbiologist*
R.J. Redden, *Ph.D., plant breeder*
S.R. Singh, *Ph.D., entomologist*
J.B. Smithson, *Ph.D., plant breeder*
E.E. Watt, *Ph.D., plant breeder*
H.C. Wien, *Ph.D., crop physiologist*
P.C. Duffield, *Ph.D., coordinator — Tanzania*
F.E. Brockman, *Ph.D., agronomist — Tanzania*
P.N. Patel, *Ph.D., breeder/pathologist — Tanzania*
V.D. Aggarwal, *Ph.D., plant breeder, Upper Volta*

VISITING SCIENTIST

G. Nsowah, *Ph.D., physiology*

POSTDOCTORAL FELLOWS

J.P. Baudoin, Jr., *associate expert FAO*
P. Matteson, *Ph.D., entomologist*
B. Ndimande, *Ph.D., plant pathologist*
H.J. Vetten, *Ph.D., plant pathologist*
W.J. Horst, *Ph.D., plant nutritionist*
T.P. Singh, *Ph.D., plant breeder*
Z. Russom, *Ph.D., plant breeder*

ROOT AND TUBER IMPROVEMENT PROGRAM

S.K. Hahn, *Ph.D., assistant director and breeder*
G.S. Ayernor, *Ph.D., biochemist/food technologist*
W.N.O. Ezeilo, *B.S., coordinator, cassava center, NAFPP, Nigeria*
H.C. Ezumah, *Ph.D., breeder, Program National Manioc (PRONAM), Zaire*
P.H. Haynes, *M.S., project leader and agronomist, Program National Manioc (PRONAM), Zaire*
G. Heys, *B.S., production agronomist*
K. Leuschner, *Ph.D., entomologist*
K.V. Nwanze, *Ph.D., entomologist, Program National Manioc (PRONAM), Zaire*
R.P. Pacumbaba, *Ph.D., pathologist, Program National Manioc (PRONAM), Zaire*
Sidki Sadik, *Ph.D., physiologist/tissue culture*
E.R. Terry, *Ph.D., pathologist*
J.E. Wilson, *Ph.D., breeder*
G.J. Persley, *pathologist (Research Fellow)*
A.K. Howland, *research associate — breeding*
J.O. Kalabare, *research assistant — breeding*
M.O. Akoroda, *research assistant — breeding*

POSTDOCTORAL FELLOWS —

A.P.O. Dede, *Ph.D., pathologist*
W. Claussen, *Ph.D., physiologist*
R.B. Kagbo, *Ph.D., agronomist*
E.N. Maduagwu, *Ph.D., biochemist*

TRAINING

W.H. Reeves, *Ph.D., assistant director and head of training*
D.W. Sirinayake, *production training officer (anglophone)*
L. Babadoudou, *Ing. Tech., production training officer (francophone)*
G. Cambier, *Lic., translator/interpreter*

RESEARCH AND TRAINING SUPPORT UNITS

COMMUNICATIONS AND INFORMATION

R.A. Woodis, *M.S., head**
J.O. Oyekan, *B.S., communications officer, editorial*
C. Achode, *Ph.D., translator*
J. Loudon, *M.S., editor*

VISITING SCIENTISTS

E. Bortei-Doku, *M.S.*
W.B. Ward, *M.S.**

FARM MANAGEMENT

D.C. Couper, *B.S., farm manager*
S.L. Claassen, *M.S., assistant farm manager*
E. Bamidele, *farm superintendent*

LIBRARY AND DOCUMENTATION CENTER

S.M. Lawani, *M.S., head*
G.O. Ibekwe, *B.S., principal librarian*
E.N.O. Adimorah, *B.S., documentalist*
E.F. Nwajei, *B.A., acquisitions librarian*
Lynette Yip-Young, *documentalist, IDRC**
B.O. Adenaike, *B.S., bibliographer, IDRC*

BIOMETRICS/STATISTICS

B. Gilliver, *M.S., biometrician*
M.A. Jaiyeola, *computer programmer*

ANALYTICAL SERVICES

B.O. Nana, *B.S., research assistant*
O. Fapojuwo, *B.S., research assistant*

PHYSICAL PLANT SERVICES

J.G.H. Craig, *assistant director*
A.C. Butler, *buildings and side services officer*
Donald Cockburn, *refrigeration services officer*
J.M. Ferguson, *fabrication services officer*
C.W. Robertson, *electrical services officer*
N. Georgallis, *scientific and electronic services officer*
O.O. Fawole, *automotive services officer*
H.C. Kinnersly, *heavy equipment services officer*
S.O. Odetayo, *electronics superintendent**

Left during the year.

COLLABORATION AND TRAINING

FARMING SYSTEMS PROGRAM

COLLABORATORS

Dr. J.N. Sasser, *Plant Pathology Department, North Carolina State University, Raleigh, North Carolina. International Meloidogyne Project.*

EMBRAPA/MANAUS, and EMBRAPA/BELAN
University of Monogoro, Tanzania

Dr. E. De Langhe, *Katholieke Universitut Leuven, Lenven, Belgium*

Mr. L. Ahialegbedji, *Meteorological Service, Lomé, Togo*

Mr. A.K.E. Ussher, *Meteorological Service, Accra, Ghana*

RESEARCH FELLOWS AND SCHOLARS

D. Friesan, *soil chemistry*
E. Bachman, *agric. economics*
L. Diehl, *agric. economics*
B. Mambani, *soil physics*
G.E. Okoro, *soil fertility*
H. Pfeifer, *soil chemistry*
G.A. Agbahungba, *soil microbiology*
A.H. Azontonde, *soil physics*
H.M. Spiro, *agric. economics*
G.B. Douagbeu, *weed science*
Naku-Mbumba, *agronomy, plantain*
D. Akangbe, *agric. economics*
P. Fotzo, *agric. economics*
B. Fawcett, *agric. economics*
E. Scarlett, *agric. economics*
C. Dixon, *soil chemist*
T. Bouare, *agronomy, plantain*
S. Osei-Yeboah, *soil physics*
I.S. Barrie, *soil physics*
P. Mondialis, *soil physics*
N.O. Aisueni, *soil microbiology*
J.M. Crawray, *pedology*
J.N. Sellahewa, *soil physics*
R.M.K. Wickremasin, *soil physics*
M. Armon, *soil physics*
K.M. Setsoafia, *soil fertility*
C. Mongkolsawat, *soil physics*
N. Sachak, *agric. economics*
Betty I. Okoh, *soil microbiology*
N.O. Ezekwesili, *nematology*
A. Kaba, *agric. engineering*
S.T. Gbanya, *agric. engineering*
J. Alegre, *soil physics*
A.I. Khatib, *soil physics*
S.B. Adesanmi, *agric. engineering*
A. Famogbiele, *agric. engineering*

CEREALS IMPROVEMENT PROGRAM

COLLABORATORS

Dr. S. Fagade and J. Olufowote, *NCRI, Ibadan, Nigeria*

Dr. B. Lyschik, *German-Ghanian Agricultural Development Project, Tamale, Ghana*

Dr. A.G. Carson, *Crops Research Institute, Tamale, Ghana*

Dr. A.N. Aryeetey, *University of Ghana, Kpong, Ghana*

Mr. N. Ayama, *NORCAP, Abakaliki, Anambra State, Nigeria*

Mr. N. Arega, *Adarice Production Company Ltd., Adani, Anambra State, Nigeria*

Mr. Limburg, *Organization des Voluntaires, Neerlandais, Save, Republic of Benin*

Mr. C.H. Riedel, *Project Action Rurale, Se Republic of Benin*

Mr. Schalbroeck, *Institute de Science Agronomic de Burundi, (ISABU) Burundi*

Mr. Van Gils Lambert, *Division of Agric. Extension, ENSA, Univ. of Yaounde, Cameroon*

Dr. J.M. Menyonga, *Institute for Perennial Crops, Cameroon*

Mr. E. Limburg, *Action Rurale, B.P. 5, Save, Republic of Benin*

Dr. M.K. Akposoe, *Crops Research Institute, Council for Scientific and Industrial Research, P.O. Box 3785, Kumasi, Ghana.*

Mr. Carlos Schwarz de Silva, *Dept. de experimenta cause Producao de Arroz (DEPA) C.P. 71, Bissau, Rep. Guinea Bissau*

Mr. E.J.R. Hazelden, *Kenya Seed Co. Ltd., P.O. Box 553, Kitale, Kenya E. Africa.*

Mr. W.R. Dingle, *U.N.D.P., P.O. Box 274, Monrovia, Liberia*

Mr. Pouelas Knapp, *Baptist Demonstration Farm, P.O. Box 200, Kyela, Tanzania*

Mr. J. Marquette, *IRAT Mission au Togo, B.P. 1163, Lome-Togo*

Mr. J. Fraeyhoven, *FAO Project Centre du experimentation du Riz et de Cultures Irrigues, Farakoba, Bobo Dioulasso, Upper Volta*

Dr. D.W. Sperling, *National Maize Res. Program, Ilonga, A.R.I., Private Mail Bag Kilosa, Tanzania*

Dr. Q. Haque, *Coordinator, Food Legumes and Cereals Program, CARDI, University of West Indies, St. Augustine, Trinidad—West Indies*

Dr. S. Parasram, *Commodity-Leader-Maize, CARDI, University Campus, St. Augustine, Trinidad, West Indies*

Dr. Thomas G. Hart, *CIMMYT/Lubumbashi, c/o Food and Agricultural Officer, USAID American Embassy, Kinshasa, Zaire*

Mr. R.Q. Craufurd, *Dept. of Agriculture, Research Branch, Mount Makulu Res. Station, P.O. Box 7, Chilanga, Rep. of Zambia*

Dr. Carlos de Leon, *Maize Pathologist, CIMMYT, Londres-40, Mexico 6 D.F.*

Dr. R.L. Paliwal, *Associate Director, Maize Program, CIMMYT, Londres-40, Mexico 6, D.F.*

Dr. James L. Brewbaker, *Centro Inter. Agric., Tropical Apartado Aereo 6713, Cali Colombia, S.A. (Colombia)*

Chief P.U. Ohunyon, *Shell-BP, Warri, Bendel State, Nigeria*

Ministry of Agriculture and Natural Resources, Bendel State, Nigeria

Ministry of Agriculture and Natural Resources, Rivers State, Nigeria

M. Arraudeau, *IRAT, Bouake, Ivory Coast*

Mr. K.A. Ayotade, *NCRI, Badeggi, Niger State*

RESEARCH FELLOWS AND RESEARCH SCHOLARS

I.N. Timti, *research fellow, maize pathology*

A.M. Alghali, *research fellow, entomology*

S.R. Vodouhe, *research scholar, rice breeding/physiology*

C.A. Dixon, *research training associate, soil chemistry (FSP/Rice Physiology) (CIP).*

S.N. Fomba, *research scholar, rice pathology*

Z.L. Kanyeka, *rice breeding.*

GRAIN LEGUME IMPROVEMENT PROGRAM

COLLABORATORS

D. Boulter, *Department of Botany, University of Durham, England*

M. Evans, *Department of Botany, University of Durham, England*

R.J. Summerfield, *Plant Environment Laboratory, Reading University*

F. Minchin, *Plant Environment Laboratory, Reading University*

H.F. van Emden, *Department of Horticulture and Agriculture, Reading University*

K.A. Skipp, *Plant Growth Substances and Systemic Fungicides Unit, Wye College, University of London*

H. Marschner, *Institute of Crop Science, Technical University of Berlin*

R. Marechal, *Faculte des Sciences Agronomiques de l'Etat, Gembloux, Belgium*

C. le Marchand, *Faculte des Sciences Agronomiques de l'Etat, Gembloux, Belgium*

P. Dobie, *Tropical Products Institute, London Road, Slough Berks, England*

RESEARCH FELLOWS/RESEARCH SCHOLARS

Moffi Ta'Ama, *entomology*

B.M. Khaemba, *agronomy*

S.B.C. Wanki, *agronomy*

C. Roesingh, *entomology*

M. Sadiq, *plant breeding*

A. Vander Reijden, *plant breeding*

P. Swain, *plant breeding*

ROOT AND TUBER IMPROVEMENT PROGRAM

COLLABORATORS

O.B. Arene, *Program Leader of Cassava and Pathologist, National Root Crop Research Institute, Umudike, Nigeria*

I. Baldry, *Tropical Product Institute, London, U.K.*

D. Boulter, *Department of Botany, University of Durham, U.K.*

R.D. Cooke, *Tropical Product Institute, London, U.K.*

L.S.O. Ene, *Assistant Director and Breeder, National Root Crop Research Institute, Umudike, Nigeria*

A.A.A. Fayemi, *Department of Agronomy, University of Ibadan, Nigeria*

D.J. Greathead, *Commonwealth Institute of Biological Control, London, U.K.*

G.G. Henshaw, *Department of Plant Biology, University of Birmingham, Birmingham, U.K.*

R.A.D. Jones, *Rice Research Station, Rokupr, Sierra Leone*

T.A.O. Ladeinde, *Department of Agricultural Biology, University of Ibadan, Nigeria*

S. Lyonga, *Coordinator, National Root Crop Improvement Program, Njombe, Cameroon*

H. Maraite, *Laboratoire de Phytopathologie, Universite Catholique de Louvain, Belgium*

J. Meyer, *Laboratoire de Phytopathologie, Universite Catholique de Louvain, Belgium*

H.H. Shorey, *Division of Biological Control, University of California, Riverside, California, U.S.A.*

RESEARCH FELLOWS AND SCHOLARS

M.T. Dahniya, *Research Fellow, breeding*

M.M. Msabaha, *Research Scholar, breeding*

I.L. Ezekwe, *Research Scholar, biochemistry*

W. Olusanya, *Research Scholar, entomology*

J. Kasirivu, *Research Scholar, pathology*

C. Makambila, *Research Scholar, pathology*

M. Akoroda, *Research Scholar, breeding*

V. Lawin, *Research Scholar, breeding*

K.D. Kpeglo, *Research Scholar, breeding*

CONFERENCE AND SEMINAR PAPERS

FARMING SYSTEMS PROGRAM

Aina, P.O., R. Lal, and G.S. Taylor. 1977. *Effects of Vegetal Cover on Soil Erosion, In Role of Soil Physical Properties in Maintaining Productivity of Tropical Soils,* held at IITA, Ibadan, Nigeria. 6-10 December, 1977.

Caveness, F.E. *Cassava Seedling Susceptibility and Damage by the Root-knot Nematode, Meloidogyne Incognita.* Occasional Publication Number 2. The Nigerian Society for Plant Protection, Ibadan, Nigeria, 1977.

Caveness, F.E. *Limited Plant-Parasitic Nematode Control with Slash-and-burn Farming.* Occasional Publication Number 2. The Nigerian Society for Plant Protection. Ibadan, Nigeria, 1977.

Caveness, F.E. *Cowpea, Lima bean, Cassava, Yams and Meloidogyne* spp. *in Nigeria.* Paper presented at the International Seminar on *Meloidogyne.* Bari, Italy. October, 1977.

Caveness, F.E. *Nematology at the International Institute of Tropical Agriculture.* Seminar at the University of California, Riverside, California. 30 September, 1977.

Caveness, F.E. *Root-knot Nematode in West Africa and the International Meloidogyne Project.* Seminar at the Institute of Agricultural Research, Ahmadu Bello University, Zaria, Nigeria. 19 November, 1977.

Caveness, F.E. *Cassava Seedling Susceptibility and Damage by Root-knot Nematode.* Seventh Annual Conference, Nigerian Society for Plant Protection. IART, Moor Plantation, Ibadan, Nigeria. 7-9 March, 1977.

Falayi, O. and R. Lal. 1977. *Crust Characteristics and Seedling Emergence.* Conference on "Role of Soil Physical Properties in Maintaining Productivity of Tropical Soils," held at IITA, Ibadan, Nigeria. 6-10 December, 1977.

Harrison-Murray, R., and R. Lal. 1977. *High Soil Temperature and the Response of Maize to Mulching in the Lowland Humid Tropics.* Conference on "Role of Soil Physical Properties in Maintaining Productivity of Tropical Soils," held at IITA, Ibadan, Nigeria. 6-10 December, 1977.

Juo, A.S.R. *Chemical Characteristics of Soil in the Humid Tropics as Related to Soil Management and Classification.* Paper presented at the Review Seminar of IITA Soil Research Collaborators, held at University of Reading, England. 29 March—2 April, 1977.

Juo, A.S.R. *The Importance of Surface Reactivity of Sesquioxides, Phosphate and Silica Sorption and Solubility to Classification of Soils in the Tropics.* Presented at the International Soil Classification Workshop held at Rio de Janeiro, Brazil. 20 June—1 July, 1977.

Lal, R. 1977. *Criteria for Screening Rice Varieties for Drought Tolerance.* Rice in Africa Conference held at IITA, Ibadan, Nigeria. 7-11 March, 1977.

Lal, R. 1977. *Modification of Fertility Characteristics by Management of Soil Physical Properties.* Conference on "Role of Soil Physical Properties in Maintaining Productivity of Tropical Soils," held at IITA, Ibadan, Nigeria. 6-10 December, 1977.

Lal, R. 1977. *Climatic Aspects of Soil and Water Conservation in the Humid Tropics.* WMO/FAO Technical Conference on the Application of Meteorology in Africa, IITA, Ibadan, Nigeria. 12-16 April, 1977.

Lal, R. 1977. *Erosivity in Tropical Countries.* Expert Consultation for Assessing Methodology for Soil Degradation, FAO, Rome, Italy, 18-20 January, 1977.

Lal, R. 1977. *Soil Management in the Humid Tropics of West Africa.* Third Annual Review of Collaborative Research on Soils of the Humid Tropics. University of Reading, U.K. 29 March—2 April, 1977.

Lal, R. 1977. *Physical Properties of Tropical Soils in Relation to their Classification.* Third Annual Review of Collaborative Research on Soils of the Humid Tropics. University of Reading, U.K. 29 March—2 April, 1977.

Lal, R. 1977. *Effects of 6 years of No-Tillage and Conventional Plowing on Fertilizer Response of Maize.* A.S.A. Meeting, Los Angeles, U.S.A., 13-18 November, 1977.

Lal, R., and D.J. Cummings. 1977. *Changes in Soil and Micro-Climate by Different Methods of Forest Removal.* A.S.A. Meeting, Los Angeles, U.S.A., 13-18 November, 1977.

Lal, R. 1977. *No-Tillage System and Residue Requirement.* FAO/UNDP, Conference on Organic Recycling. 6-12 December, 1977, Beau, Cameroon.

Lal, R. 1977. *Research Consideration for Soil and Water Conservation and Management.* Food and Agriculture, Malaysia 200:87-100.

Lal, R. 1977. *Physical Properties of Tropical Soils.* Conference on "Role of Soil Physical Properties in Maintaining Productivity of Tropical Soils," held at IITA, Ibadan, 6-10 December, 1977.

Lawson, T.L. 1977. *Possible impact of Agroclimatological Studies on Food Production in the Humid Tropics with Particular Reference to West Africa.* WMO/FAO Technical Conference on the Application of Meteorology to Agriculture in Africa, IITA, Ibadan, Nigeria, April 12-16, 1977.

Lawson, T.L., R.G. Dumsday, and J.C. Flinn. 1977. *An analysis of the effects of weather on maize yields in a Humid Tropical Environment.* WMO/FAO Technical Conference on the Application of Meteorology to Agriculture in Africa, IITA, Ibadan, Nigeria, April 12-16, 1977.

Lawson, T.L., and R. Lal. 1977. *Response of maize (Zea mays L.) to surface and buried straw mulch on a Tropical Alfisol.* International Conference on "Role of Soil Physical Properties in Maintaining Productivity of Tropical Soils," IITA, Ibadan, Nigeria, December 6-10, 1977.

Lawson, T.L. 1977. *Consumptive water use for cowpea.* International Conference on "Role of Soil Physical Properties in Maintaining Productivity of Tropical Soils," IITA, Ibadan, Nigeria.

Maurya, P.R. and R. Lal. 1977. *Effects of Straw Mulch and Soil Moisture Regimes on Upland Rice Growth and Production.* Rice in Africa Conference held at IITA, Ibadan, Nigeria. 3-11 March, 1977.

Maurya, P.R., and R. Lal. 1977. *Effects of Gravel Concentration, Inter-Gravel Density, and Soil Moisture Regime on Radical Elongation.* In "Role of Soil Physical Properties in Maintaining Productivity of Tropical Soils," held at IITA, Ibadan, Nigeria. 6-10 December, 1977.

Wien, C., R. Lal, and E.L. Pulver. 1977. *Effects of Transient Flooding on Growth and Yield of Some Tropical Crops.* Conference on "Role of Soil Physical Properties in Maintaining Productivity of Tropical Soils," held at IITA, Ibadan, Nigeria. 6-10 December, 1977.

Wilson, G.F. 1977. *Potential for no-tillage in vegetable production in the tropics.* Fifth Africa Symposium on Horticultural Crops, Khartoum University, Sudan.

Wilson, G.F. 1977. *The potential for legume cover crops in no-tillage cropping in the tropics.* International Conference on "Role of Soil Physical Properties in Maintaining Productivity of Tropical Soils," IITA, Ibadan, Nigeria.

Winch, F.E. and C.D. Kivunja. 1977. *Rice in Tropical Africa: The Relative Importance of Rice in Tropical Africa and the need to increase the Farm Level Economic Data Base.* Invited paper for Rice in Africa Workshop, IITA, Ibadan, March 7-11, 1977.

Winch, F.E. and C.D. Kivunja. 1977. *Review of Production and Trade of Rice, Maize, Cassava, Yam and Sweet Potato in Selected Countries of Tropical Africa.* Paper prepared for the Technical Advisory Committee mission to IITA, Ibadan. October, 1977.

Winch, F.E. 1977. *Selection, Training and Supervision of Field Enumerators Employed for Village-Level Economic Surveys.* Village-Level Socio-Economic Studies Workshop held at IITA, Ibadan. November 14-25, 1977.

CEREALS IMPROVEMENT PROGRAM

Alluri, K., R.S. Vodouhe, K.J. Treharne and I.W. Buddenhagen. 1977. *Evaluation of drought avoidance of rice varieties.* Rice in Africa Conference held at IITA, Ibadan, Nigeria. March 7-11, 1977.

Alluri, K. 1977. *Effect of methods of fertilizer application on traditional and broadcastable seedlings.* Rice in Africa Conference held at IITA, Ibadan, Nigeria. March 7-11, 1977.

Perez, A.T. and I.C. Mahapatra. 1977. *Case studies of technology transfer in West Africa: Nigeria and Sierra Leone.* Presented at the Rice in Africa Conference, IITA, Ibadan, Nigeria. March 7-11, 1977.

Perez, A.T. 1977. *NAFPP swamp rice program for 1976.* Presented at the NAFPP National Swamp Rice Workshop, Moor Plantation, Ibadan, Nigeria. January 25-26, 1977.

Virmani, S.S., A.F. Tubman, and P.M. Worzi. 1977. *Rice development and Research activities in Liberia.* Paper presented at Rice in Africa Conference held at IITA, Ibadan, Nigeria. March 7-11, 1977.

Virmani, S.S., J.O. Olufowote and A.O. Abifarin. 1977. *Rice improvement in tropical anglophone Africa.* Paper presented at the Rice in Africa Conference, IITA, Ibadan, Nigeria. March 7-11, 1977.

Virmani, S.S., F. Sumo and P.M. Worzi. 1977. *The 1976 highlights of rice research activities in Liberia.* Paper presented at the WARDA Annual Research Review Meeting, Monrovia, Liberia. May 23-27, 1977.

GRAIN LEGUME IMPROVEMENT PROGRAM

Nangju, D. and K.O. Rachie. 1977. *Effect of genotype and environment on yield and some agronomic characteristics of cowpea.* Proc. Sabrao's Third International Congress, Canberra, Australia.

Nangju, D. 1977. *Effect of tillage methods on growth and yield of cowpea and soybean.* Proc. International Conference on "Role of Soil Physical Properties in Maintaining Productivity of Tropical Soils," IITA, Ibadan, Nigeria. December 6-12, 1977.

Pulver, E., F. Brockman, D. Nangju and H.C. Wien. *IITA's program on nitrogen fixation.* Proceedings of Advisory Meeting on potential uses of isotopes in the study of biological, dinitrogen fixation. Vienna, Austria. November, 1977.

Wien, Lal and Pulver. 1977. *Effects of transient flooding on growth and yield of some tropical crops.* International Conference on "Role of Soil Physical Properties in Maintaining Productivity of Tropical Soils." IITA, Ibadan, Nigeria. December, 1977.

ROOT AND TUBER IMPROVEMENT PROGRAM

Hahn, S.K., A.K. Howland, and J.E. Wilson. 1977. *Breeding of root and tuber crops.* Paper presented at the National Seminar on Root and Tuber Crops held at the National Root Crop Research Institute, Umudike, Nigeria.

Terry, E.R. 1977. *Cassava bacterial disease.* Paper presented at the Cassava Protection Workshop held CIAT, Cali, Colombia.

Terry, E.R. and O.B. Arere. 1977. *Identification of cassava diseases and scoring for susceptibility of cultivars.* Paper presented at NAFPP Workshop, NRCRI, Umudike, Nigeria.

GENETIC RESOURCES UNIT

Steele, W.M. and S.D. Sharma. *Organization of African rice exploration, conservation and evaluation.* A paper presented at the Meeting on Africạn Rice Species, Paris (IRAT/ORSTOM), January, 1977.

Sharma, S.D. and W.M. Steele. *Collection and conservation of the existing rice species and varieties in Africa.* "Rice in Africa" In: Buddenhagen, I., and G.J. Persely. (Eds. London: Academic Press.)

PUBLISHED BY THE INTERNATIONAL INSTITUTE OF TROPICAL AGRICULTURE, OYO ROAD, P.M.B. 5320, IBADAN, NIGERIA.