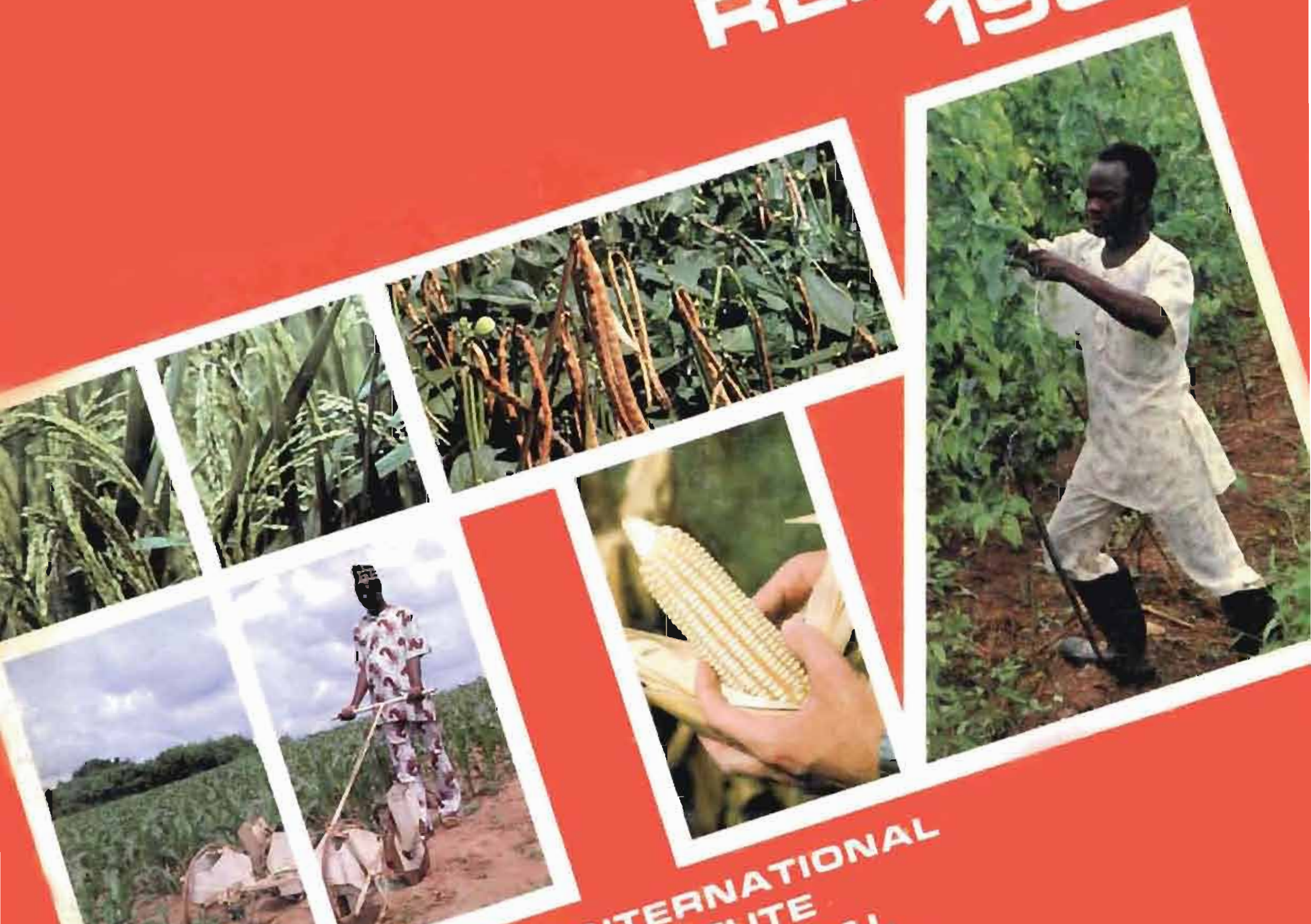
ANNUAL REPORT 1981



INTERNATIONAL INSTITUTE OF TROPICAL AGRICULTURE

About IITA

The International Institute of Tropical Agriculture (IITA) was established on July 27, 1967, as an autonomous, non-profit corporation by a decree of the Federal Military Government of Nigeria. It was formally organized at the first meeting of the Board of Trustees in Ibadan during July, 1968. The Federal Republic of Nigeria provided 1,000 hectares of land for IITA's site and the Ford Foundation gave the initial capital for buildings and development.

Support for research and day-to-day operations in 1981 came from the Ford Foundation, the Canadian International Development Agency (CIDA), the Overseas Development Ministry of the United Kingdom (ODM), the U.S. Agency for International Development (USAID), the World Bank, the International Fund for Agricultural Development (IFAD), and the governments of Australia, Belgium, Japan, The Netherlands, Nigeria, Norway, and the Federal Republic of Germany.

The Institute is governed by an international Board of Trustees.

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International Institute
of Tropical Agriculture (IITA)

Annual Report 1981

Contents

Board of Trustees

Foreword

This Annual Report, like previous ones, gives an overview of the activities in which the Institute has been engaged during the year. The information reported here is the product of the scientific community of IITA and is dedicated to scientists all over the world who share our concern with tropical food crop production. Because of the urgency of the food crisis in Africa and because of the Institute's location, its research is focused on Africa. But the results of this research may also be useful for the tropical environments of other continents.

Scientists at IITA report on their work at conferences and symposia and in various scientific journals, monographs, and review papers. By these means, they communicate their research results, invite criticism, and influence the course of research in several institutes. But interaction of this type is greatly limited by a scarcity of good library facilities. Not all national institutes have libraries large enough to provide a wide range of scientific journals. And yet it is essential that scientists in these institutes have access to the results of research. This publication is addressed particularly to those scientists; it is intended to provide them with a useful reference in their work. Because of the breadth of the Institute's program, the Annual Report cannot deal with any subject in great detail, nor can it discuss the results in relation to other publications, as a journal article would.

The format of this Annual Report has been greatly modified from that of previous reports. The reporting is structured around specific research projects, and the scientists cooperating in each project have been identified. This change has been introduced for the sake of brevity and to aid the readers in contacting scientists for further clarification, information, or material. We hope that this approach will foster a spirit of partnership between the scientists at IITA and those working in national institutes. This type of cooperation is crucial to the formulation of research networks and to the planning and implementing of joint efforts by national scientists, with IITA acting as a catalyst. We welcome readers' reactions to the changed format and invite suggestions for further improvement.

For IITA, the year 1981 has been a very productive one. The Institute's message on land development and management is getting increasing attention from policy makers, planners, and scientists. And IITA scientists continue to make further refinements in the technology. Success in breeding for resistance to cassava mealybug and green spider mite, as well as the discovery, introduction, testing, and release of natural enemies of the mealybug, are important steps toward containing these exotic pests threatening the African cassava industry. The Institute has launched a major program for developing hybrid maize, to produce germplasm that is even more productive and responsive to good management than that now available. The superiority of IITA upland rice varieties in the fragile tropical soils of Africa, Latin America, and Asia has been firmly established. The so-called "60-day cowpea," with its highly determinate growth habit and very early maturity has captured the imagination of many scientists and farmers. The thrips-resistant cowpea variety TVX 3236 is now being rapidly distributed in Nigeria.

Gains such as these would not have been possible without the full cooperation of scientists in various national institutes and the foresight of the donor community which generously supported the Institute's work. We gratefully acknowledge both groups for their contributions to the mission of IITA.

Ermond Hartmans
Director General

Farming Systems Program

Introduction

Research in farming systems in 1981 went through considerable re-orientation and some changes in priority have been made. A large body of data accumulated over the past ten years is being reviewed. Research in farming systems from 1981 onwards will give strong emphasis in two areas:

1) Developing an integrated approach to on-farm research. Several pilot projects were initiated at the end of 1981 with national research institutions and World Bank financed agricultural development projects.
2) Developing a package of integrated land and biomass management practices for sustained food production for farmers in the humid and sub-humid tropical regions.

Long-term soil management experiments at IITA's main station at Ibadan and at the high rainfall sub-station at Onne have shown that with judicious fertilizer use, suitable crop rotation and minimum tillage with mulch, yields can be sustained for periods over 10 years on small farms without reversing the land to bush or planted fallow. However, results from a 40 hectare land clearing and management experiment at IITA show that there are no precise answers yet for large-scale food crop production in tropical Africa. Large-scale farms require mechanization for seed-bed preparation, planting and harvesting as well as careful management of cropping cycles, fertilizers, herbicides and pesticides. In an integrated land management package for large scale farming, zero tillage is one essential component. Effective methods of weed control, development of more efficient planting and harvesting machines, effective mulch cropping systems and cover crops are other factors requiring further research. We, therefore, expect to use the large experimental fields at IITA for an integrated set of experiments with a multidisciplinary approach.

Another fundamental issue is the rapid degradation of the kaolinitic soils in some older experimental fields at IITA as a result of continuous tractor plowing and absence of systematic crop rotation. Research on soil restoration was initiated during 1981 using planted fallow, cover crop and alley cropping systems. Increased attention will be given to exploring additional shrub and cover crop species. Moreover, cooperative work with the International Livestock Center for Africa (ILCA) on the soil restorative processes under pasture and grazing conditions has been initiated.

IITA Weather: General Weather Conditions in 1981

T. L. Lawson

Drier and warmer weather prevailed in 1981 with below average rainfall in all months except June, July and September (Fig. 1). The late start of the rains caused a corresponding delay in the beginning of the cropping season. This, coupled with the normal but more pronounced dry period in August, reduced the length of the season and adversely affected yields.

Insolation was favorable, particularly during the second season, but evaporative demand was generally below normal. A summary of values of pertinent variables is given in Table 1.

RAINFALL AND EVAPORATION. The first rains consisted of 2 isolated showers in late February and early March. The rain season did not start until late March, but was soon followed by a 3-week period of negative water balance during April. This 'false start' of the rains proved disastrous to crops sown early. The first 4 months of the year ended with a 25 percent deficit in cumulative rainfall and a concurrent 11 percent deficit in evaporative demand.

The cropping season did not have a regular positive moisture balance until May (Fig. 2). Rainfall for the 4 months was 5 percent short of normal and pan evaporation was also much lower (−21 percent) than the long-term mean. June was very wet with frequent high-intensity showers and associated gusty winds. The month ended with a total of 229.1 mm of rain, 22 percent above normal, and this greatly improved the cumulative moisture balance.

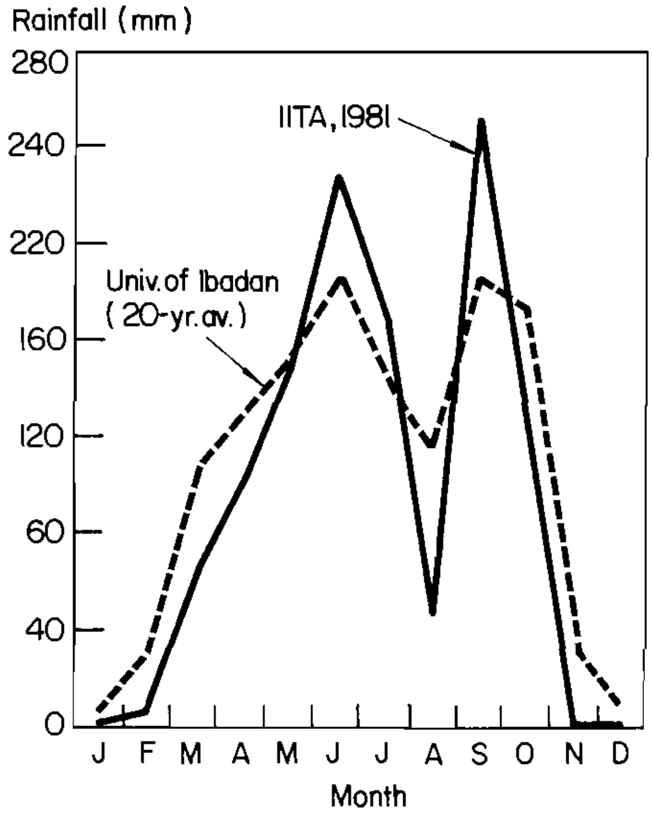

Fig. 1. Mean monthly rainfall, (IITA, 1981).

High levels of soil moisture continued through early July with almost daily rains. Heavy rainfall on 6 July caused water logging in some areas. The second half of July was comparatively dry, but soil moisture conditions remained good. The second rain season was preceded by an unusually severe drought in August with ony 49.3 mm of rain compared to the mean of 113.3 mm.

September was the wettest month of the year with a total rainfall of 250.0 mm, 56 percent of which came in the first 3 storms. The heaviest of these on 3 September, 1981, dropped 64.0 mm water at a maximum rate of over 100 mm/hr for a 32-minute period. Coming at the beginning of the season, it caused a lot of erosion due to the limited surface

Table 1. Summary of climatic data, IITA, 1981.

Month	Total rainfall	Total evaporation mm	Solar radiation gm-cal/cm^2/day	Temperature °C Min	Temperature °C Mean	Temperature °C Max	Relative Humidity % Min	Relative Humidity % Mean	Relative Humidity % Max
Jan.	0	129.37	385.82	21.7	27.0	32.2	37	67	97
Feb.	6.0	155.25	459.22	23.9	29.3	34.6	33	64	95
Mar.	61.7	173.60*	440.42	24.1	29.1	34.1	42	68	94
Apr.	101.1	144.30*	462.54	23.2	27.3	31.3	55	75	95
May	143.8	124.3*	432.25	22.5	26.4	30.2	59	77	94
Jun.	229.1	117.0*	433.13	22.5	26.2	29.8	63	79	95
Jul.	170.1	85.56*	328.98	22.1	24.7	27.2	71	83	94
Aug.	49.3	86.10	334.45	22.3	24.8	27.2	69	82	95
Sept.	250.0	98.70*	408.28	22.4	25.6	28.8	65	80	95
Oct.	145.6	123.38*	450.30	22.8	26.7	30.5	61	79	96
Nov.	0	120.17	452.33	22.1	27.3	32.4	46	71	96
Dec.	0	116.87	390.27	23.3	28.0	32.6	44	71	97

**Values adjusted for days with missing data.*

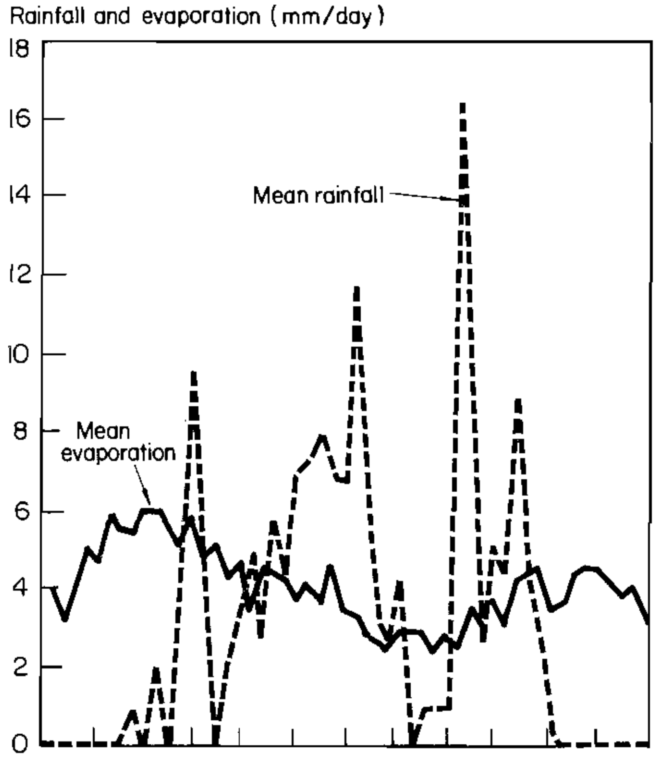

Fig. 2. Weekly mean rainfall and evaporation (IITA, 1981).

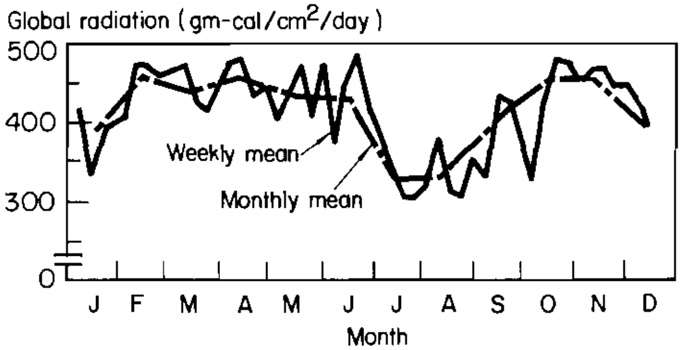

Fig. 3. Weekly and monthly mean solar radiation (IITA, 1981).

cover. Heavy rains generally continued throughout the rest of the season.

The rainfall for the year was 9 percent below normal, i.e. 1156.7 mm compared to 1271.1 mm. This fractional difference was comparable to the shift in evaporative demand, 1458.4 mm compared to 1590.0 mm.

SKY CONDITIONS AND SOLAR RADIATION. Unusually cloudy mornings, clear afternoon skies and limited harmattan in January and February resulted in above-average insolation in those early months. There was above-normal cloudiness in March and May. Solar radiation (Fig. 3 and Table 1) generally remained below average throughout the first season. The second cropping season, by contrast, had a better insolation regime. Solar radiation was above normal for the rest of the year.

TEMPERATURE AND RELATIVE HUMIDITY. Maximum temperatures (Fig. 4 and Table 1) were generally below

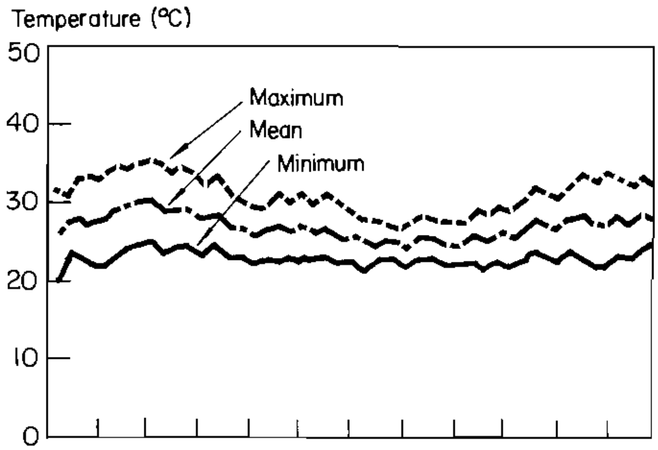

Fig. 4. Weekly mean maximum, minimum and mean air temperature (IITA, 1981).

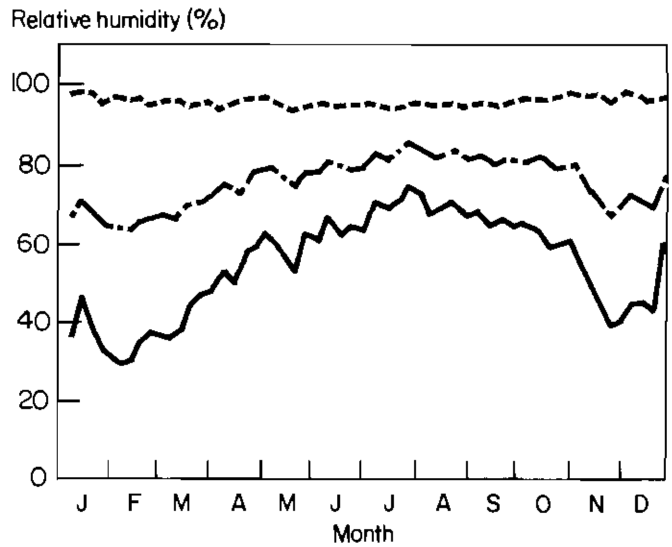

Fig. 5. Weekly mean maximum, minimum and mean relative humidity (IITA, 1981).

average except for March and October-December while minimum temperatures were above normal throughout the year.

Despite the late rains, air moisture was comparatively higher than usual from January through May (Fig. 5). This was followed by near normal conditions for most of the second half of the year. Wind speeds were also stronger than normal for most of the year with an unusual predominance of southwesterly winds during the dry season months. Strong gusts during the heavy rainstorms caused considerable lodging, particularly in rice and maize.

Agroclimatology

Light regime and productivity in mixed crops

T. L. Lawson

The 1980 Annual Report gave partial results of a study on light and moisture competition in maize/cassava* mixed crops in which the modification of light regimes through changes in stand geometry was shown to affect maize yields. Higher maize yields were related to more light reaching the maize. Analysis of cassava yields in 1981 also showed positive relationship between yield and radiation at full canopy. This is expressed by:

$$Y = \frac{25}{1 + 32.840e - 0.753x}$$

where Y is the yield in t/ha and x the amount of light reaching the cassava at 8 weeks after planting (WAP) expressed as a percentage of total available light. (Fig. 6, Table 2).

Results show that cropping patterns aimed at increasing the light available to the crop adversely affect yield. This relationship is, however, not linear (Fig. 7). The adverse effect of any one of the two crops in a mixture on the other is most pronounced when that crop in a mixture attains at least 80-85 percent of its yield as a sole crop.

Further analysis of cassava yields in relation to the light the cassava received after harvesting the maize shows positive relationship between the two variables (Fig. 8). The formula used is: $Y = -26.982 + 0.776x$; $r = 0.899^*$ where Y is yield in 40S x S70 and x is the percent radiation measured at 28 WAP.

These and similar results (IITA Annual Report, 1980) imply that radiation limits yield underlining the importance of selecting suitable cropping patterns.

Table 2. Effect of planting geometry and relative plant population on cassava yields in maize/cassava crop mixtures (1980/1981).

Treatment	Plant density (maize/cassava) 1000 pl/ha	Plant placement (maize/cassava)	Yield* t/ha	
1	25/12.5	80 × 50/80 × 100 cm		
2	25/12.5	160 × 25/80 × 100 cm (double rows)	23.96	de
3	25/12.5	25 − 75 × 80/80 × 100	19.25	bc
4	40/10	50 × 40 (double rows)/125 × 80	12.44	a
6	0/12.5	− /80 × 100 cm	25.31	d

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

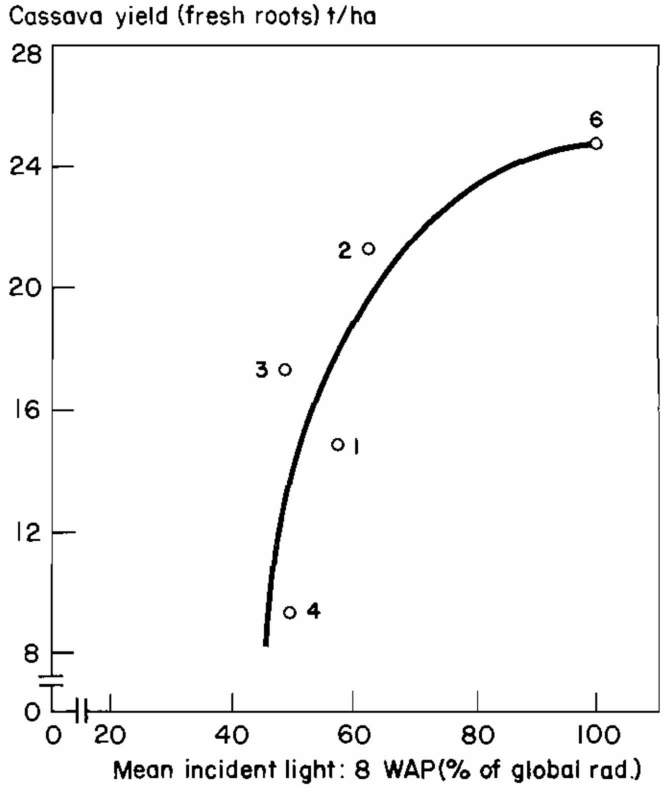

Fig. 6. Cassava yield as a function of incident light on cassava at 8 WAP in maize/cassava mixed crops. *(Numbers on the graph refer to treatments as defined in Table 2.)*

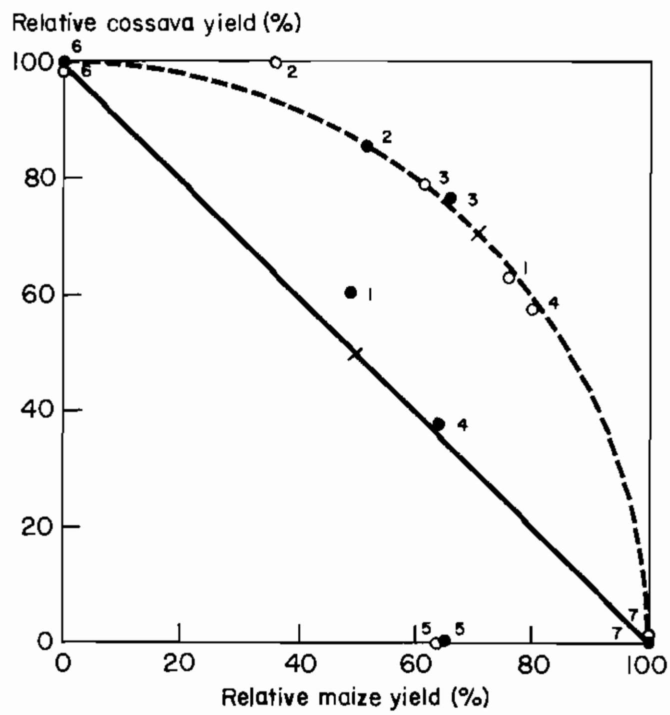

Fig. 7. Relative cassava and maize yield in maize/cassava mixed crops. *(Numbers on the graph refer to treatments as defined in Table 2. Treatments (5) and (7) are sole maize crops at 25,000 and 50,000 pl/ha respectively).*

Crop canopy structure and microclimate

T. L. Lawson

Choice of plant architecture offers a method of inducing favorable changes in the microclimate of crop mixtures to raise productivity. Maize and cassava varieties with different leaf structural characteristics were used to observe differences in light and soil moisture in or under their respective canopies.

MAIZE. In a mixed cropping experiment, the pattern of light transmission was monitored from the early growth to full canopy development for the maize variety/TZPB with spreading leaves and variety Kewesoke, which has erect leaves. Both varieties were interplanted with cassava variety TMS 30572 and TMS 30001. Soil moisture under the crop mixtures was also measured.

Results show that more light (5-10 percent) is transmitted through Kewesoke to the cassava than through TZPB. This

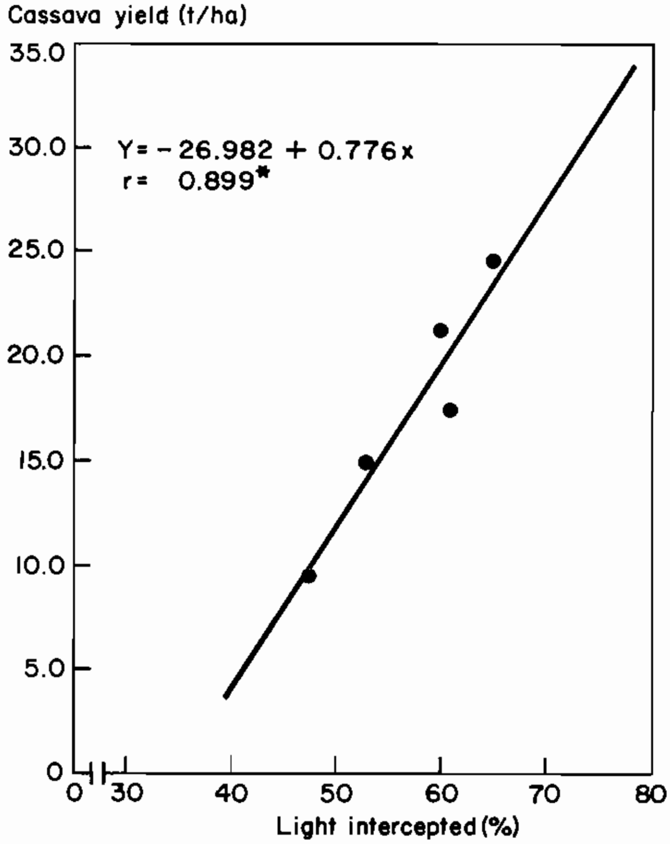

Fig. 8. Cassava yield in a maize/cassava mixed crop as a function of percent light intercepted by the cassava canopy at 28 WAP (1/11/80).

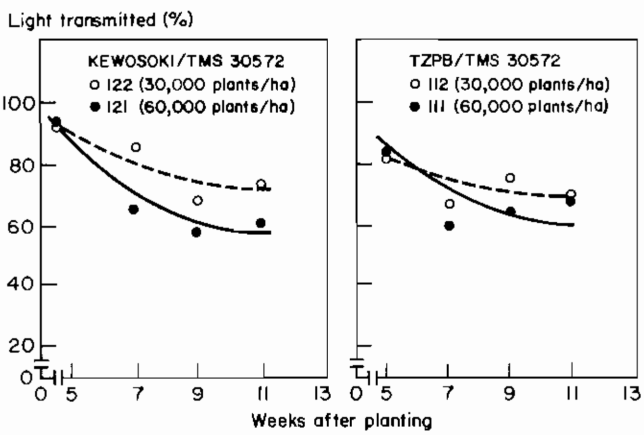

Fig. 9. Percent light transmitted through the upper canopies of maize in maize/cassava crop mixtures as a function of time (1981).
0 = 30,000 maize plants per ha.
0 = 60,000 maize plants per ha.

is particularly true at the lower plant density (30,000 pl/ha) (Fig. 9). The difference in transmitted light at 30,000 plants/ha compared to 60,000 plants/ha was greater for the erect leaved Kewesoke than for TZPB, which has larger leaves. By contrast, there is little or no difference in mean soil mois-

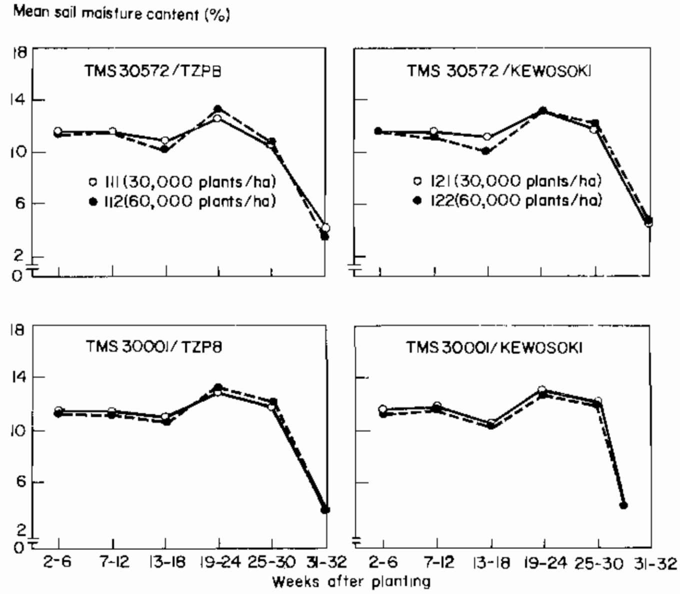

Fig. 10. Mean soil moisture content (%) as a function of time in maize-cassava crop mixtures (1981).
0-0 = 30,000 plants/ha.
0-0 = 60,000 plants/ha.

ture under the two maize varieties, regardless of plant population and intercropping with cassava (Fig. 10).

CASSAVA. A parallel study was conducted involving two cassava varieties, TMS 30001 and an unnamed variety, TMS "x" in pure stands. Large differences in transmitted light and moderate differences in soil moisture were observed in the first few months of growth WAP (Figs. 11 and 12).

Weed growth under the two cassava varieties studied and the weed weight from each plot were taken in the 11th WAP. Better light conditions under TMS "x" encouraged weed growth resulting in a mean fresh weight of 33.160 kg/plot and a dry weight of 4.756 kg/plot compared to 4.125 kg/plot fresh weight and 0.463 kg/plot dry weight under TMS 30001.

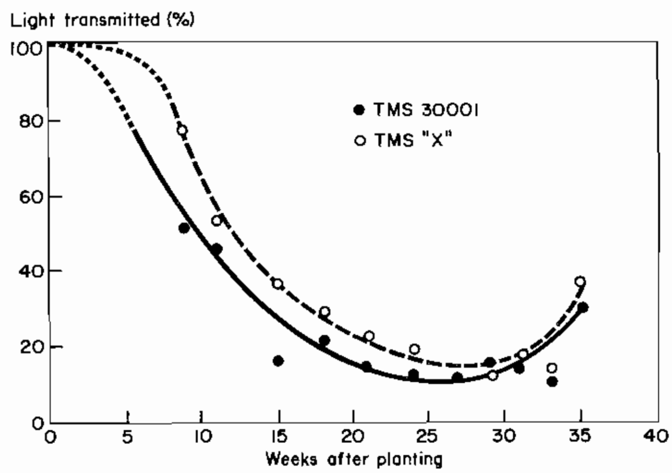

Fig. 11. Effect of cassava canopy and leaf structure on light transmitted through the canopy to the ground.

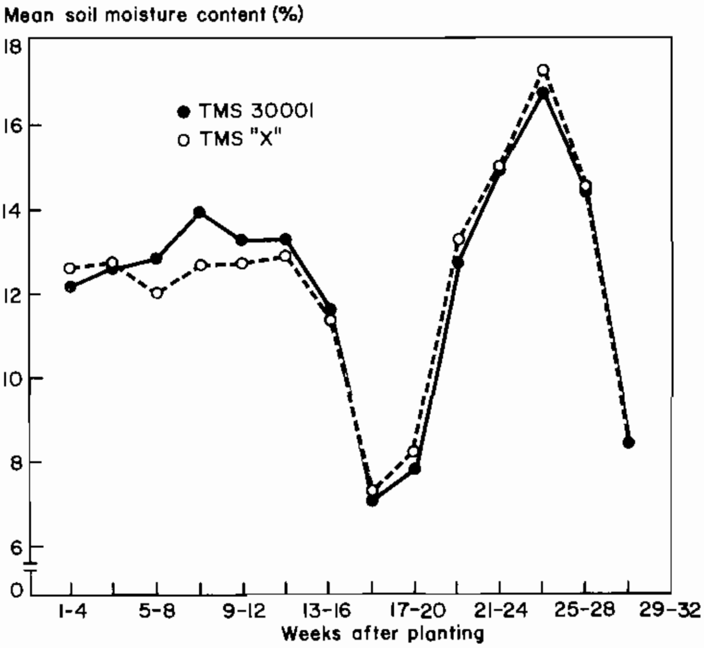

Fig. 12. Mean soil moisture content under cassava with normal leaves (Variety TMS 30001) and with strap leaves (variety TMS "x").

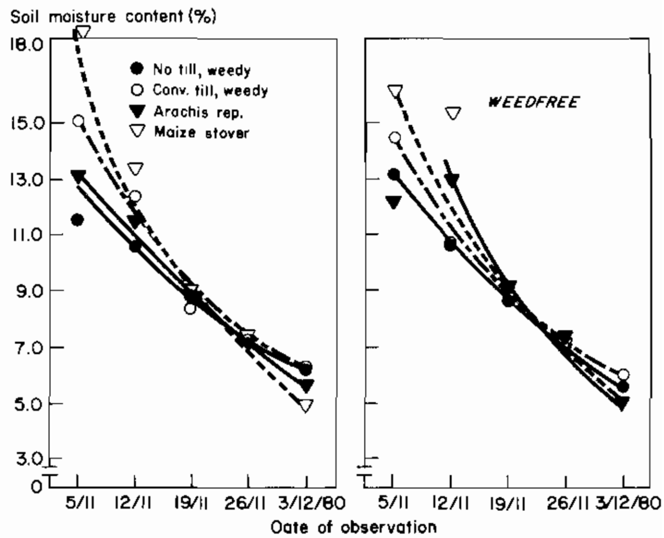

Fig. 13. Trend in soil moisture content under different mulch-crop combinations (1980).

Soil moisture regime under different mulch/crop combinations.

T.L. Lawson

Live mulch is a good means of maintaining permanent surface cover to prevent soil erosion, control weeds and maintain productivity. However, it is possible that live mulch, through transpiration, could decrease the moisture available to the main crop. To investigate this, data were collected to find out the pattern of moisture depletion in the surface layers of the soil (0-30 cm) under different mulch/crop combinations and tillage systems during 1980 and 1981 (Figs. 13 and 14). Results show that:

1) Live mulch generally increased moisture retention following rainfall. This is most likely due to less runoff and better infiltration resulting from the soil being protected from the rain and from better soil structure.
2) There was higher moisture content under weed-free conditions.
3) *Psophocarpus palustris* was, in most cases, better than *Centroscema* and *Arachis repens* in maintaining high soil moisture content under weed-free conditions in 1980.
4) The rate of moisture depletion is faster under the various mulch-crop combinations, particularly with regard to live mulch.
5) Conventional tillage in most cases resulted in higher moisture levels.

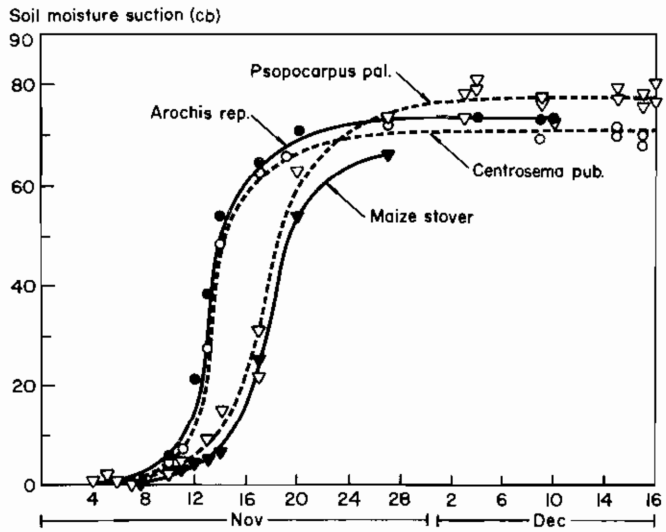

Fig. 14. Soil moisture suction under different mulched maize (1980).

Evapotranspiration—yield models: cowpea

T. L. Lawson, T. Diniz

In a re-examination of the evapotranspiration—cowpea yield prediction model (Annual Report 1980), the maximum evapotranspiration/pan evaporation ratio, ETm/Epan, previously taken to be 1.0 throughout the growing season was modified to 0.8 for the first 3 and the last 2 weeks of the growing cycle. The value of 1.0 was retained for the rest of the period. The results showed a better relationship between yields and estimated total evapotranspiration. The parameters of the derived equation are given in Table 3,—the equation being in the form of $Y_c = a + BAET$ where Y_c is cowpea yield, a, the intercept, b, the regression coefficient and AET, the estimated total evapotranspiration.

The 1978 data were also analyzed giving results comparable to those of 1977. The overall equation based on the 3 years maintained a high degree of yield predictability. Multiple regression analysis, based on cumulative evapotranspiration for the pre-flowering and post-flowering periods did not improve the level of prediction.

Table 3. Intercept, a, regression coefficient, b, and simple correlation coefficient, r, for cowpea yield prediction.

Year	Source of variation		Parameters a	b	r	(r) +
1976	TVu 3629	(n = 10)	−26.78	0.75	.98**	(.90**)
	TVu 4557	(n = 10)	−25.07	0.74	.90**	(.81**)
	Both varieties	(n = 20)	−25.93	0.74	.94**	—
1977	TVu 3629	(n = 11)	3.74	0.60	.74**	(.71*)
	TVu 4557	(n = 11)	3.78	0.55	.61*	(.59)
	Both varieties	(n = 22)	3.02	0.58	.68**	
	All values 1976&77	(n = 42)	−15.03	0.69	.86**	

+(r): Correlation coefficient from the previous analysis.
**, ** Denote significance at 5% and 1% level, respectively.*

Evapotranspiration—yield models: maize

T. L. Lawson, T. Dinis

In the analyses of the yield of sequentially planted maize (Annual Report 1973, 1974, 1975), the ratio ETm/Epan during the first and last 3 weeks of the 12-week growing period was taken as 0.8, with 1.0 retained for the middle period. The ratio of actual to maximum evapotranspiration was taken to be equal to that of the actual to maximum soil moisture content at field capacity. The best prediction was achieved in 1974-1976 (Table 4).

The analysis for the years 1977 through 1979 showed rather low correlation, ranging from a non-significant correlation coefficient of .08 in 1979 to .48 in 1978. The data were reanalyzed on the basis of the cumulative evapotranspiration for the periods 1-6 WAP (pre-flowering) and 7-12 WAP weeks (post-flowering), in one instance and in another 1-6 WAP, 7-9 WAP (flowering and early grain fill) and 10-12 WAP (late grain fill). The resulting multiple linear regression equations with parameters shown in Table 5 gave much better results.

Table 4: Intercept, a, regression and correlation coefficients b & r for simple linear regression relating maize yield to cumulative evapotranspiration coefficients.

Years	a	b	r
1974	−210.45	35.46	.89**
1975	−1550.35	28.64	.82**
1976	−2481.59	30.90	.94**
1974-76	−2060.04	31.47	.86**

Maximum evapotranspiration of rice (variety ITA 117)

T.L. Lawson, K. Alluri

To complement earlier studies (Annual Report 1979) on OS6, a tall upland rice variety with low tillering ability, field measurements of water requirement were carried out using a variety ITA 117, which is of relatively short stature and high in tillering.

The ultimate objective is to deduce some modal value(s) for the crop from the set of results obtained. The drainage lysimeters were used as in the previous studies.

Maximum evapotranspiration, ETm, for the variety ITA 117 totalled 531 mm and 489 mm on Iwo and Alagba soils respectively. Corresponding mean daily values were 3.99 mm/day and 3.68 mm/day; these compare with 4.44 mm/day (Iwo) and 3.87 mm/day (Alagba) previously obtained for OS6 in the dry season and 3.38 mm/day (Iwo) in the 1st-2nd (wet) season for the same variety.

The comparative values of evaporative demand were found to be 4.53 mm/day in the dry season and 3.29 mm/day in the wet season for OS6 and 3.38 mm/day for ITA 117. These values compared to the corresponding relative maximum evapotranspiration values suggest a higher rate of water use by ITA 117 compared to OS6. This is confirmed by the respective ETm/Ep values: 1.18 (Iwo soil) and 1.09 (Alagba soil) for ITA compared to 0.98 (Iwo) and 0.85 (Alagba) for OS6 in the dry season, and 1.03 (Iwo) in the wet season. These figures reflect some seasonal differences as well.

As in the previous studies higher yields and water use efficiency were obtained on the Iwo soil (Table 6).

Table 5. Intercept, a, regression coefficient, b, b_1, c, c_1, c_2, and correlation coefficients, r(2) and r(3), for the different types of equation relating evapotranspiration to maize yield.

Equation type	Parameters	Years 1974	1975	1976	1977	1978	1979	1974-79	1974, 75, 76 & 78	1974-76
(2)	a	−1593.40	−1176.99	230.65	2876.07	−4162.38	1660.96	577.35	−677.10	−1667.78
	b	27.41	17.20*	49.12	−15.55	−30.66*	6.57	7.78	15.43**	23.06**
	b_1	37.52**	37.31	9.50	8.45	23.07*	2.54	21.96	34.11**	36.13**
	r (2)	.90	.85	.82	.62	.78	.10	.59	.80	.87
(3)	a	−505.68	−980.18	−2177.45	5201.46	3231.04	1740.22	564.38	−700.18	−1644.27
	c	19.28	−9.65*	25.13**	−49.54	−19.58	4.12	8.24	17.34**	23.52**
	c_1	20.53	−3.29*	37.82**	42.36	8.69	13.30	19.23**	23.92**	32.50**
	c_2	49.38**	31.80**	28.53**	31.60	43.07	−5.12	24.75**	43.62**	39.15**
	r (3)	.92	.85	.95	.78	.83	.15	.59	.82	.87
	n	13	15	15	14	15	14	86	58	43

Note: 1, (*) and (**) indicate 5% and 1% levels of significance respectively for t− Tests.
2, Equation type (2) $Ym = a + b\,AET_{1-6} + b_1AET_{7-12}$; (3) $Ym = a + cAET_{1-6} + c_1AET_{7-9} + c_2AET_{10-12}$.
Where Ym is maize yield in kg/ha, AET is actual evapotranspiration and 1-6, 7-9, 7-12 and 10-12 denotes periods in weeks after planting.

Table 6. Plant height, yield, mean maximum evapotranspiration ETm/Ep ratio and moisture use efficiency of rice variety ITA 117.

Parameter	Soil type	
	Iwo	Alagba
Mean plant ht (cm)	89	77
Yield (kg/ha)	6060	4390
ETm (mm/day)	3.99	3.68*
ETm/Ep	1.18	1.09*
Water use efficiency (WUE)	1.14	0.90*

ETm: Maximum evapotranspiration, E pan: Class A pan evaporation.
**Estimated value.*

Soil and Land Management

Land Clearing and Development

R. Lal, D.C. Couper, S.L. Claassen

Watershed management experiments were initiated in April 1979 on a 44-ha watershed to study the effects of different methods of land clearing, post-clearing tillage systems on runoff rate and erosion, soil properties, hydrological parameters and crop yield. This experiment has been designed to provide basic information on ecological factors and hydrological characteristics that are altered by different methods of land clearing and, in turn, influence rate of soil degradation and crop production.

The importance of the research information being obtained can be realized by the fact that about 6-10 million ha. of land are being developed annually in the humid and sub-humid tropics. Some of these land development schemes, however, are being implemented with little regard to soil and climatic problems. The objective of this experiment, therefore, is to provide guidelines on appropriate methods of land development and post-clearing soil management on the basis of soil and hydrological characteristics.

There were 6 treatments:

1) **Traditional farming.** This treatment involved incomplete clearing by manual operations and crops grown without adding agricultural chemicals.
2) **Manual clearing and no-tillage.** Complete manual clearing was done with native tools. After drying the vegetation, biomass was burnt *in situ.* Subsequent management involved no-tillage and no terracing.
3) **Manual clearing and conventional tillage.** Subsequent to clearing done as described in treatment (2); seedbed preparation was done by conventional plowing and harrowing. Terraces and grass waterways were made to control erosion.
4) **Shear blade and no-tillage.** Shear blade mounted on a D-8 type crawler tractor was used to clear the forest in windrows 50 m apart. Subsequent management was done with the no-tillage system.
5) **Treepusher and no-tillage.** Clearing and windrowing was done by a treepusher mounted on a D-8 crawler tractor. Crops were grown under no-tillage.
6) **Treepusher and conventional tillage.** Clearing was done as described in treatment 5. The land was then terraced. Conventional plowing and harrowing were used to prepare the seedbed.

All 6 treatments were replicated twice on sub-watersheds of about 3 ha each. All 12 sub-watersheds were equipped with 4.5′ H-Flume to monitor runoff rate, and water samples for each rainfall were obtained by a Coshocton Wheel Sampler.

The mean grain yield in 1981, three years after clearing, was 3.5 and 2.5 t/ha for maize and 447 and 205 kg/ha for cowpea for no-tillage and conventionally plowed treatments. Irrespective of the treatments, there were significant yield losses during harvesting. Low harvest efficiency for maize was due to lodging and for cowpea due to pods being too close to the ground.

Although runoff and soil erosion, three years after clearing, were not severe for any of the treatments, more runoff and soil erosion were observed from the treepusher/conventionally plowed treatment (Table 7).

Table 7. Effects of land clearing methods and tillage systems on soil compaction, runoff and soil erosion during 1981.

Treatment	Penetrometer resistance (kg/cm^2)	Bulky density (g/cm^3)	Runoff (mm)	Soil erosion (kg/ha)
Traditional farming	1.23	1.27	0.4 a#	1 a
Manual clearing—no tillage	1.67	1.40	0.4 a	2 a
Manual clearing—conventional tillage	0.70	1.38	19.4 b	101 b
Shear blade—no tillage	2.19	1.38	14.1 b	173 b
Tree pusher—no tillage	1.81	1.47	13.9 b	265 c
Tree pusher—conventional tillage	0.60	1.37	32.3 c	543 d

 # Duncan multiple range test at 5% levels of significance.

Soil compaction was measured by bulk density and penetrometer resistance. These measurements were made in the second season about 2 weeks after plowing. As would be expected, plowing decreased compaction and penetrometer resistance in all plowed plots (Table 7). Consequently, all no-till plots had more bulk density and more penetrometer resistance than plowed treatments. After harvesting, however, the bulk density and penetrometer resistance in plowed plots were equal to or more than the no-till plots. Raindrop impact, crusting, and consolidation substantially increased the bulk density of the plowed treatments within 3 months after plowing.

Three years after clearing, the influence of methods of land clearing or runoff and erosion is less than in the first year. The no-till plots show symptoms of soil compaction, although the adverse effects of compaction in the seedling zone are alleviated by plowing. The soil in the conventionally plowed treatments, especially those cleared by treepusher methods, has been severely degraded. Although there was soil compaction in the no-till treatments, soil physical and chemical properties are better in no-till than in plowed treatments.

Soil Degradation and Restoration

A.S.R. Juo

SOIL DEGRADATION. There are 3 forms of soil degradation: physical, chemical and biological. Results of long-term crop and soil management research on the forest Alfisols at IITA have indicated a steady decline of soil productivity due

Table 8. Degradation of a forest Alfisol (0-15 cm) as a result of continuous cultivation after 9 years.

Treatment	pH (H_2O)	Total N %	Exch Ca	Exch Mg	Fine earth# bulk density (0-7.5cm) g/cm^3	Earthworm* activity No./250cm^2	N Mineralized** (65 days) g/g
			——meg/100g——				
Maize, Residue removed	5.0	0.14	0.85	0.11	1.36	0.02	37
Maize, Residue mulched	5.4	0.18	2.05	0.23	1.22	1.79	n.d.
Natural bush (check)	6.6	0.23	3.13	1.11	0.84	12.98	77

**Hyperiodillus cast count during a 4-day period; monitored during the 8th year of the experiment.*
***(NH_4 + NO_3) nitrogen; Laboratory incubation.*
n.d. = Not determined.
 # Corrected fine earth bulk density; the soil contains moderate amounts of quartz gravel.

to soil degradation (IITA Annual Report 1978, 1979, 1980). Results from a field experiment comparing soil properties under fallow and continuous no-till maize after 9 years are given in Table 8 (IITA Annual Report 1980).

Physical degradation such as soil erosion and soil compaction caused loss of nutrients and soil organic matter, and restriction of root growth. Chemical degradation such as acidification and decomposition of soil organic matter caused decrease in cation exchange capacity, nutrient deficiency (i.e. Mg, S, Zn) and soil toxicity (i.e. Al, Mn).

Manganese toxicity symptoms are frequently observed on legumes such as cowpeas and soybeans growing in acidified (pH below 5.0) and low organic matter fields at IITA. Maize in the plots where crop residues were removed after each harvest showed acute Mg deficiency symptoms which correspond with the low exchangeable Mg level in soil.

As a result of the poor physical and chemical environment, the continuously cultivated plots have lower earthworm activity and a lower rate of N mineralization than those in plots under natural bush fallow.

SOIL RESTORATION. Natural regrowth and planted fallow species (Guinea grass, *Stylosanthes* and pigeon pea) were established in a degraded field previously under 6-year cultivation with upland rice and maize using conventional tillage. A treatment of no-till, fertilized, continuous maize with stover returned as mulch was included as a control. The fallow plots received no fertilizer application. After 4 years, the fallow plots were cleared manually and plant material left in the field as mulch (excluding woody parts). The field was planted to maize using a hand-operated no-till planter and sprayed with glyphosate (Roundup) 2 weeks before planting. First season maize yield and soil total N data sampled before land clearing are given in Table 9.

Table 9. Effect of fallow on maize yield, IITA, 1981 first season (Fallow period: 4 years; Soil: Dxic Paleustalf, Iwo Series).

Pre-clearing vegetation (Fallow crops)	Total N in soil# (0 - 15cm) %	Maize (TZPB) yield, Kg/ha Grain	Stover
Bush regrowth	0.15a	3698 a	4345 a
Stylosanthes	0.15a	2794 b	3156 b
Guinea grass	0.19a	2700 b	3544 ab
Pigeon pea	0.16a	2679 b	2700 bc
No-till maize* (Check)	0.16a	2400 b	2162 c

**N-P-K-Zn applied at rates of 90-30-30-5 kg/ha. No fertilizer applied in bush regrowth plots.*
#Soil samples taken in March 1981 before clearing.

The bush regrowth plots (without fertilizer application) gave significantly higher grain yield than the no-till maize treatment (with N, P, K, and Zn applications). Grain yields of the 3 planted fallow plots, though statistically not significant, were consistently higher than that of the continuous maize treatment.

Better growth and higher grain maize yield in the natural bush regrowth plots could not be attributed to the difference in soil organic matter status before clearing as indicated by the results of total N content of all treatments. However, the quantity and quality (i.e. C/N ratio and nutrient content) of plant residue returned to the field after clearing may be an important factor.

Soil Tillage Studies

Effects of tillage systems on soil and grain yield of rice

L.T. Ogunremi, R. Lal, O. Babalola

The objective of this investigation was to study the effects of different tillage methods on lowland paddy rice growth and yield under two different soil moisture regimes.

These experiments were initiated in 1981 in an alluvial sandy loam. There were three treatments: (a) conventional dry and wet plowing and rotavating, (b) no-tillage and pre-seeding weed control with Paraquat, and (c) compaction with a roller to increase the proportion of micro-pores and decrease the infiltration rate. These three tillage treatments were established as the main plots. There were two water management treatments: (a) rainfed with no supplementary irrigation, and (b) supplementary irrigation during drought periods to ensure surface flooding to at least 5 cm. The experiment was a split plot design with three replications.

Rice seedlings, 3 to 4 weeks old, were manually transplanted in each of the treatments. Periodic observations were made for plant height, tillers, and leaf area index. Grain yield and yield components were recorded at maturity. Observations were also made for the changes in soil physical properties.

The rate of infiltration decreased with soil compaction. There was little change in infiltration rate by puddling or no-tillage. The decrease in infiltration by compaction was caused by a decrease in total porosity and in the relative proportion of macro-pores. These changes in soil physical properties for this coarse-textured, sandy loam cannot be generalized to soils of different texture and mineralogical composition.

Crop growth, as measured by plant height, leaf area index and the number of productive tillers per unit area, was better in the compacted than in other treatments. The density of perennial aquatic weeds was greater in no-till and compacted treatments than in puddled treatment. With supplementary irrigation, compaction produced significantly more yield than no-till and the conventional puddling treatments (Table 10), but there was no significant difference in grain yield between no-till and puddling. Grain yield under supplementary irrigation was significantly greater than with the rainfed treatment for all three tillage systems (Table 10). Grain yield in rainfed treatments was not significantly different for all three tillage systems investigated, and in the irrigated the only difference was between compacting and no-tillage.

Table 10. Effects of tillage methods and moisture regime on grain yield (t/ha) of lowland rice on a sandy loam.

Tillage methods	Irrigated	Rainfed
Compaction	7.3	5.7
Puddling	6.6	5.1
No-tillage	6.1	5.6

LSD (.05)
(i) Tillage 1.0
(ii) Moisture regime 0.6

It may be concluded that for coarse-textured soils of high infiltration rate, prevention of seepage losses by decreasing the relative proportion of macro-pores has an important beneficial effect on rice growth and yield. Drought stress was not a problem with supplementary irrigation. Excessive leaching of applied fertilizer may have resulted in nutrient deficiency for highly permeable no-till and puddling treatments. Low grain yield in rainfed treatments is partly attributed to drought stress and the beneficial effects of compaction were not effective because of water shortage. Tillage requirements for lowland rice, therefore, should be evaluated in terms of soil texture, water management and its control.

Nitrogen requirement in tilled and no-till systems

B.T. Kang, N.C. Navasero

Despite increased interest in no-tillage crop production for certain areas of the humid and sub-humid tropics, very little information is available on fertilizer and nitrogen requirement for no-tillage crop production in the tropics. Field trials have, therefore, been carried out at Ikenne in the forest zone on Alagba soil series (Oxic Paleustalf) and at Ogbomosho, Savanna zone, on Apomu soil series (Psammentic Usthorthent) since 1978 to determine the N requirement for continuous tilled and no-till maize. The experiment uses a split plot design with four replications. Maize was grown during the main season. Cowpea was grown during the minor season at Ikenne only.

The results of the 1981 observations are given in Tables 11 and 12. Results on the Alagba soil in the Forest Zone and on the Apomu soil in the Savanna zone consistently showed that with no or low N rates, maize grain yield was higher from the tilled plots. With continuous cropping and at N rates ≥60 Kg N/ha, maize yield was higher with no-tillage in Ikenne (Table 11). However, results from the Savanna zone at Ogbomosho were inconsistent. Unlike the 1980 results, 1981 maize yields at Ogbomosho were higher with tillage even at high N rates.

The minor season cowpea crop under tillage at Ikenne showed higher plant dry matter and seed yields with tillage (Table 12). However, cowpea dry matter yield showed no

Table 11. Effect of tillage and nitrogen rates on grain yield of maize grown on Oxic paleustalf at Ikenne and on Psammentic ushorthent at Ogbomosho (1981).

N-rate (kgN/ha)	Ikenne (kg/ha) Tilled	No-till	Mean	Ogbomosho (kg/ha) Tilled	No-till	Mean
0	3195	2533	2864	894	539	716
30	3499	3368	3433	2092	880	1486
60	3824	4277	4051	3411	2076	2743
90	3513	4040	3777	4255	2710	3467
120	3805	3756	3781	4944	3049	3996
150	3694	4179	3936	5896	4350	5123
Mean	3588	3692		3577	2268	

LSD (.05) Between tillage means; Ikenne, 732; Ogbomosho, 811.
Between N-rate means; Ikenne, 360; Ogbomosho, 615.
Between N-rates with same tillage treatment; Ikenne, 510; Ogbomosho, 870.
Between N-rates of different tillage treatment; Ikenne, 848; Ogbomosho, 1110.

Table 12. Effect of tillage and nitrogen rates on plant dry matter and seed yield of cowpea cultivar VITA-6 grown on Oxic Paleustalf at Ikenne (1981).

N-Rate (kgN/ha)	Dry matter (kg/ha) Tilled	No-till	Mean	Seed yield (kg/ha) Tilled	No-till	Mean
0	4440	3060	3749	1279	1163	1217
30	3780	3800	3786	1273	1192	1233
60	4650	4020	4331	1249	1186	1218
90	3910	3320	3616	1220	1166	1193
120	4690	4050	4371	1304	1144	1224
150	4680	4410	4416	1399	1209	1304
Mean	4315	3775		1286	1177	

LSD (.05) Between tillage means; dry matter 688; seed yield 204.
Between N-rate means; dry matter 752; seed yield 113.
Between N-rates with same tillage treatment; dry matter 1063; seed yield 170.
Between N-rates of different tillage treatments; dry matter 1168; seed yield 245.

response to residual N applied to maize. There was significant response to residual N at the rate of 150 kgN/ha with no-tillage. With tillage or no tillage, seed yield showed some increase from residual N applied to maize.

Effect of tillage methods and soil properties on yam production

H.O. Maduakor, R. Lal

Tillage requirements for tropical root crops can be different from those of grain crops because considerable "root room" is required for adequate tuber development. Farmers in the tropics, in general, and in south-east Nigeria, in particular, spend considerable time and labor in preparing yam mounds and ridges. It is estimated that 150-240 mandays are required to cultivate one acre of yam using the traditional mound system. If the soil is coarse-textured, well drained, and relatively deep, it may be possible to produce a satisfactory crop of yam on a flat seedbed.

In the savanna region with high surface soil temperature and periodically low soil moisture, ridges and mounds are usually mulched after planting. Furthermore, no-tillage is also gaining support as a method of soil and water conservation. The objective of this experiment was to examine the effects of methods of seedbed preparation and mulching on growth, development, and yield of yam for a coarse-textured, well-drained Ultisol in southeastern Nigeria.

Field experiments were initiated in 1980 and were repeated in 1981 at IITA's high rainfall sub-station at Onne, near Port Harcourt, Nigeria. The soil at the experimental site is derived from coastal sediments and is classified as loamy, silicious, isohyperthermic oxic paleudult.

The design was a completely randomized block with 3 replicates. Each block consisted of 4 plots to which 4 treatments were randomly applied. The treatments were (i) ridges, mulched, (ii) ridges, unmulched, (iii) flat, mulched, and (iv) flat, unmulched. The ridges, 1 m from crest to crest and about 50 cm high, were made with a tractor. Seed yams were planted at 1 m x 1 m. Appropriate plots were mulched immediately after planting. Periodic measurements were made for plant height, dry matter production, leaf area index and root density. Tuber yield and yield components were monitored at harvest.

Root length and weight were not affected significantly by treatments (Table 13). Mulched treatments had lower total root length. Most of the feeder roots were concentrated in the upper part of the soil profile. Leaf area index and dry matter accumulation were the lowest for unmulched ridges.

Table 13. Effects of method of seed bed preparation on yield of yam tuber (t/ha) and root density (g/cm^3).

Treatment	Root density (g/cm^3)	Tuber yield (t/ha)
Ridges without mulch	0.274	15.7
Ridges with mulch	0.216	17.4
Flat without mulch	0.224	16.0
Flat with mulch	0.212	17.5
LSD (.05)	ns	4.0

The effects of treatments on the yield of yam harvest after 213 days are given in Table 13. Fresh tuber weight and average length of the tubers were higher for mulched than for unmulched treatments. This difference, however, is not statistically significant at the 5 percent level. The mean tuber yield was 16.6 t/ha and 15.9 t/ha for mulch and unmulched treatments, respectively.

Nutrient Management

Effect of continous fertilizer use and cropping on fertility status of an Entisol and an Alfisol

B.T. Kang

Little information exists on productivity and soil fertility management practices for continuous crop production for the major soils of West Africa. Fertilizer trials were, therefore, initiated in 1972 on a benchmark Entisol (Apomu soil series, Psammentic Usthorthent) and on a benchmark Alfisol (Egbeda soil series, Oxic Paleustalf) at IITA Ibadan, southern Nigeria, to investigate long-term soil response to N, P, K, Mg, S and Zn under continuous cropping. The trials used a randomized complete block design with 4 replications. An annual cropping pattern of maize (main season crop) followed by cowpea (minor season crop) has been used for the past 7 years.

In 1972, the bush was left to regenerate in part of the experimental area. These plots were then cleared and cropped in 1981. In half of the plots, plant residue was retained

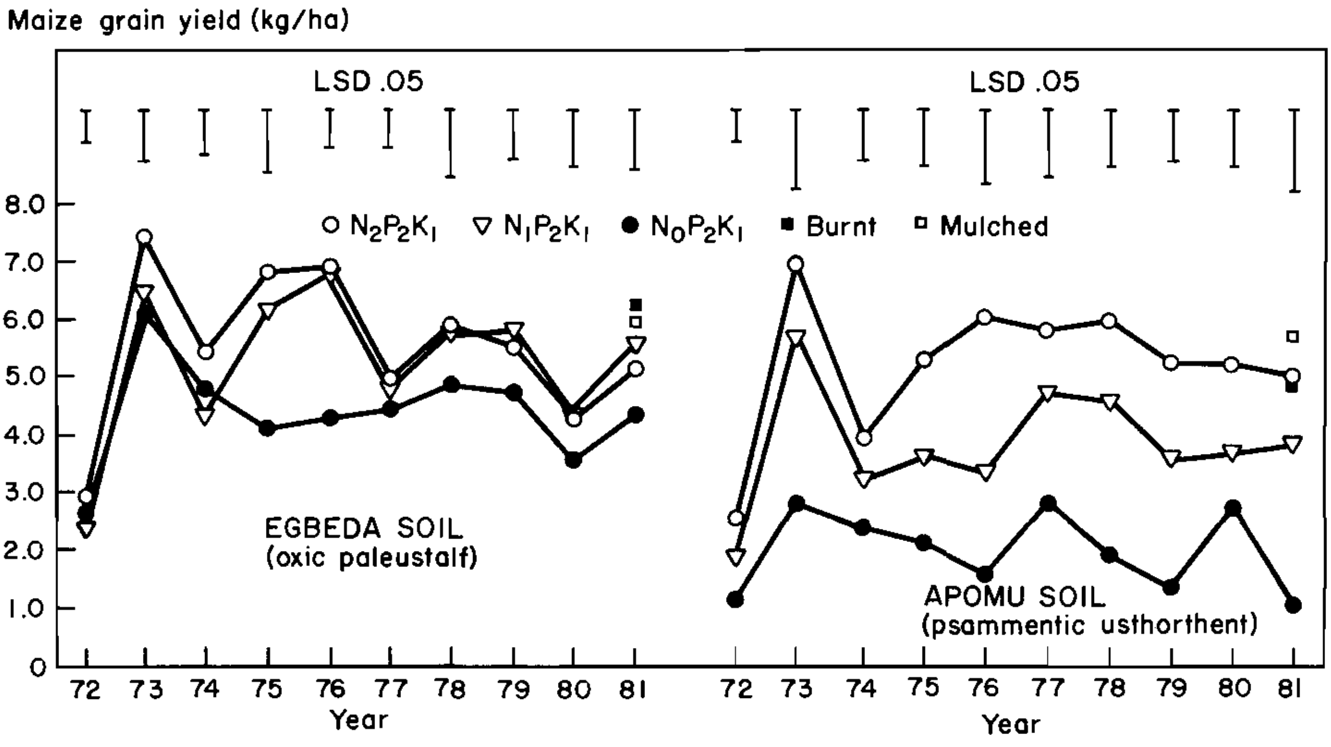

Fig. 15. Maize response to N on Egbeda and Apomu soils in long term fertility trials at Ibadan, Nigeria.
(N-rates: Egbeda soil; N = 0, N_1 = 60, N_2 = 120 kg N/ha; Apomu soil 1972-1974, N_0 = 0, N_1 = 60, N_2 = 120 kg N/ha; 1975-1981; N_0 = 0, N_1 = 75, N_2 = 150 kg N/ha).

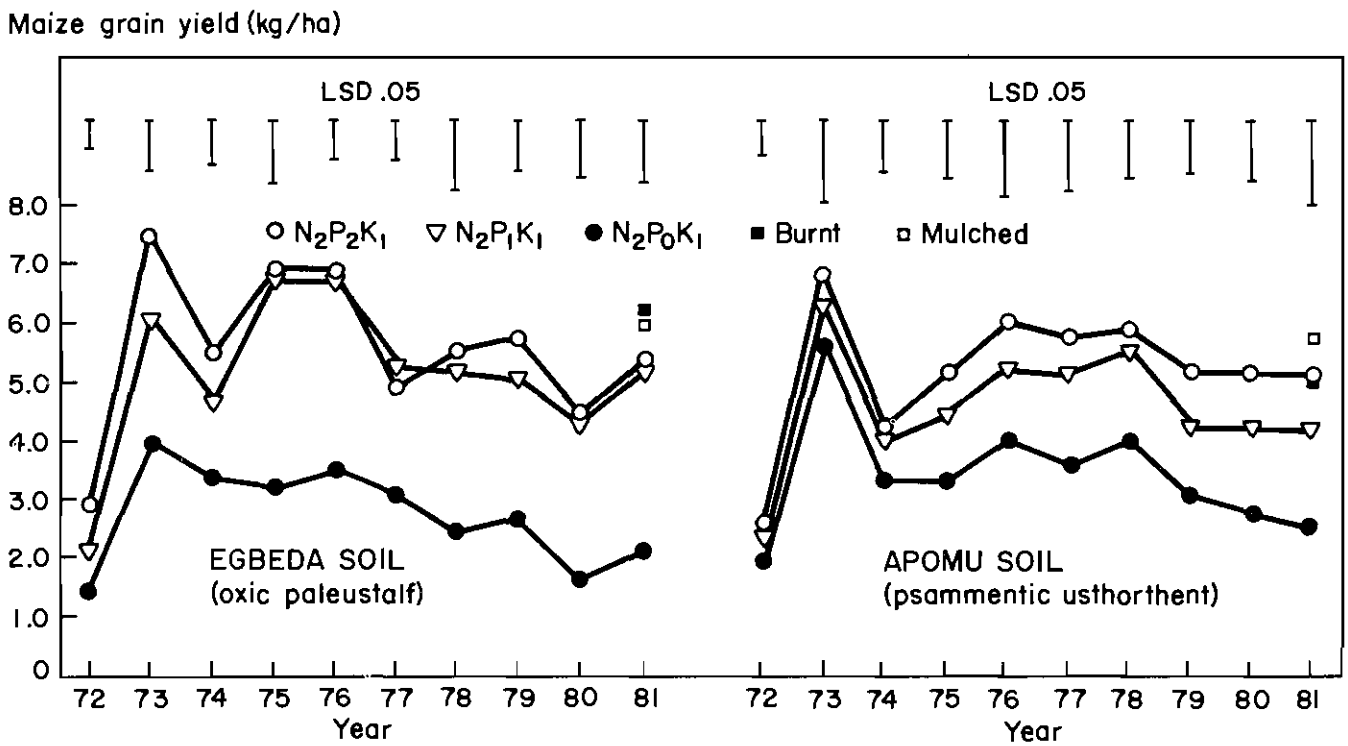

Fig. 16. Maize response to P on Egbeda and Apomu soils in long term fertility trials at Ibadan, Nigeria.
(P-rates: P_0 = 0, P_1 = 30, and P_2 = 60 kg P/ha).

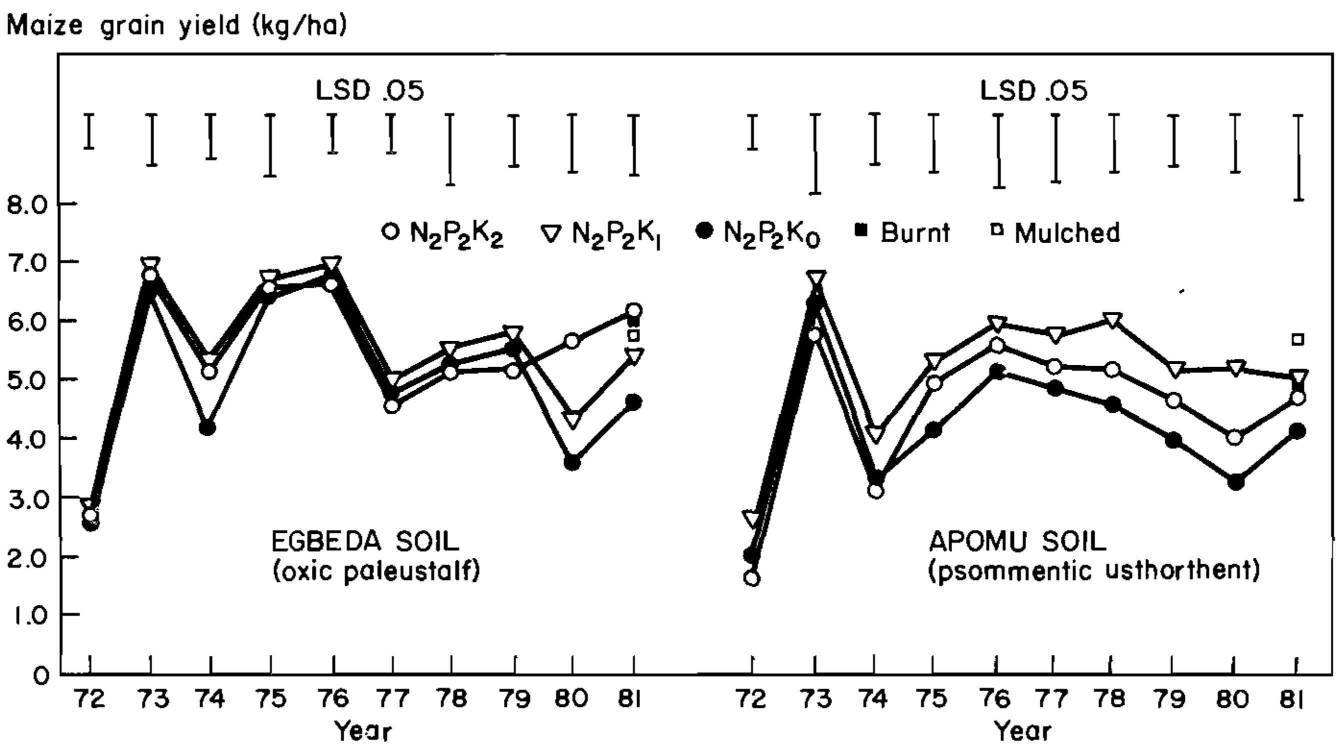

Fig. 17. Maize response to K on Egbeda and Apomu soils in long term fertility trials at Ibadan, Nigeria.
(K-rates: K_0 = 0, K_1 = 40 and K_2 = 80 kg K/ha).

as mulch following land clearing, but it was burnt in the remaining plots.

Results of response to N, P and K for the main season maize grain yields for the past 10 years are given in Figs. 15 to 17. On the Egbeda soil, maintenance dressing with 60 kg N/ha appears to be adequate for the main season maize crop. There are some indications that higher N response and higher yield may be obtained if a higher rate of K was used. The significant response to the higher K rate of 80 kg/ha, first observed in 1980 was also evident in 1981 (Fig. 17).

Higher maize stover yields were obtained from fallow plots with residue mulching or burning compared to fertilized plots. However, there were no differences in grain yield between these treatments (Fig. 17).

The second season cowpea, VITA-6, also showed some seed yield response to K at 80 kg/ha. Though plant dry weight was significantly higher on the mulched or fallow plots compared to fertilized plots, there was no difference in cowpea seed yields.

On the Apomu soil, maintenance dressing with a higher N rate of > 150 kg N/ha and 60 kg P/ha is needed for the main season maize crop. The yield depressing effect observed earlier with application of 80 kg k/ha (Fig. 17) disappeared in 1981. This may be related to further decline of K content in the soil with continuous cropping. Higher maize grain yield and significantly higher maize stover yield were obtained from fallow mulched plots compared to those from fallow burnt or fertilized plots. Second season cowpea dry matter yield was also significantly higher on the fallow plots compared to those from the fertilized plots. There was, however, no difference in cowpea seed yield among the treatments. The higher maize and cowpea yields observed on the fallow mulched plots are attributed to higher N content.

It appears that on a small plot basis sustained high maize and cowpea yields, comparable to those observed following bush fallow, can be obtained on Egbeda soils with judicious fertilizer use. However, on sandy Apomu soils, either higher N rates (>150 kg N/ha) or using fallow may be needed for sustaining maize yields.

Response of pluvial rice to phosphorus

B.T. Kang, J.L. Kiazolu

A large body of information exists on the phosphate requirements of flooded rice. However, available data for pluvial rice is very scanty. Field and plot experiments were, therefore, carried out to determine the response of rice varieties OS-6, ITA 116, ITA 117 and ITA 122 to phosphorus under pluvial conditions using a split plot design with 4 replications. The field experiment was carried out at Ikenne on an Alagba soil series (Oxic Paleustalf). In the pot experiment, the same soil series, collected from the Ikenne, was used.

Results from the pot experiment (Table 14) showed: (1) varieties of OS-6 and ITA 116 gave similar grain yields with or without P application, (2) both varieties gave significantly higher yields than ITA 117 and ITA 122, (3) rather higher external P concentrations were required for the 4 varieties to obtain maximum grain yield – 0.03 ppm P for ITA 117, 0.06 ppm P for OS-6 and ITA 122, and 0.12 ppm P for ITA 116.

Grain yields for the 4 varieties in the field experiment showed the same trend as those in the pot experiment (Table 15), except that the external P requirement was lower under field conditions. In the field trial, OS-6 did not respond to P application, while varieties ITA 116, ITA 117 and ITA 122 showed significant responses to low P only. The external P requirement of the last mentioned 3 varieties was estimated at 0.03 ppm P.

Table 14. Effect of Phosphorus concentration on yield of four pluvial rice varieties grown in pots in an Alfisol (Oxic paleustalf).

External P concentration (PPM)	Varieties Yield (grams/pot) OS 6	ITA 116	ITA 117	ITA 122	Mean
0.003	14.03	13.98	8.88	10.55	11.85
0.0075	19.38	20.73	15.80	17.05	18.23
0.015	23.63	22.33	19.05	18.63	20.91
0.03	24.15	27.05	23.28	23.08	24.39
0.06	29.73	26.68	24.00	24.98	26.34
0.12	29.18	29.18	21.85	24.65	26.21
0.24	28.93	28.95	23.90	26.30	27.02
0.48	29.15	28.33	25.00	26.63	27.28
Mean	24.77	24.65	20.22	21.48	

LSD (.05) Between phosphorus means 0.94.
Between variety means 0.70.
Between varieties for same phosphorus rate 1.99.
Between varieties for different phosphorus rates 1.96.

Table 15. Effect of phosphorus concentrations on yield of four Pluvial rice varieties grown on an Alfisol (Oxic paleustalf) at Ikenne, southern Nigeria.

External P concentration (PPM)	Varieties Yield (t/ha) OS 6	ITA 116	ITA 117	ITA 122	Mean
0.003	3.65	3.50	2.35	2.93	3.11
0.03	3.63	4.23	3.13	3.65	3.66
0.06	3.65	4.23	3.00	3.33	3.55
0.12	3.83	4.08	3.13	3.33	3.59
0.24	3.50	4.05	2.88	2.80	3.31
0.48	3.80	4.05	3.28	3.20	3.58
Mean	3.68	4.02	2.96	3.20	

LSD (.05) Between phosphorus means 0.20.
Between variety means 0.20.
Between varieties for same phosphorus rate 0.49.
Between varieties for different phosphorus rates 0.47.

The lower P requirement under field conditions was expected considering the more extensive root growth possible enabling plants to explore a large soil volume. Without P application and at a low P rate, OS-6 and ITA 116 outyielded varieties ITA 117 and ITA 122. The highest yield was obtained with variety ITA 116.

The higher yields from varieties OS-6 and ITA 116 without or with a low rate of P application may, in part, be attributed to their deeper and more extensive root system, enabling the plants to better utilize soil as well as applied P (Fig. 18). Phosphorus application also increased root growth of the 4 varieties.

Response of two cassava cultivars to potassium and magnesium

B.T. Kang

To determine potassium and magnesium requirements for continuous cassava production on a strongly acid Ultisol, a field trial was carried out for 3 cropping seasons at IITA's Onne

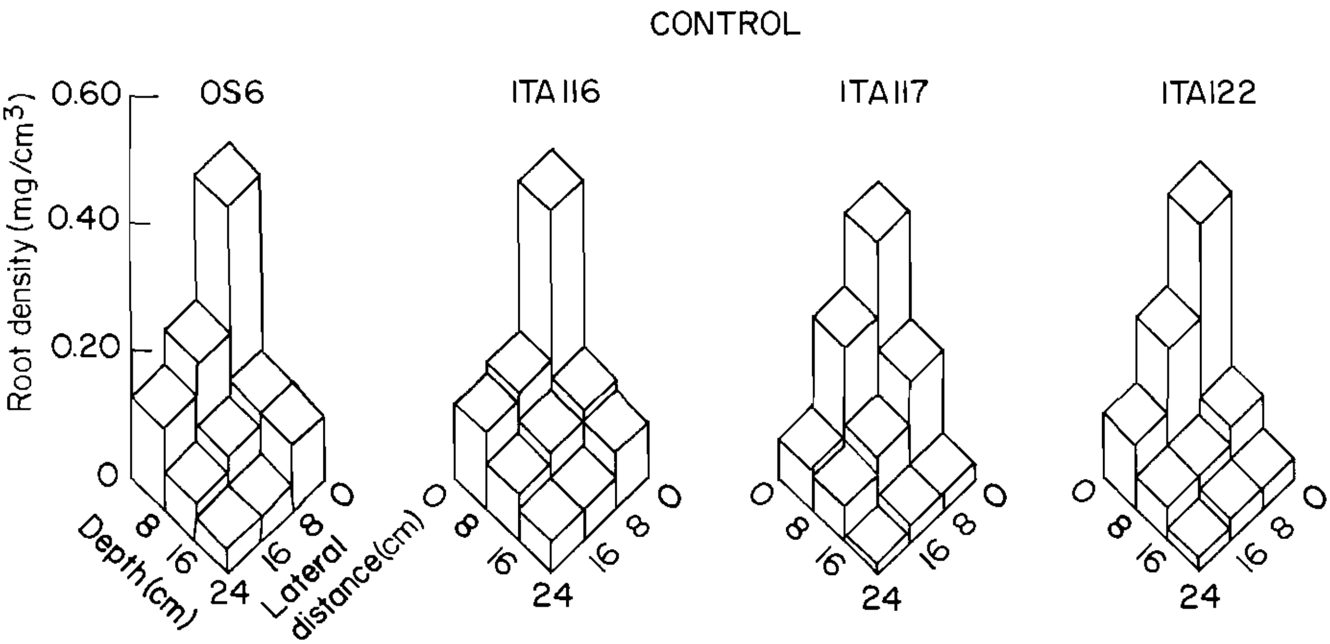

Fig. 18. Root distribution of four rice varieties grown under pluvial conditions with no P application on Alagba soil at Ikenne. Observation made at 60 days after planting.

substation. The trial was carried out using a split plot with 4 replications. Two cassava varieties, TMS 30395 and TMS 30211, were compared in this experiment. Prior to the trial, the land was under *Eupatorium* fallow.

Results of the 3 croppings show that:

1) During the first cropping following land clearing, variety TMS 30395 gave some response to K application. Potassium application depressed tuber yield for variety TMS 30211 and at high rates (120 kg K/ha) K also depressed yield for variety TMS 30395.
2) Significant tuber yield response to application of 30 kg K/ha was observed in the second cropping with both varieties.
3) During the third cropping, both varieties responded significantly to the application of 60 kg K/ha (Table 16). Although during this cropping both varieties showed tuber yield increases with Mg application, a significant response to application 20 kg Mg/ha was observed with variety TMS 30211.
4) For the 3 croppings, there is little difference in tuber yield between varieties TMS 30395 and TMS 30211. These results suggest that for continuous cassava production a maintenance dressing of 60 kg K/ha and 20 kg Mg/ha per crop appears to be adequate at Onne. High critical K levels in index leaves were observed at Onne. This was estimated at about 2.0 percent, which was rather high. The critical Mg level was estimated at about 0.36 percent.

Response of four cassava varieties to nitrogen and potassium

B.T. Kang, A.S.R. Juo, G. Heys

To determine the nitrogen and potassium requirement of 4 cassava cultivars grown on newly cleared Ultisol, a field trial

Table 16. Effects of potassium and magnesium application on tuber yield of cassava grown on Typic Paleudult at Onne in South-eastern Nigeria (1981).

Fertilizer treatment k	mg	Variety 30211 Fresh	Dry	Variety 30395 Fresh	Dry	Mean Fresh	Dry
(kg/ha)		(tons/ha)					
0	40	13.89	5.69	14.50	5.66	14.26	5.68
30	40	15.25	6.35	15.72	6.29	15.48	6.32
60	40	18.43	7.32	17.25	6.90	17.84	7.11
120	40	18.95	7.44	18.76	7.32	18.65	7.38
120	0	16.12	5.79	16.57	6.26	16.29	6.03
120	20	19.72	6.36	17.00	6.97	18.38	6.67
Mean		17.06	6.49	16.64	6.57		

LSD (.05) Fresh tuber yield:

Variety means 1.19; fertilizer treatment means 1.85; fertilizer treatment for same variety 2.62; fertilizer treatment among varieties 2.64.

Dry tubers yield:

Variety means 0.66; fertilizer treatment means 0.75; fertilizer treatment for same variety 1.06; fertilizer treatment among varieties 1.15.

was carried out at IITA substation at Onne on a Typic Paleudult. Prior to the trial, the land was under *Eupatorium* fallow. The trial was carried out using a split-plot design with 4 replications.

In the first year of cropping, variety TMS 30572 gave highest tuber yield of 28.4 t/ha followed by varieties TMS 30337, TMS 4488 and TMS 30555 with average yields of 26.5, 24.3 and 20.8 t/ha respectively (Table 17). On this newly cleared land, no positive yield responses were observed either to N or K applications. Instead, tuber yields were depressed with increasing rates of N application, particularly with no K application. Variety TMS 30395 showed least and variety TMS 30337 showed highest yield depressions with increasing rates of N application.

N leaching and utilization by maize and upland rice at Onne

Y. Arora, A.S.R. Juo

Field data dealing with leaching losses of fertilizer ions in the humid regions of Africa are scarce. As part of the nutrient leaching studies conducted at IITA, a field experiment was established at Onne to study the leaching and utilization of applied N by maize and upland rice with split applications of calcium ammonium nitrate (CAN) in a coarse-textured Ultisol (Typic Paleudult).

Maize variety TZPB was planted in the first season (April-July), and upland rice variety TOx 86-1-1 was planted in the second season (July-December) in the same field. Maize received a total of 150 kg N/ha as CAN. Soil samples, up to 120-cm depth, were taken at 4-week intervals throughout the 2 growing seasons.

Soil analysis showed that nitrate N leached readily in both the bare fallow and the cropped plots. The downward movement of nitrate followed a wave pattern, and the rate of movement was slower in the second season than in the first. A substantial amount of NH_4-N persisted in the surface soil over 4 weeks in plots that received CAN during the early part of the first season.

Splitting N from 1 to 3 applications reduced leaching losses from 53 to 28 percent of applied N (Table 18). Splitting N into 2 applications significantly increased grain yield of maize and upland rice, but further splitting into 3 applications increased the yield of rice only (Table 18). Estimated total recovery of applied N by the 2 crops and in the soil (0-120 cm) was 47, 56 and 72 percent for 1, 2 and 3 applications, respectively.

N fertilizer efficiency and leaching at Mokwa

L.A. Nadi, Y. Arora, A.S.R. Juo

In collaboration with the Institute for Agricultural Research (IAR) of Ahmadu Bello University, Nigeria, a field experiment to study N fertilization and leaching in the subhumid region was established at IAR's Mokwa station. First year results are given in Table 19.

Maize variety NS-1 greatly responded to N application and calcium ammonium nitrate (CAN) gave higher grain and stover yields of maize than urea. Total recovery of applied N by the crop and the soil (0-120 cm) was 56 and 42 percent for CAN and urea, respectively.

In comparison with total N uptake by first season maize at Onne as given in Table 18, 1 application of 150 kg N/ha of CAN at planting at Mokwa (subhumid savanna) was as effective as 2 split applications of CAN at the same rate under Onne conditions. Soils and landforms at both locations are comparable. Both are coarse-textured, kaolinitic Ultisols derived from sedimentary materials. The Ultisols at Mokwa are less leached and have the ustic soil moisture regime. The upland soil at Mokwa is classified as Oxic Paleustult.

Table 17. Nitrogen and potassium responses of four cassava cultivars grown on Ultisol at Onne (1981).

Treatments kg/ha N	K	Variety TMS 30572	TMS 30555	TMS 4488	TMS 30337	Mean
		(Tuber yields, t/ha)				
0	0	28.3	20.1	26.8	31.6	26.7
50		26.9	21.5	25.1	21.8	23.8
100		24.3	18.1	22.4	29.3	23.5
150		27.7	16.3	21.6	22.8	22.1
0	50	25.2	23.5	20.7	29.8	24.8
50		25.8	23.0	23.8	25.9	24.6
100		32.8	19.4	25.2	26.6	26.0
150		22.4	21.4	22.5	24.0	22.6
0	100	30.8	22.7	24.4	28.8	26.7
50		35.7	20.0	24.0	22.9	25.7
100		27.9	22.6	25.9	28.3	26.2
150		27.7	20.0	25.2	25.8	24.7
0	150	29.5	23.5	24.8	30.7	27.1
50		29.7	22.4	24.2	29.6	26.5
100		32.3	19.7	25.2	24.1	25.3
150		27.7	19.3	27.6	22.2	24.1
Mean		28.4	20.8	24.3	26.5	
LSD (.05)		5.3	6.2	6.9	8.5	
LSD (.05) Between variety means 4.40						

Liming acid soils in the high rainfall tropics for sustained maize and cowpea production

A.S.R. Juo

Although tree and root crops are more adapted to the strongly acidic, infertile soils (Ultisols and Oxisols) in the high rainfall tropics, the development of more productive maize (usually harvested and consumed as green maize) and grain legumes could substantially improve the present low protein diet of the rural population.

Results from a 6-year liming and crop rotation experiment at IITA's Onne substation show that relatively low rates of lime can be adequate to sustain crop yields under a continuous maize-cowpea rotation system. Soils in the area are acidic (pH 4.5 in H_2O), coarse-textured Ultisols (Typic Paleudults) derived from coastal sediments. Mean annual precipitation is 2,450 mm and is mono-modal. The rain season starts in early March and ends in late November.

With an adequate supply of N, P, K and Mg, liming at a rate of 0.5 t/ha maintained yields of maize variety TZPB near maximum (4 t/ha) for 3 years after liming (Fig. 19). Sustained maize yields for 6 years or longer were possible with lime rates of 2 and 4 t/ha. The critical level of exchangeable Al saturation for the maize for 90 percent maximum yield was about 35 percent, which is equivalent to a soil pH (H_2O) value of 4.8.

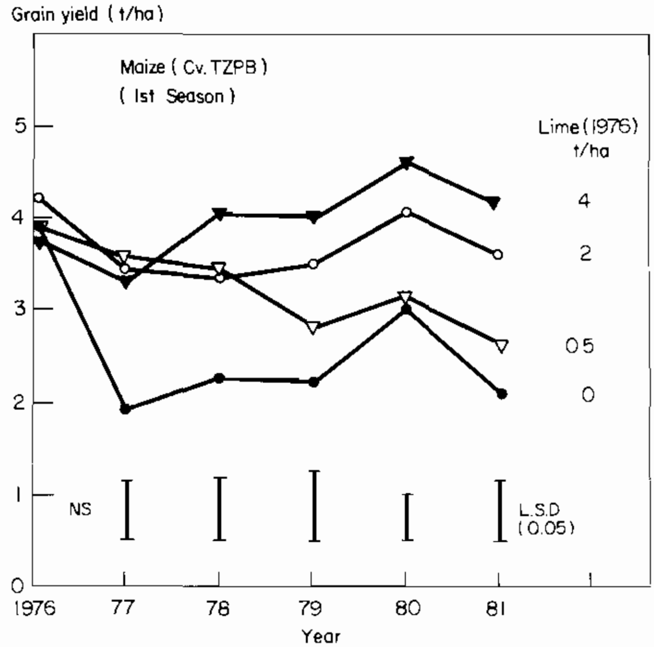

Fig. 19. Residual effect of lime on grain yield of maize grown in a coarse-textured Ultisols (Typic Paleudult) under high rainfall conditions at Onne.

Table 18. N fertilizer efficiency and leaching in maize and upland rice grown in rotation at Onne. Data are mean values of both unlimed and limed (2 t/ha) plots.

N Treatment*	Yield: Grain	Yield: Stover	N Uptake by crop (above ground)	Retention of Applied N in soil (0-120 cm)	Estimated recovery by crop and soil (0-120 cm)**
	kg/ha				%
			Maize (Cv.TZPB), 1st season		
One application	2673	3660	58.0	45.9	52.1
Two split	3354	4307	77.7	37.8	59.7
Three split	3547	4135	87.6	57.2	79.1
LSD (0.05)	619	650	17.3	—	—
			Upland Rice (Cv. ITA 118), 2nd Season		
One application	1643	2963	52.7	51.6	46.5
Two split	1907	3246	59.7	46.8	55.5
Three split	2573	4312	78.9	55.2	71.5
LSD (0.05)	338	390	9.3	—	—

* *Calcium ammonium nitrate (CAN) applied at the rate of 150 kg N/ha to maize in first season and 90 kg N/ha to rice in the second season under no-tillage and stubble conservation.*

** *Calculation of recovery of applied N at the end of second season is based on total application of 240 kg N/ha.*

Table 19. IAR/IITA collaborative trial on N fertilizer efficiency and leaching at Mokwa (1981).

Treatment*	Maize (NS-1) Yield: Grain	Maize (NS-1) Yield: Stover	Total N uptake by crop	Relation of applied N in soil (0-120cm)	Estimated recovery by crop and soil (0-120 cm)
	kg/ha				%
Check	383	2391	12.2	—	—
Calcium ammonium nitrate (CAN)	4253	6514	81.3	29.3	65.5
Urea	3443	4727	63.6	23.3	49.7
LSD (.05)	867	1736	18.2	—	—

* *150 kg N/ha applied at planting and conventional tillage. N, P, K, S and Zn applied at recommended rates.*

Cowpea performs well at Onne without additional fertilizer application when planted as a late rain season crop (late September or early October) in rotation with maize. IITA varieties such as VITA-1 and VITA-4 show strong tolerance to high Al acidity and have maintained a yield of 1.3 t/ha at about 50 percent exchangeable Al saturation in the surface soil (Fig. 20). Below 50 percent Al saturation, cowpea roots were abundantly nodulated with indigenous cowpea rhizobia.

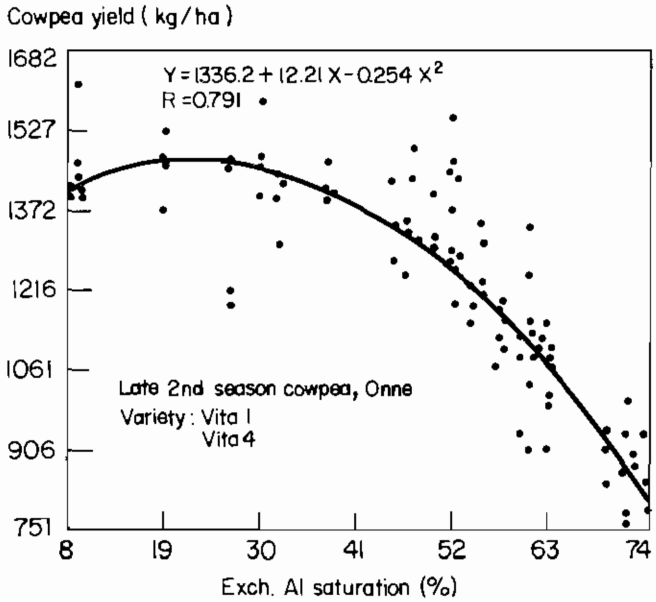

Fig. 20. Relationship between exchangeable aluminum saturation in soil and cowpea yield.

Early sowing of cowpea immediately after maize harvest in July-August is not recommended because of severe insect and disease infestation as well as temporary water-logging at the peak in the rain season.

Applied lime leaches readily from the surface soil, particularly at high rates of application. There were rapid declines of pH, exchangeable Ca, effective CEC and a steady increase of exchangeable Al in the limed surface soil (Figs. 21 and 22). A previous study (IITA Annual Report 1980) showed that the lime was leached in the form of neutral calcium salts and had little effect in amending subsoil acidity. Thus, recycling of the leached Ca in the subsoil horizons would require deep-rooting species tolerant of high exchangeable Al levels.

Because the relatively low rates of lime sustained yields for 3 years or more for the coarse-textured kaolinitic soils in the humid regions an annual dressing of 200-400 kg/ha of lime should be sufficient to maintain maize and cowpea yields. At such lime rates, lime could be regarded as a Ca fertilizer rather than a major soil amendment.

The introduction of cowpea as a dry season crop in the high-rainfall region deserves special attention. The tolerance of cowpea to high soil exchangeable Al levels and the abundance of cowpea rhizobia in acid soils should make this crop more attractive to smallholder farmers than other food legumes that are more susceptible to Al toxicity.

Soil-Plant-Water Relationships

Plant-water relations and yield of two root crops

B.S. Ghuman, R. Lal

In the humid tropics, crops experience diverse soil moisture regimes because of erratic rainfall. Studies are needed to understand more clearly plant behavior and yield under water excess or stress conditions. Such studies are important for

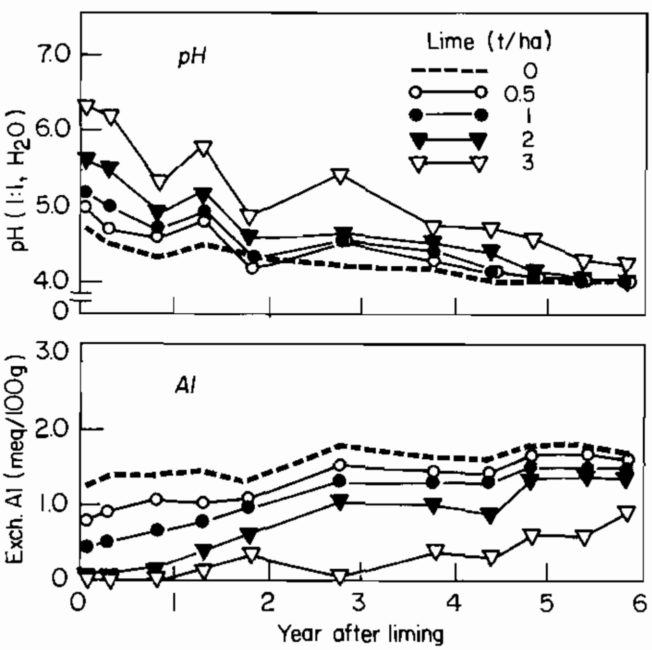

Fig. 21. Changes in pH and exchangeable Al in the surface soil (0-15cm) at Onne over a period of 6 years in plots receiving different rates of lime.

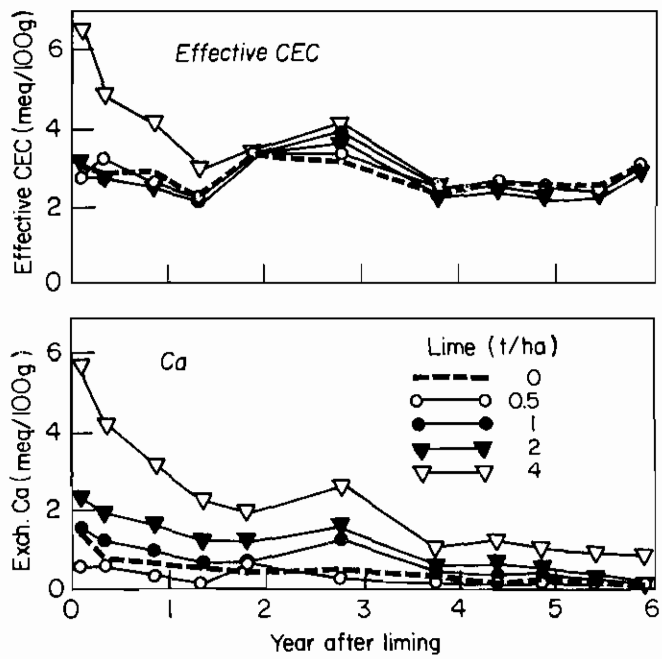

Fig. 22. Changes in effective CEC and exchangeable Ca levels in the surface soil (0-15 cm) at Onne over a period of 6 years in plots receiving different rates of lime.

the development of improved soil and crop production systems and for the selection of suitable varieties adaptable to adverse soil and environmental conditions.

The present study was undertaken to see the effect of different soil moisture regimes on stomatal resistance, leaf water potential and yield of cassava and sweet potato. Different soil moisture regimes were created by different water table depths and flooding in field lysimeters.

Four water table depths—15, 30, 50 and 70 cm—were maintained in lysimeters packed with Apomu sandy loam soil at 1.4 g cm^{-3} bulk density.

In addition, 3 other treatments studied were:

1) Transient flooding (TF) in which plants were flooded for 2 days per week for 2 weeks.
2) Continuous flooding.
3) Control, in which plants were irrigated equal to pan evaporation.

Treatments were started after establishing plants. Before starting the various treatments, the plants in all lysimeters were treated similar to the control. Treatments were replicated 3 times in a completely randomized design. Two stem cuttings of each of two cassava cultivars, TMS 30001 and Isunikankiyan, were planted in a lysimeter on 13 October, 1980. Similarly, two vinetip cuttings carrying 5 to 6 leaves of two sweet potato varieties, TIS 2148 and TIS 2295, were planted on 13 October, 1980.

Leaf diffusive resistance was measured with Lambda model LI-60 porometer. Leaf water potential was measured by the pressure chamber method. For these measurements, fully expanded leaves that were similarly exposed to solar radiation were selected. Plants were harvested for roots at 146 days and 137 days after planting cassava and sweet potato, respectively.

CASSAVA. Leaf diffusive resistance at 1500 hours increased with decreasing water table depth and transient flooding due to impeded water absorption associated with restricted aeration in soil with shallow water table depth or flooding. TMS 30001 had lower resistance (2-15 sec cm^{-1}) than Isunikankiyan (4-17 sec cm^{-1}) in all treatments, but in TF, the reverse occurred. Leaf water potential of TMS 30001 varied between −1.8 to −4 bars, while it varied between −2 to −3 bars for Isunikankiyan. Leaf diffusive resistance (LDR in sec cm^{-1}) of both cultivars was related linearly to leaf water potential (LWP in −bars) as indicated by the equations:

TMS 30001
LWP = −0.207 LDR + 4.623, r = 0.94
Isunikankiyan
LWP = −0.111 LDR + 3.810, r = 0.86

Continuous flooding increased leaf diffusive resistance and decreased leaf water potential more in variety TMS 30001 as compared to variety Isunikankiyan (Table 20). Maximum storage roots (39.5 g/plant with TMS 30001 and 20.3 g/plant with Isunikankiyan) were obtained in the treatment with water table at 70-cm depth. Flood inhibited tuberization in both cultivars. Further, Isunikankiyan failed to produce storage roots in the control and 15 and 50-cm water table depth treatments. The difference in root production between the two cultivars indicates that there is scope for screening varieties that can yield high under diverse soil moisture regimes.

SWEET POTATO. Leaf diffusive resistance increased with time during the day in all the treatments, but in the control maxima (13 sec cm^{-1} with TIS 2295 and 5 sec cm^{-1} with

Table 20. Leaf diffusive resistance and leaf water potential of two cultivars of cassava under poor aeration conditions.

Days after submergence	Leaf diffusive resistance (sec cm^{-1})		Leaf water potential (−bar)	
	30001	Isunik	30001	Isunik
0	2.8	3.0	2.4	2.7
1	7.0	4.4	2.2	2.6
2	18.2	8.1	3.1	2.6
3	19.4	9.6	3.1	2.7
5	21.0	8.2	2.6	2.2
14	24.0	8.3	5.4	3.0

TIS 2148) occurred around 15 hours. Variety TIS 2295 had higher resistance (1.5 to 13 sec cm^{-1}) than TIS 2148 (1.5 to 5 sec cm^{-1}). On the other hand, TIS 2148 had lower (−3 to −11 bars) leaf water potential than TIS 2295 (−3 to −7 bars). The leaf diffusive resistance was related linearly to leaf water potential as given by the regression equations:

TIS 2148
LWP (−bars) = 1.522 LDR + 1.93, r = 0.83
TIS 2295
LWP (−bars) = 0.426 LDR + 5.03, r = 0.95

Under continuous flooding, the leaf water potential of both varieties increased for the first 5 days after flooding and then decreased with time. Similarly, there was no appreciable change in leaf diffusive resistance during the first 5 days of continous inundation. After 5 days, the resistance increased slowly to 6.4 sec cms$-^{1}$ in TIS 2148 and 7.9 sec cm^{-1} in TIS 2295. At harvest, TIS 2148 gave maximum storage root yield (159.9 g/plant) in the 15 cm water table treatment and minimum (27.2 g/plant) in the control, whereas TIS 2295 yielded maximum (112.2 g/plant) in the 50 cm water table treatment and minimum (12.7 g/plant) in the control.

The results show that sweet potato is more tolerant of submergence and poor aeration than cassava.

Water percolation and leaching

B.S. Ghuman, R. Lal

Soil water percolation and/or redistribution after infiltration stops depends upon the quantity of water applied, initial soil moisture content, soil type and structure and redistribution period. In the past, soil water investigations dealt primarily with uniform soil profiles in laboratory columns or field soils free from gravel. Only a few studies have been conducted on layered profiles. Such studies, however, did not emphasize the redistribution or percolation of soil water after infiltration into soils containing gravel.

In the tropics, gravelly soils form a substantial portion of agriculturally important soils. Water application methods or soil management practices that increase soil moisture retention are important.

The present study reports the effect of method of water application on percolation and/or redistribution of infiltration under conventional and zero tillage.

Soil water movement studies were carried out on a piece of land which was under two tillage practices for several years. Conventional tillage consisted of disc plowing to a depth of 20 cm followed by two harrowings. No tillage plots were sprayed at a rate of 2.5 1/ha of Paraquat for weed control, and crop residue was left on the soil surface as mulch.

Two plots, each measuring 1.45 x 1.45 m, were prepared on soil under conventional or no tillage. The plot area was bounded by a wooden frame that went 15 cm into the soil and was about 15 cm above the ground. The frame was constructed to stop lateral soil water movement at the surface. Five cm of 0.02N $CaCl_2$ solution was added as (a) rain, and (b) flood. In rain application, irrigation water (i,e, $CaCl_2$ solution) was applied with a garden hose and ponding was not allowed at any time during infiltration. For flood application, water was ponded on the soil surface. Three samples from each depth interval of 10 cm from 0 to 80 cm were extruded for water and chloride measurements (a) immediately after infiltration and (b) 24 hours after infiltration for the rain and flood application. Water content was determined thermo-gravimetrically. Chloride was determined by titrating a known aliquot of extract from 1:2 soil water suspension with N/100 $AgNO_3$. Results were presented as volume of water and chloride content distributions for depth.

Effect of water application method on water and chloride movement in no-till soil is shown in Fig. 23. Regardless of the method of application, water penetrated past 80-cm depth immediately after infiltration due to high initial soil wetness (21.6% on volume basis); consequently its recovery was less than 100 percent. For rain application, 22.8 percent of water percolated past 80 cm immediately after infiltration (0 hr. of redistribution) against 75.9 percent 24 hours after infiltration started. But for flood application, only 4.5 percent water percolated at 0 hour of redistribution compared to 58.3 percent after 24 hours of infiltration. The chloride profiles show that less chloride was leached down to 80 cm when water was applied as rain than as flood.

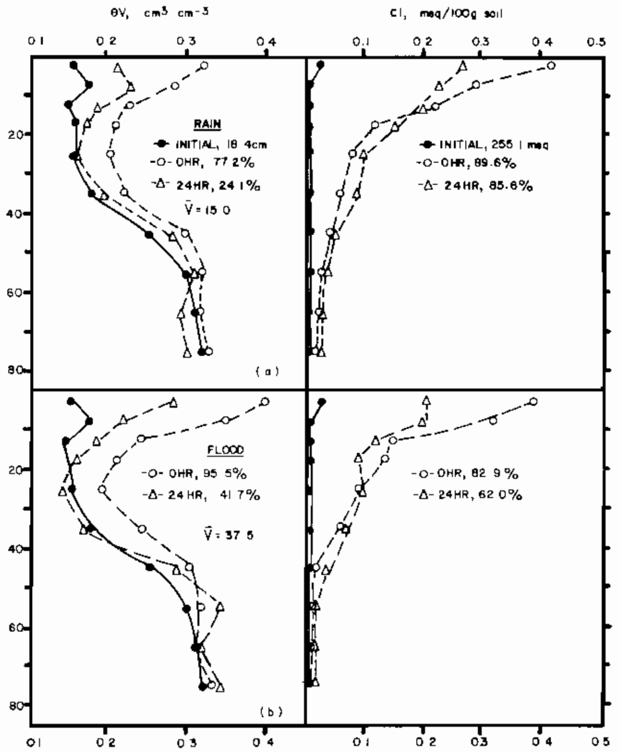

Fig. 23. Water content, θ_v and chloride, Cl^-, distributions with depth for different redistribution times (in₃hr) in soil under zero tillage at $\theta_\lambda = \theta_\lambda = 0.216\ cm^3 cm^{-3}$. Five cm of 0.02N Ca U₂ solution was added as (a) rain, and (b) flood; v̄ represents average infiltration rate in cm hr^{-1}.

The results for the conventionally tilled soil are given in Fig. 24. The soil was at 0.195 cm^3 initial moisture content. At 0 hour of redistribution, the percent recovery of water in 0-80 cm profile was 47.3 percent for rain application in comparison to 56.5 percent for flood application. After 24 hours of infiltration and redistribution, only 7 percent of water was recovered for rain against 33.3 percent for flood irrigation. More chloride was recovered immediately after infiltration for flood than rain application. But after 24 hours, the recovery trend was reversed.

Figs. 23 and 24 show that there was less water percolation in zero tilled compared to conventionally tilled soils under both water application methods. This was attributed to well developed structure of soil under zero tillage.

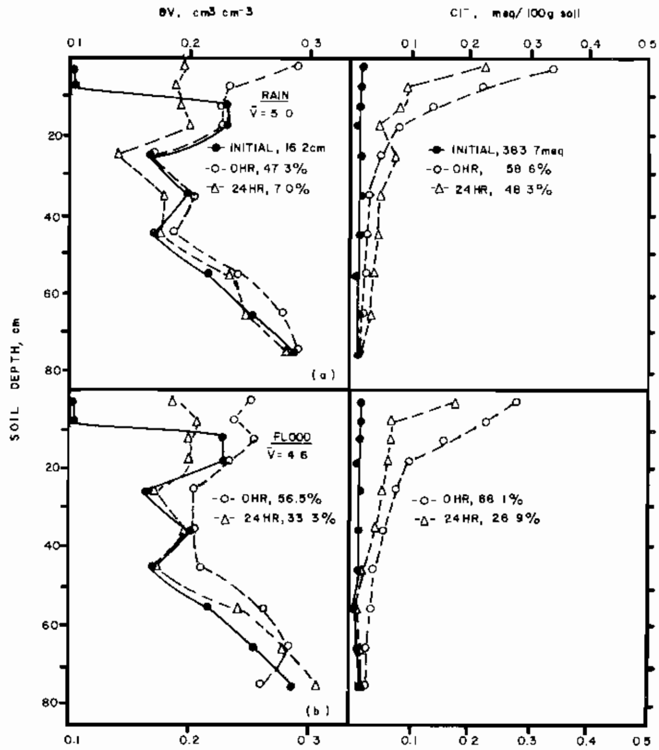

Fig. 24. Water content, θ_v and chloride, Cl^-, distributions with depth for different redistribution times (in hr) in soil under conventional tillage at $\theta_i = 0.195\ cm^3 cm^{-3}$. Five cm of 0.02N call solution was added as (a) rain, and (b) flood; v̄ represents average infiltration rate in cm hr^{-1}.

Soil temperature regime

G.S. Ghuman, R. Lal

Root zone temperature is a crucial factor in determining the yield potential of a crop because it strongly affects the water and nutrient status and their availability. The physiological functions of the roots are also influenced by soil temperature. In spite of this, the literature on soil temperature for different crops at various growth stages is insufficient for a fuller understanding of soil temperature/crop growth interaction in the tropics. The present study was conducted to observe the effect of temperature on maize and cowpea crops grown on the flat.

To study the effect of canopy cover on soil temperature, the planting dates were staggered. Seven plots, each 5 x 3 m, were prepared. One plot was kept crop and weed-free, 3 were planted to maize and the remaining 3 to cowpea. These crops were sown on April 20, May 8 and May 29, 1981, in the first, second and third plots, respectively. Maize was planted at 75 cm between the row and 25 cm within the row. Cowpea was planted at 50 x 15 cm. Crops were adequately fertilized.

Hourly, soil temperature measurements were made at 1 cm, 5 cm and 20 cm with thermistor probes attached to a Grant recorder. Thermistors were buried in the center of an uncropped plot, in the intra-row zone of the central row of cropped plots. Percent ground area covered by crops was determined by tracing the canopy surface on a 1m x 1m transparent plastic sheet placed on a lucite plate held in a stand. The incoming solar radiation was measured in the open near the experimental area with a pyrheliograph.

Figure 25 shows soil temperature under maize canopy at 1 cm and 20 cm on June 16, 1981. As the ground area covered (GAC) was increased from 0 to 59.7 percent, the temperature range (maximum temperature—minimum temperature) decreased from 10.6° to 4.3°C at 1 cm depth and from 3.2° to 1.6°C at 20 cm depth. Similar to maize, the soil temperature range decreased from 10.7° to 2°C, and 2.5° to 0.6°C at 1 and 20 cm depths, respectively under cowpea when the crop cover increased from 0 to 100 percent.

The data for soil temperature were analyzed and the equations developed are given in Table 21. The multiple correlation coefficients (R) ranged between 0.78 and 0.91, and 0.85 and 0.90 for maize and cowpea, respectively. For the combined data for maize and cowpea, the R value varied between 0.80 and 0.89. The equations reveal that crop cover was the most important factor influencing soil temperature, followed by soil moisture and radiation.

Figure 26 presents the estimated and observed soil temperatures at 5 cm under increasing cowpea cover on 4 representative days differing in energy load. Solid lines are the

Table 21. Regression equations relating mean and maximum soil temperature at 5 cm depth with percent ground cover, soil moisture content and radiation level.

Eq. No.	Regression equation	Correlation coefficient (R)
	Cowpea	
1	$\bar{T} = 32.115 - 0.019\,C - 0.097\,\theta - 0.001\,R_1$	0.86
2	$T = 35.459 - 0.047\,C - 0.152\,\theta + 0.002\,R_1$	0.89
	Maize	
3	$\bar{T} = 32.549 - 0.032\,C - 0.131\,\theta - 0.000R_1$	0.81
4	$T = 35.923 - 0.074\,C - 0.214\,\theta + 0.003\,R_1$	0.87
	Pooled data (Maize and Cowpea)	
5	$\bar{T} = 31.623 - 0.020\,C - 0.097\,\theta + 0.000\,R_1$	0.80
6	$T = 34.189 - 0.048\,C - 0.148\,\theta + 0.004\,R_1$	0.85

$\bar{T}$ = Mean temperature (C°).
T = Maximum temperature (C°).
θ = Gravimetric soil moisture content (gw/gs).
C = Percent ground cover.
R_1 = Radiation (g.cal/cm^2/day).

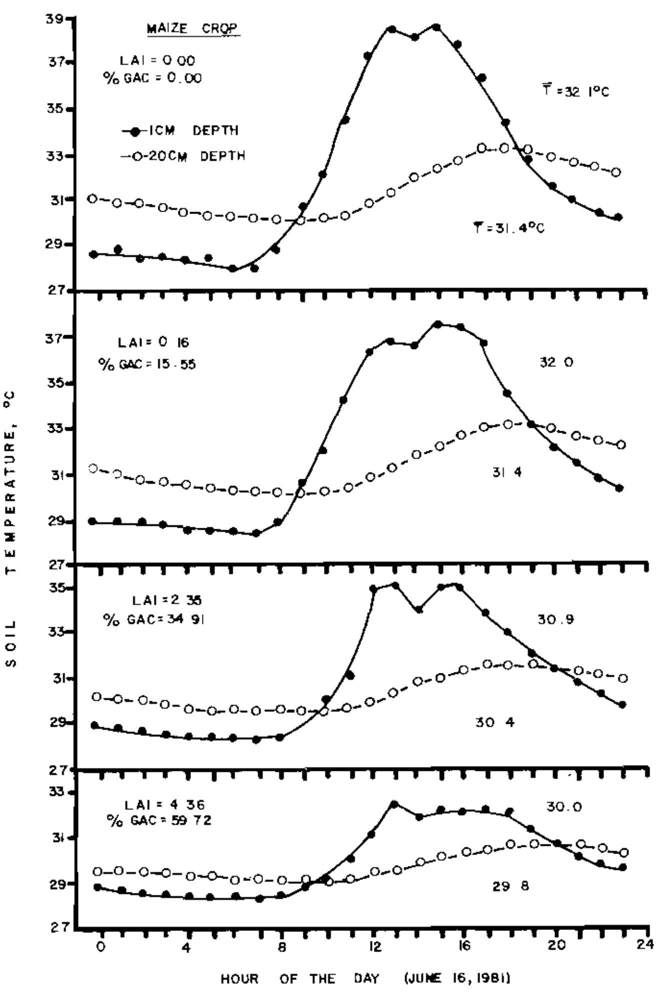

Fig. 25. Diurnal soil temperature variation at 1 and 20 cm depths under maize crop for several leaf area indices (LAI) or percent ground area covered (GAC) on June 16, 1981. Radiation received on this day was 420 gcal cm^{-2}. The number near the curve indicates the mean temperature ($\bar{T}$) for that depth.

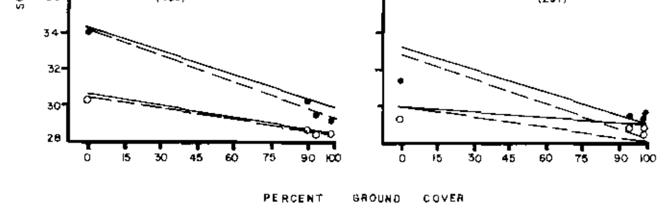

Fig. 26. Estimated and observed soil temperatures at 5 cm depth as a function of percent ground covered by cowpea on 4 representative days. The number in parentheses below the date is the radiation received in gcal cm^{-2} day^{-1}.

result of Eq. 1 and 2 for cowpea cover, and the broken lines are drawn from Eq. 5 and 6 for the pooled data (Table 21). Equations were solved with varying values of C whereas R_1 and Θ (taken as an average for all plots) were considered to be constant for a given day. Computed temperatures agreed well with the observed. Further, soil temperature diminished by increasing canopy cover.

The sowing on April 20 for maize and cowpea yielded 3.3 and 1.8 t/ha of grains. With delayed plantings, the maize grain yield for the second and third sowings decreased by 14 and 52 percent respectively, and that of cowpea by 46 and 78 percent. The results of this study indicate that sowing maize and cowpea should be completed before the end of April so that crops are not exposed to relatively high soil temperature and to severe soil moisture stress in their later growth stages which would, otherwise, decrease yield.

Cropping Systems Agronomy

Cassava response to simulated damage by maize harvester

P.S.O. Okoli, G.F. Wilson

Expanding the benefits of maize/cassava intercropping to large-scale farming will depend on the development of suitable mechanization. Toward this objective, the likely response of cassava to damage caused by a maize picker was tested in a trial in which damage was simulated by cutting the cassava at different heights.

The maize was drilled and cassava planted by hand at 100 cm apart on 100 cm ridges. The densities were 40,000 and 10,000 plants/ha for maize and cassava, respectively. At maize harvest cassava was cut to simulate machine damage at 80 cm, 60 cm and 40 cm. At cassava harvest, approximately 15 months after simulated injury, the recovery, as measured by plant height and leaf area index, number of branches, stem diameter and tuber yield (Table 22) showed no significant response to injury.

Stem dry weight showed significant differences but these did not follow a trend and so were not considered meaningful. The results suggest that mechanical harvesting of maize is feasible if damage is similar to that simulated.

Cassava response to shade under field conditions

P.S.O. Okoli, G.F. Wilson

In maize/cassava intercropping, shading by maize is believed to be a major factor affecting cassava growth and development. The extent to which various degrees of shading influence cassava development was tested by exposing young cassava plants to 0, 20, 40 and 60 percent shade for 9 weeks, about the same period of shading expected in maize/cassava intercropping. The shade was made of black polyethylene strips 2 cm wide spaced to achieve the desired degree of shading at a height of 3 m above ground. The sides were protected by the same strip to 0.5 m above ground. The design was a randomized complete block with 4 replications.

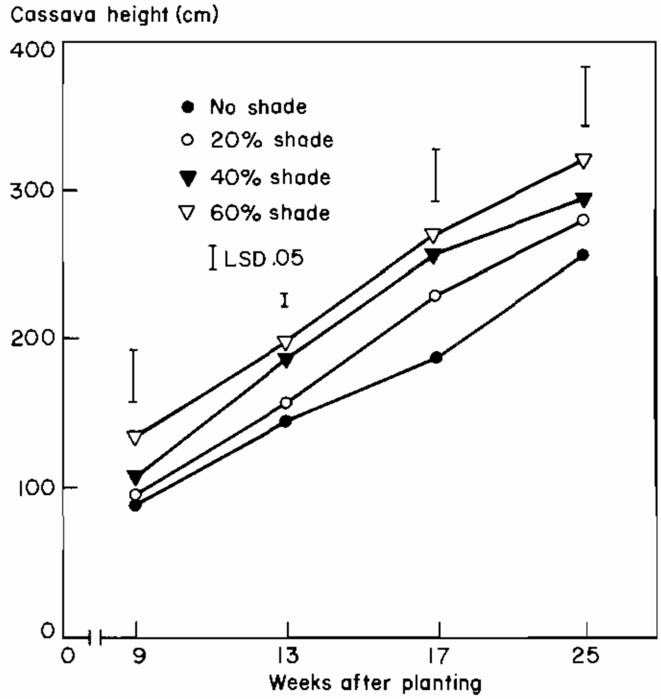

Fig. 27. Effect of shade treatments on cassava height.

Plant height indicated a distinct trend in which plant height increased with the degree of shading. At 60 percent shade, the plants were generally significantly taller than the controls (Fig. 27). The leaf area index, however, showed no distinctive trend (Fig. 28). Tuber weight showed significant differences between no shade and 20 percent against 40 percent and 60 percent at 17 weeks after planting (Table 23). At 25 weeks after planting, however, only the unshaded plants were significantly higher. The results suggest that there is a shade threshold above which cassava plants cannot recover to produce normal yield and that the threshold could lie above 40 percent shade.

Table 22. Effect of cutting height on cassava recovery as measured by some growth parameters and yield.

Cutting	No. of branches	Leaf area index	Plant height (cm)	Stem dia. (cm)	Stem dry wt. g/pl.	No tubers/ plant	Tuber yield (t/ha) fresh
Uncut	8.5	1.7	330	3.0	174	5.5	29.9
80 cm	8.3	1.6	327	3.0	159	5.5	27.2
60 cm	9.5	1.5	310	2.8	187	6.3	30.5
40 cm	8.8	1.6	306	2.9	166	5.5	27.8
LSD (0.05)	1.4	0.3	29	0.4	9.6	0.8	6.8
CV (%)	10	15	6	8	14	8.4	14.9

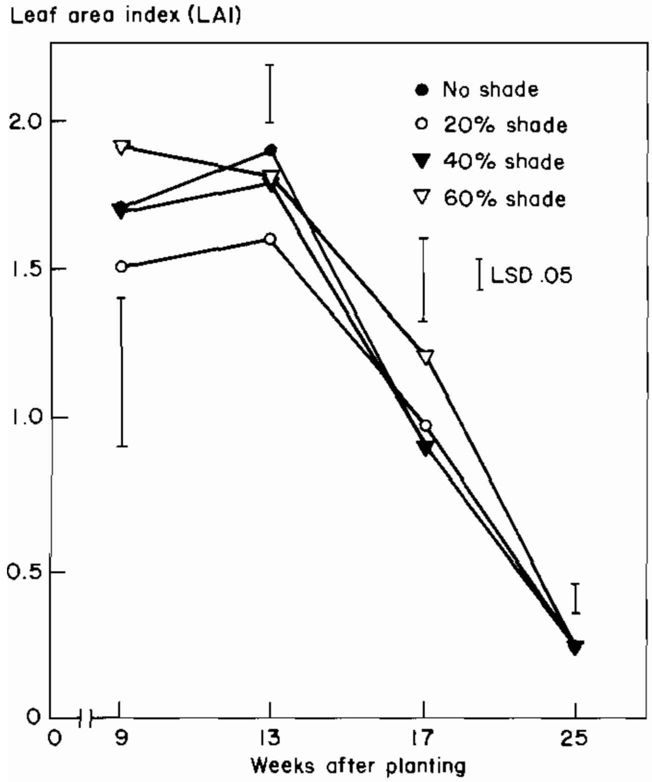

Fig. 28. Effect of shade treatments on cassava leaf area index.

Table 23. Effect of shade on fresh weight, dry weight and number of tubers at 17 and 25 WAP.

Shade	Fresh weight (kg/pl.)		No. of tubers	
WAP	17	25	17	25
No shade	1.44	2.38	11	12
20% shade	1.28	2.28	11	12
40% shade	0.91	2.15	11	9
60% shade	0.82	1.62	10	10
LSD (0.05)	0.33	0.66	3	3
CV (%)	15	16	41	15

Cassava maize/melon/okra intercropping

H.C. Ezumah, T.L. Lawson, T.A.T. Wahua, B.N. Okigbo, J. Ikeorgu

Traditional farmers in the humid tropics usually prefer to grow a range of crops to minimize risk and cope with subsistence and cash requirements. Studies have shown that intercropping, especially mixed cropping, is the rule. The cassava/maize intercropping package recommended by Nigeria's National Accelerated Food Production Project (NAFPP) appears to be a compatible and stable mixture. However, in traditional cropping systems in which cassava/maize constitute one of the dominant components, several low-canopy vegetables like melon, okra, African spinach and other leaf vegetables are also included. It is suspected that non-inclusion of vegetables in the NAFPP package is one reason why farmers have adopted this package slowly.

Preliminary investigations have shown that the inclusion of melon in a cassava or maize mixture gave equal or even higher mixture yield of cassava or maize than when grown in pure stands. This study was carried out to determine (1) the role of vegetables in a cassava/maize microenvironment; (2) whether under the NAFPP maize/cassava package the inclusion of melon and/or okra would further improve the yields of cassava and maize when grown at optimum populations and (3) what components of the cassava/maize microenvironment are affected by the presence of these vegetables.

Two cassava cultivars (TMS 30001 and TMS 30572), maize (TZPB), okra (V45) and melon (*egusi* melon) were mixed in every possible crop combination to form 17 treatment combinations and 5 sole crop treatments. These treatments were arranged to fit into a randomized complete block design and replicated 3 times.

Plant populations used in 1980 preliminary studies were adjusted in 1981:

Crop	Plant population *(plants/ha)*	
	1980	*1981*
Cassava	10,000	10,000
Maize	40,000	20,000
Okra	40,000	20,000
Melon	40,000	20,000

The same plant populations and planting patterns were maintained in sole cropping as in mixed cropping.

Soil sampling (0-20 cm soil depth) for N,P,K, organic matter and volumetric soil moisture content was carried out during 4 strategic growth stages: planting, melon complete cover, maize anthesis and harvest of all crop except cassava. Soil temperature was determined with ordinary laboratory thermometer insulated against radiation while leaf water potential was determined by the pressure bomb method. No light measurement was carried out during the 1981 period.

Planting of all crop species was done at the same time and planting was on the flat. Complete fertilizer 15-15-15 at the rate of 200 kg/ha was applied 2 weeks after planting.

Cassava/melon

Contrary to earlier reports, melon in cassava/melon mixture did not lead to higher cassava yield than in pure stands of cassava (Table 24). However, cassava root yield in pure stands and in cassava/melon mixture did not differ in 1980 and 1981 trials. Inclusion of melon in cassava/maize mixture seemed to reduce cassava root yield in 1981. Perhaps a melon plant population of 20,000 pl/ha was too high.

Table 24. Root yield of cassava grown in pure stands and in mixtures in 1980 and 1981*.

	Root yield (t/ha)	
	1980	1981
Sole	12.89	25.46
Cassava + melon	12.61	22.03
Cassava + maize + melon	11.92	14.90
LSD	3.61	4.07

* *Harvested at 10 months. Mean of two cassava cultivars.*

Maize/melon

In 1981, sole crop maize and maize intercropped with either melon, okra or both gave comparable yields even though rodents reduced the yield of maize in the mixtures (Table 25).

It appears that the population of melon was still high at 20,000 plants/hectare.

Table 25. Grain yield of maize in pure stands and in mixture.*

	Grain yield (t/ha)
Sole maize	2.29
Maize + melon	1.24
Maize + okra	1.36
Maize + melon – okra	1.70
LSD	0.80

**Maize at 20,000 plants/ha; melon and okra at 20,000 attacked by rodents and birds before harvest.*

Melon and okra in cassava/maize mixtures

Inclusion of okra and melon in a cassava/maize mixture seemed to favor higher maize grain yield with a corresponding lower cassava root yield. A cassava/maize/okra/melon mixture proved to be better than cassava/maize/melon in terms of overall economic yield (Table 26). There is still need to adjust the populations of the vegetables in the mixture.

Table 26. Yields of cassava and maize when grown alone and in mixture with melon and okra (1980 and 1981).

	Cassava (fresh roots, t/ha)		Maize (Grain, t/ha)	
	1980	1981	1980	1981
Sole crop	12.89	25.46	2.95	2.29
Cassava + maize	11.48	19.40	2.42	3.07
Cassava + maize + melon	11.92	14.90	1.94	2.42
Cassava + maize + melon + okra	9.29	16.40	1.79	2.00
LSD	3.61	4.07	1.39	0.80

LEAF AREA DISTRIBUTION. The pattern of leaf area distribution shown in Fig. 29 suggests that melon probably makes an initial demand on the microenvironment before the other crops in the mixture. Cassava was the last to make maximum demand. Both okra and maize had similar anthesis dates.

TOTAL N. The rapid decrease in total N with growth was a result of nutrient leaching and plant use. Both maize and melon appeared to be suitable for inclusion in cassava based intercropping. A possible rhizosphere interaction in a cassava/maize mixture may be responsible for the little or no variation in N. Melon, by virtue of its leaf area, may have checked nutrient loss through erosion.

This investigation was repeated both in the greenhouse and in the field. No consistent trend of P and/or K nutrition in the mixtures was noticed. A greenhouse investigation is on to clarify these. Organic matter variation in the cassava/maize/vegetables intercropping followed the trend of total N

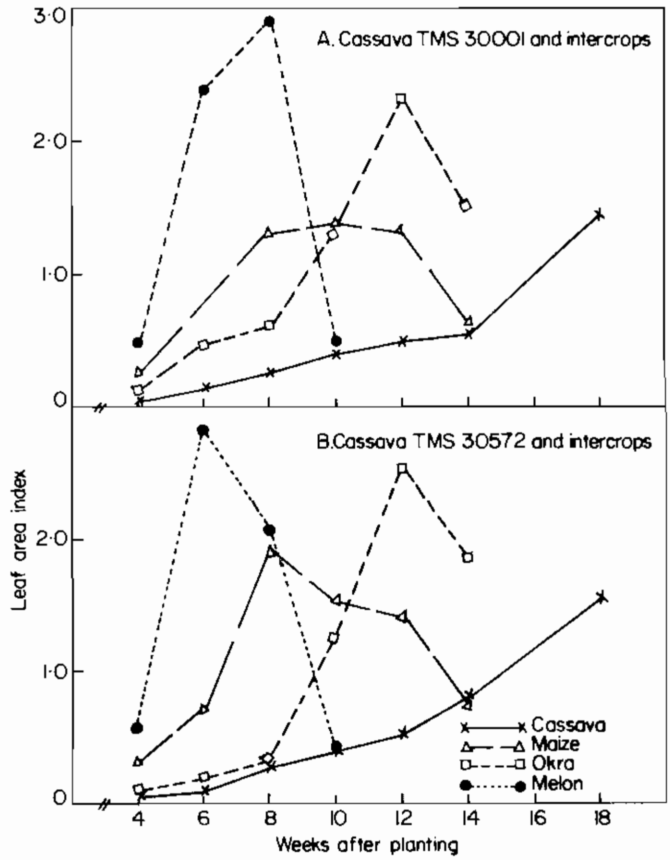

Fig. 29. Leaf area index of cassava and its intercrops.

Table 27: Variation in percent total N of soil under cassava grown alone or intercropped with maize, okra and melon.

	Days after planting			
	0	33	57	120
Sole cassava	0.110	0.071	0.064	0.083
	(.100)	(64.55)	(58.18)	(75.45)
Cassava + maize	0.084	0.076	0.071	0.079
	(100)	(90.48)	(84.52)	(94.05)
Cassava + maize + melon	0.07	0.051	0.063	0.074
	(100)	(72.86)	(90.00)	(105.71)
Cassava + maize + okra	0.101	0.071	0.067	0.06
	(100)	(78.22)	(66.34)	(59.40)
Cassava + maize + okra + melon	0.11	0.074	0.082	0.094
	(100)	(67.27)	(74.55)	(85.46)

Figures in parentheses are percent variation from 0 day after planting.

(Table 27). Work is in progress to investigate possible microbial interaction in the rhizosphere of intercropped cassava/maize/melon.

SOIL MOISTURE CONTENT. Moisture requirements of the crops in both the sole crop and mixtures increased with growth (Table 28). A higher degree of competition for soil

Table 28. Variation in soil moisture content under various cropping systems with cassava (percent of dry soil).

	Days after planting			
	33		57	120
	(0-10)cm	(0-20)cm	(0-20)cm	(0-20)cm
Sole cassava	11.38	16.80	13.16	11.68
Cassava + maize	6.83	12.20	11.09	8.44
Cassava + maize + melon	5.70	11.23	10.36	8.55
Cassava + maize + okra	5.95	10.58	8.66	7.14
Cassava + 3 crops	6.86	10.85	9.82	8.38

moisture was observed between 0-10 cm depth. Intercropping increased water need of cassava but not as much as twice the sole crop value. It was significant to observe that moisture content of soil in cassava + 3 crops was better than in cassava/maize + okra. Melon, therefore, appeared to conserve the moisture of intercropped cassava and maize.

SOIL TEMPERATURE. Intercropping generally reduced the difference between morning, noon and night temperatures (Fig. 30). Soil temperature under melon varied less than 2°C during the day. This situation is especially favorable for microbial activities.

PLANT WATER STATUS. The leaf water status of cassava in cassava/maize/melon was similar to that of sole cassava and cassava/maize mixtures. Generally, however, the highest value of leaf water potential does not appear critical for cassava with respect to yield reduction (Table 29).

From the results above, the following conclusions could be made:

1) Inclusion of okra or melon in a cassava/maize mixture improved the yield of maize but not cassava.

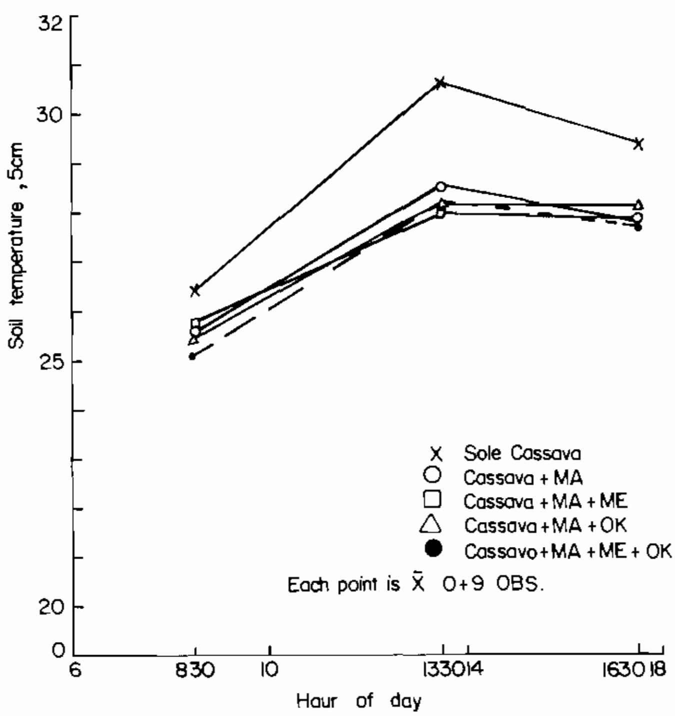

Fig. 30. Variations in soil temperature in cassava and its intercrops.

Table 29. Leaf water water potential (ψL) of cassava grown in various crop mixtures.

	ΨL (− bars)
Sole cassava	2.67
Cassava + maize	3.42
Cassava + maize + melon	4.08
Cassava + maize + okra	6.67
Cassava + maize + melon + okra	5.17
M LSD	1.88

2) Melon in a cassava/melon or maize/melon mixture did not increase the mixture yield and did not lead to a reduction in mixture yield. Therefore land productivity is increased.
3) Cassava/maize okra/melon mixtures could be a more compatible mixture than either cassava/maize/melon or cassava/maize/okra cropping systems.
4) Melon, by virtue of its profuse leaf area, reduced diurnal soil temperature and also checked nutrient and soil moisture loss.

Competition among crops in mixtures

H.C. Ezumah, R.L. Redden, E. Kueneman, J. McGuire

The performance of crops in mixtures is related to their ability to utilize physical resources such as light, nutrients and water required for growth and development. Where these resources are limiting, competition among the crops may take place. A series of experiments on the relative crowding coefficient or competitive powers (k) of several grain crops were conducted in 1981. The assumptions in using the factor are that crops grown in mixtures form replacement series and that each crop species has its own characteristics (k) the magnitude of which indicates whether the crop has produced more than, equal to or less than expected in the mixture of (k) for the component crops is greater than 1. Product values less than or equal to 1 are interpreted as indicating less yield or no loss in yield from the mixture.

The objective of the experiments was to determine the factors of competition such as light, nutrients, and water, and modifiers of competitive ability such as differences in maturity dates of component crops, and differences in architecture. and then to ascertain the most critical periods of competition. Competition due to differences in maturity date (maize/soybean), in nitrogen (maize/cowpea) and in potassium (cassava/maize) were evaluated. Results from cassava/maize were inconclusive.

MAIZE-SOYBEAN MIXTURES. Two varieties of maize, TZE, an early maturing (90 days) type, and TZSR, a normal 120-day maize, were intercropped with 3 varieties of soybean, TGM 618 (very early, 105-day), M 216 (medium maturity, 115-120 days) and TGM 107 (late, 135-140 days). The crops were planted in a replacement series with optimum monocrop maize and soybean populations of 40,000 and 266,666 plants per ha, respectively. Time of planting and nutrient application minimized deficiencies attributable to season and nutrients. Biomass yields were obtained at time of optimum vegetative growth and at harvest. These were compared using crowding coefficients and relative yields.

BIOMASS YIELD. Both the relative yields (Fig. 31) and the products for biomass at 50 days after planting (DAP) (Table 30) are less than 1, showing that there was mutual depression in dry weight, a measure of growth or photosynthate accumulation, for the two species in mixtures. Generally, soybean appears to be the more competitive component of the mixture (Table 30). Early maize was seriously depressed by TGM 618 (km = 0.48 vs. ksb 1.43) while M 216 depressed late maize (km = 0.43 vs. ksb 2.59). Depression of TGM 107 could not be attributed to presence of late maize since late maize only exploits its legitimate portion of the environment (km = 0.91 approaches 1). TGM 107 failed to fully exploit its portion of the environment (ksb = 0.46), but late maize did not take advantage of this weakness since km was about 1.0. In all other combinations, soybean and maize were equally competitive and mutually exclusive since km × ksb approaches 1 (Table 30 or rm × rsb approaches 1, Fig. 31).

Thus, early maturing soybean depressed biomass of early maize more than medium and late maturing soybean, showing that the wider the difference in maturity date between maize and soybean destined for mixed cropping, the higher the competition for biomass growth between them (Fig. 31).

GRAIN YIELD. The relative crowding coefficients and their products for maize and soybean grain yields in all the combinations studied are greater than 1, suggesting that competitiveness was involved for grain yield. Nevertheless, early maize (90 days) planted in mixture with early soybean (105 days) produced lower yields than early maize intercropped with late soybeans (120 and 135 days respectively) (Table 31 and Fig. 32). On the other hand, total grain yield of late maize (120 days) planted with late soybean (135 days) was less than early and medium maturity soybean intercropped with late maize (Fig. 32). This again shows that the wider the differences in maturity date, the more compatible are component crops for mixing.

MAIZE-COWPEA MIXTURES. TZPB and cowpea (TVU 2333-904) were established for two seasons in a replacement series at optimum monoculture populations of 40,000 and 50,000 plants/ha for maize and cowpea, respectively (Table 33). TZE, an early type, was used in the second season. While one set of treatments received N at 90 ppm, all treatments received blanket application of P, Mn and K at 30, 10 and 50 ppm. The experiment was repeated in potted soil in the greenhouse. This ensured limited soil volume (12 kg) and likelihood of inducing competition. Maxi-

Table 30. Relative crowding coefficients (k) or competitive power in maize-soybean intercrop.

	Maize variety					
Soybean	TZE		Biomass 50 DAP	TZSR		
variety	km	ksb	(km)(ksb)	km	ksb	(km)(ksb)
TGM 618	0.48	1.43	0.66	0.32	0.53	0.16
M 216	0.83	0.96	0.80	0.43	2.59	1.11
TGM 107	0.92	1.04	0.96	0.91	0.46	0.42
			Grain yield (maturity)			
TGM 618	4.67	1.97	9.22	7.83	7.55	59.12
M 216	5.85	5.27	30.83	5.35	8.25	44.10
TGM 107	4.16	6.91	28.76	3.80	3.67	12.05

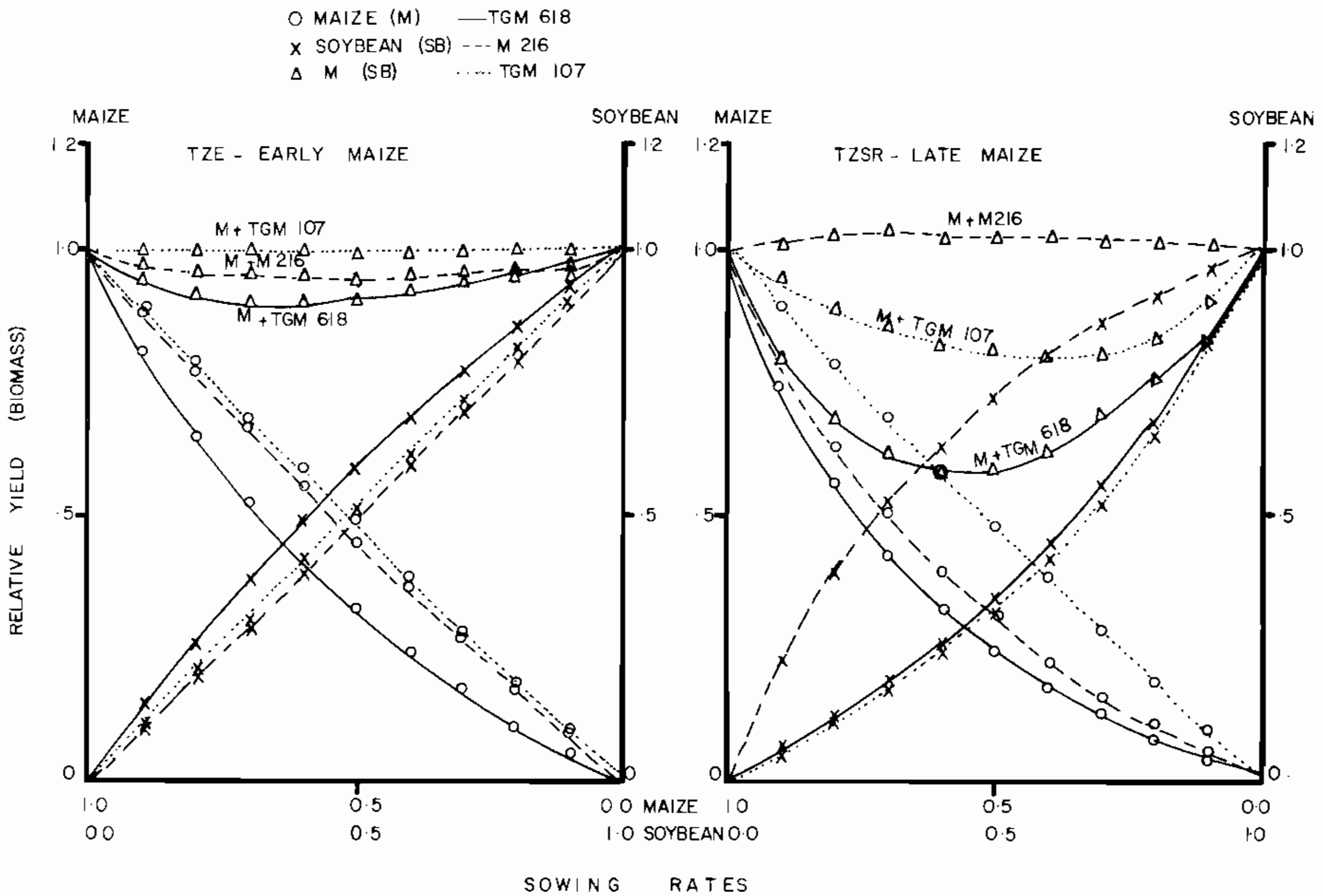

Fig. 31. Relative effects of maize-soybean mixture—biomass yield—50 DAP.

mum number of plants of both species per pot was 4. Therefore, a pot with 0.5:0.5 ratio contained 2 plants of each species.

GRAIN YIELD. Strong response to added N was observed in biomass and grain yields of maize and cowpea in mixtures (Tables 32 and 33). This response was more pronounced in the greenhouse at 45 DAP (Table 32) compared with field (Table 33). Though both crops responded to N, maize response was higher when grown in mixture with cowpea (Table 33). The higher the proportion of legume in the mixture, the less maize responded to applied N for its biomass yield (Table 32).

Table 32. Biomass yield of maize and cowpea grown in mixture under greenhouse conditions.

	45 days after planting				
	Proportions sown				
	M 100	M/CP 75/25	M/CP 50/50	M/CP 25/75	CP 100
			g/pot		
Without N	13.5	18.7/10.3	18.0/16.3	16.5/23.7	31.0
With N (90 ppm)	19.5	37.0/17.0	54.0/24.0	53.0/22.0	40.3
N Resp. (Relative) %	144	198/165	300/147	321/92.8	130

Table 31. Mean yields of maize and soybean established in replacement series.

TZE Variety Density ratios Maize S B	Maize	TGM 618	Maize	(kg/ha grain) M 216	Maize	TGM 107
100-0	1314	0	1332	0	1371	0
75-25	951	857	1094	565	1111	786
50-50	708	1281	910	786	852	757
25-75	482	1883	746	892	672	919
0-100	0	2081	0	1522	0	1214
TZSR Variety						
	TZSR	TGM 618	TZSR	M 216	TZSR	TGM 107
100-0	1225	0	1346	0	1286	0
75-25	984	800	1117	717	1109	557
50-50	875	943	995	868	1029	681
25-75	732	1086	756	943	678	690
0-100	0	1775	0	1530	0	924

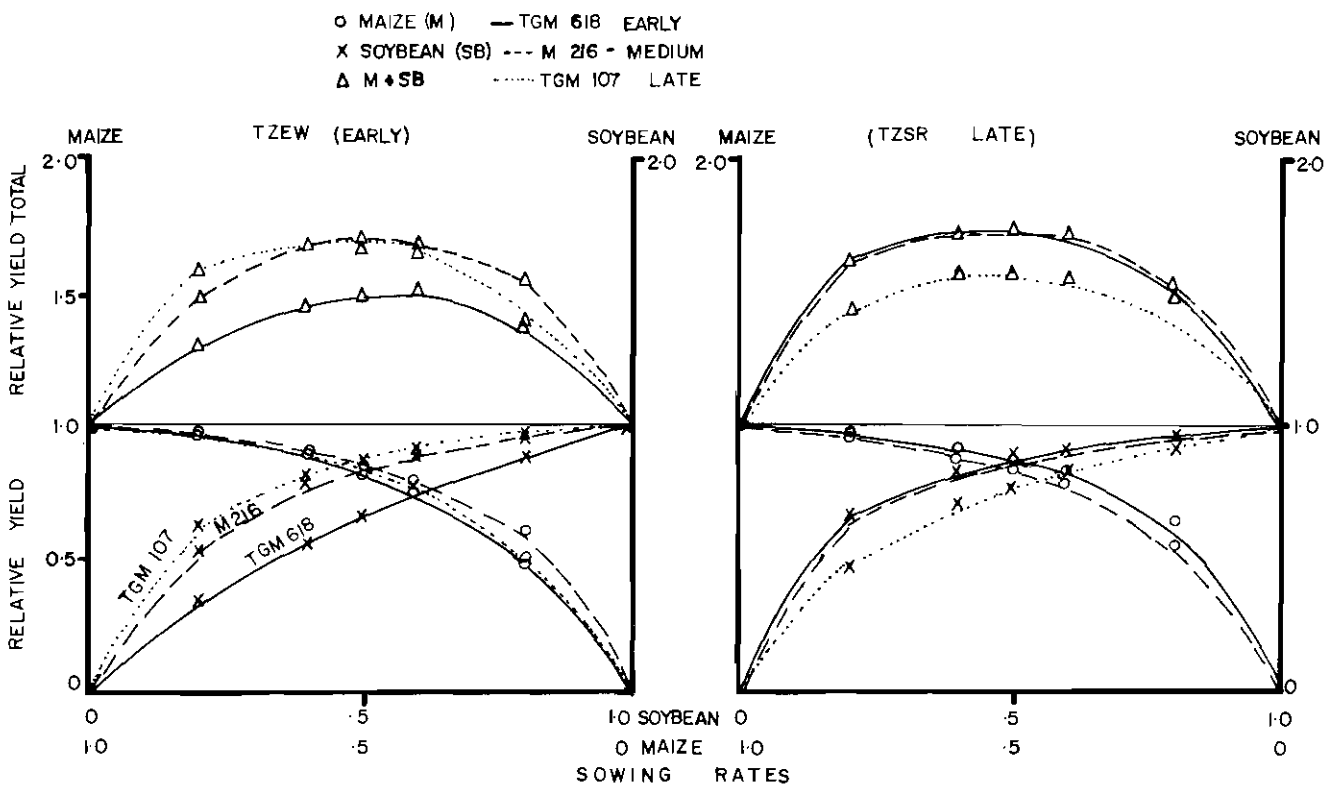

Fig. 32. Relative yield of maize and soybean in intercrop.

BIOMASS YIELD. In the absence of applied N, maize and cowpea competed strongly and were mutually exclusive in their biomass yields under greenhouse conditions. Thus km, kp and kmxkp approximated 1 in columns without N (Table 34). N would be expected to be limiting in the potted soil. When N was added, cowpea biomass was produced non-competitively with respect to N effect at 45 DAP (kp = 3.30). Thus at this stage (45 DAP), cowpea depended on sources of N other than applied N and appeared to offer no competition to maize for the N at 60DAP when it was already nearing senescence. N effect of field biomass of both crops at harvest was also non-competitive (kmxkp = 7.59).

GRAIN YIELD. Grain yields of both maize and cowpea were produced competitively in the presence of N (kmxkp approached 1) and non-competitively in the absence of N (Fig. 33, Table 34). Therefore, in absence of applied N at which time the growth of both plants is depressed, N affecting grain other than the applied N or the pool of available N was in excess of the needs of both crops.

CROP MANAGEMENT IMPLICATION. Interference between crop species grown in mixtures is not always competitive and mutually exclusive. Maize (and other cereals) will benefit more from the nitrogen excreted by relatively early maturing cowpea than it will from late maturing ones. Indications are that after about 45 days, cowpea (a) either depends more on N from sources other than applied N (perhaps rhizobial N) and/or (b) since it is senescing after 45 days, it relies on retranslocation of the N it has already absorbed.

Table 34. Competitive power, k for maize/cowpea mixture.

Parameter and Medium	With N Km	Kp	(Km)(kp)	Without N Km	Kp	(Km)(kp)
Greenhouse						
Top dry weight 45 DAP	1.05	3.30	3.47	1.38	1.07	1.48
Top dry weight 60 DAP	6.68	1.25	8.35	1.06	1.02	1.08
Grain weight	0.93	0.67	0.62	8.67	1.74	15.1
Field						
First season	0.34	2.53	0.86	5.41	2.74	14.70
Second season	1.65	1.10	1.82	2.16	4.33	9.35
Second season biomass	3.74	2.03	7.59	4.31	1.14	4.91

Alley Cropping

Alley cropping is the technique of growing crops between alleys formed by tree or shrubs, usually legumes, that are cut back and kept pruned during the cropping period. The leaves and twigs of the trees or shrubs, when added to the soil, serve as mulch and nutrient source. Previous trials have demonstrated the potential of the technique for maintaining reasonable yield while enhancing nutrient recycling and soil conservation. The following reports present results of trials measuring crop performance in alleys formed by various tree or shrub species, the potential contributions from the alley species and techniques for managing the system.

Evaluation of a leguminous shrub species on alley cropping

G.F. Wilson, M. Reed

Maize in association with *Gliricidia sepium, Leucaena leucocephala, Tephrosia candida* and *Cajanus cajan*

In this trial, in which fertilizer was not applied, the nutrient contributed by the alley species played an important part in maintaining productivity. Table 35 shows mulch and potential N contribution from the alley species in 2 m alleys in the fourth year after establishment. Yield of maize planted in the first rain season at 30,000 plants/ha ranged from 2 to 4 t/ha (Fig. 34). Differences among yields were not significant though yields of maize grown in *L. leucocephala* alleys were comparatively low. Earthworm activity, which is regarded as an important factor in maintaining good soil tilth, was about the same in all treatments (Fig. 35).

The performance in the check plot (natural regrowth) suggests that fairly high soil productivity can be maintained with natural regeneration.

LEAF FALL FROM SHRUB LEGUME AT N SOURCE. The major proportion of the biomass accumulated by shrubs or trees in alley cropping is returned to the soil at cutting back and pruning (Table 35). There are, however, indications that

Table 33. Maize/cowpea intercrop: effects of N on yield under field conditions.

	Grain yield (kg/ha) Sole Maize	75/25	50/50	25/75	Sole Cowpea
			First season:		
Without N	5610	4010/425	3984/595	2467/798	826
With N (45 kg/ha)	6996	5005/528	4968/714	2946/1023	910
Rel. N effect (%)	125	125/124	125/120	119/128	110
			Second Season:		
Without N	721	687/451	477/653	330/864	976
With N (45 kg/ha)	1217	1052/428	867/910	451/958	1051
Rel. N effect (%)	169	153/95	182/139	137/111	108
			Field Biomass Second season: kg/ha		
Without N	1075	675/513	575/888	425/1438	1575
With N	2338	1350/838	1075/1375	750/1788	2038
Rel. N effect (%)	217	200/163	187/155	176/124	129

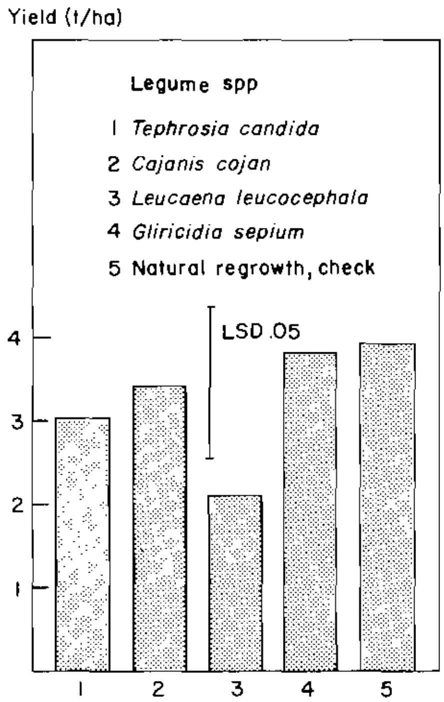

Fig. 34. Effect of shrub legume species on maize grain yield.

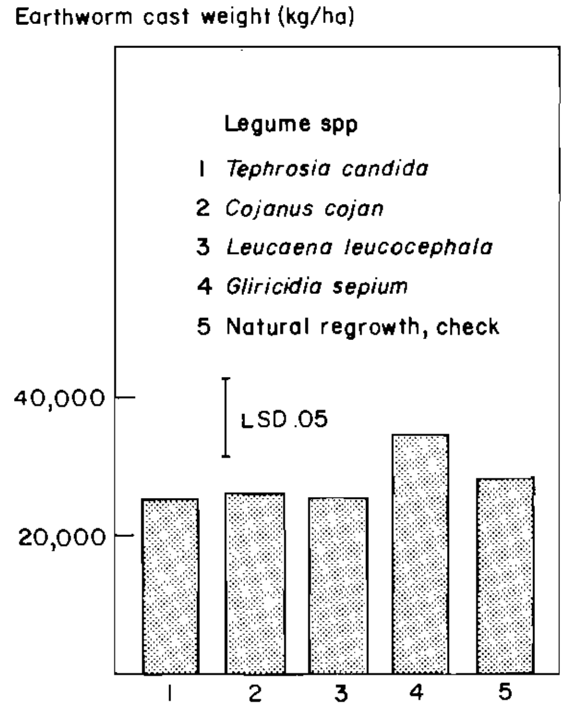

Fig. 35. Effect of shrub legume species on earthworm cast.

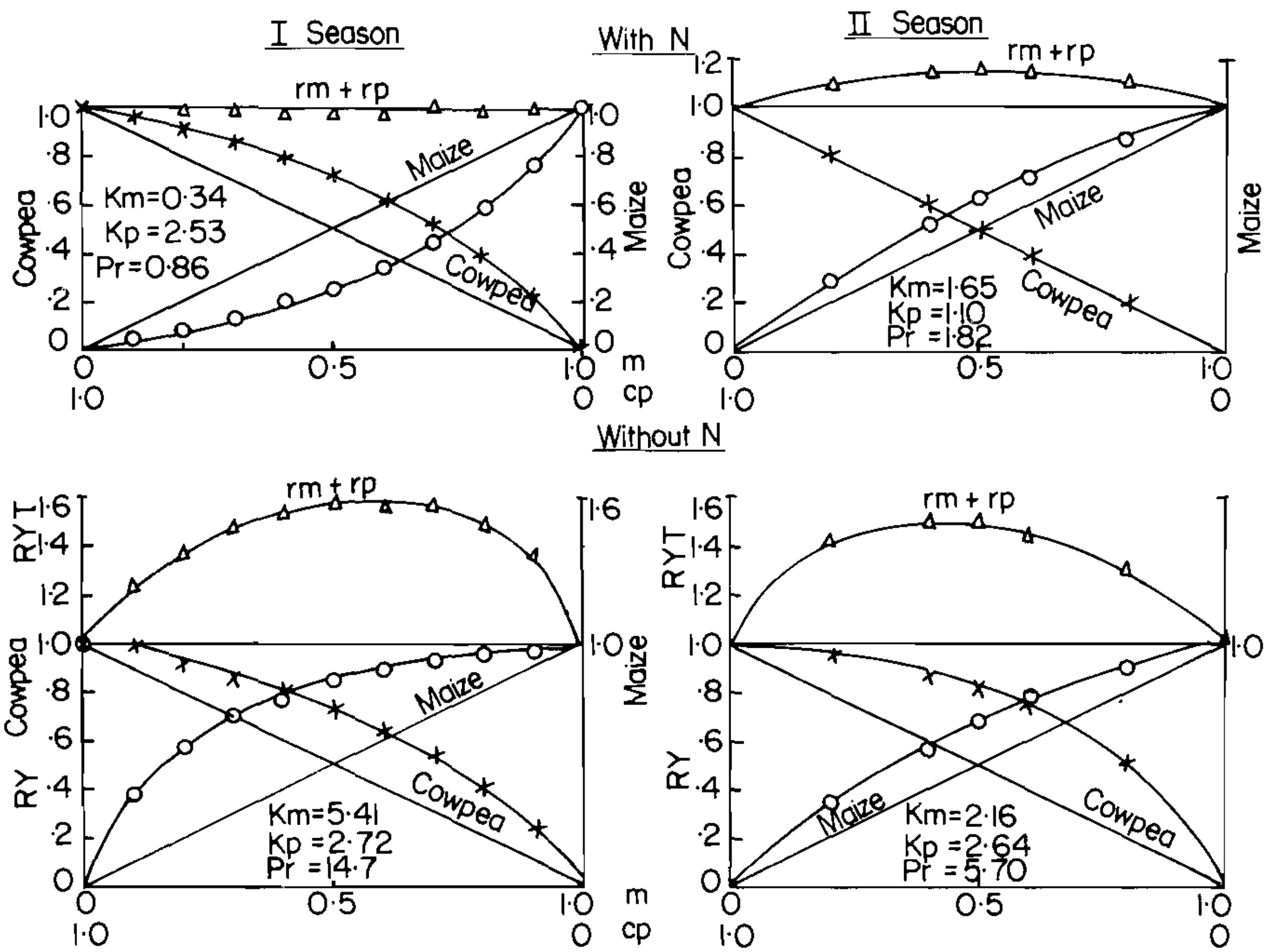

Fig. 33. Relative yield of maize and cowpea intercrop.

Table 35. Leaf yield and estimated N contribution of shrub legume at cutting back and first pruning.

Legume	Dry wt. kg/ha			N in total dry matter	
	Cutting	Pruning	Total	%	kg/ha
Tephrosia candida	2843	608	3453	3.8	131
Cajanus cajan	1837	475	2312	3.6	83
Leucaena leucocephala	4633	962	5595	4.2	234
Gliricidia sepium	4748	1538	6286	3.7	233

biological activities associated with soil restoration are maintained mainly by leaf fall. To check the quantitative contribution of leaf fall during the dry season (December-March), leaves were collected on fine wire mesh at bi-weekly intervals. *Tephrosia candida* had the highest leaf fall and *Leucaena leucocephala* the lowest (Fig. 36). Peak leaf fall was in early January for *T. candida* and in mid-February for *leucaena* (Fig. 37).

The high levels of nitrogen accumulated in leaves of trees and shrub legumes are considered exploitable sources of biological nitrogen for crop production. The contribution of leaves of *L. leucocephala* as N source was further evaluated in the following trials.

Leaves were classified relative to their position on branches as young or old. These leaves were dried either in the oven or by air in small heaps or by air in large heaps. N levels were significantly higher in young than in old leaves, but drying method had no effect on leaves within age groups (Table 36).

In a pot trial in which N from fresh and dry *Leucaena* leaves was evaluated by maize dry weight accumulation at 40 days after planting, N at 100 ppm from fresh leaves, when incorporated, was as effective as 50 ppm N from calcium ammonium nitrate, CAN (Table 37). Incorporation was significantly better than surface application with fresh, but not with dry *Leucaena* leaves.

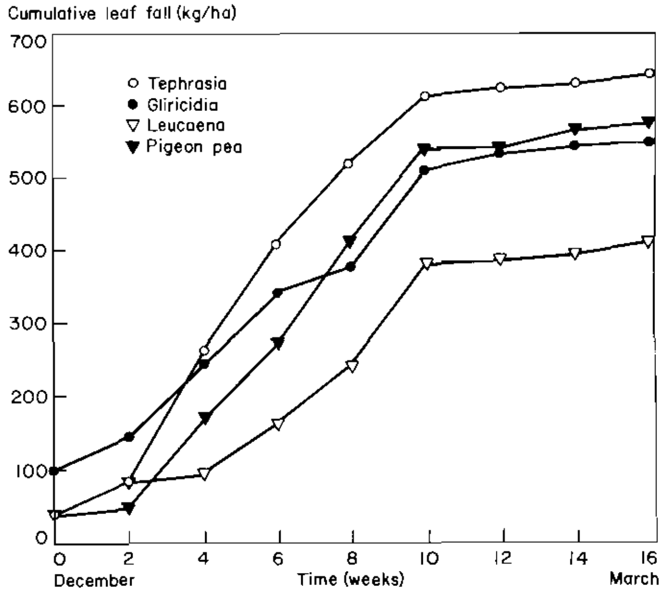

Fig. 36. Cumulative leaf fall under some shrub legume species.

Table 36: Effect of leaf age and drying method on *Leucaena* leaf N content.

Drying method	Leaf age	N content %
Oven	Young	5.02 A
Air, small heap	Young	4.27 A
Oven	Old	3.93 B
Air, small heap	Old	3.86 B
Air large heap	Old	3.82 B

Numbers followed by the same letter are not significantly different at 5% probability.

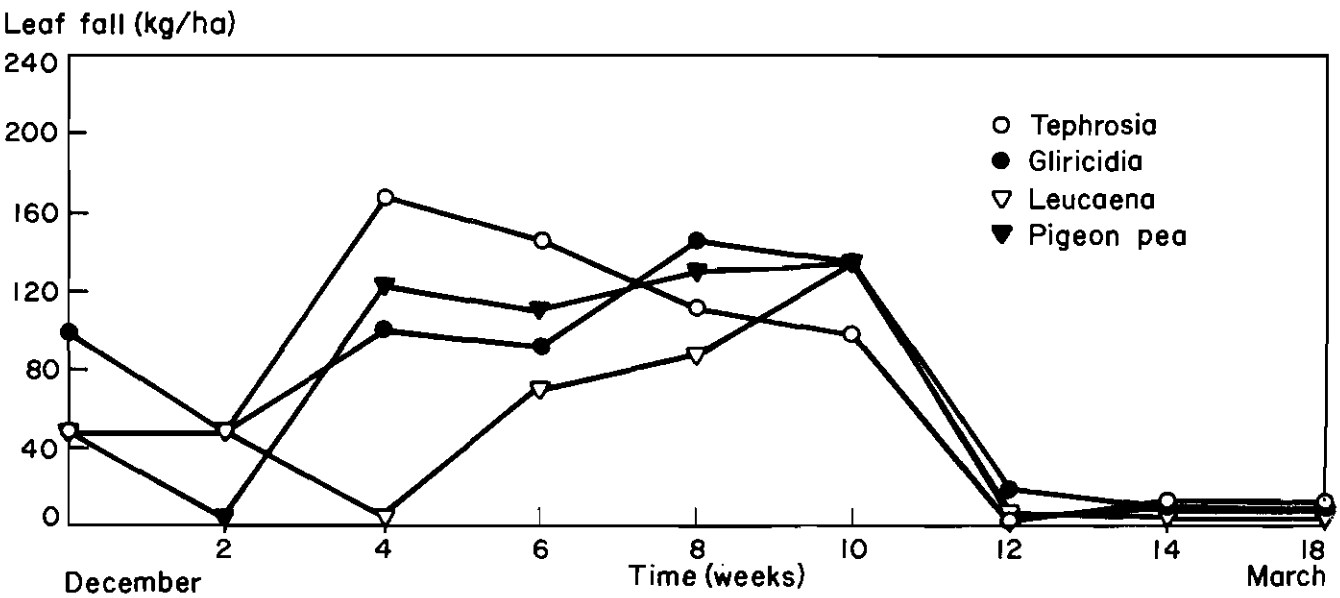

Fig. 37. Dry season leaf fall in shrub legume fallow (1980/81).

Table 37. Dry weight of above ground part of maize as affected by N source and application methods at 40 DAP.

N Rate mg/kg Soil	Source	Method of application	Maize Tissue dry wt (gm)
100	CAN[1]	Incorporated	21.15 A[2]
100	Fresh *Leucaena*	Incorporated	16.65 B
50	CAN	Incorporated	16.08 B
50	Fresh *Leucaena*	Incorporated	8.45 C
100	Dry *Leucaena*	Incorporated	6.43 CD
50	Dry *Leucaena*	Incorporated	5.60 CD
100	Dry *Leucaena*	Surface	5.28 CD
—	(Control)	—	4.50 D
50	Fresh *Leucaena*	Surface	4.48 D
100	Fresh *Leucaena*	Surface	4.05 D
50	Dry *Leucaena*	Surface	3.65 D

1) Calcium ammonium nitrate.
2) Numbers followed by the same letter are not significantly different at the 5% level by the Duncan Multiple Range Test.

Table 38. Maize yield as affected by N source.

N Rate (kg/ha)	Source	Grain yield (t/ha)
100	CAN	3.18 A
100	CAN + maize stover (MS)	3.16 A
100	Dry *Leucaena* leaf (DL)	3.12 A
50	DL + MS	3.09 A
50	CAN	3.06 A
50	Fresh *Leucaena* leaf (FL)	2.94 A
100	FL	2.91 A
50	DL	2.89 A
100	DL + MS	2.84 AB
50	CAN + MS	2.81 AB
100	FL + MS	2.75 ABC
50	FL + MS	2.74 ABC
—	MS	2.22 BC
—	Control	2.14 C

In a field trial, all leaves, fresh and dry, were incorporated before planting maize. Pure *Leucaena* leaf was significantly better than the control or where maize stover was incorporated, but the differences were not striking. There were indications that incorporating maize stover with *Leucaena* reduced the *Leucaena* effect (Table 38).

CONTROLLING *LEUCAENA* AS A WEED. The major constraint to using *L. leucocephala* in shrub fallow or alley cropping is a tendency for it to become a weed during cropping. Trials aimed at eliminating this problem showed that effective control was possible with atrazine at 3.0 kg/ha (Fig. 38) and plowing the seeds below 11 cm (Fig. 39). With these two control methods, *Leucaena* fallow is feasible with both no-tillage and conventional tillage.

Evaluation of a non-leguminous shrub species in alley cropping.

G.F. Wilson

The potential of a non-leguminous shrub *Acioa barteri* for alley cropping was tested in comparison with *Gliricidia sepium* and natural regrowth. The shrubs were cut back prior to planting maize. The leaves and small twigs were spread on the plots. A. *barteri* and *G. sepium* were spaced 50 cm apart along 200-cm alleys. The design was a split plot with type of fallow as the main plot and fertilizer and no fertilizer

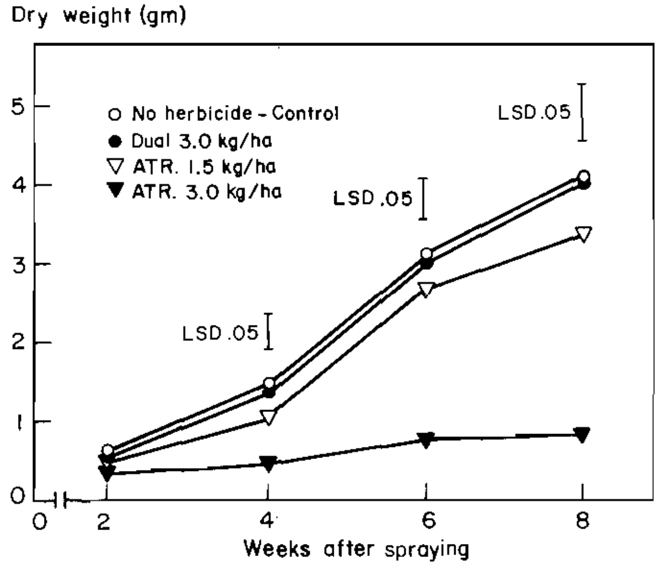

Fig. 38. Effect of herbicide on growth of *Leucaena* seedlings.

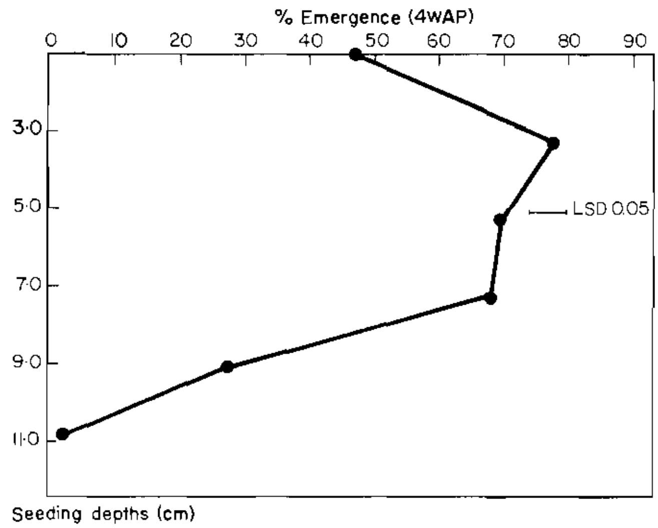

Fig. 39. Effect of seedling depth on *Leucaena* seedling emergence.

as subplots. There were 3 replications. Fertilizer was 60 kg/ha N, 125 kg/ha P and 60 kg/ha K broadcast before maize was planted in the first rain season.

Cowpea was tested in the second season on the residual fertilizer. The residues (leaf and twig only) left by *G. sepium* and *A. barteri* after pruning were 13 t/ha and 31 t/ha respectively. Decomposition of *G. sepium* leaf was rapid and almost complete in 6 weeks. Leaves of *A. barteri* decomposed slowly, persisting as mulch throughout both growing seasons (Fig 40). Because of this neither weeding nor herbicide application was necessary in *A. barteri* alleys.

Maize yield as affected by the treatments is shown in Table 39. Yields of fertilized plots were generally higher than on plots that did not receive fertilizer. *A. barteri* and *G. sepium* with fertilizer were also superior to natural regrowth. There was no significant difference between treatments for cowpea seed yield (Table 40).

Table 39. Effect of planted fallow species on maize grain yield.

Species	Fertilized (t/ha)	Unfertilized (t/ha)	Mean
Acioa barteri	4.5	3.2	3.9
Gliricidia sepium	5.2	4.4	4.8
Natural regrowth	4.4	2.8	3.6
Mean	4.7	3.5	

LSD (0.05) *Species* = *1.1*
Fert. = *0.8* *CV (a)* *16.7%*
Fert. within species = *1.4* *CV (b)* *17.3%*
Fert. between species = *1.5*

Table 40. Effect of planted fallow species on cowpea seed yield.

Species	Residual fertilizer (kg/ha)	Unfertilized (kg/ha)	Mean
Acioa barteri	617	630	623
Gliricidia sepium	785	630	707
Natural regrowth	806	838	822
Mean	736	699	

LSD (0.05) *Species* *362*
Fert. *154*
Fert. within species = *267* *CV (a)* = *31.4%*
Fert. between species = *407* *CV (b)* = *18.6%*

Leucaena-maize/cowpea-alley cropping

B.T. Kang, G.F. Wilson, T.L. Lawson

Further investigations were carried out in 1981 to study the N contribution from *Leucaena leucocephala* alley-cropped with maize, cowpea and pluvial rice. In this system, the food crops were grown in spaces between *Leucaena* rows which are spaced 4 m apart. The *Leucaena* hedges were periodically pruned to control shading and also to provide green manure to the companion crops.

The trial was initiated in 1978 on a low fertility Apomu soil (Psammentic Ustorthent) at IITA using a systematic design. In this trial, the *Leucaena* hedge was pruned at a height of 150 cm.

The 1981 main season maize variety TZPB suffered from drought during the first 6 weeks of growth, resulting in poor yield. Maize grain and stover yields responded significantly to an application of 40 kg N/ha. Despite the low yields obtained, addition of *Leucaena* prunings with N application almost tripled grain yields compared to the treatment with no addition of prunings (Fig. 41).

Because the 1981 minor season maize variety TZSR yellow was badly affected by stemborers, it was replaced by the cowpea variety VITA-6. For the minor season cropping, half of the experimental area was tilled. Cowpea dry matter yield showed some response to residual N applied to the previous maize crop and also to the addition of *Leucaena* pruning (Fig. 42). However, addition of prunings did not affect cowpea seed yield and residual N even depressed seed yield.

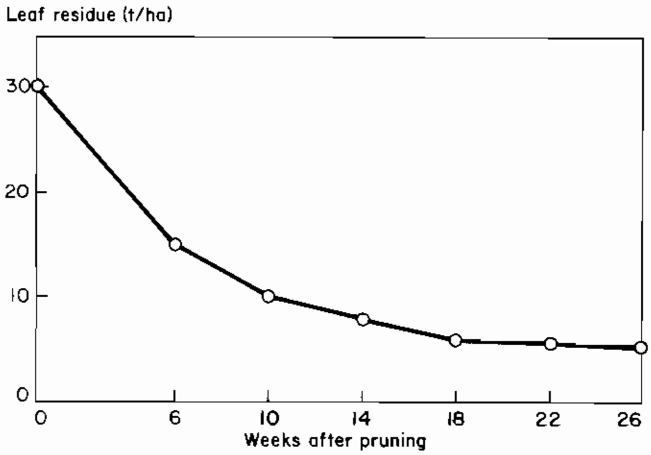

Fig. 40. Changes in amount of leaf (*A. barteri*) residue with time.

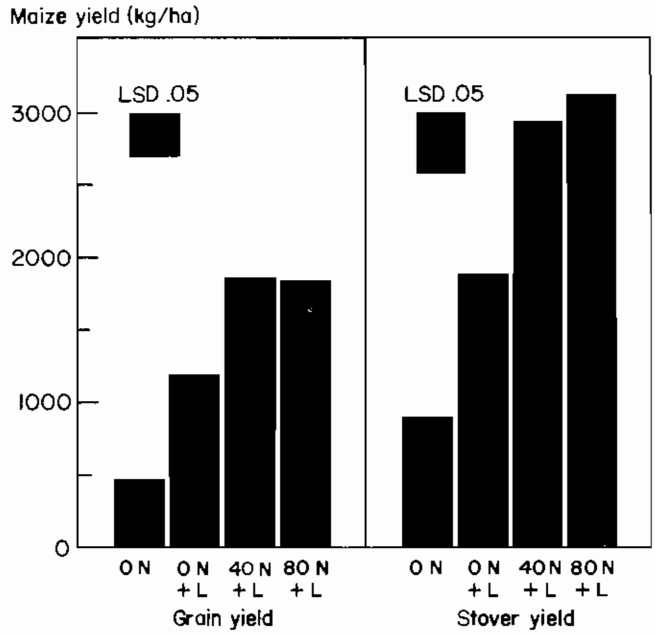

Fig. 41. Effect of alley cropping with *Leucaena leucocephala* and N rates on maize grain and stover yields (+ L = + *Leucaena* prunings).

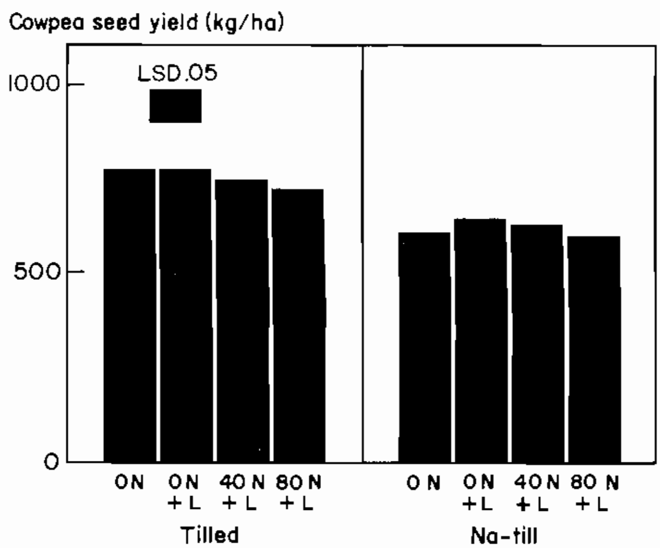

Fig. 42. Effect of alley cropping with *Leucaena leucocephala* and N rates and tillage on seed yield of cowpea (+ L = *Leucaena* prunings).

Dry matter and seed yields were higher from tilled than from the no-till treatment. The lower yields with no-till might be due to more root competition with the *Leucaena*; this needs further study. High dry matter and N yields from the prunings were also obtained in 1981 (Fig. 43). Unlike in the previous years, there was significant response to residual N applied to maize on both dry matter and N yields. This may be the result of poor maize yields leaving more of the applied N to be utilized by the *Leucaena*.

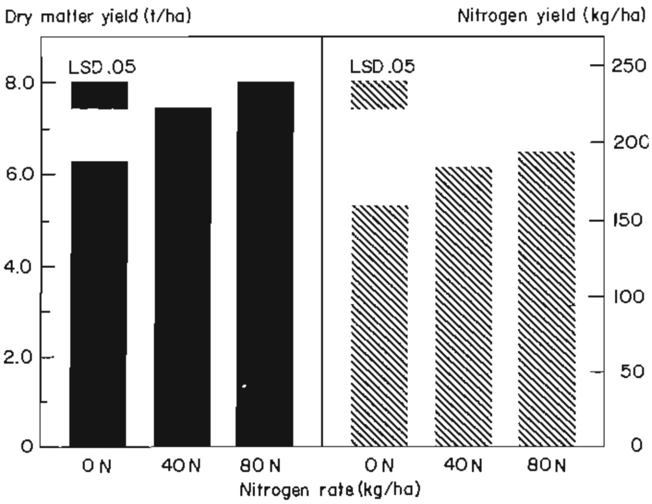

Fig. 43. Effect of alley cropping with *Leucaena leucocephala* and N rates on dry matter and N yields of *Leucaena* prunings.

Leucaena-pluvial rice-alley cropping

B.T. Kang, G.F. Wilson, K. Alluri

The trial was set up at Ikenne in 1981 on an Alagba soil series (Oxic Paleustalf) using a systematic design. *Leucaena* hedge was pruned at a height of 60 cm. During the first year of the alley cropping trial there was no effect of N applied to the rice on either dry matter or N yields of the *Leucaena* prunings. Average total dry matter and N yields of the prunings (for 3 cuttings) were 1.53 t/ha and 68 g N/ha respectively. Despite the fact that during early growth the alley-cropped rice grew better, particularly with no N application, the growth differential was not translated into grain yield (Table 41). It even appears that alley cropping and N application had some depressing effect on rice grain yield.

Table 41. Effect of alley cropping with *Leucaena* and N application on grain yield of rice variety ITA 117.

N-rate (kgN/ha)	Alley cropped (kg/ha)	Control (sole crop) (kg/ha)
0	2572	2468
30	2545	2734
60	2375	2417
90	2288	2397
Mean	2445	2504
SE(x)	159	140
LSD (.05)	474	413

Time of planting and maize grain moisture content

G.F. Wilson, P.S.O. Okoli

Large-scale mechanized maize production in the humid tropics appears feasible only when planting can be timed to facilitate fully mechanized harvesting. The second rain season of the bimodal rainfall zone offers this opportunity, provided other major constraints such as streak disease and stem borer are controlled.

Tests with streak resistant cultivar TZSRY, planted with the systemic insecticide, carbofuran, showed that fairly low grain moisture content (15 percent) could be achieved at harvest in the second season. Grain moisture content changes during the early dry season for three planting dates (July 16, July 30 and August 12, 1981) are shown in Figure 44. Early plantings dried first, but had the highest lodging percentage. Lodging was 54, 39 and 36 percent for July 16, July 20 and August 12 planting dates respectively. Actual machine harvest of the August 12 planting gave approximately 2.5 t/ha with 15.8 percent moisture.

This low yield reflects losses due to lodging. The earliest planting date was unsuitable as grain moisture reduction began much earlier before the rains ceased. The other dates are feasible for mechanized maize production if lodging could be reduced.

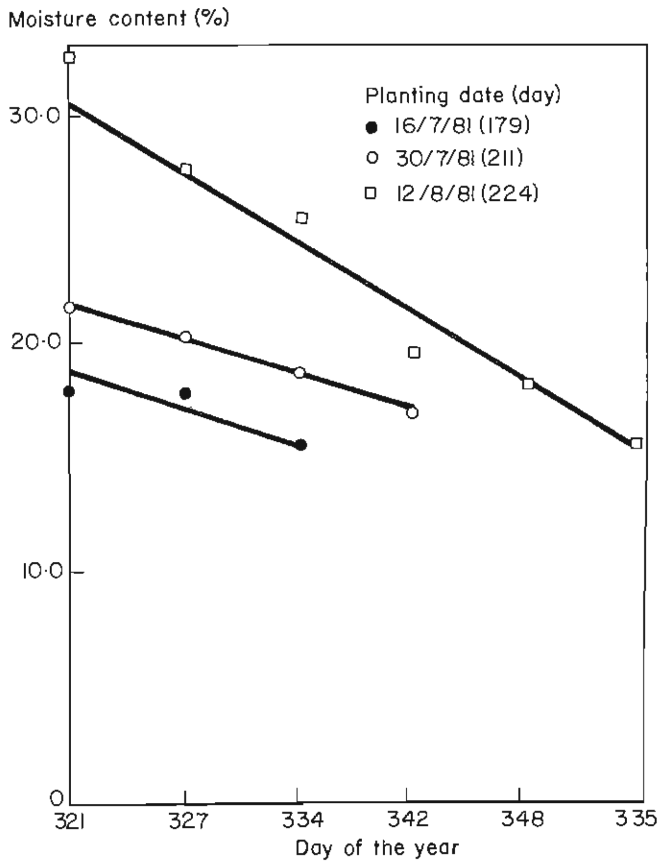

Fig. 44. Effect of time of planting on maize grain moisture content, (harvested at last reading).

Gliricidia tops as N-source and effect of placement.

B.T. Kang

The effectiveness of *Gliricidia sepium* tops as N source for maize was studied on a sandy Apomu soil series (Psammentic Usthorthent). The trial was carried out using a randomized complete block design with 4 replications.

The results showed that *Gliricidia* tops applied at rates of 5 and 10 t/ha, equivalent to 53 and 106 kg N/ha respectively, significantly increased maize grain and stover yields. Banding and incorporating *Gliricidia* tops is more effective than surface application without incorporation either in narrow band or broadcast over entire plot (Fig. 45). As N source, *Gliricidia* tops are less effective than urea.

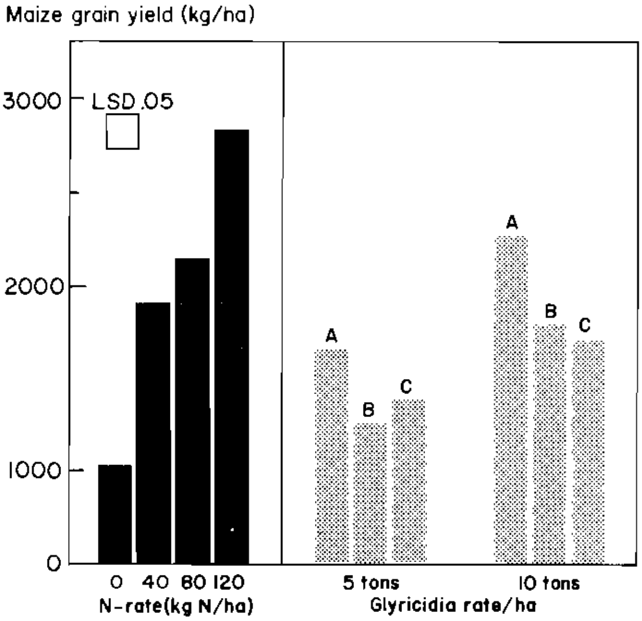

Fig. 45. Effect of application of nitrogen and *Glyricidia* tops on grain yield of maize grown on Apomu soil (Psammentic Usthorthent) at Ibadan. (*Glyricidia* top placement; A = band incorporated; B = band and applied at surface; C = surface broadcast).

Decomposition rate of *Leucaena* tops

M. Reed, B.T. Kang, G.F. Wilson

Results of previous trials showed that fresh *Leucaena* tops can be utilized as N source. Since fresh tops contain only about 30 percent dry matter, drying will reduce handling problems in a cut-and-carry system. However, drying may affect the effectiveness of the material as N source. Field investigations were, therefore, carried out to determine the decomposition rate of the material following drying and its effectiveness as N source.

As shown in Table 42, the decomposition rate of fresh and dried *Leucaena* tops and maize stover was faster when the material was buried in the soil. Drying the *Leucaena* tops significantly reduced decomposition rate. When buried, the half life of the fresh material was estimated at 6 days, compared to 11 days for the dried *Leucaena* tops and 30 days for dried maize stover. Because of the slower decomposition rate the dried material was less effective as N source.

Table 42. Decomposition rates of fresh and dried *Leucaena* tops and maize stover.

	Days					
	4	11	18	32	46	66
Treatments	Decomposition rate (%)					
Fresh *Leucaena* surface applied	25.5	40.3	48.0	53.4	65.5	54.3
Fresh *Leucaena* buried	24.2	53.8	73.6	79.4	91.9	91.5
Dry *Leucaena* surface applied	12.6	14.9	38.2	37.8	43.1	44.6
Dry *Leucaena* buried	12.1	34.3	61.0	69.8	77.0	73.6
Maize stover surface applied	—	1.9	6.5	8.5	8.6	16.2
Maize stover buried	3.9	15.5	34.7	55.9	50.5	64.7
SEx	2.1	1.9	3.4	5.0	5.0	3.8
LSD (.05)	6.4	5.5	10.0	14.8	14.7	11.4

Mulch Management

No-tillage crop production is best done where there is enough plant residue to form an effective soil cover. Previous work has shown that various leguminous cover crops grown during the fallow period provide mulch when they are killed by herbicide or when they die naturally during the dry season. Of the legumes tested, *Mucuna utilis* was found to produce good mulch compatible with a range of crops and production techniques. The experiments described below are part of a project aimed at developing and refining methods of using cover crop mulch for efficient no-tillage food crop production.

Effects of phosphorus and spacing on *Mucuna* mulch

G.F. Wilson

Phosphorus at 0, 30, 60 and 90 kg/ha P_2O_5 was applied on spacings of 75 cm x 25 cm; 75 cm x 50 cm and 75 cm x 75 cm. Neither phosphorus level nor spacing significantly affected the development of *Mucuna utilis*. The mulch left by the *Mucuna* residue averaged 4,500 kg/ha (dry weight) at the end of the dry season.

Live mulch systems

I.O. Akobundu, B.T. Kang, T.L. Lawson, K. Mulongoy

Three live-mulch treatments of *Arachis repens, Centrosema pubescens*, and *Psophocarpus palustris* were compared with maize stover mulch (10 t/ha), conventional tillage and no-tillage systems of maize production. All plots received 60 kg/ha of N, P_2O_5 and K_2O. Weed control treatments consisted of weeding selected treatments once, keeping some treatments weed-free and leaving others unweeded. Maize was planted by hand. In the live mulch plots, strips 15 cm wide were sprayed with Paraquat at the rate of 0.4 kg/ha.

Uncontrolled weed growth significantly reduced maize grain yield in the conventional and no-till plots, but not in the

Centrosema or *Psophocarpus* live mulch plots. The intensity of weed interference at 0 kg/ha nitrogen was similar to that at 60 kg/ha nitrogen on maize plots that were weeded once or left unweeded throughout the season.

These data suggest that maize response to nitrogen fertilizer requires that weed interference be removed. Use of live mulch demonstrates major savings in cost of crop production with regard to weed control and N fertilizer use.

Effect of N level and residual P on maize grown in *Mucuna* mulch

G.F. Wilson

N levels of 0, 30 and 60 kg/ha were applied on residual P used in establishing *Mucuna utilis*. The N application was split up with 1/3 applied at planting and 2/3 at 4 weeks after planting. The N treatment was repeated on the same plots with a second maize crop in the second rain season.

In the first season 60 kg/ha N significantly increased maize yield at 30 kg/ha P but had no significant effect at other P levels (Fig. 46). The difference in maize yield among P levels was not significant. In the second season, there was no consistency in response to N but, in general, there were indications that N was necessary for good yields (Fig. 47). The no N plants showed severe chlorosis. The interaction between N and P was significant in the second season. The results suggest that additional N is necessary for good yields, but that at high P levels (60 to 90 kg/ha) 30 kg/ha N is as effective as 60 kg/ha N.

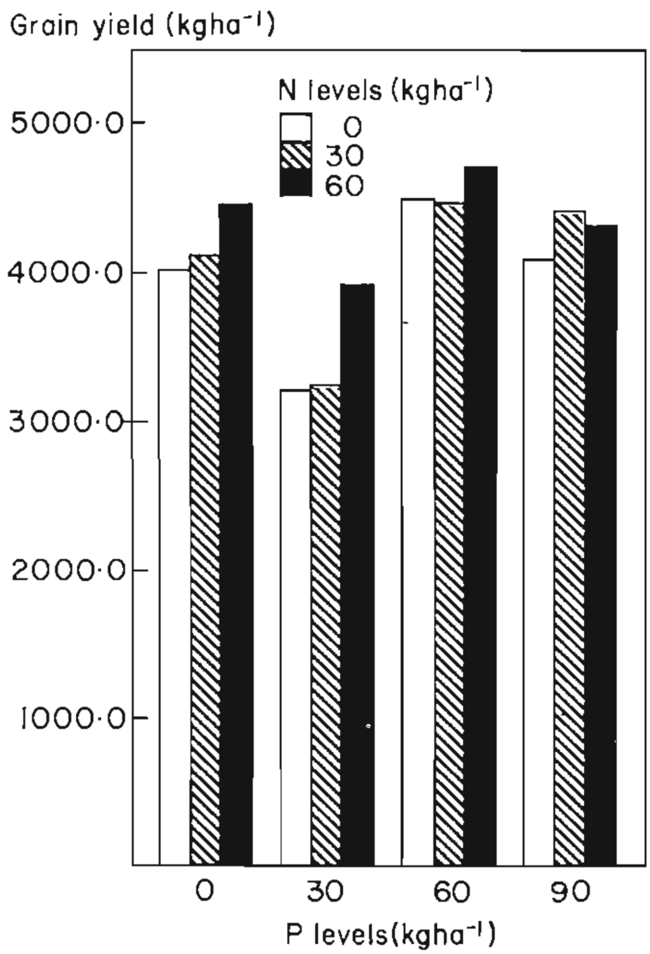

Fig. 46. Effect of P and N levels on first season maize yield.

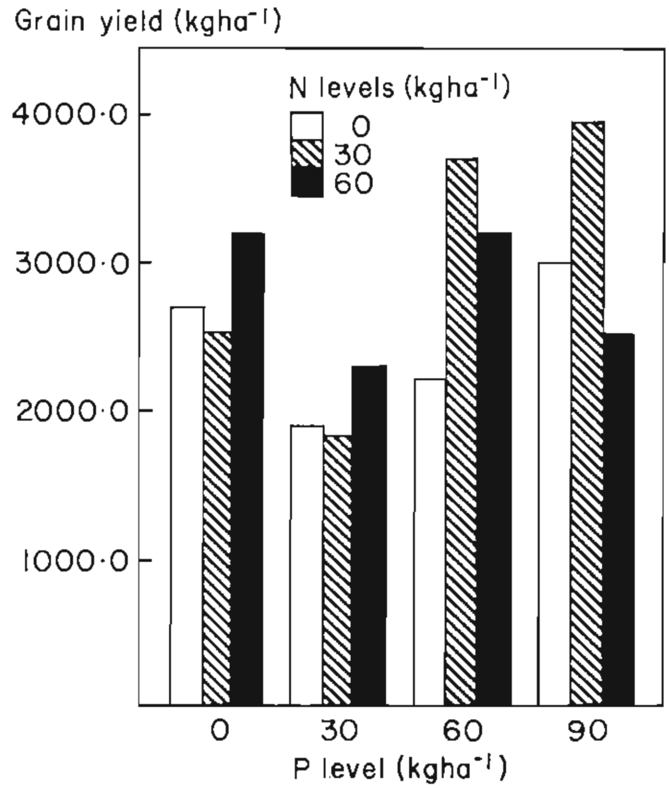

Fig. 47. Effect of P and N levels on second season maize grain yield.

Maize emergence in mulch from *Mucuna utilis*

G.F. Wilson

Poor stand, usually caused by poor seedling emergence, has been a major problem in no-tillage with plant residue mulch. With hand planting and careful separation of the mulch, good emergence is achieved, but with some mechanical planters poor stands are common. Good maize establishment has been achieved in *Mucuna* mulch with hand planting and tractor-drawn mechanical no-till planters.

A test with the rolling injection no-till planter (RIP) has shown that maize can be established through *Mucuna* mulch very efficiently with this small planter (Fig. 48). Even where the mulch thickness was doubled by placing one mulch layer on top of another, emergence was similar to that with no mulch or with a single mulch layer. This compatibility between mulch from *Mucuna utilis* and RIP extends the advantages of mulch cropping to medium and small farmers who need some form of mechancial planter to speed up planting.

Mulch from *Pueraria phaseoloides*

G.F. Wilson

Mulch from *Pueraria phaseoloides* differs from that of *Mucuna utilis* in that *Pueraria* survives the dry season (3-4

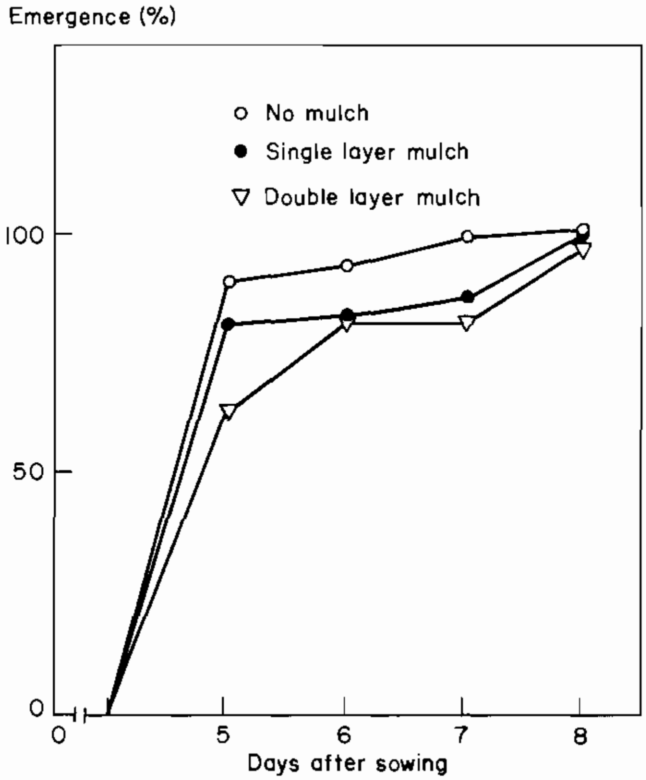

Fig. 48. Effect of *Mucuna utilis* residue thickness on maize germination.

months) and must be chemically killed to provide mulch and the mulch is also heavier (8-10 t/ha, dry matter). Maize emergence is poor with both conventional tractor-drawn no-till planters and the rolling injection planter. Hand planting is slow as the mulch must be pushed back to avoid subsequent closure and smothering.

To check maize response to mulch from *Pueraria*, a trial was established with mulch and no-mulch (residue removed) as main treatments and N levels (0, 30, 60 kg/ha N) as sub-treatments in a split plot design with 4 replications. At all N levels, no-mulch gave higher yields than mulch, but the differences were not significant (Table 43). Yield response to N levels was also slight though chlorosis was observed in the no N treatments. Lower yields in mulch plots were due to slightly poor stands resulting from poor emergence.

Table 43. Effect of *Pueraria* mulch and N levels on maize yield.

N kg/ha^{-1}	Mulch	No mulch kg/ha^{-1}	Mean
0	2841	3267	3054
30	3182	3722	3452
60	2898	3920	3409
Mean	2973	3636	

LSD (0.05) N levels same mulch treatment 868
LSD (0.05) N levels different mulch treatment..............1212
LSD (0.05) Between N levels 612
LSD (0.05) Between mulch treatment..................1009

In another trial *Pueraria* was killed with Glyphosate at the start of the second rain season and the response to N at 0, 30, 60 and 90 kg/ha measured. A third of the N was applied at planting and two-thirds at four weeks after planting. All plots received 60 kg/ha P_2O_5 and 40 kg/ha K_2O at planting. There was significant response to N at 90 kg/ha, but not to the other rates (Table 44). In the following first rains when the treatments were repeated on the residual *Pueraria* mulch and maize residue, there was no response to N (Table 45).

Table 44. Effect of N levels in *Pueraria Phaseoloides* on maize grain yield.

N levels kg/ha^{-1}	Grain yield kg/ha
0	1966
30	2422
60	2326
90	2879
LSD (0.05)	741
CV	19%

Table 45. Residual effect of *Pueraria Phaseoloides* mulch and N levels on maize grain yield.

N levels kg/ha^{-1}	Grain yield kg/ha^{-1}
0	5551
30	5452
60	5702
90	5798
LSD (0.05)	1546
CV	17%

Effect of fallow and mulch on maize establishment

C. Garman, A.S.R. Juo, I.O. Akobundu

Seed emergence and stand establishment of no-till maize as affected by type of fallow and amount of residue mulch were evaluated using a rolling injection planter. The fallow plots were manually cleared at the end of the dry season in 1981 after a four-year fallow. Plant residues, except woody parts, were retained as surface mulch.

The 4 fallow treatments were: natural bush regrowth, pigeon pea, Guinea grass and *Stylosanthes*. A continuous no-till maize treatment was included as a control. The experimental design was a 5 x 5 Latin square. The cleared fallow plots were left for two weeks for regrowth and then sprayed with Glyphosate (Roundup) at a rate of 6 liters/ha. Maize was planted with a hand-operated rolling injection planter and a preemergence herbicide (Primextra 2.5 kg/ha) was applied at planting. Two dates of planting were tested: (1) 16 days after clearing or 2 days after Glyphosate application in April; (2) 36 days after clearing or 22 days after Glyphosate application in May.

During the first planting, 2 seed treatments were included: Carbofuran-treated and untreated check. During the second planting, all seeds were treated with Carbofuran.

Table 46 shows that in the fallow treatments, large amounts of mulch significantly affected maize establishment after the first planting or 16 days after clearing. Treating maize seed with Carbofuran (Furadan) slightly improved emergence and stand establishment, particularly in plots cleared from *Stylosanthes*. Thus, factors other than poor seed-soil contact also affected seed emergence and subsequent stand establishment in the newly cleared fallow plots. Poor stand establishment in the no-till continuous maize plots after the first planting was due to poor soil moisture in the early part of the rain season and the highly compacted surface soil as shown by the high values of penetrometer readings (Table 46).

The second date of planting in May (36 days after clearing), however, gave uniformly good stand establishment in all treatments. This is because sufficient time was allowed for the mulch to "settle" and decompose, facilitating more effective operation of the no-till planter. Better stand establishment in the continuously cropped plots after the second planting was attributed to better soil moisture, particularly between planting and emergence. Moisture content in the surface soil ranged from 12 percent to near field capacity during this period.

Effect of mulching and burning

B.T. Kang

In traditional farming systems, burning plant residue is commonly used for seedbed preparation. However, the effect of burning plant residue yearly on soil productivity and crop performance has not been adequately studied. Two trials were, therefore, initiated in 1978 at Ikenne on an Alagba soil series (Oxic Paleustalf) and at Onne (Typic Paleustalf) to investigate the interaction between annual burning, residue mulching, fertilizer use and liming. The trials were carried out using the split plot design with 4 replications.

The 4-year results from Ikenne showed very little difference in main season maize grain yield between residue mulching and residue burning. The only difference was observed with the NK treatment where residue burning gave consistently higher yields. It appears that one of the main beneficial effects of burning on this slightly acid Alfisol is to liberate more P for the crop.

The 4-year results from Onne showed very little difference in main season maize grain yields between residue mulching and burning with no fertilizer and NPK + lime treatments (Table 47). In 1981, the fourth year of cropping, there was significant response to residual lime applied at rate of 1 ton $CaCO_3$/ha in 1980 with either residue mulching or burning. Higher residual lime response was observed with mulching. With NPK application, yield was higher when crop residue was burnt.

Magnesium deficiency symptoms were observed in the second season cowpea plants from the no Mg treatments. However, no Mg response was observed in cowpea seed yield (Table 48). Cowpea plant dry matter yields showed some response to fertilizer application. Significant dry matter yield responses were observed only with NPK, Mg, Zn and liming treatment with mulching and with NPK, Mg, Zn treatment with burning. Cowpea seed yield also showed significant response to NPK with either mulching or burning the crop residue. There was no significant difference in seed yield between mulched and burnt treatments.

Table 46. Effect of mulch, date of planting and soil property on maize establishment after land clearing.

Type of fallow	Mulch yield# at clearing t/ha	Cone penetrometer reading Pa at surface	Maize Establishment First Planting, %		Maize Establishment Second planting, % (Carbofuran-treated)
			Untreated	Carbofuran	
Bush regrowth	16.0	41	14a+	27a	84a
Guinea grass	19.6	51	27ab	40b	85a
Pigeon pea	12.8	119	29ab	40b	72a
Stylosanthes	4.8	119	52bc	72c	80a
Maize (control)	—	200	39c	50d	82a
Mean			32	46*	

#Weight of air-dry matter, woody parts excluded.
+Duncan's multiple range test.
**T-test between two means in first planting showed significance for Carbofuran treatment.*

Table 47. Effect of plant residue management and fertilizer application on main season grain yield of maize variety TZPB grown on Ultisol (Typic Paleudult) at Onne.

Fertilizer Treatment	1978 M*	1978 B**	1979 M	1979 B	1980 M	1980 B	1981 M	1981 B
Control	1740	1190	556	595	1493	1391	2493	2162
NPK	3412	2727	2190	2036	3083	3327	3700	3552
NPK Mg Zn	2878	2802	1682	2233	3138	3588	3643	4034
NPK Mg Zn + Lime	3495	3008	1799	2355	3377	3702	4432	4422
Mean	2881	2431	1557	1805	2772	3002	3567	3542
LSD (.05) (I)***	671		249		585		854	
(II)	—		—		505		396	
(III)	679		746		715		908	

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

Table 48. Effect of plant residue management and fertilizer application on dry matter and seed yields of cowpea, variety VITA-6 grown on Ultisol (Typic Paleudult) at Onne (1981).

Fertilizer	Dry matter			Seed yield		
Treatment	Mulched	Burnt	Mean	Mulched	Burnt	Mean
	(kg/ha)					
Control	1530	1346	1438	808	848	828
NPK	1822	1773	1798	1020	1058	1039
NPK Mg Zn	1676	2013	1845	1000	1055	1027
NPK Mg Zn + Lime*	2514	2034	2274	1096	1279	1188
Mean	1542	1792		981	1060	
LSD (.05) (I)**	587			390		
(II)	507			100		
(III)	720			142		
(IV)	840			405		

Lime applied in 1980 at rate of 1 ton $CaCO_3$/ha.
***LSD (I) Between plant residue management means. (II) Between fertilizer treatment means. (III) Between fertilizer treatments within residue management. (IV) Between any two fertilizer treatments with different residue management.*

Live mulch for intensive cropping

I.O. Akobundu, B.T. Kang, T.L. Lawson, K. Mulongoy

Maize can be grown in established live mulch covers of *Centrosema pubescens* and *Psophocarpus palustris* without weeding and with nitrogen fertilizer. To assess crop response under intensive cropping in an Alfisol, maize was grown continuously for two seasons each year for three years (1979-81) in a field subjected to several land management systems, including no-tillage, conventional tillage, and live mulch. Nitrogen fertilizer levels were used as subplot treatments plus a blanket application of 60 kg/ha of P_2O_5 and K_2O in all plots.

Results of the three-year research show that maize yields under continuous cropping without nitrogen fertilizer were higher in a live mulch system (2.0 t/ha) compared to no-tillage (0.8 t/ha) and conventional tillage (1.0 t/ha). Maize in live mulch showed little or no response to nitrogen fertilizer. Good maize yields on a sustained basis and at low input levels were obtained with *Centrosema pubescens* and *Psophocarphus palustris* as live mulch.

Maize yields in the conventional tillage system declined steadily with subsequent cropping and this decline was not overcome by the application of nitrogen (Fig. 49). In the no-tillage system, low maize yields were obtained when no nitrogen fertilizer was applied. High maize yields were possible in the no-tillage systems with the application of 60 kg/ha or more of nitrogen.

The pattern of moisture depletion in the soil surface (0-30 cm) showed that the depletion rate was, generally, faster with live mulch which contributed to higher moisture retention following rainfall (Fig. 50). This is due to protection of the soil surface against raindrop impact, maintenance of better soil structure, and better infiltration rate. Moisture retained was highest under *Psophocarpus palustris* (Fig. 50).

Earthworm activity was influenced by the land management system. The *Eudrillus* (granular cast) type of worm was the only one found in the conventional tillage plots while the *Hyperiodillus* (columnar cast) accounted for over 99 percent of the worm casts present in live mulch plots (Table 49). The fact that the highest earthworm activity occurred in the live mulch plots is an indication of a more favorable environment for biotic activity.

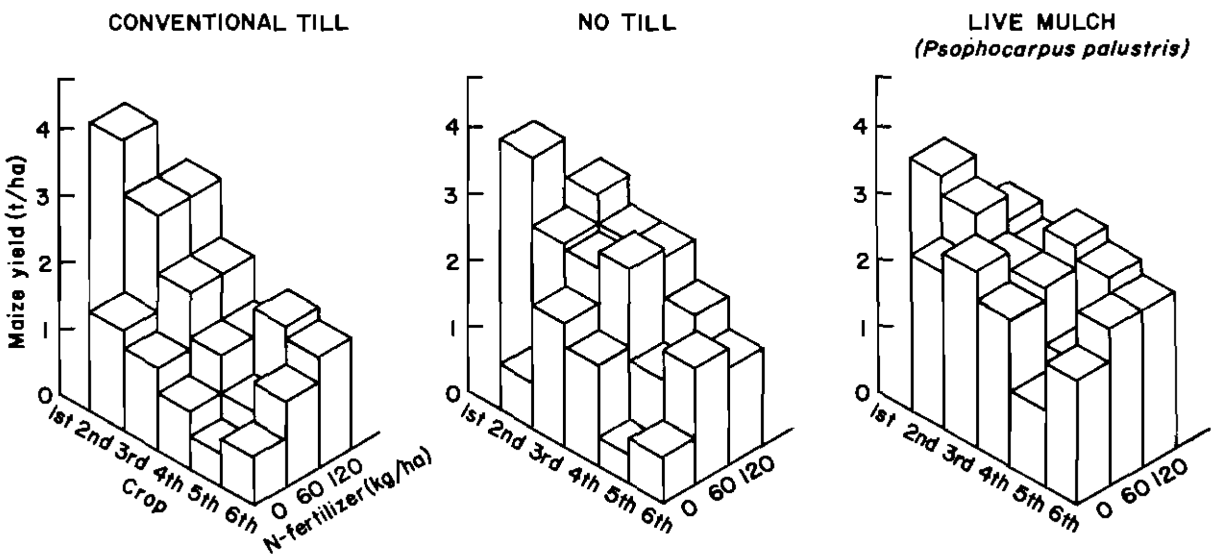

Fig. 49. Effect of land management, nitrogen fertilizer, and crop intensity on maize yield (IITA, 1979-81).

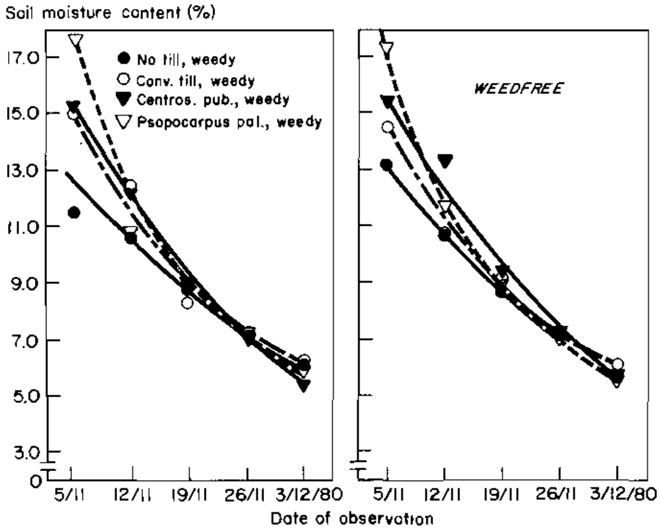

Fig. 50. Trend in soil moisture content under different mulch-crop combinations (1980).

Table 49. Effect of land management on type of earthworm activity in maize plots (late season, 1981).

	Hyperiodillus (Columnar casts)		*Eudrillus* (Granular casts)	
Land management	No/m^2	D.W. g/m^2	No/m^2	D.W. g/m^2
No-tillage	3.3	3.3	4.0	15
Conv. tillage	0	0	8.0	32
Maize stover	34.7	43.3	4.0	9.7
Arachis repens	64.7	130.3	0.0	0
Centro	52.0	65.7	0.7	1.0
Psopho	41.0	88.0	0.3	0.7
LSD (0.05)	24.4	54.1	4.2	15.4

Weed Management

The primary objective of IITA's weed management studies is to develop integrated weed management practices that minimize drudgery, are economical at low input levels, efficient and appropriate for the major cropping systems of the humid and subhumid tropics. This year's studies focus on control of itchgrass (*Rottboellia exaltata* L.) weed control in no-till systems, the effect of crop residue on weed growth, and the efficacy of pre-emergence herbicides.

Itchgrass interference and control in maize

I.O. Akobundu

The most troublesome annual grass weed on large-scale cereal and grain legume farms in the subhumid tropics is itchgrass. This weed has an aggressive growth habit and is difficult to control.

Two field experiments were carried out on an Alfisol (Apomu sandy loam) on a site that had heavy itchgrass infestation. In each of the trials, the field was plowed, harrowed and fertilized before maize was planted. One of the studies was to determine the effect of time of itchgrass emergence on maize yield. Maize at 40,000 plants/ha was exposed to itchgrass that emerged 0, 2, 4, 6 and 8 weeks after planting (WAP) the maize. Itchgrass population density of approximately 10 plants/m^2 was maintained by drilling itchgrass seed between maize rows at specific dates and thinning the seedlings to the desired population. The plots were kept free of other weeds and volunteer itchgrass.

In the second experiment, selected herbicides or herbicide mixtures were applied at specific dates using a CP-3 knapsack sprayer calibrated to deliver at a rate of 200 1/ha. Weed control ratings for itchgrass and other annual weeds were recorded for each of the treatments.

The trial on the effect of time of itchgrass emergence on maize yield shows that itchgrass seeds that emerged within the first 4 WAP caused significant reduction in maize yield (Table 50). Dry matter production was also higher in plots in which itchgrass emerged within the first 4 WAP compared to plots in which the weed emerged at later dates.

Table 50. Effect of time of itchgrass emergence on maize yield and dry matter production in itchgrass.

Time of emergence WAP	Itchgrass D.W.	Maize grain yield
	(kg/ha)	
0	8785	2229
2	4170	2908
4	5730	2777
6	630	3545
8	740	3266
LSD	2006	621
CV (%)	32	14

The best control of itchgrass was observed in plots in which pendimethalin (1.5 or 2.5 kg/ha) was used as a pre-emergence herbicide (Table 51). However, this herbicide did not satisfactorily control annual weeds such as *Tridax procumbens* and *Synedrella nodiflora* (Table 52). A tank mixture of atrazine and pendimethalin (2.0 + 2.0 kg/ha) satisfactorily controlled both itchgrass and other annual weeds during the first 10 WAP. Although seedlings of late germinating itchgrass reinfested the plots, maize yield was not significantly reduced by these weeds. Trifluralin at the rate used in this study (1.0 kg/ha) did not satisfactorily control itchgrass. Over 70 percent reduction in maize yield was noted when this weed was not controlled.

Table 51. Effect of herbicide treatments on maize yield and control of itchgrass.

Treatment	Rate	Time	Control rating	Itch-grass D.W.	Maize grain yield
	(kg/ha)		%	—kg/ha—	
Pendimethalin	1.5	PE	86	654	2361
Pendimethalin	2.5	PE	92	400	2264
Atrazine + pendimethalin	2.0+2.0	PE	86	1187	2488
Trifluralin	1.0	PE	28	3791	1325
Trifluralin	1.0	PPI	74	3137	1389
Hand weeding	—	3+8 WAP	100	391	2739
Unweeded check	—	—	0	6639	772
LSD (0.05)			21	2065	673

Table 52. Effect of herbicides on weed control in maize.

Treatment	Rate	Time	Eo	Tp	Sb	Sn	C	Tt
			Weed control rating					
	(kg/ha)		%					
Pendimethalin	1.5	PE	96	50	58	19	73	90
Pendimethalin	2.5	PE	75	65	81	48	100	98
Atrazine + pendimethalin	2.0 + 2.0	PE	96	100	83	100	89	96
Trifluralin	1.0	PE	41	43	90	59	59	85
Trifluralin	1.0	PPI	70	23	88	63	85	98
Hand weeding		3+8 WAP	100	100	100	100	100	100
Unweeded check			0	0	0	0	0	0
LSD (0.05)			40	57	34	52	37	8

Eo = *Eupatorium odoratum;* Tp = *Tridax procumbens;*
Sb = *Sesbania* spp; Sn = *Synedrella nodiflora;*
C = *Calopogonium mucunoides;* Tt = *Talinum triangulare.*

Although itchgrass emerging 6 WAP did not seriously reduce maize yield, weed growth at this time or later could interfere with harvesting.

The problem of late germinating itchgrass was not solved by any of the herbicides tested. There is a need, therefore, to identify the economic threshold of itchgrass in maize and a population density at which this weed will not interfere with crop growth, yield or harvest operations.

No-till weed control and plant residue management

I.O. Akobundu, B.N.A. Addy

The effects of type and amount of crop residue on weed biomass and on the efficacy of a pre-emergence herbicide were investigated in the field and in the greenhouse at IITA. In the field experiment, plant residue treatments consisted of maize stover, pigeon pea, bush fallow, Guinea grass and stylo. All plots were sprayed with glyphosate at 3 kg/ha before maize was planted. Type of plant residue was the main plot and each plot was subdivided so that each subplot received either a pre-emergence herbicide or was an untreated check.

In the greenhouse, the efficacy of varying rates of a formulated mixture of atrazine and metolachlor applied pre-emergence was assessed over a range of maize stover residue levels using greenhouse pots. Phytotoxic action of the herbicide was assessed by bioassay.

The effect of tillage on the performance of selected cassava herbicides was investigated in the field in a Ultisol, sandy loam on a site that had been under secondary bush fallow for 3 years. Tillage treatments were the main plots and these included, (a) plowing, harrowing and ridging; (b) plowing and harrowing, and (c) no-tillage. Subplot treatments were the weed control treatments. Fallow vegetation was first killed with glyphosate applied at the rate of 3.6 kg/ha before tillage.

In the field experiment involving types of plant residue, the highest weed density at 4 WAP was observed in the maize stover plots (Fig. 51). This treatment had the lowest amount of crop residue (4 t/ha field dry weight) and this residue level was not enough to cover the soil surface. Consequently, weeds were not smothered.

Although pigeon pea stover had high residue weight, ground coverage was poor because most of the dry matter came from the woody stems and branches. As a result, weed population at 4 WAP was high. Weed density was moderate in bush fallow and fallow and stylo residues and low in the Guinea grass plot. The Guinea grass plot had the highest amount of plant residue which effectively smothered weeds. A pre-emergence herbicide (atrazine + metolachlor, 2.5 kg/ha) applied 3 weeks after the various crop residues were spread, effectively kept weed population low in all crop residue plots.

Weed biomass data taken at 6 WAP show clearly that ground coverage is more important than the type of residue in the action of pre-emergence herbicides (Fig. 52). The best ground coverage was in the Guinea grass plot. It is also in this plot that the lowest weed biomass was recorded. Smothering weeds by Guinea grass mulch was as good as when a herbicide was used in the other mulches.

The difference between herbicide treated and untreated plots in the bush fallow, Guinea grass and stylo was not significant, showing that plant residue interfered with the activity of the herbicides. The presence of stem branches from the bush fallow may have accounted for the high dry matter weight while actual ground coverage was of the same order as in stylo. On the other hand, there was significant difference between treated and untreated plots in maize stover and pigeon pea where complete ground coverage by plant residue was not achieved. This difference suggests that where there was good ground coverage, more herbicide might have been intercepted.

In a follow-up study on the role of crop residue levels in the performance of pre-emergence herbicides, maize stover mulch in excess of 5 t/ha was found to intercept more than 60 percent of the pre-emergence herbicide that would have

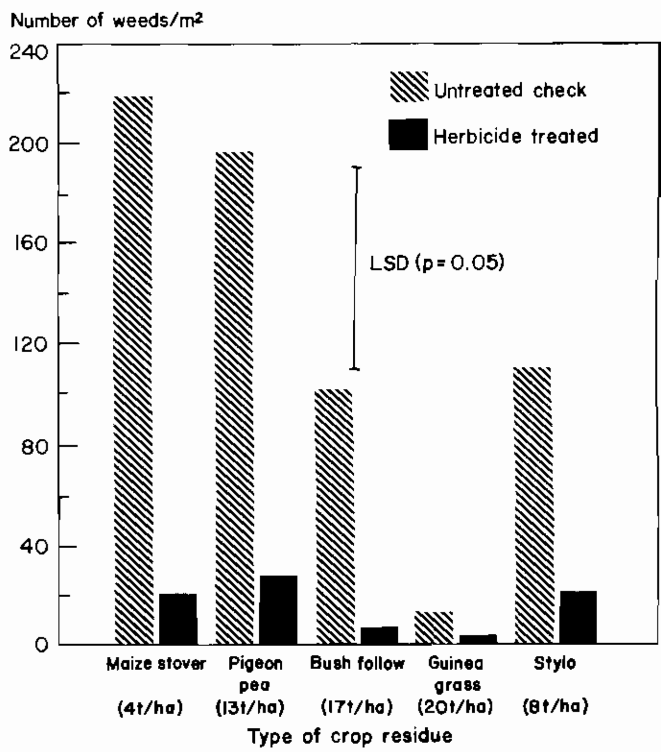

Fig. 51. Effect of type of crop residue and pre-emergence herbicides on weed density at 4 WAP.

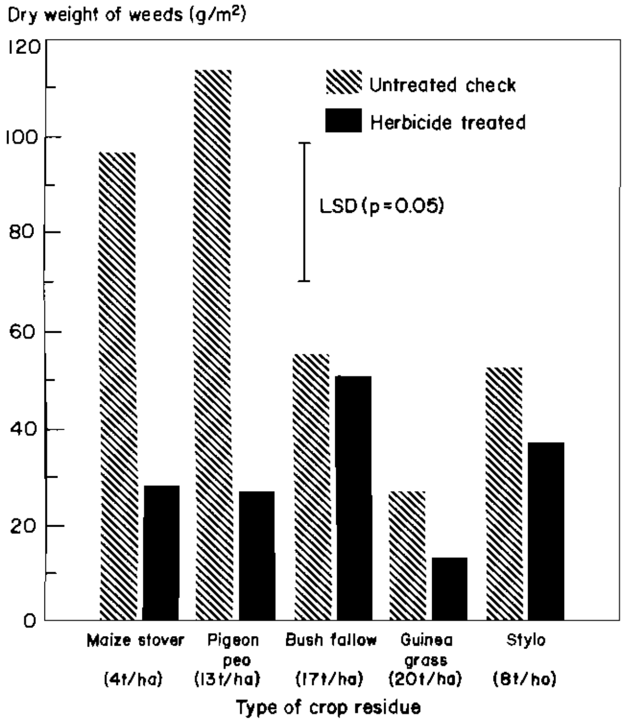

Fig. 52. Effect of type of crop residue and pre-emergence herbicides on weed biomass at 6 WAP.

reached the soil surface (Table 53). As residue level increased there was a corresponding increase in the amount of herbicide intercepted.

The effects of tillage and weed control on cassava production were investigated in a Ultisol that was cleared from forest and fallowed for 2 years prior to this study. Cassava (cv. TMS 30572) plant height was taken at 10 WAP when at least 50 percent canopy had developed. Lowest plant height was recorded in the no-till plots (Table 54). Plant height in the plow-and-harrow plot was intermediate while tallest plants were in the ridged plots. Weed control treatments did not significantly affect plant height at this sampling date.

Overall differences in tuber yield 12 months after planting showed that cassava yield was identical in the ridged plot-and-harrow plots and that these were significantly higher than the yield in the no-till treatment (Table 55). Uncontrolled weed growth caused 35, 37 and 40 percent reduction in root yield in the ridged, plow-and-harrow, and no-till plots respectively. Cassava root yield was poor in the herbicide treated no-till plots because of poor weed control. The same herbicide rate that led to low weed biomass in the ridged and conventional tillage plots resulted in significantly higher weed biomass in the no-till plots (Table 56).

Table 53. Effect of maize stover levels on amount of metolachlor in the soil at 3 weeks after treatment (WAT).

Concentration of metolachlor	Residue level (t/ha) 0	5	10	15	Mean
(Kg/ha)	Concentration of metolachlor at 3 WAT (g/ha)				
0.9	117(0*)	63(46)	86(26)	40(67)	77(46)
1.2	171(0)	23(87)	140(18)	63(61)	99(55)
1.5	315(0)	99(69)	50(84)	95(70)	140(56)
1.8	400(0)	122(70)	95(76)	27(93)	174(80)
Mean	203(0)	77(62)	72(65)	59(71)	

**Values in parentheses show amount of herbicide intercepted by crop residue as percent of the amount present in the check plot.*

Table 54. Effect of tillage and weed control methods on cassava plant height at (10 WAP) Onne, 1981.

Weed control	Rate	Time	Ridge	Conv. till	No-till	Mean
	(kg/ha)		(cm)			
Atrazine						
+ metolachlor	3.0	PE	79.1	68.1	38.8	62.0
Fluometuron						
+ metolachlor	2.0+2.0	PE	80.9	66.9	42.7	63.5
Diuron + paraquat	3.0	Post E	79.5	56.8	46.9	61.1
Hoe weeding	—		79.8	56.1	47.1	61.0
Weed-free	—		88.6	63.0	47.0	66.2
Unweeded check	—		79.0	67.8	46.7	64.5
Mean			81.1	63.1	44.9	

LSD (0.05) Tillage = 7.4 cm; weed control = 4.9 cm.
Weed control for same tillage treatment = 8.6 cm.
Weed control for different tillage treatments = 10.7 cm.

Only a mixture of Paraquat and Diuron applied as a directed spray 4 WAP controlled weeds effectively throughout the growing season. Poor weed control by the pre-emergence herbicide in the no-till plots might be due to herbicide interception by the crop residue followed by new weed growth.

Harvesting is one of the high labor inputs in cassava production. A harvesting technique that minimizes root breakage, reduces time spent harvesting, reduces root loss and increases the market value of produce is desirable in cassava production. Highest root breakage was observed in the no-till plot and this differed significantly from the conventional and ridged plots (Fig. 53). Although the effect of weed interference was not significant within each tillage system, root breakage was generally higher in unweeded plots than in plots that were kept weed-free.

Evaluation of Harvesting Machines and Tools

Cassava harvesting under two tillage systems

C. Garman, N.C. Navasero

Cassava (var. TMS 30527) was planted using two systems: one without tillage on a field which had been under no-till

Table 55. Effect of tillage and weed control methods on root yield in cassava (Tms 30375), Onne (1981).

Weed control	Rate	Time	Ridge	Conv. till	No-till	Mean
	(kg/ha)		(t/ha)			
Atrazine						
+ metolachlor	3.0	PE	13.8	11.7	6.1	10.5
Fluometuron						
+ metolachlor	2.0+2.0	PE	12.2	13.1	6.3	10.5
Diuron + paraquat	3.0	Post E	13.4	11.9	10.1	11.8
Hoe weeding	—	—	13.4	14.0	9.0	12.1
Weed-free	—	—	17.0	18.1	11.6	15.6
Unweeded check			11.1	11.4	7.0	9.9
Mean			13.5	13.4	8.3	

LSD (0.05) Tillage = 2.7 t; weed control = 1.3 t; weed control for same tillage treatment = 2.2 t; weed control for different tillage treatments = 3.3 t.

Table 56. Effect of tillage and weed control methods on weed biomass (16 WAP) in cassava (cv. Tms 30375), Onne (1981).

Treatment	Rate	Time	Ridge	Plow& harrow	No-till	Mean
	(kg/ha)		(t/ha)			
Atrazine						
+ metolachlor	3.0	PE	5.8	11.6	21.2	12.9
Fluometuron						
+ metolachlor	2.0+2.0	PE	5.3	6.6	15.5	9.1
Diuron + paraquat	3.0	Post E	0	0	0	0
Hoe weeding	—	—	5.3	5.3	4.7	5.1
Weed-free	—	—	0	0	0	0
Unweeded check			25.1	24.6	22.1	24.0
Mean			6.9	8.0	10.6	

LSD (0.5) Tillage = 6.2. Weed control = 4.6t.
Weed control for same tillage treatment = 8.0t.
Weed control for different tillage treatments = 9.5t.

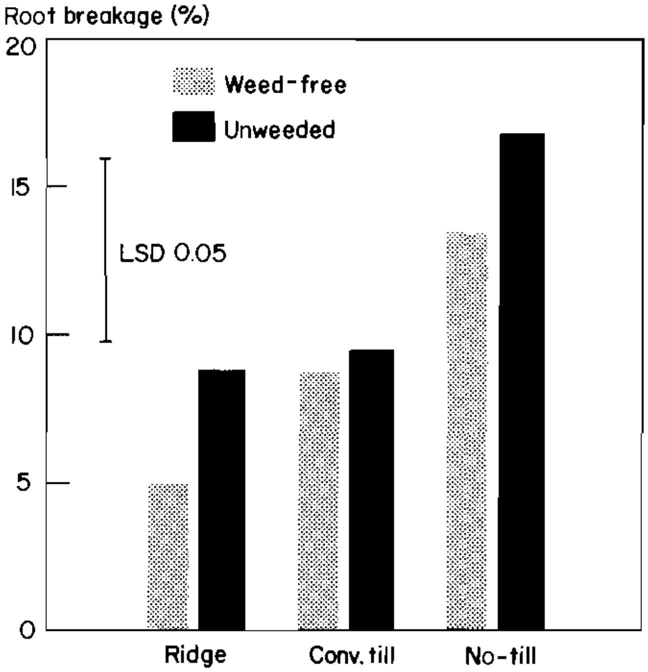

Fig. 53. Effect of tillage and weed interference on root breakage in cassava.

for the previous 2 years, and the other with conventional ridge tillage prior to planting.

On the no-till plots the weeds were killed with herbicide and a hole was punched in the ground at a 45° angle with a pointed metal bar. The cassava cutting was put in the hole and then the earth above the cutting was stepped on. On the conventional ridge plots, the field was plowed and then ridged. Planting was the same way as with no-till. The cassava was harvested 18 months later during the dry season with the IITA cassava lever.

Maximum force required to pull the cassava in the two tillage systems was not much different (Table 57). Harvesting was almost twice as fast on no-till due to cassava being nearer the surface. The losses, including roots or parts left in the soil, were 5 times less on the no-till plots (Table 58).

The cassava planted on no-till tended to have its tubers growing horizontally at an angle of up to 15° from the soil surface. The conventional ridge-tilled cassava tubers grew downwards at an angle of about 30°-60° from the soil surface. The ends of the tubers under conventional till broke more often, thus giving a higher loss rate.

Table 57. Force to pull cassava: no-till vs. conventional till.

	No-till	Conventional
Maximum force to pull one plant (average)	121 kg	113 kg
Maximum force to pull a kg of root harvested (average)	37 kg	28 kg
Yield per plant	3.3 kg	4.0 kg

Table 58. Rate of harvesting cassava with IITA hand lever.

No-till	Conventional ridge
113 kg/hr	60 kg/hr
34 plants/hr	15 plants/hr
4.5% Root loss	27% Root loss

Mechanical harvesting of cowpea

N.C. Navasero, C. Garman, S.R. Singh, O. Nwazojie

Cowpea, among other staple crops in most African countries, lacks a suitable method of mechanical harvesting. The tedious and labor-intensive harvesting that requires picking pods several times to completely harvest a season's crops makes cowpea expensive. Varieties of unfavorable plant types are seen in many farmers' fields which impair smooth harvesting. These unwanted plant types also impair design and development of suitable mechanical harvesters.

These problems are further complicated by the cropping systems followed by most African farmers. Cowpea is usually planted in small land patches with stumps and other debris left after land clearing. Some of these problems may be solved if farmers:

1) select upright varieties which mature uniformly;
2) avoid spreading cowpeas and
3) avoid planting cowpeas with leathery pods at maturity.

The purpose of this project was to point out possible directions in mechanizing cowpea production.

An experiment was conducted to determine the performance of a plot harvester on two types of cowpeas. A 7-horsepower self-propelled harvester with an adjustable cutter bar (1 m wide), a belt conveyor and a collecting box was used.

Tests were done using 3 cutting heights on both the upright 04-0267-IF and the spreading VITA 5 cowpea grown under zero tillage. Each adjustment was tried 6 times on a 5-meter row to keep the yield as constant as possible.

Grain harvested, grain left in the field and total dry matter picked up by the harvester were recorded. Total grain yield was taken as the sum of the grain harvested plus the losses.

Enormous differences in yield were noted between upright and spreading cowpeas at all cutting heights (Table 59). Table 60 shows that a significant amount of total dry matter entered the harvester for both cowpeas cut at 0 to 5 cm

Typical growth pattern on no-till cassava, variety TMS 30527.

Typical growth pattern on conventionally ridged cassava, variety TMS 30527.

Table 59. Effect of cutting height in mechanically harvesting 2 types of cowpeas, upright 04-0267-IF and spreading VITA 5.

Planting type/ cutting height	Harvest	Losses	% Loss	Dry matter	Total yield	Remarks
1. Upright/0-5cm	263.50	39.33	13.21	437.67	297.83	Thick mulch at harvest
2. Upright/6-10cm	199.83	106.50	35.17	166.83	302.83	Mulch not disturbed
3. Upright/11-15cm	187.17	187.17	52.02	122.00	359.83	
4. Spreading/0-5cm	162.67	145.50	44.97	288.67	323.58	No mulch at harvest
5. Spreading/6-10cm	113.33	146.42	55.31	163.08	264.75	
6. Spreading/11-15cm	94.17	212.50	69.29	115.75	306.67	

Table 60. Effect of cutting height in harvesting no-till cowpea mechanically (Variety 04-0267-IF and VITA-5).

Cutting height (cm)	Harvested grain	Losses	Total dry matter	Yield
0-5	213.08 a	92.42 a	363.17 a	310.71
6-10	156.58 b	126.49 b	164.96 b	283.79
11-15	140.67 b	199.83 b	118.88 b	333.25
	CV=20.49	CV=38.81	CV=51.92	CV=19.17

Numbers followed by different letters are significantly different at the 5% level of significance by Duncan's Test.

Table 61. Mechanical harvesting of upright versus spreading type of cowpea.

Cowpea variety	Harvested grain	Losses	Total dry matter	Grain yield
04-0267-IF (upright)	216.83*	111.00*(35%)	242.17	320.17
VITA-5 (spreading)	123.39	168.14 (56%)	189.17	298.33

Significant at 1% level.

high. It was observed that mulch was also picked up by the harvester causing abnormal increase in dry matter. Total grain yield was the same in all trials. More than half of the grain yield of the spreading type of cowpea was left in the field (Table 61).

Other factors observed affecting efficiency of mechanical harvesting were:

1) Occasional stopping caused by stones caught between the cutter bar blades and between the cutter bar and the conveyor at lower cutting heights.
2) Due to uneven surface, the harvester was unable to cut some portions.
3) Pods, especially at higher cutting heights, fell in front of the cutter bar instead of being swept by the reel toward the conveyor.
4) Even at lower cutting heights, it was not possible to cut and pick up all runners of spreading cowpeas. Frequently runners got wrapped on the reel and when they were not cut by the cutter bar, they caused damage to the reel.
5) Most losses in upright cowpeas were caused by the peduncles breaking or bending before harvesting.

Effect of cytokinin on bud formation

R. Swennen, G.F. Wilson, E. de Langhe

The effect of cytokinin on bud formation was tested by injecting 10^{-2}M benzyl [a] denine solution in mother plants. The injection of 2 ml each was administered from the sixth week after planting at intervals of 2 days for a total of 5 injections.

Six weeks after the first peeper was sighted, the plants were dug out and the number of peepers and buds counted.

The cytokinin had no significant effect on the growth of the treated plant (Table 62) nor did it affect the number of peepers visible above ground, but it significantly stimulated bud formation (Table 63). The indication that cytokinin stimulates bud formation is potentially useful in developing methods for supressing post-flowering sucker proliferation or for generating large numbers of meristem tips for rapid multiplication by *in vitro* meristem tip culture.

The effect of mulch and fertilizer

R. Swennen, G. F. Wilson

The effect of mulch from *Eupatorium odoratum* applied at about 40 t/ha and inorganic fertilizer applied at 300 kg/ha N; 250 kg/ha P_2O_5 and 550 kg/ha K_2O per year was compared on three *Musa* sp. (medium and giant false horn plantain and a banana, "paranta"). Treatment combinations, growth and yield response are shown in Table 64. The plants were spaced 200 cm x 200 cm.

Growth and development in the control (no mulch, no fertilizer) were so poor that yields were negligible and thus were not considered in the analysis. Both giant plantain and "paranta" banana responded significantly to the mulch/fertilizer combination, but with medium plantain, the combination was not significantly superior to mulch or fertilizer used separately. The performance under mulch and fertilizer confirms previous results. This trial is continuing as the performance under mulch and fertilizer is expected to differ in subsequent ratoons.

In adjacent observation plots in which medium plantain has been maintained with mulch or fertilizer, the mulched plot yields were 4 times that of the fertilized plot in the fourth ratoon.

Table 62. The effect of cytokinin on growth (height and girth) of plantain from time of injection to 6 weeks after injection.

	Height		Girth	
	Time (in weeks)			
Treatment	0	6	0	6
		(cm)		(cm)
Control	60.79	88.90	19.86	27.38
Cytokinin	61.18	87.04	19.50	30.58

Table 63. The effect of cytokinin on bud and peeper stimulation on plantain corm.

Treatment	No. of	
	Buds	Peepers
Control	4.83 a[1]	2.00 a
Cytokinin	6.42 b	2.05 a

[1]*Numbers in the same column followed by the same letter are not significantly different* by the Duncan's Multiple Range Test (data was analysed after a square root transformation).*
**At the 5% level of significance.*

Socio-Economic Analysis and Evaluation

Economic evaluation of alley cropping *Leucaena*-maize

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An agro-economic maize-*Leucaena* experiment was carried out at IITA in the 1981 first and second seasons to evaluate alley cropping with *Leucaena*. The objectives of the experiment were: (i) to monitor labor and other inputs, (ii) assess the effects of alley cropping with *Leucaena* on maize yields and (iii) to determine the economic viability of maize-*Leucaena* alley cropping.

In order to assess whether *Leucaena* is compatible with N and herbicides, 2 x 2 x 2 factorial design was used comprising *Leucaena* and herbicide at two levels each. First and second season maize was grown in a plot of about 0.23 ha which had been left under fallow in 1980. The plot was divided into 4 replicates along the contours with each of the replicates subdivided into 8 plots of 6 cm by 10 m and 3 of the plots in a replicate already established with *Leucaena*.

Leucaena and herbicide were taken as main plot treatments and N (at 80 kg/ha in 2 applications) taken as subplot treatment, superimposed on the other treatments by a split plot. In the *Leucaena* plots, *Leucaena* trees were cut in April 1981, prunings left in the plots as mulch, and the stems removed.

Table 64. Plantain and banana response to mulch and fertilizer.

Treatment		Giant		Medium		Paranta	
		Height	Yield	Height	Yield	Height	Yield
Mulch	fertilizer	cm	t/ha	cm	t/ha	cm	t/ha
–	–	239.2a	—	197.8a	—	205.9a	—
–	+	380.8c	18.0a	328.8b	16.7a	330.7bc	7.5a
+	–	321.7b	17.2a	298.2b	15.8a	288.5b	9.5a
+	+	413.9c	31.3b	366.7c	19.8a	344.3c	13.3b

Numbers in the same column followed by the same letter are not significantly different at the 5% level of significance by the Duncan's Multiple Range Test.

During the first and second cropping seasons, *Leucaena* tops were pruned 2½ weeks after planting, weighed and returned as mulch. The herbicide plots were sprayed with Paraquat at 3 litres active ingredient/ha before planting and atrazine at 2.5 kg active ingredient/ha after planting. The control plots were weeded with a hoe 2 weeks after planting. All plots were dressed with P and K fertilizers at 60 kg/ha and 30 kg/ha respectively both for the first and second season crops.

Leucaena stands planted at 2 cm x 0.5 m produced 13,333 to 19,000 stems/ha, and yielded 15.5 t/ha fresh weight of *Leucaena* wood or 8.6 t/ha dry weight. In the first season, *Leucaena* tops produced 6.2 t/ha fresh weight yielding about 78 N kg/ha and *Leucaena* prunings yielded 6.6 t/ha fresh weight equivalent to 69.8 N kg/ha at 3.2 percent dry leaf N content. During the second season, *Leucaena* tops amounted to 3 t/ha giving 32 N kg/ha and *Leucaena* fresh prunings weighed 3 t/ha equivalent to 24.74 N kg/ha.

This implies that in the *Leucaena*-N plots, N level in the first season was about 228 kg/ha, of which 148 N kg/ha was supplied by *Leucaena* leaflets and 80 kg/ha of chemical N, while in the second season the N level was about 137 N kg/ha of which 57 N kg/ha was from *Leucaena* leaflets and 80 kg/ha supplemented by chemical nitrogen.

Leucaena stands occupy 20 to 26 percent of the land, which is regarded as a cost.

Cutting about 15,000 *Leucaena* trees required 185 man-hours/ha or 30.8 man-days/ha at 6 hours per day. This included shredding *Leucaena* leaflets. Pruning *Leucaena* shoots took 145.9 man-hours/ha or 24.22 man-days/ha and 113.89 man-hours/ha or 19 man days/ha for the first and second season, respectively.

Table 65 shows labor inputs in man-hours/ha per treatment for the first and second season maize-*Leucaena* and percentage increase in labor costs for both seasons. During the first season, the *Leucaena* N treatment increased labor inputs by 117 percent over the control treatment, but it only increased by 37 percent during the second season.

Due to cutting *Leucaena* trees, the *Leucaena* treatment increased labor inputs by 110 and 25 percent in the first and second seasons, respectively. The *Leucaena*-herbicide and *Leucaena*-N-herbicide treatments increased labor inputs by 85.8 and 95.6 percent in the first season and by less than 20 percent in the second season due to the labor saving effect of the herbicide. However, the *Leucaena* alone treatment increased total labor costs for both the first and second seasons by 58.5 percent, *Leucaena*-N by 68.8 percent. *Leucaena*-N-herbicide by 50.1 percent and *Leucaena*-herbicide by only 38.8 percent (Table 65).

Table 65. Labor inputs in man-hours/ha per treatment for the first and second seasons, IITA (1981).

Treatment	Labor inputs man-hours/ha 1st season	2nd season	% increase in labor costs 1st & 2nd season
Control	424.35	651.74	—
Leucaena	889.64	815.6	58.5
Nitrogen	466.01	731.54	11.3
Herbicide	422.97	279.86	−34.7
Leucaena-nitrogen	921.3	895.4	68.8
Leucaena-herbicide	788.35	705.35	38.8
Leucaena-nitrogen-herbicide	830.01	785.15	50.1
Herbicide-nitrogen	464.62	359.66	−23.4

Table 66 shows maize grain yield response to various treatments for the 1981 first and second seasons. *Leucaena* increased maize grain yield by 1832 kg/ha (93.6 percent) and 1728 kg/ha (228 percent) in the first and second seasons respectively. *Leucaena*-N and *Leucaena*-herbicide increased maize yield by 1670 kg/ha (85.3 percent) and 1401 kg/ha (71.6 percent) in the first season and 1738 kg/ha (229.3 percent) and 927 kg/ha (122.3 percent) in the second season. Nitrogen alone increased yields by less than 40 percent and herbicide alone increased yields by 58 percent in the first season and depressed yields in the second season.

Table 67 shows the economic contribution of maize-*Leucaena* alley cropping experiment at IITA, 1981. In all the analyses, *Leucaena* treatment gave highest economic returns of $496.08 per ha for both first and second season maize, equivalent to a marginal rate of return of 2.33 and a cost benefit ratio of 1.32 for the two seasons. *Leucaena* herbicide gave a net return of $139.47 per ha, equivalent to a marginal rate of return 1.97 and a cost benefit ratio of 1.068; *Leucaena*-N gave a net return of $130.23, equivalent to a marginal rate of return of 1.563 per additional unit cost and a cost benefit ratio of 1.053.

The three economic indicators: increased net return, marginal rate of return and cost benefit ratio, all show *Leucaena* having comparative advantage over both N and herbicides

Table 66. Maize grain yield response to treatments in alley cropping for first and second seasons, IITA (1981).

Treatment	First season Yield (kg)	First season Increase in yield (kg)	Second season Yield (kg)	Second season Increase in yield (kg)	Both 1st and 2nd seasons Yield (kg)	Both 1st and 2nd seasons Increase in yield (kg)
Control +	1957	—	758	—	2715	—
Leucaena +	3789	1832	2486	1728	6275	3560
Nitrogen	2749	792	998	240	3747	1032
Herbicide	3094	1137	616	142	3710	995
Leucaena-nitrogen	3627	1670	2496	1738	6123	3408
Leucaena-nitrogen-herbicide	3192	1235	2153	1395	5345	2630
Herbicide-nitrogen	3342	1385	1049	291	4391	1676
Leucaena-herbicide	3358	1401	1685	927	5043	2328

+ = *hand weeded and no fertilizers*

Table 67. Economic contribution of treatments in maize-*Leucaena* alley cropping experiment (1981).

Treatment	Net return from 1st and 2nd season maize ₦ per/ha	Increased net return from 1st season alone N/ha	Marginal rate of return per ha 1st and 2nd season	Cost benefit ratio + per/ha 1st season	2nd season	1st & 2nd
Control	−292.18	—	—	—	—	—
Leucaena	330.72	272.8	2.33	1.516	0.939	1.32
Nitrogen	−247.36	113.92	Loss (a)	1.459	0.35	0.791
Herbicide	320.207	247.3		1.824	0.424	1.178
Leucaena-N	86.82	155.22	1.563	1.32	0.797	1.053
Leucaena-herbicide	92.98	198.04	1.97	1.433	0.693	1.068
Leucaena-N-herb.	− 38.91	77.96	Loss	1.233	0.727	0.975
Herbicide-N	97.37	255.23		1.644	0.533	1.097

(a) Second season crop was badly hit by drought.

as well as the interaction between *Leucaena*-N or *Leucaena*-herbicides. Although all treatments suffered a loss during the second season due to severe drought, *Leucaena* suffered only 6 percent loss as compared to other treatments, which suffered over 20 percent loss each. Nitrogen or herbicide separately had a loss of 60 percent each.

Although *Leucaena* occupies about 20 percent of the land and while cutting and pruning *Leucaena* increases labor costs by about 58 percent, the economic contribution of *Leucaena* is more than 2 times that of N, 1¼ times that of herbicide-N and 1½ times that of *Leucaena*-N. So, maize-*Leucaena* alley cropping seems to be a promising sub-system that should be tested even further.

Economics of no-till maize production

M. Ashraf

Improved technologies for maize production such as zero-till, alley cropping and mulching are unlikely to be accepted by farmers unless the new technologies can meet the test of economic profitability. A budgeting study was conducted during 1981 to assess the profitability of the zero-till system.

An assessment of mechanized maize production cost budgets was conducted during 1981 on a 50-ha field at IITA. Although the project was designed for land clearing and soil erosion studies, it provides a useful base for making an initial evaluation of new technologies. The project has 13 treatment plots of varying sizes, ranging from 2.5 to 4 ha. Five of the plots were manually cleared, 4 cleared with the tree pusher and the remaining 4 with the shear blade. To these land clearing treatments, conventional tillage and zero-till methods were added as post management treatments. Fixed and variable costs associated directly with maize production in selected plots during the third year of cropping were used in the study.

Nearly all field operations were mechanized for both conventional and zero-till methods. Therefore, the cost calculations include the cost of machinery used for land preparation, planting, applying herbicides and fertilizers, harvesting, transportation and storage. The cost/ha of producing maize under fully mechanized systems ranged from $749 to $834 (Tables 68 and 69). As expected, a major part of total cost was related to machinery followed by fertilizers and herbicides. Because of mechanization, labor costs were small. The costs of production differences between the 2 tillage methods were not significant.

Table 68. Cost of maize production for conventional and zero-tillage methods, 1981 early maize ($/ha).

Cost item	Conventional tillage MC	TP	Zero tillage MC	TP	SB
Farm machinery					
Fixed cost	$237	$233	$235	$224	$234
Rep. & Maint.	100	99	99	93	98
Fuel cost	19	19	16	17	16
Farm Labor					
Skilled labor	44	43	39	40	40
Unskilled labor	56	56	57	56	57
Herbicides	126	91	178	175	179
Fertilizers	195	199	183	199	201
Seed	9	9	9	9	9
Total cost	$786	$749	$816	$813	$834

MC = Manual clearing.
TP = Tree pusher clearing.
SB = Clearing with shear blade attachment.

Table 69. Cost of maize production by farm operations under conventional and zero-tillage methods, 1981 early maize ($/ha).

Farm operation	Conventional tillage MC	TP	Zero tillage MC	TP	SB
Mowing	$ 10	$ 9	$ 9	$ 12	$ 9
Harrowing/plowing	30	26	—	—	—
Herbicides	129	94	182	181	185
Planting	35	36	28	38	38
Fertilizers (a)	212	218	197	216	217
Harvesting	199	199	217	217	217
Transportation	37	37	37	37	37
Crib storage	134	130	146	112	131
Total cost	$786	$749	$816	$813	$834

a) Fertilizer cost calculations are based on average world market prices. Variation in fertilizer application arises from variation in net area of different plots and number of terraces.

After allowing for a 5 percent normal harvesting loss, the average yield was 4.4 t/ha for the conventionally tilled fields and 4.3 t/ha for zero-till. Harvesting operations were frequently disrupted in wet fields, especially in fields where tall inter-row weeds and stumps were not removed. Approximately one-half ton of dry maize/ha was missed by the harvesting machine, and follow up sweep by laborers was necessary to hand pick the lost maize.

Using an average market price of $375 per ton, the average crop yield gross returns were calculated for the various treatment plots (Table 70). Net return margins ranged from $575 to $988/ha. The largest net return was obtained in the zero-till plots on the manually cleared fields.

Table 70. Economics of maize production for conventional and zero-tillage methods, 1981 early maize.

	Conventional tillage		Zero tillage		
Item	MC	TP	MC	TP	SB
Yield t/ha	4.45	4.29	4.81	3.70	4.33
Value $/ha	$1669	1609	1804	1388	1624
Cost of production $/ha	$ 786	749	816	813	834
Net returns $/ha	$ 883	860	988	595	790
Benefit: Cost ratio	2.1	2.1	2.2	1.7	1.9

The benefit-cost ratios for both tillage systems calculated on the basis of the activities related to maize production were about 2.

Results of this study must necessarily be considered within the context of the original project, which is an on-going evaluation of the effects of methods of land clearance and post-clearance tillage systems on soil erosion. Production costs were higher than might be expected in commercial farming operations.

Economic evaluation and operations analysis of a Farmobile

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Among energy-conserving and low-cost farm implements being developed at IITA is a Farmobile, which is essentially a two-wheeled walking tractor with a trailer. The Farmobile has the following features: (a) a 5-7 h.p. diesel engine, (b) a trailer with a carrying capacity of 0.5 tons for carrying inputs and labor to the field and farm produce to stores and market, (c) a 4-row maize/rice/cowpea planter which can be mounted on the draw bar between the tractor and trailer, (d) a spraying system with a 4 m boom, (e) line markers for planting and spraying and (f) a mower to cut regrowth to facilitate herbicide application.

An economic evaluation was carried out on 2 hectares of no-till maize with the following objectives:

1) to test the operational efficiency of the Farmobile and evaluate its field capacity as well as the quality of work done.
2) to observe its field operational problems, breakdowns and any mechanical hitches.
3) to determine the economic capabilities of a Farmobile for a small-or medium-scale farmer.

In the 1981 evaluation, the Farmobile was tested for spraying, and spray/plant operations plus transportation of harvested maize.

Due to high bushes, the field was first mowed, left for two weeks and then sprayed with "Roundup."

For the first season, TZB and TZPB maize varieties were planted and in the second season, cowpea 4R-0267-IF and sweet corn were planted. For spraying in the first season, the chemicals were mixed and put in 4 five-litre bottles attached to a controlled droplet applicator (CDA) 4 m boom. For spray/plant, 4 rolling injection planters were attached to the trailer draw bar and line markers attached to the trailer. During the spraying, beside the operator, a second man was used to position poles for guiding the operator. For the second season, the CDA spraying system was changed to a low volume pneumatic system using a low-volume flood jet nozzle and one pressure container for the chemicals.

OPERATIONAL EFFICIENCY AND WORK RATE. Table 71 shows work rate and time spent for spraying and spray/plant operations. The work rate was 3 hrs/ha for spraying alone and 7 hrs/ha for spray/plant during the first season. The work rate was improved to 6 hrs/ha for spray/plant during the second season. Of the total time spent in the field during an operation 41 to 70 percent was effectively used. This implies that for the actual operations the Farmobile can spray at the rate of about 1 hr/ha and spray/plant at the rate of about 4 hrs/ha.

Table 71. Work rate and percentage time effectively used by a Farmobile for spraying and spray/plant operations, first season maize and second season sweet corn/cowpea (1981).

	Operation	Duration in minutes	% time for stops	% time for mixing chem.	% time effectively used	Work rate tractor hrs/ha	Man-hrs. used per ha
1st season	Spraying only	295	24	35	41	3	6
1st season maize	Spray/plant	271	33	19	48	7	7
2nd season sweet corn/cowpea	Spray/plant	75	10	20	70	6	13

The major mechanical problems observed on the farmobile were poor traction and weak transmission, especially when fully loaded. Others are weak reverse mechanism and frequent loss of balance at small slopes and when turning.

QUALITY OF WORK. Observations were also made about the quality of work done including chemical use. seeding rate and crop establishment. The CDA spraying system used during the first season was calibrated to use 20 litres of mixed chemicals/ha. But during the actual operation it used 22-26 1/ha thus wasting 10 to 30 percent of the chemicals.

During the second season, with pneumatic spraying systems, the rate of waste was much less. The seeding rate for TZB and TZPB maize varieties was expected to be 25 kg/ha, but 30 to 50 kg/ha were actually used, wasting 20 to 100 percent of the seed.

However, there were no gaps in spraying and weed control was quite good. Maize establishment during the first season was good. During the second season, establishment of cowpeas and sweet corn was also good.

ECONOMIC RETURNS. For all spraying and spray/plant operations carried out on 2 ha during the first season, the Farmobile took a total of 23 hours, equivalent to 3.8 man/days (at 6 hrs/day). During the second season 4 hrs (or 0.6 man/days were used for a 0.5 ha/field.

Table 72 gives a partial budget analysis comparing only costs with and without the Farmobile and considering benefits against losses.

In this case, benefits include the value of economic resources saved and the additional revenue, while losses include extra costs incurred and any income foregone. For a farm of 2 ha the benefits from saved labor and additional farm revenue amounted to ₦1,066.65 compared to ₦639.26 for the extra costs incurred. The Farmobile contributed a profit of ₦213.69/ha, giving a marginal rate of return of 1.67 units per additional unit cost.

Results from testing the Farmobile suggest that its field capacity can be further increased by improving its mechanical condition and the system of mixing the chemicals.

Table 72. Partial farm budget analysis: economic benefits of a Farmobile.

	1981 farm size: 2 ha
Benefits due to Farmobile* (in naira)	
1) Value of labor saved for spray and spray/plant	₦ 144.15
2) Labor saved for transportation of harvest	₦ 141.11
3) Additional revenue	₦ 781.39
Subtotal	₦1,066.65
Extra costs incurred (in naira)	
1) Due to Farmobile	232.70
2) Extra herbicides	166.27
3) Extra fertilizers	152.85
4) Extra labor (including harvesting)	87.44
Subtotal	₦ 639.26
Additional profit per ha	213.69/ha
Marginal rate of return	1.67

**Other benefits include:*
1) Timeliness of the spraying and planting operations.
2) Increase in the scale of operation.

Root and Tuber Improvement Program

Introduction

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

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

Producing genetically improved clones and developing improved cultural methods in the tropics are high priority objectives. Collaboration with national root and tuber improvement programs provides extensive evaluation and selection opportunities over a wide range of environments. The major insect pests on cassava in Africa are the cassava mealybug (*Phenacoccus manihoti*) and the cassava green spider mite (*Mononychellus tanajoa*). They are believed to have been introduced into Africa from Latin America. They have become widely spread and are limiting cassava production in some areas and are a threat to all of Africa. To combat the new pest problems, 2 research approaches have been adopted—host plant resistance and biological control.

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

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

Cooperative programs have been established with the Programme National du Manioc (PRONAM) in Zaire and the Cameroon National Root Crops Improvement Program (NCRCIP) in Cameroon.

Cassava

S.K. Hahn and N.M. Mahungu

Cassava clone TMS 50395 shows superior and stable performance over IITA improved standard variety TMS 30572. TMS 50395 gave a fresh root yield of 28.8 t/ha and is resistant to the major cassava diseases, CMD and CBB. Mealybug (CM) resistant cassava clone TMS 4(2) 1425 outyielded the standard variety and is resistant to CMD and CBB diseases and the cassava green spider mite (CGM). Promising low cyanide cassava clones give relatively good yields against IITA's standard variety and are resistant to CMD and CBB.

Plant resistance to CGM has been identified and is highly correlated with leaf pubescence The combination of high density and hair presence per unit area may be the best basis for selection.

Biological control shows great promise in effectively checking cassava mealybug. Temperature in Nigeria was shown not to be a limiting factor for field establishment of 2 imported natural enemies (a coccinellid beetle and an encyrtid wasp) of this important pest.

Depending on population density, 2 root-knot nematode species reduced cassava root production by 17, 50 and 98 percent at IITA.

Studies on cassava root size and HCN content showed that root size had no effect on the final cyanide content of gari, but large and medium tubers should be used for high *gari* yield.

Large numbers of cassava breeding lines can now be rapidly and reliably screened for low cyanide content with the development of an automated cyanide analysis method. Studies on HCN in cassava roots and leaves showed significant correlation coefficients for total and free HCN. Leaves could be used in large-scale preliminary screening, but for greater reliability analysis of roots will be necessary.

Cassava nutrient trials showed that a single application of either N or K may not increase yields, but the 2 elements together can produce more tubers of a larger size.

Day length effect trials demonstrated that cassava is not a short-day plant. Early flowering varieties are day-neutral while medium and late flowering varieties are long-day plants.

Genetic Improvement

Varietal trials

S.K. Hahn and E.M. Chukwuma

PERFORMANCE OF THE BEST CASSAVA VARIETIES AT IITA, (1981 FIRST SEASON). This uniform yield trial was planted on 23 May, 1980, and harvested on 19 May, 1981, and evaluated 12 clones, 9 from IITA and 1 from the National Root Crops Research Institute (NRCRI), Nigeria, V/1421, and 2 Nigerian checks, 60444 and 60506. A randomized complete block design with 4 replications was used. The spacing was 1 x 1m. No fertilizer was applied. Each plot consisted of 40 plants in 4 rows, and only the 2 inner rows were considered for analysis. Data were collected on fresh yield, dry matter content in the root, *gari* quality and *gari* yield, as well as CMD, CBB, and CGM infestation.

Cassava clone TMS 50395 shows superior and stable performance over IITA improved standard variety TMS 30572. Fresh root yield of TMS 50395 was 28.8 t/ha (Table 1). This clone is resistant to CMD and CBB. *Gari* quality is good and *gari* yield is as high as that of TMS 30572. However, the dry matter content in the roots is lower in TMS 50395 (26.4 percent) than TMS 30572 (30.2 percent).

PERFORMANCE OF DRY SEASON MATERIAL AT IITA (1981 FIRST AND SECOND SEASONS). Twelve clones were evaluated in this uniform yield trial. For the 1981 first season, the materials were planted on 23 May, 1980, and harvested on 13 May, 1981. For the second season, the

Table 1. Performance of the 10 best cassava varieties tested at IITA, 1980-81 first season.

Clone no.	Fresh yield (t/ha)	Dry matter (%)	Dry yield (t/ha)	CMD score	CBB score	CGM score	*Gari* quality	Garification rate (%)
TMS 50395	28.8	26.4	7.6	2.0	1.1	3.0	G	22
TMS 4(2)0763	21.6	31.1	6.7	2.3	1.6	4.0	G	20
TMS 50193	18.8	20.3	3.8	2.0	1.5	2.0	G	18
TMS 30572	18.1	30.2	5.5	2.0	1.1	2.8	VG	22
TMS 30001	18.1	25.5	4.6	1.8	1.1	4.0	VG	22
TMS 4(2)1443	17.9	26.9	4.8	2.0	1.1	4.0	VG	22
TMS 30337	17.2	22.6	3.9	2.5	1.5	3.3	G	24
U/1421	15.7	26.1	4.1	2.0	1.4	2.8	VG	25
TMS 50207	15.0	24.5	3.7	2.0	1.5	3.3	G	22
TMS 50548	14.1	23.1	3.3	2.4	1.9	2.8	VG	20
60444	12.9	18.8	2.4	3.0	2.5	4.3	P	8
60506	12.3	20.7	2.6	3.0	2.1	3.8	G	16
S.E.	2.2							
LSD (.05)	6.2							

materials were planted on 12 September, 1980, and harvested on 7 September, 1981.

The same design as above was used and data were collected on the same variables. This trial could not be carried out on off-site locations because of CM and CGM problems. Table 2 shows that the mealybug resistant variety, TMS 4(2)1425, outyielded IITA improved standard variety TMS 30572 in the 1981 first season trial at IITA. It is also resistant to CMD, CBB and CGM. Dry matter content in the roots is high while *gari* quality and yield are comparable to TMS 30572.

PERFORMANCE OF LCN MATERIALS AT IITA (1981 FIRST SEASON). This uniform yield trial was planted on 23 April, 1980, and harvested on 4 May, 1981, and it evaluated 13 clones. The same design as above was used and data were collected on the same variables. TMS 30001, TMS 6068 and TMS 518 are promising lines among the low cyanide cassava tested (Table 3) because normally low cyanide clones are lower yielding than high cyanide ones. Their fresh root yields were relatively high compared with IITA improved standard variety TMS 30572. They are resistant to CMD and CBB. *Gari* quality and *gari* yield of TMS 30001 and TMS 518 are comparable to TMS 30572.

PERFORMANCE OF THE BEST CASSAVA VARIETIES AT ONNE (1981 FIRST SEASON). Thirteen clones were evaluated in this uniform yield trial. The materials were planted on 16 June, 1980, and harvested on 3 June, 1981. The same design as above was used and data were collected on fresh yield, dry matter content in the root, and dry yield, as well as CMD and CBB infection. At Onne, TMS 30337 gave the highest fresh root yield of 31.0 t/ha (Table 4). It is resistant to CMD and CBB.

PERFORMANCE OF CASSAVA VARIETIES AT MOKWA (1981 FIRST SEASON). This uniform yield trial was planted on 8 July, 1980, and harvested on 17 June, 1981, and it evaluated 12 clones. The same design as above was used, and data were collected on the same variables. At Mokwa, TMS 30572, which is resistant to CMD and CBB, gave highest fresh root yield of 30.0 t/ha (Table 5).

Screening cassava for low cyanide

V.P. Rao, S.K. Hahn

A major constraint in screening large numbers of breeding lines for low cyanide (HCN) content has been lack of a

Table 2. Performance of dry season materials tested at IITA, 1980-1981 first and second seasons.

Clone no.	Fresh yield (t/ha) 1st	2nd	Dry matter (%) 1st	2nd	Dry yield (t/ha) 1st	2nd	CMD score 1st	2nd	CBB score 1st	2nd	CGM score 1st	2nd	*Gari* quality	Garification rate (%)
TMS 4(2)1425	21.6	12.1	34.8	28.9	7.5	3.5	2.1	2.0	1.1	1.4	1.3	3.0	VG	22
TMS 30572	19.6	9.3	31.3	34.5	6.1	3.2	2.0	2.0	1.1	1.1	2.4	4.0	VG	21
TMS 40081	19.2	—	27.3	—	5.2	—	1.8	—	1.0	—	1.9	—	VG	19
TMS 30555	19.0	9.6	27.5	33.1	5.2	3.2	2.0	2.0	1.1	1.3	2.3	4.3	G	21
TMS 30001	17.2	—	29.1	—	5.0	—	1.9	—	1.1	—	3.3	—	VG	14
TMS 4(2)0599	17.0	—	26.2	—	4.5	—	2.5	—	1.8	—	2.3	—	G	12
TMS 40092	15.3	—	29.4	—	4.5	—	2.3	—	1.6	—	2.5	—	G	14
60506	14.9	2.7	26.7	31.2	4.0	0.8	2.8	2.6	2.0	2.1	3.0	4.0	G	14
TMS 4(2)0267	14.2	6.4	29.2	32.9	4.1	2.1	2.3	2.0	1.3	1.4	1.5	2.5	G	18
TMS 4(2)0378	12.9	10.9	20.6	25.4	2.7	2.8	2.6	2.1	1.6	1.8	2.9	4.3	M	11
TMS 40160	10.1	5.7	27.3	34.2	2.8	1.9	2.5	2.0	1.8	1.3	2.4	4.0	G	17
60444	7.0	0.7	22.7	26.3	1.6	0.2	3.0	3.0	2.5	2.8	2.6	3.7	P	9
S.E.	2.0	1.3												
LSD (.05)	1.3	3.9												

Table 3. Performance of the LCN materials at IITA, 1980-81 first season.

Clone no.	Fresh yield (t/ha)	Dry matter (%)	Dry yield (t/ha)	CMD score	CBB score	CGM score	*Gari* quality	Garification rate (%)
TMS 30572	21.9	31.2	6.8	2.0	1.4	2.3	VG	18
TMS 30001	18.4	28.6	5.3	1.9	1.1	3.0	VG	16
TMS 6068	17.5	31.3	5.5	2.4	1.8	2.5	VP	14
TMS 518	17.0	30.0	5.1	2.1	1.6	3.0	VG	17
TMS A/41369	15.5	25.2	3.9	2.0	1.6	3.3	G	14
TMS 60444	14.1	25.4	3.7	2.8	2.8	3.0	M	12
TMS 3109-N-17	14.0	30.3	4.2	3.4	2.3	3.0	VG	15
TMS 30474	13.7	30.4	4.2	2.0	1.4	2.3	G	14
TMS 3109-N-7	13.6	32.4	4.4	2.5	2.1	3.3	VG	16
TMS 6085	7.9	30.1	2.3	2.5	2.0	3.3	M	14
TMS 6051	7.4	22.4	1.7	2.5	2.0	2.8	VP	9
TMS 50067 B	5.1	28.6	1.5	2.5	2.4	3.0	P	11
TMS 50105	4.2	21.0	0.9	2.0	1.3	3.3	VP	9
S.E.	2.9							
LSD (.05)	8.3							

Table 4. Performance of the 10 best cassava varieties tested at Onne, 1980-1981 first season.

Clone no.	Fresh yield t/ha	Dry matter (%)	Dry yield (t/ha)	CMD score	CBB score
TMS 30337	31.0	27.1	8.4	2.0	1.0
1095-0D	29.7	33.6	10.0	1.0	1.0
60606	25.0	31.2	7.8	2.8	2.3
1240-B	24.1	35.2	8.5	2.0	1.0
163	23.9	33.8	8.1	3.0	2.0
TMS 30572	23.4	34.0	8.0	2.0	1.3
4488	22.9	34.4	7.9	2.0	1.0
TMS 50171	21.9	35.7	7.8	2.0	1.0
4092	21.3	38.9	8.3	2.5	1.3
60447	19.9	28.9	5.8	2.5	2.3
U/1421	18.3	36.1	6.6	1.5	1.0
518	14.0	33.9	4.7	2.0	2.0
210/360	9.7	31.1	3.0	3.0	2.5
S.E.	2.7				
LSD (.05)	7.9				

Table 5. Performance of the 10 best cassava varieties tested at Mokwa, 1980-1981 first season.

Clone no.	Fresh yield t/ha	Dry matter (%)	Dry yield (t/ha)	CMD score	CBB score
TMS 30572	30.0	27.9	8.4	1.5	1.0
27	21.7	27.7	6.0	2.6	1.3
TMS 41627	17.8	19.3	3.4	3.0	1.1
193	16.5	25.2	4.2	2.3	1.3
TMS 41644	16.4	23.4	3.9	2.8	1.3
599	15.8	23.2	3.7	2.1	1.1
60506	13.8	23.5	3.2	2.9	1.6
TMS 51176	11.7	21.7	2.5	2.4	1.1
41919	11.0	22.6	2.5	2.5	1.5
TMS 51368	10.1	35.2	3.6	2.1	1.1
1784	9.5	21.4	2.0	2.1	1.3
TMS 51109	8.7	23.4	2.0	2.4	1.1
S.E.	3.6				
LSD (.05)	10.4				

rapid and reliable analytical technique. To overcome this, the automated method for HCN analysis has been developed.

DESCRIPTION OF THE AUTOANALYZER MANIFOLD. The sample was segmented by air and mixed with phosphate buffer, pH 7.0, in a 5-turn coil (Fig. 1). Linamarase containing 3 units/ml activity hydrolyzed bound cyanide while mixing in a long heating coil (approx. 5 minutes) at 27°C. When only free cyanide was to be determined, the enzyme was substituted by phosphate buffer, pH 6.0.

Sodium hydroxide NaOH (0.2 N) was then added to the stream to raise the pH because cyanohydrin dissociates to HCN very rapidly above pH 6.0. The sample was then passed through a 6-inch dialyzer. The cyanide diffused through the dialyzer into a stream of NaOH (0.01) and reacted with buffered chloromine T to form cyanogen chloride. The cyanogen chloride then reacted with pyridine bipyrazolone solution to form a red complex. Two 20-turn delay coils were inserted into the system at this point to allow a stable change of color from red to blue. The blue color was finally detected in a 15.0 x 2.0 mm flow cell with 600 mm interference filters and was recorded on a precalibrated chart. The chart was calibrated using cyanide standards (KCN and linamarine) of known concentration. The peaks recorded on the charts were directly proportional to the cyanide content in the sample.

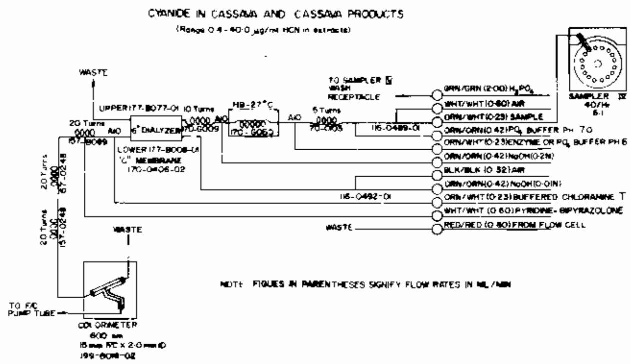


Fig. 1. Flow diagram for the automated method for HCN analysis.

Figure 2 shows that complete hydrolysis of linamarine was achieved with linamarase having an activity of above 2.3 units/ml. The figure suggests that an enzyme with 30 units/ml activity is good enough to hydrolyze up to 60 percent of linamarine present in the solution.

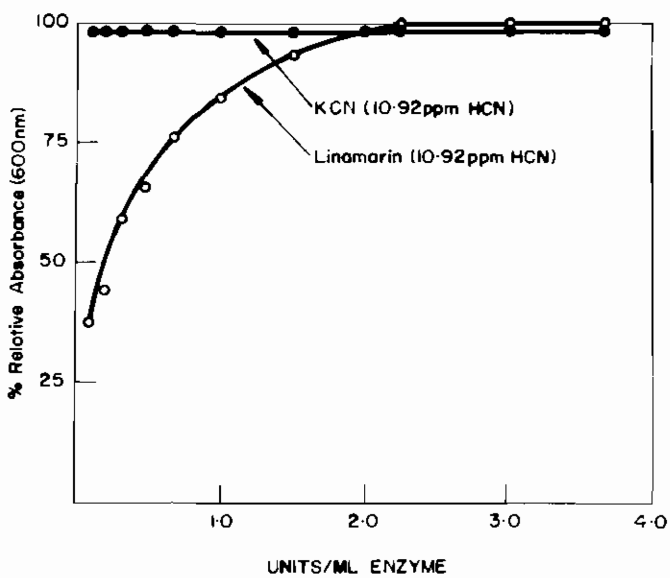


Fig. 2. Complete hidrolisis of linamarine by linamarase above 2.3 units/ml of activity.

The extracts stored at 4°C were not changed in total cyanide content even 1 month after extraction (Fig. 3), but free cyanide increased generally from 8 to 15 percent of total cyanide during storage of 1 month at 4°C. Thus, to determine accurately the free cyanide content, it was essential to assay as soon as possible. If only total cyanide is to be determined for screening large numbers of breeding lines, the samples could be stored for as long as 1 month at 4°C.

COMPARISON OF THE AUTOMATED METHOD WITH THE MANUAL METHOD. As Table 6 shows, the 2 enzymatic methods (automated vs. manual) compared very well for both peeled storage root samples and leaf samples from different breeding lines. The automated method can handle 300 analyses a day (40 samples/hour) compared to 40 samples a day by the manual method.

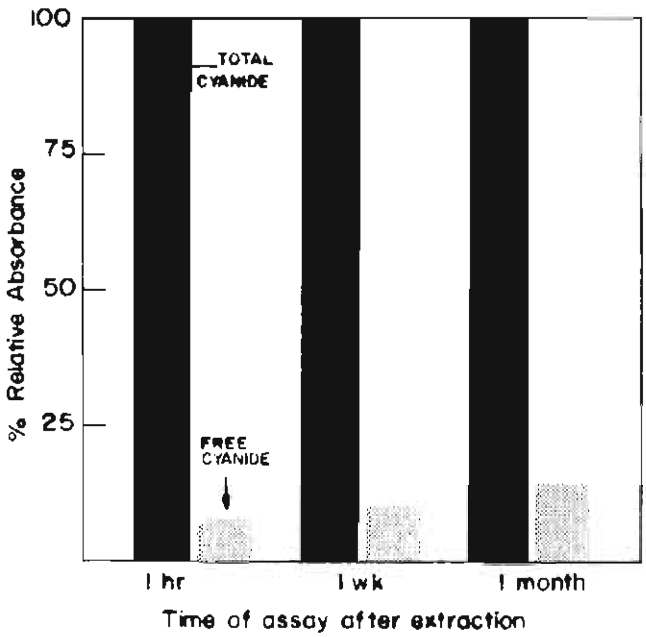


Fig. 3. Free and total HCN concentrations after extraction over time.

SCREENING BREEDING LINES WITH THE AUTOMATED METHOD. A total of 568 lines were tested using the automated method. From the low cyanide population, 65 percent contained less than 5.0 mg HCN/100 mg fresh weight in the peeled storage roots (Fig. 4).

LOW CYANIDE VARIETY. Through breeding cassava for low cyanide at IITA, a low cyanide variety, TMS 30001, which is resistant to both CMD and CBB, high yielding and good in quality, has been produced. The cyanide content of the variety was also reduced drastically as fermentation progressed. The variety is an early bulking type with good plant characteristics.

Pubescence in cassava and resistance to both CM and CGM

S.K. Hahn, S.Y. Ng, E. Chukwuma

CM and CGM both attack young shoot tops. CM causes bunchy top symptoms characterized by reduced stem internodes and leaves, as well as curled stems and leaves. CGM causes yellow speckles in the leaves, drastic leaf area reduction of 95 percent and die-back of shoots when heavily attacked.

Experiments on resistance to both CM and CGM and on a mechanism associated with the resistance were carried out at IITA using 60 clones selected from IITA's germplasm collection.

Cuttings of 25 cm length from each clone were planted at a spacing of 1 x 1 m in September, 1980. A randomized complete block design was used with 2 replications. Each plot consisted on an average of 10 plants on a 10-m long ridge. Five months later (February, 1981), the plants were evaluated for CM and CGM resistance. Subjective ratings were used based on a scale of increasing severity from 1 to 5 as reported in IITA Annual Report 1979.

Table 6. Determining cyanide content (mg HCN/100 g fresh weight) in cassava root and leaf by the automated and manual methods.

Cassava Variety	Manual method Total	Manual method Free	Automated method Total	Automated method Free
Root				
1	3.04	0.37	3.05	0.35
2	5.40	0.67	5.66	0.63
3	2.08	0.20	2.01	0.19
4	2.42	0.23	2.67	0.25
5	2.35	0.26	2.38	0.25
6	5.16	0.40	5.68	0.44
7	8.76	0.76	8.69	0.79
8	1.25	0.13	1.33	0.13
Leaf				
1	24.2	—	22.9	—
2	27.7	—	27.1	—
3	33.5	—	34.0	—
4	20.0	—	24.1	—

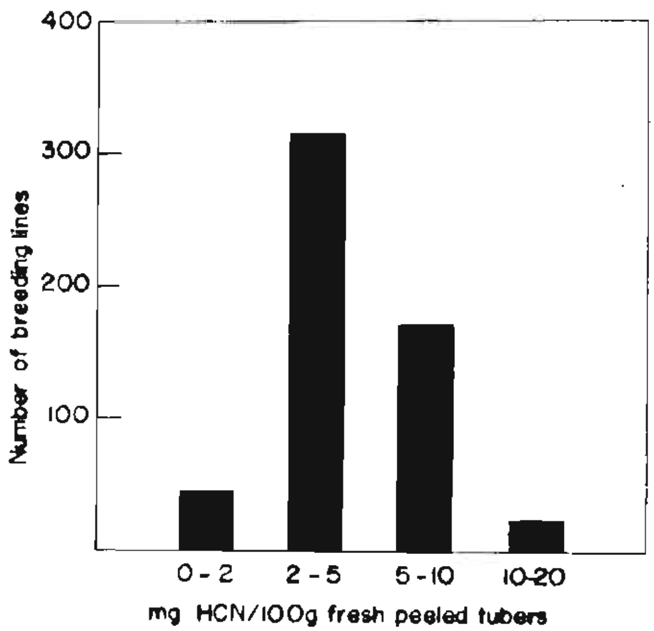


Fig. 4. Distribution of low HCN cassava breeding lines screened by the automated method.

Hairs per 1 cm^2 on the upper- and under-surface of the central loop and on the petiole of a young, fully expanded leaf and on young tip stems were counted 4 months after planting. These counts were made on an area 1 x 1 cm including the midrib at the tip, middle and basal parts of the central loop from 3 plants per plot and averaged as mean hairs per plot.

Clones used in this study differed significantly in CM and CGM scores and number of hairs per 1 cm^2 on the observed parts of the young tip shoots. Average CM scores ranged from 2.0 to 5.0. The average number of hairs on respective parts of young tip shoots are summarized in Table 7. Clones that showed relatively low CM and CGM scores are given in Table 8. Their hair counts per 1 cm^2 on respective parts of

Table 7. Numbers of hairs/cm^2 among parts of young tip shoots of cassava in relation to CM and CGM damage rating scores.

	Hairs/cm^2		Correlation	
Part	Mean	Range	CM	CGM
Leaf upper-surface	850	0-5013	−0.62**	−0.71**
Leaf under-surface	302	0-2792	−0.60**	−0.62**
Petiole	66	0-604	−0.57**	−0.57**
Stem	52	0-515	−0.56**	−0.56**

Actual date from 60 clones were used for analyses.
***Significant at 1% level.*

Table 8. Clones with high pubescence and resistance to both CM and CGM.

	Hairs/cm^{2*}				Rating	
Clone	L(UP)	L(UN)	Petiole	Stem	CMB	CGM
TMS 61677	5013	2118	604	515	2.0	2.5
TMS 60142	4550	2792	464	713	2.0	2.0
X TMS 50332	4237	962	158	201	2.5	3.0
TMS 61324	3388	1310	373	233	2.0	2.0
TMS 42025	2480	1195	238	210	2.0	(3.5)
TMS 4(2)1425	2188	347	79	91	2.0	2.0

**Average hairs of 6 samples.*

young tip shoots are also given. The relationships between hair counts on the leaf upper- and under-surface and petiole of the fully developed leaf and stem of young tip shoots are summarized in Table 9. To relate the number of hairs per 1 cm^2 on leaf upper- and under-surface and on petiole and stems of young shoots with the average CM scores and average CGM scores, correlation coefficients were calculated and are given in Table 9.

The results indicate that resistance of cassava to both CM and CGM is greatly ascribed to hair density along the midrib on the upper-surface of leaves (Figs. 5 and 6).

These results suggest that if the hair density was increased further through breeding, the CM and CGM resistance may be further improved accordingly. The CM and CGM scores were significantly associated (r = 0.69), indicating that improved resistance for CM and CMG go together.

The broad sence heritabilities were estimated for CM and CGM resistance and for pubescence on the upper leaf surface (Table 10). This indicates that selection for resistance to CM and CGM can be easily made under field conditions.

Among the CM and CGM resistant clones, TMS 4(2)1425 and TMS 60142 gave high root yields in Nigeria and their consumer acceptance quality was good. They showed high *gari* yield as well.

Table 9. Relations (r) in number of hairs/cm^2 among parts of young tip shoots of cassava.

Part	Leaf under-surface	Petiole	Stem
Leaf upper-surface	0.92	0.88	0.83
Leaf under-surface		0.91	0.96
Petiole			0.89

Data from 60 clones were used for analyses.

Table 10. Heritabilities (H) of CM and CGM resistance and pubescence.

Characteristics	H ± SE
CM resistance	0.97 ± 0.09
CGM resistance	0.79 ± 0.04
Pubescence	0.93 ± 0.01

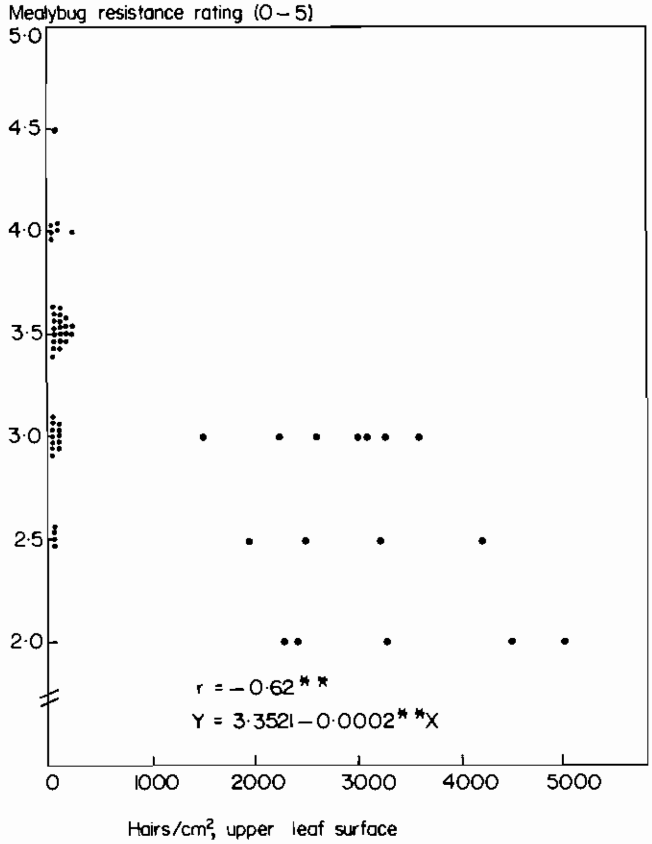


Fig. 5. Relationship between hairiness on the fully expanded leaf upper surface and CM resistance scores.

Entomology

Impact of released natural enemies on CM population

H.R. Herren, K.M. Lema

For biological control of CM, natural enemies were sought in South and Central America, the presumed origin of the pest. Several species of natural enemies have been brought, via quarantine into IITA where they are being studied in detail for mass production and field releases. One predator, *Scymnus sp.* (Coccinellidae), and one parasitoid, *Apoanagyrus lopezi* (Encyrtidae), were released into an experimental (1/6/ha) cassava field at IITA. Preliminary results are reported.

The first release was carried out by placing on each of 16 marked release sites potted cassava plants infested with CM and containing larvae and pupae of *Scymnus* sp. as well as mummies (dead CM containing immature parasitoids).

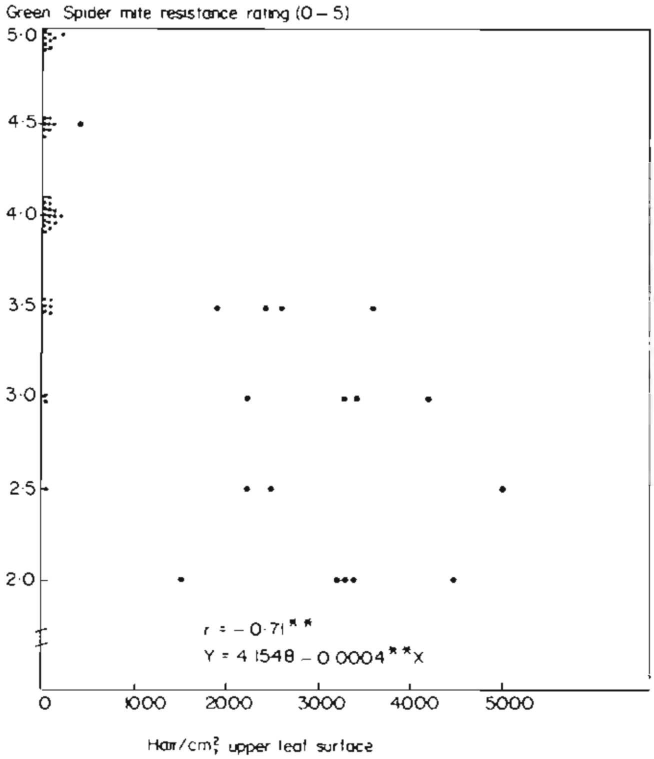


Fig. 6. Relationship between hairiness on the fully expanded leaf upper surface and CGM resistance scores.

Cassava plant in control field. Severe bunch top symptoms and very short regrowth are very common.

Subsequent releases were made by collecting about 10-20 females and 10 males of the natural enemies in vials from mass production cages. One vial was placed under a cassava plant on each release site and the insects were allowed to escape from the vials. More than 2,200 *Scymnus* and 1,150 *A. lopezi* were released between early November, 1981, and 27 January, 1982. One field of about the same size as the release field and located about 50 m away from the infested field was used as a control.

Fifteen cassava plants were randomly selected throughout the fields, and one sample was taken from each selected plant. The sample consisted of the upper 10 cm of the shoot. The top of the shoot was bent into a paper bag before being cut to collect all adult *Scymnus* that could otherwise have dropped on the ground. CM and natural enemies were counted in the laboratory.

Reduction in pest population was a combined action of both the predator and the parasitoid. The average number of CM and predators in the release and control fields for each sampling date are shown in Table 11. In November, pest population went from 0.47 to 3.00 CM/sample in the release field and from 2.67 to 15.73 CM/sample in the control field. The CM population in the control field increased sharply from 24 December 1981, to 29 January, 1982, and reached its peak in late January, 1982. The population was 4.00, 27.80, 46.07, 59.40 and 63.60 CM/sample on 3 and 24 December, 1981 and 6, 14 and 29 January, 1982, respectively. During the same period, pest population was 16.07, 60.73, 57.40, 13.13 and 9.80 CM/sample in the release field. In February 1982, pest population levels were 32.87 and 12.00 CM/sample in the control, and 5.07 and 1.00 CM/sample in the release field, on 4 and 19 February, 1982 (Table 11), respectively.

Table 11. Population levels of CM and its natural enemy in release and control fields.

	Average N./Sample* ($\bar{X}$ ± SE)		
	Release field		Control field
Date	Scymnus	CMB	CMB
Nov. 12	—	0.47 ± 0.26	2.67 ± 2.25
27	—	3.00 ± 1.17	15.73 ± 6.28
Dec. 3	—	16.07 ± 7.21	4.00 ± 1.51
24	—	60.73 ± 16.38	27.47 ± 16.87
Jan. 6	0.80 ± 0.56	57.40 ± 16.52	46.07 ± 10.18
14	1.33 ± 0.79	13.13 ± 4.33	59.40 ± 27.05
29	4.67 ± 1.31	9.80 ± 4.73	63.60 ± 16.65
Feb. 4	4.40 ± 1.20	5.07 ± 1.75	32.87 ± 13.85
19	1.00 ± 0.41	1.00 ± 0.55	12.07 ± 3.43

**One sample = last 10cm of the upper portion of the shoot.*

Predator population increased from an average of 0.80 beetles/sample on 6 January 1982, to 1.33 and 4.67 on 14 and 19 January, 1982 before decreasing to 4.40 and 1.00 on 4 and 19 February, 1982 respectively (Table 11). Figure 7 shows the trend in population change in both the release and control fields. About 2 months after the first release, CM population was drastically reduced in the release field while that in the control field was steadily increasing (Fig. 7).

Early in December, 1981, CM population in the release field increased sharply due to infested plants used in the first release, i.e., due to an artificial infestation of the field. From

A cassava plant in release field. No bunch top symptoms and long regrowth but only short areas with dense internodes.

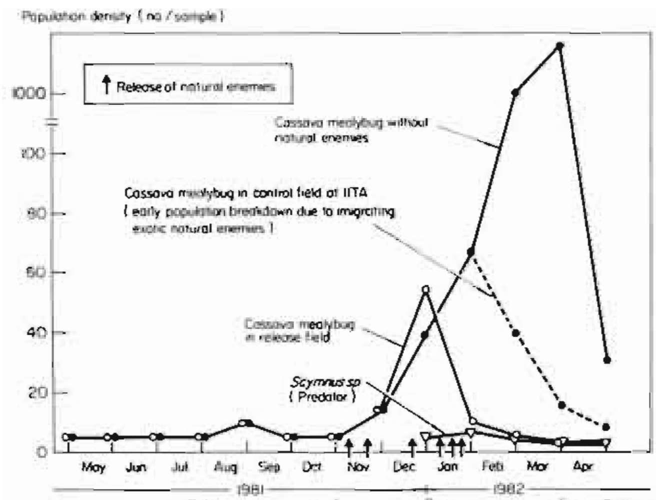


Fig. 7. Impact of released exotic natural enemies at IITA (1981-82).

late December, 1981, onward, however, pest population in the release field declined tremendously while the predator population was increasing (Table 11 and Fig. 7).

Counts on number of mummies per terminal shoot by mid-February, 1982 indicated an average of 10 per shoot. Each plant had an average of 4 shoots and the whole release field with 1,600 plants had 6,400 shoots. Thus, over a 2-month period, the released population had increased by a factor of 55, not accounting for losses due to emigration. These results show that the released natural enemies are promising and effective in checking the pest. Releases over large areas can now be undertaken.

Temperature relationships of two imported natural enemies of CM

K.M. Lema, H.R. Herren

Lack of adaptation to climatic conditions has been associated with failure for some imported natural enemies to establish in a new environment and to control pests.

To avoid the mass rearing and releasing of unadapted natural enemies, the effect of temperature on the development of the 2 imported natural enemies of CM, *Scymnus* sp. and *Apoanagyrus lopezi* was assessed under controlled conditions.

Adult *Scymnus* were collected from the cultures and confined with CM eggs in Petri dishes. After 5 hours, these predators were removed from the dishes. The dishes containing the predator eggs were then placed in growth chambers at 20°, 27° and 30.5°C (65-75 percent relative humidity). Each egg was observed three times daily at 7.30, 13.30 and 17.00 hours. The duration of each developmental stage was recorded.

Exochomus sp., predator of cassava mealybug feeding on mealybug honeydew.

For the life cycle of *A. lopezi*, cassava plants infested with CM were introduced into parasitoid rearing cages for a 5-hour parasitization. Then the plants were removed from the cages, and 1 plant was placed in each chamber at 20°, 23.5°, 27° and 30.5°C. After 10-15 days the leaflets were removed from the plants and, together with pieces of stems containing CM, put in Petri dishes. The dishes were checked 3 times daily until adult emergence was completed. The developmental time of the parasitoid was the time elapsed from oviposition to adult emergence under each temperature.

Table 12 shows the duration of various developmental stages of *Scymnus* sp. under the 3 constant temperatures. The incubation period for the egg was, on the average, 7.90, 3.88 and 3.56 days at 20°, 27° and 30.5°C respectively. The larval stage including the prepupa lasted 16.74, 7.95 and 7.71 days at 20°, 27° and 30.5°C, respectively. The pupal stage was completed under these 3 temperatures after 8.67, 4.69 and 4.15 days. The total life cycle from the egg to adult required 33.31, 16.52 and 15.42 days at 20°, 27° and 30.5°C respectively, (Table 12). At these same temperatures the mortalities were 22.73, 20.00 and 6.90 percent for the eggs and 21.43, 8.70 and 14.81 percent for the larvae at 20°, 27° and 30.5°C, respectively (Table 13).

The mean times-to-adult in days of *A. lopezi* are shown in Table 14. It takes 28.87, 18.58, 14.32 and 12.44 days for the parasitoid to complete its life cycle from egg to adult at 20°, 23.5°, 27° and 30.5°C, respectively.

It appears from these results that temperature is not a limiting factor for the establishment of these 2 natural enemies. This was confirmed by field observations. The 2 natural enemies readily established and reproduced after release into an experimental cassava field at IITA. The life cycles of the predator and parasitoid are shorter than those of the host (IITA Annual Report, 1980). The advantage of a shorter life cycle for these natural enemies is that their generation time is shorter than that of their host regardless of the ambient temperature.

Table 12. Developmental time (Days) of _Scymnus_ sp. at three constant temperatures ($\bar{X} \pm SE$).

	Temperature (°C)		
Devel. Stage*	20	27	30.5
Egg	7.90 ± 0.34	3.88 ± 0.22	3.56 ± 0.44
Larva			
1st	3.72 ± 0.36	1.88 ± 0.47	1.94 ± 0.17
2nd	2.60 ± 0.68	1.22 ± 0.42	1.14 ± 0.45
3rd	3.29 ± 0.91	1.45 ± 0.51	1.25 ± 0.55
4th + PP	7.13 ± 1.13	3.40 ± 0.50	3.38 ± 0.68
Pupa	8.67 ± 0.87	4.69 ± 0.47	4.15 ± 0.49
E-A	33.30 ± 0.73	16.52 ± 0.18	16.42 ± 0.27

**PP = prepupal, E-A = egg to adult.*

Table 13. Mortalities of immature stages of _Scymnus_ sp. at 3 constant temperatures.*

	Eggs			Larvae			
Temp. (°C)	N	Dead	% Mort.	N	Lost	Dead	% Mort.
20	22	5	22.73	17	3	3	21.43
27	30	6	20.00	24	1	2	8.70
30.5	29	2	6.90	27	0	4	14.81

**No mortality was observed in the pupal stage.*

Table 14. Mean times-to-adult (days) of _A. lopezi_ at four constant temperatures ($\bar{X} \pm SE$).

Temp. (°C)	Mean times-to-adult
20	28.87 ± 2.12
23.5	18.58 ± 1.44
27	14.32 ± 1.24
30.5	12.44 ± 1.82

Mechanism of resistance to cassava green spider mite (*M. tanajoa*)

Studies on the mechanism of resistance to cassava green spider mite (CGM) were carried out on 2 susceptible cassava clones TMS 30001 and TMS 30337, and 2 resistant clones TMS 4(2)1425 and TMS 60142. The clones were planted in plastic pots in the greenhouse and infested artificially 2 months after planting with CGM. The infestation was repeated weekly by hanging a mite infested cassava leaf on the upper leaf of each test plant. To determine the presence or the absence of pubescence in clones, two different observations were made on a weekly basis for two months.

In the first observation (A), samples were treated chemically to obtain a transparent single-celled layer of epidermal tissue and the number of hairs was counted in an area 0.42 mm^2 with a microscope at 400 X. CGM damage was noted, based on a scale of 1 to 5 as follows: (1) mites on bud leaves, no obvious damage; (2) mites on leaves, moderate yellow to white spots on young unfolded and first expanded leaves; (3) heavy speckling of terminal leaves, slight deformation of bud leaves (25 percent); (4) severe deformation of bud leaves (50 percent), mites on nearly all leaves with whitish appearance and some defoliation; and (5) shoot dead or does not produce new leaves, defoliation of upper leaves.

In the second observation (B), samples were collected only from pubescent clones and the hairs were counted in different parts of the leaf in an area 1 mm^2 with a binocular at 250 X. Leaves from the top to the bottom of the plant were designated: first (topmost young leaf), second, third, fourth, fifth and sixth. Each leaf was also divided into (a) bottom, (b) middle and (c) top sections.

Of the four clones investigated, resistant clones TMS 60142 and TMS 4(2)1425 were pubescent whereas susceptible clones TMS 30001 and TMS 30337 were glabrous. Damage ratings indicated significant difference between clones in their response to CGM attack. The severity of damage was less where the number of hairs was high. Clone TMS 60142, which is more resistant that clone TMS 4(2)1425, had a higher density of hairs (Table 15).

It appears that pubescence is responsible for resistance to CGM as shown by the high negative coefficient of correlation ($r = -0.95$) between number of hairs and degree of resistance.

Table 15. Mean number of hairs in relation to mite damage rating score (1-5).

	Mean number hairs		Mite score
Clone	A	B	
TMS 60142	4.65	70	1.95
TMS 4(2)1425	2.35	13	2.60
TMS 30337	0	0	3.90
TMS 30001	0	0	4.30

Pathology

Permeability changes in cassava leaves infected with *Xanthomonas campestris* pv. *manihotis*

S.K. Asiedu, E.R. Terry, R.L. Pelletier

A test was carried out to determine whether permeability alteration of cassava leaf tissues could be related to varietal tolerance or resistance to *Xanthomonas campestris* pv. *manihotis* infection. The cassava varieties Isunikankiyan, TMS 30001 and TMS 30572 in order of increasing tolerance to CBB were used.

Twenty-five leaf discs (13 mm diameter) were cut from detached leaves, vacuum infiltrated with bacterial suspension (10^8 cells/ml), incubated in humidity chambers at laboratory temperature (about 23°C.) and exposed to light for 12 hrs. The control discs were from leaves infiltrated with sterile distilled water. The discs, sampled at 12-hour intervals, were rinsed and submerged in 50 ml of sterile distilled water. Conductivity of the bathing solution was measured immediately and again after 4 hours without agitation using a conductivity electrode ($K = 1$) and meter (Karl Kolb model). The increase in conductivity (umhos) was calculated as an indication of electrolyte leakage.

The average values for conductivity in excess of the control treatments are shown in Figure 8. Conductivity change was first detected within 24 hours of infection in the susceptible variety. After 48 hours, the trend of conductivity increase was similar in both resistant and susceptible varieties. But, at about 96 hours after infection, there was from 3 to 5 times increase in susceptible relative to resistant or tolerant varieties. At this time, angular spots were observed in all varieties. Increase in conductivity was closely correlated with the appearance and the extent of microscopically visible symptoms.

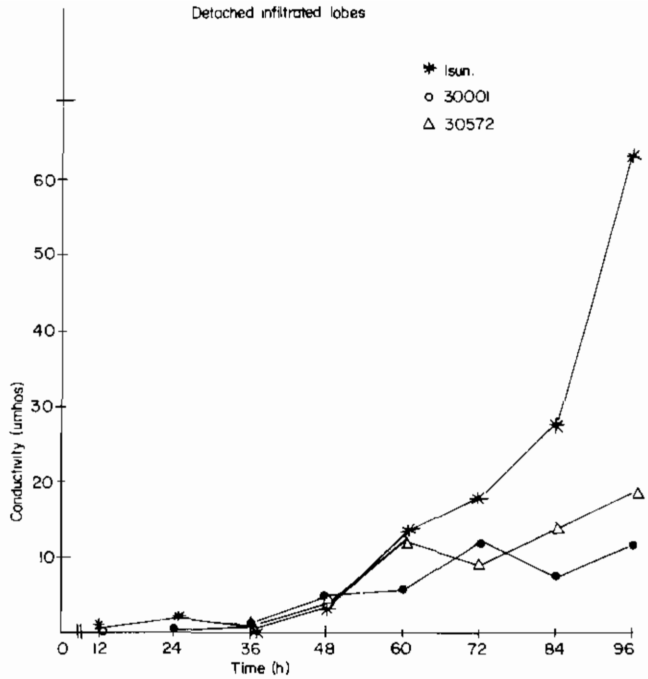


Fig. 8. Conductivity change of bathing solution surrounding leaf discs cut from cassava leaves previously infiltrated with bacterial suspension (10^8 cells/ml) in sterile distilled water.

Preliminary photometric analysis of bathing solutions showed that K^+ is the most leached cation while Ca^{++}, Mg^{++} and Na^+ are less leached. Further studies will be conducted to give quantitative measures for these cations.

Altered cell permeability is a characteristic of diseased plants and often occurs before symptoms are evident. Change in cell permeability in cassava due to pv. *manihotis* infection has been demonstrated. Varietal differences in permeability change in relation to resistance to pv. *manihotis* infection will be further studied for its possible use in tests for resistance.

Pathogenicity of some isolates of *C. manihotis*

A. Muimba-Kankolongo, E.R. Terry

To characterize the pathogenicity of isolates of CAD's causal agent, *Colletotrichum manihotis*, Henn, 18 isolates were obtained from diseased stem samples collected in different locations in Nigeria. They were inoculated on 1-month-old plants of 3 cassava clones, 70775, 63385 and 30001 by the stem-puncture method. Controls used at each level consisted of a plug of a sterile Martin medium (MM) inserted into the puncture points. Canker length was then recorded 10, 20 and 25 days after inoculation.

Results indicate that there were significant differences ($P = 0.05$) among isolates and among clones throughout the period of observation (Table 16). In check plants, the cankers did not exceed 1.5 mm. Twenty-five days after inoculation, clone 70775 was more susceptible than clones 63385 and 30001. Isolates Ib10, ON27, ON30, OW33 and OW37 were highly pathogenic on clone 70775; isolates Ab4, Ab25, Ib9, Ib10, IITA17 and OW37 on clone 63385; and isolates Ib9, Ab25, ON26, ON27 and OW37 on clone 30001.

In addition to the differences in lesion length, their induced pattern of virulence also varied. Isolates Ib10 and ON27, which were more pathogenic on clone 70775, induced significantly low lesions on clone 63385 and 30001. There was no significant clone isolate interaction denoting a total absence of specific races within the isolates tested. Isolates Aj40 and IK46 were least pathogenic on the 3 clones tested. In conclusion, isolates, even though qualitatively similar in cultural characteristics, differ in genetic systems conditioning their virulence to specific hosts. Therefore, it may be important to use the most virulent isolate to screen for resistance against CAD.

Role of insects in the etiology of CAD

Muimba-Kankolongo, E.R. Terry

To establish the role of insects in the etiology of CAD, *Pseudotheraptus devastans* Dist (Coreid), an insect pest found feeding on cassava plants, was used in this study. One-month-old plants of clone 30001 were subjected to the following treatments: (i) spray inoculation of *C. manihotis* (ii) spray inoculation of *C. manihotis* followed by *P. devastans* feeding; (iii) *P. devastans* feeding followed by spray inoculation of *C. manihotis*; (iv) feeding alone; and (v) no feeding and no inoculation (check).

Size of cankers was recorded 4 days after plants had been treated while the death of plants was assessed at 4-day intervals for 2 weeks. For the biological relationships between *P. devastans* and *C. manihotis*, sterilized and unsterilized body parts of the insect were cultured and observed for recovery of the CAD pathogen.

Canker length varied significantly (P = 0.05) with treatments (Table 17). Canker length was greater when feeding preceded inoculation (mean = 18.0 mm) than when inoculation came before feeding or treatments in which feeding alone constituted the treatment. No canker was produced by *C. manihotis* inoculum alone and control treatments.

About 98.7 percent of the plants in the combined inoculum plus feeding treatment and 88.4 percent of the plants in the feeding plus inoculation treatments were dead at completion of the test. Only 2.9 percent of the plants in the inoculum alone treatment were dead (Table 17). In general, check plants and feeding-alone plants were alive at the end of the investigation.

Table 18 indicates that cultures made successively from the insect sucking apparatuses, insect-crushed fluids and gut materials yielded *C. manihotis* conidia in some cases along with *Glomerella cingulata* (perfect stage of *Colletotrichum* sp.). Nevertheless, results of confidence limits showed that percentages of fungal recovery were much like random variability in the population of *P. devastans* in carrying the fungus.

Table 17. Effect of *C. manihotis* inoculum and feeding *P. devastans* on the size of cankers and survival of cassava plants.

Treatment	% mortality of plants at indicated period (days)* 4	8	12	Length of cankers (mm)**
P. devastans feeding	0	0	0	11.9
P. devastans feeding + *C. manihotis* inoculum	60.0	84.6	88.4	18.0
C. manihotis inoculum + *P. devastans* feeding	65.4	98.7	98.7	14.9
C. manihotis inoculum	0.8	2.9	2.9	0
Control	0	0	0	0
LSD (0.05)	4.2	23.8	21.7	2.8

**Values estimated from 4 replications and 5 plants per treatment.*
***Values recorded four days after plants had been treated.*

Table 16. Pathogenicity of 18 isolates of *C. manihotis* on 3 cassava clones after hot-stem puncture inoculation*

		Length of lesions (mm) at indicated period (days)**								
		70775			63385			30001		
Isolate	Source	10	20	25	10	20	25	10	20	25
Ab4	Abeokuta (Ogun State)	6.0	6.7	6.9	7.3	7.7	8.4	5.9	6.4	6.7
IITA 5	IITA block C (Oyo St.)	9.1	10.1	10.4	5.1	5.5	6.0	6.6	7.0	7.0
IITA 7	IITA block A (Oyo St.)	7.5	8.3	8.3	5.7	6.2	7.2	5.5	5.9	6.2
Ib9	Ibadan (Oyo St.)	6.3	6.9	7.2	6.3	7.3	7.6	6.0	6.2	7.3
Ib 10	Ibadan (Oyo St.)	8.9	14.5	15.9	8.4	8.9	10.0	5.6	6.3	6.7
IITA 11	IITA block B (Oyo St.)	7.3	8.5	10.2	6.2	6.9	7.1	4.9	5.5	6.2
Ab 12	Abeokuta (Ogun State)	8.0	8.6	8.9	7.0	7.3	7.4	5.1	5.5	6.0
IITA 16	IITA forest area (Oyo St)	9.4	10.4	10.7	6.0	6.6	7.0	5.8	6.2	6.4
IITA 17	IITA block BN17 (Oyo St.)	7.4	8.8	9.6	7.0	7.3	7.8	5.9	6.3	7.0
IITA 19	IITA block C (Oyo St.)	4.0	5.4	6.0	4.5	4.7	5.2	6.0	6.9	7.0
Ab 25	Abeokuta (Ogun State)	7.3	11.0	11.3	7.3	7.9	8.1	7.4	7.9	8.2
ON 26	Onne (Rivers State)	9.6	11.3	13.2	6.2	6.5	6.5	7.1	7.9	8.1
ON 27	Onne (Rivers State)	12.2	14.5	15.7	5.6	6.7	7.1	6.6	7.9	8.0
ON 30	Onne (Rivers State)	10.0	11.4	12.2	6.1	6.9	7.1	5.0	5.8	6.0
OW 33	Owerri (Imo State)	9.4	11.1	12.0	6.0	7.2	7.5	8.9	10.0	10.3
OW 37	Owerri (Imo State)	10.2	11.5	12.0	6.8	7.0	7.1	6.7	8.1	8.5
Aj 40	Ajue Village (Ondo St.)	4.2	4.8	5.1	4.1	4.9	5.3	4.2	4.8	5.3
IK 46	Ikenne (Ogun State)	4.1	5.4	6.4	3.9	4.7	4.8	4.4	5.3	5.5

**Each value is an average of 4 cankers/plant and 3 replications.*
***LSD(P=0.05) for 10 days after inoculation: between clones = 3.50; within isolates = 3.70.*
LSD(P=0.05) for 20 days after inoculation: between clones = 4.92; within isolates = 5.06.
LSD(P=0.05) for 25 days after inoculation: between clones = 4.92; within isolates = 5.26.

The feeding habit of *P. devastans* and its constant association with cassava plants point to the conclusion that these two factors are of primary importance in the etiology of CAD and that the so-called CAD, previously believed to be incited solely by *C. manihotis*, involves strong interaction between *P. devastans* and *C. manihotis*.

Table 18. Recovery of *C. manihotis* from the body and gut material of *P. devastans*.

Test	No. of insects tested	% recovery of fungi*	
		C. manihotis	*G. cingulata*
Probing of insect on MM			
sterilized	20	8.66<25<49.10	5.73<20<43.66
unsterilized	20	15.39<35<59.22	8.66<25<49.10
Sucking apparatus			
sterilized	10	6.67<30<65.25	6.67<30<65.25
unsterilized	10	55.50<90<99.75	6.67<30<65.25
Insect-crushed fluid			
sterilized	10	12.16<40<73.76	2.52<20<55.61
unsterilized	10	34.75<70<93.33	26.64<60<87.84
Gut material			
Insect which fed on cultures	10	55.50<90<99.75	12.16<40<73.76
Control	10	26.24<60<87.84	18.71<50<81.29

**Values at left and right side of the percentage are 5% confidence limits for the binomial distribution.*

Agronomy

Effect of light intensity and fertilizer application on cassava root initiation and development

I.N. Kasele, S.K. Hahn

There is little consensus on the effects of light and fertilizer on cassava root initiation and development. To investigate this, stem cuttings of TMS 30572 were planted in plastic pots. Low light intensity (60-70 percent light reduction) was obtained by placing a shade over the pots. Three levels of N and K fertilizers, 0, 240 and 480 ppm, were applied in factorial combinations. A basal dressing of 50 ppm P was also applied. Plants were harvested at 20-day intervals up to 180 days. Root samples were collected to identify root formation using iodine solution. Starch grain deposition in cells was used as the criterion. Data were taken on root number and size as well as storage cell number and size.

Figure 9 summarizes the results on changes in root number as affected by treatments. Tuber formation was earlier under unshaded conditions (20 days after planting for K and NK, and 40 days for N) and later under shaded conditions (60 days after planting for K and NK, and 80 days for N).

The number of roots was significantly higher under all N and NK applications. The single N application had less roots during the first 100 days after planting, but there was a sharp increase afterward. Shading significantly reduced the number of roots compared to unshaded conditions. The application of K alone or in combination with N significantly increased root size throughout the experimental period while the application of N alone reduced root size (Fig. 10). Under full sunlight, plants grown under high K application significantly increased their root size 80 days after planting while during the first 80 days, the combination of medium N and high K was superior. Shading produced smaller roots compared to full sunlight.

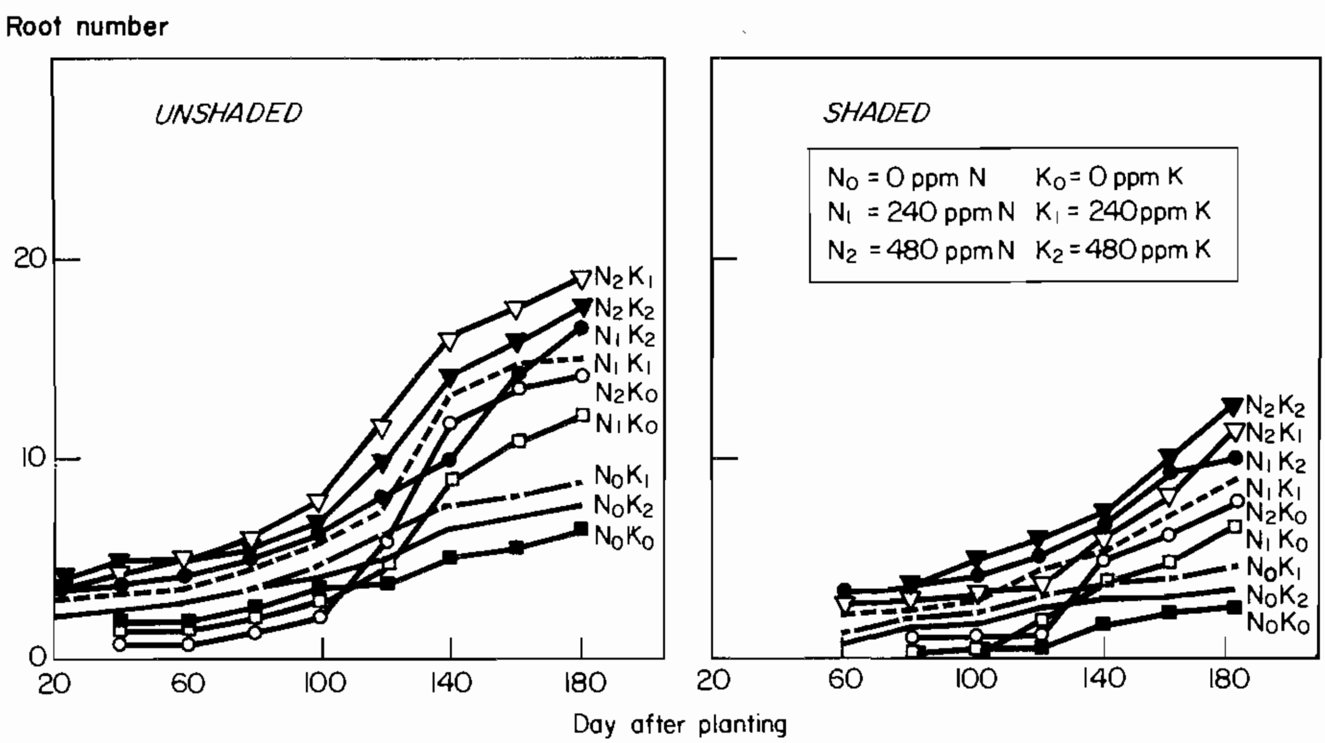


Fig. 9. Changes in root number as affected by treatments.

The application of K alone or in combination with N significantly increased storage cell number while N application alone reduced the cell number (Fig. 11). Shading also had negative effects on storage cell number for all fertilizer treatments. Overall cell number was significantly reduced throughout the experimental period. Increased cell number under higher K compared to other treatments was observed after 140 days. The size of storage cells was also affected by light intensity and NK fertilization (Fig. 12). The application of K alone or in combination with N produced large storage cells. The application of N, however, produced smaller storage cells. Shaded conditions significantly reduced storage cell size. Maximum storage cell size was reached with K alone or in combination with N in 120-140 days after planting under full sunlight conditions. Under shade, cell size was increasing but at a very low rate. These results indicate that both N and K are required for cassava root initiation, tuber size and number.

Cassava agronomic characters associated with fresh root yield

S.K. Hahn, N.M. Mahungu

In genetic improvement, it is important to know how the improvement of 1 character will cause simultaneous changes in other characters. This can be achieved by measuring the degree of association of the characters considered. This study was initiated to investigate the association, if any, between fresh root yield and some other agronomic characters of cassava.

Two composites, A and B, were used for this study. A and B included 45 and 42 randomly selected genotypes, respectively, and these were planted in a randomized complete block design with 4 replications. The spacing was 1 x 1m. HCN was determined by the enzymatic assay method.

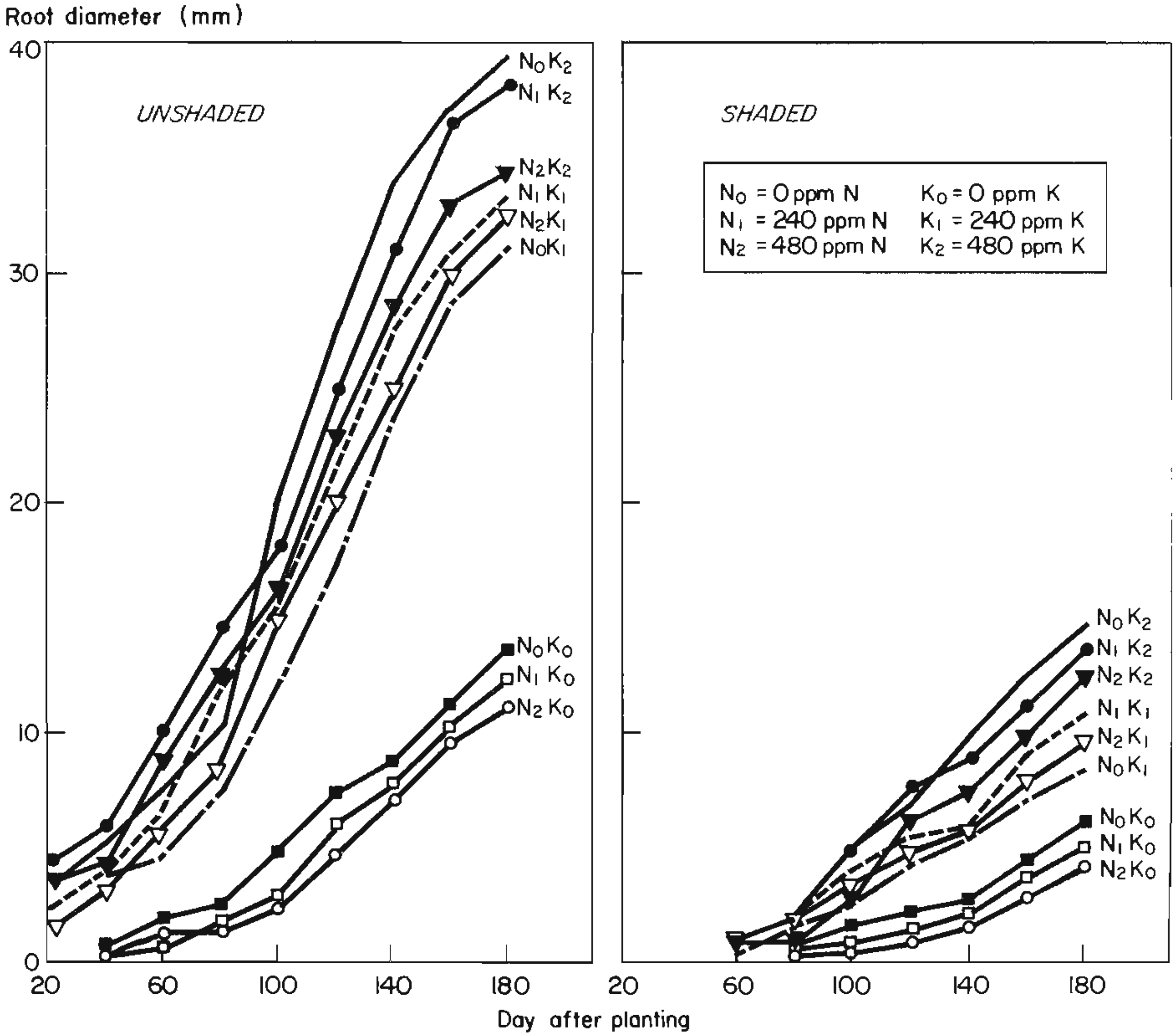


Fig. 10. Changes in root diameter (mm/tuber) as affected by treatments.

Simple correlations computed between fresh root yield and other agronomic characters showed that fresh root yield is significantly and positively associated with the number of roots per plant (r = 0.88), size of roots (r = 0.51), harvest index (r = 0.71), HCN in tubers (r = 0.19), dry matter content in tubers (r = 0.33), plant height at flowering (r = 0.22), stem girth (r = 0.52), total number of branches (r = 0.48), plant height at harvest (r = 0.42), canopy width (r = 0.44), number of first forking branches (r = 0.15) and number of stems per stand (r = 0.22).

Effect of daylength on flowering of cassava

J.A. Otoo and S.K. Hahn

The purpose of this study was to identify a photoperiodic class for flowering of cassava.

Five daylength treatments were used: (1) 8 hours; (2) 12 hours (natural daylength at Ibadan); (3) 16 hours; (4) 8/16 hours (8 hours daylight for the first 35 days after planting followed by 16-hour daylengths for the next 145 days); (5) 16/8 hours (16 hours daylight for the first 35 days after planting followed by 8-hour daylenghts for the next 145 days).

The 8-hour daylength was achieved by placing the plants in a dark chamber at 4 p.m. and puting them into natural light at 8 a.m. The 16-hour daylength was achieved by placing the plants in natural light from 8 a.m. to 4 p.m. and extending the light period from 4 to 8 p.m. Daylength treatments started immediately after first sprouting.

Uniform 25cm cassava cuttings, 12 months old, which were raised in the field under natural conditions were used. Six cassava varieties were used—2 early flowering varieties 58308 and TMS 30395; 2 medium flowering varieties, TMS 30001 and TMS 30572; and 2 later flowering varieties, TMS 50395 and Isunikankiyan. Thus, there were 5 x 6 daylength-variety treatment combinations with 3 plants per treatment. Plants were grown in 35-cm plastic pots for 180 days. Shoots

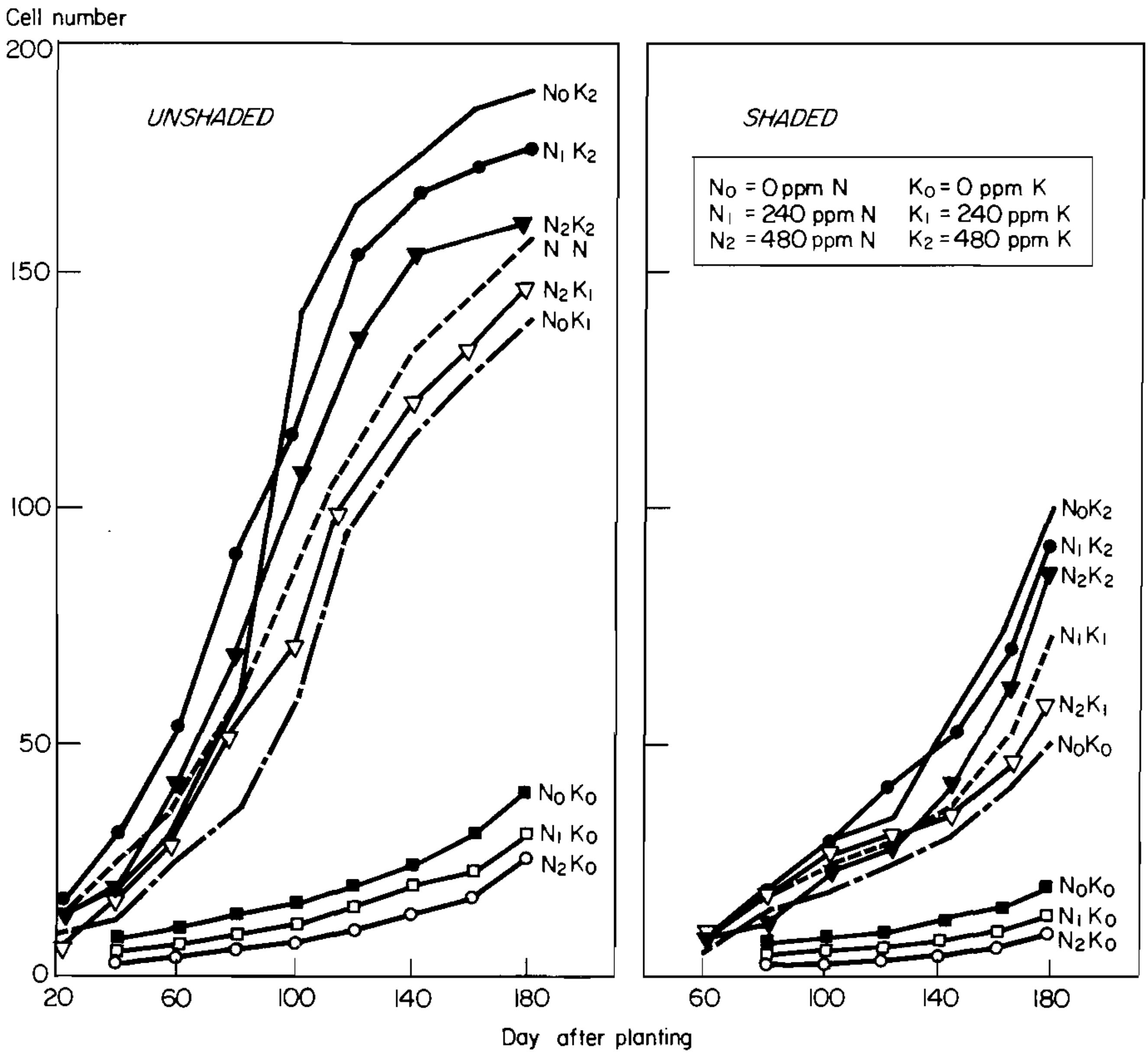


Fig. 11. Changes in storage cell number as affected by treatments.

were thinned to 1 shoot per pot 4 weeks after planting. The plants were adequately fertilized and sprayed against CGM.

The number of days from planting to the first forking of the stem was recorded as the criterion for assessing the effect of daylength on flower initiation. Forking is a type of branching in cassava that occurs at the apex of the stem when the apical meristem changes to the reproductive state. Two experiments planted on 1 April, 1980, and 1 July, 1980 were conducted.

The response of the cassava varieties to daylength for flower initiation is presented in Tables 19, 20 and 21. The response of the early flowering varieties was different from that of the medium or late varieties. While short days hastened flower initiation in the early flowering varieties, they delayed flower initiation in medium and later varieties. Long days inhibited flower initation in early varieties but hastened it in the medium and late varieties (Tables 19 and 20). The overall effect of daylength on the early flowering varieties was significantly different, thus, classifying them as short-day plants while the medium and late flowering varieties are long-day plants (Table 21).

The effects of 8-16-hour and 8-hour treatments were not significantly different for floral initiation in the early varieties (Tables 19 and 20). This indicates that approximately 30 ini-

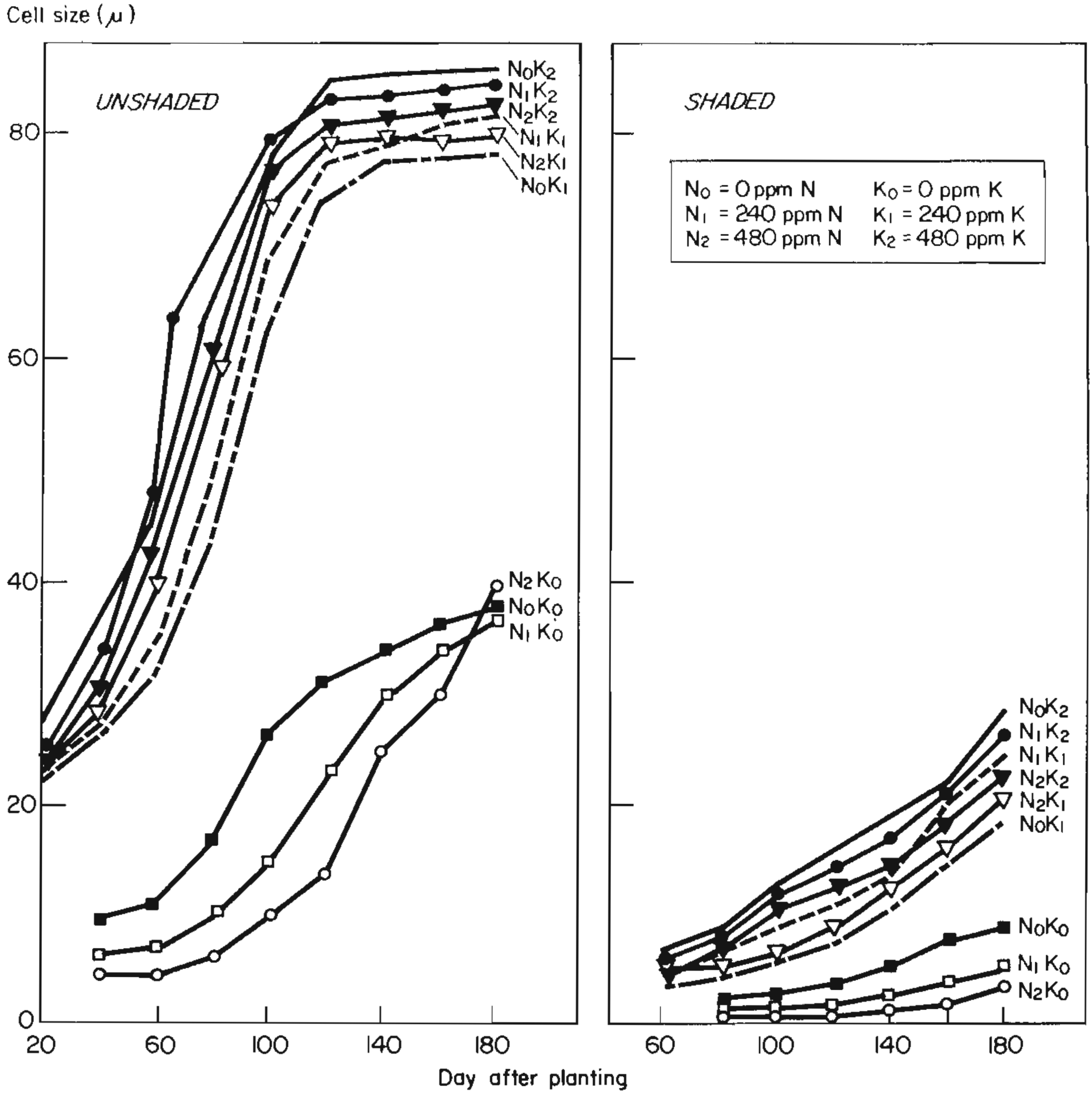


Fig. 12. Changes in storage cell size (u) as affected by treatments.

tial inductive cycles of 8-hour daylengths given after sprouting (with the 8-16-hour treatment) were enough to induce floral initiation in the early varieties. On the contrary, such 30 inductive cycles with 16-hour daylengths after sprouting delayed flower initiation in the early varieties (Tables 19 and 20).

With the medium and late flowering varieties, the initial 30 8-hour or 16-hour photoperiodic cycles after sprouting had no significant effect on flower initiation (Tables 19, 20 and 21).

Factors not conducive to flowering may occur in leaves exposed to non-inductive cycles and these may lead to the production of a transmissible inhibitor that presumably acts at the shoot apex. Such inhibitory effects might have been at play with the 8-hour daylength for the medium and late varieties and also for the 16-hour daylength for the early varieties.

Nematology

Root-knot nematodes on cassava

F.E. Caveness

Parasitism of 2 root-knot namatode species was studied on TMS 30555 and TMS 30572 planted in microplots at IITA. The microplots were concrete pipe and had a surface area of 0.26 m^2 with 1 m soil depth. One month before planting, each microplot was fumigated with an overdose of D-D mixture to eradicate all nematodes. Three weeks after planting cassava cuttings when roots had developed, each microplot was inoculated with about 10,000 eggs of *Meloidogyne incognita*, race 2, or *M. javanica*. The experiment was a completely randomized design with 20 replications. Non-inoculated microplots served as controls.

The cassava cuttings were planted at the beginning of the rains and were not irrigated in the dry season which began 8 months later. The cassava was harvested at 15.5 months after 4 months of the dry season and 3.5 months of the rain season in the second year. Counts of second-stage juveniles formed the terminal soil populations of the nematodes.

Soil sampling showed wide variation in terminal population levels. Therefore, populations were grouped from none to very high. The nematode means were none, very low (117 ± 83), low (450 ± 50), medium (950 ± 350), high (2,150 ± 350) and very high (5,150 ± 2,350).

Root gall development occurred only on feeder roots. None was observed on storage roots ("tubers"). Root-knot index (0-4 range) means showed greater gall expression by *M. incognita* (2.82) on both cassava cultivars than *M. javanica* (2.05). Mean egg count for both cultivars was 467 for *M. incognita* and 671 for *M. javanica*. Juvenile *M. javanica* populations ranged from low to very high on both cassava cultivars while *M. incognita* was medium on TMS 30572 and high on TMS 30555. *M. incognita* populations did not reach very high densities on either cassava cultivar.

The grand means of both nematodes on the 2 cassava cultivars were significantly different (P = 0.05) for stalk height, stalk weight and storage root weight (Fig. 13). The phenomenon of increased plant growth under light nematode parasitism has been observed previously.

Table 19. Effect of daylength on cassava flowering.

	Varieties		
Daylength hr	Early flowering (58308 & TMS 30395)	Medium flowering (TMS 30001 & TMS 30572)	Late flowering (TMS 50395 & ISUN)
8	45.67	157.50	159.83
12 (natural)	40.33	73.00	105.17
16	51.67	75.83	99.33
8/16	45.83	110.83	91.17
16/8	60.83	125.17	105.67
LSD 5%	8.38	38.93	40.86

Table 20. Effect of daylength on cassava flowering.

	Varieties		
Daylength hr	Early flowering (58308 & TMS 30395)	Medium flowering (TMS 30001 & TMS 30572)	Late flowering (TMS 50395 & ISUN)
8	69.33	137.50	145.33
12 (Natural)	76.00	69.50	89.17
16	86.67	90.83	91.67
8/16	71.83	119.50	114.00
16/8	95.17	103.67	102.33
LSD 5%	13.78	29.10	36.64

Table 21. Effect of daylength on cassava flowering.

	Varieties		
Daylength hr	Early flowering (58308 & TMS 30395)	Medium flowering (TMS 30001 & TMS 30572)	Late flowering (TMS 50395 & ISUN)
8	57.50	147.50	152.58
12 (natural)	58.17	71.25	97.17
16	69.17	83.33	95.50
8/16	58.83	115.17	102.59
16/8	78.00	114.42	104.00
LSD 5%	7.81	23.55	26.59

Table 22. Total HCN (mg/100g) in *gari* according to tuber size.

Clones	S	M	L	X
30001	1.13	0.51	0.26	0.63
50207	0.51	0.26	—	0.41
50548	0.74	0.90	—	0.82
50193	0.96	0.90	1.04	0.96
U/1421	0.39	0.77	—	0.58
30572	1.13	0.64	—	0.89
50395	0.90	0.90	0.78	0.86
30337	0.52	0.65	0.64	0.60
60506	0.90	0.77	0.77	0.81
4(2)1443	0.52	0.39	0.64	0.52
4(2)0763	0.64	0.78	0.87	0.76
60444	1.16	0.91	1.03	1.03
X	0.79(±0.20)	0.70(±0.25)	0.75(±0.25)	
t-test[1]	a	a	a	

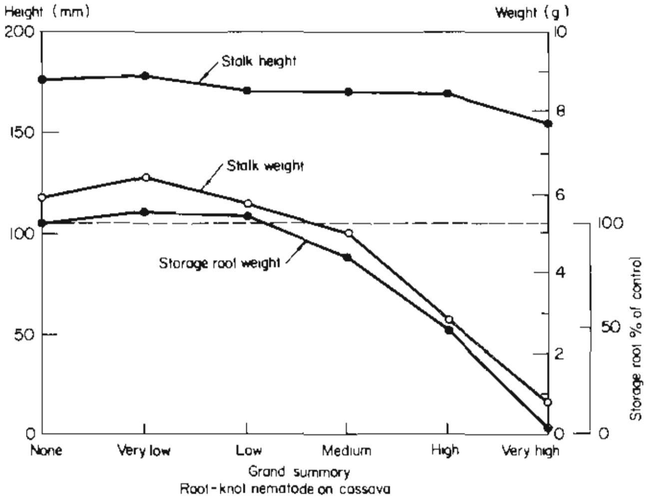


Fig. 13. Grand summary of the root-knot nematodes, *Meloidogyne incognita*, race 2 and *M. javanica* parasitism on cassava cvs TMS 30555 and TMS 30572 after a 15.5 months growth period.

A carbofuran toxicity test on cassava, white yam, water yam, sweet potato and cocoyam

F.E. Caveness, M.N. Alvarez

In the use of carbofuran, higher dosages of active ingredient per hectare are generally required for nematode control than for insect control. No toxicity information is available for the selected root and tuber crops of concern. Therefore, the effect of carbofuran on these crops was investigated.

Cassava cultivar TMS 30572, white yam cultivar Nwapoko, water yam, sweet potato cultivar Tlb-4, *Colocasia esculenta* cultivar TCe-44 and *Xanthosoma sagittifolium* cultivar TXs-17 were exposed to 4-32 kg carbofuran/ha ai in field plots. Carbofuran was placed at the bottom of the planting hole and covered with about 3 cm of soil before the tuber, corm or cassava stake was planted. Each crop was treated as an independent trial and the design was a randomized complete block with 10 replications. The growing period was 2 months during the rain season.

Subjective vigor ratings 2 months after planting showed reduced vigor for cassava and *X. sagittifolium*. None of the crops showed signs of phytotoxicity at any of the rates used. For all crops, root, tuber or corm weight was not significantly different from the controls at harvest.

Quality Evaluation

Assessment of cassava products according to root size

S.K. Hahn, N.M. Mahungu, E.M. Chukwuma, V.P. Rao

Cassava breeders, while selecting for high yielding clones, seem to prefer high yielding clones which produce medium or large roots. This study investigates the effect of root size on the quality and yield of the processed products.

Twelve cassava clones from the uniform yield trial at IITA were used for the investigation. The experimental design was the randomized complete block with 2 replications. Cassava roots from each replication and from each clone were divided into 3 marketable-size classes. Roots with a diameter less than 3 cm were called "small." Those with a diameter between 3 and 5 cm were called "medium" and those with a diameter more than 5 cm were called "large."

Fresh roots were processed into 3 products: *gari*, *chikwange* and *fufu*. *Gari* is derived from fresh roots after grating, fermenting, dewatering and roasting. Chikwange is made by fermenting, sieving, dewatering, pounding, preboiling, wrapping in leaves and boiling. *Fufu* is made through fermenting, sieving, dewatering, boiling and pounding. *Gari* is widely consumed in West Africa, *chikwange* in Zaire and *fufu* in eastern Nigeria. For this study, cassava roots for *fufu* were not divided into different sizes.

Total and free HCN were estimated following the enzymatic assay method. The mean cyanide estimation in *gari* (Table 22) for the 12 clones was 0.79, 0.70 and 0.75 mg/100 g for the small, medium and large roots, respectively. There was no significant difference among the means. This suggests that root size has no influence on cyanide content in *gari*. The yields of *chikwange*, *gari* and *fufu*, according to root size, are reported in Table 23. There was no difference in

Table 23. Percent content of some cassava products in fresh tuberous root according to tuberous root size.

	Chikwange				*Gari*				*Fufu*
Clones	S	M	L	X̄	S	M	L	X̄	All sizes
30001	18.0	28.0	—	23.0	12.0	14.0	16.0	14.0	36.0
50207	32.0	16.0	36.0	28.0	10.0	12.0	—	11.0	24.0
50548	16.0	22.0	24.0	20.7	10.0	10.0	—	10.0	28.0
50193	28.0	24.0	20.0	24.0	6.0	11.0	10.0	9.0	34.0
U/1421	26.0	30.0	33.3	29.8	11.0	14.0	—	12.5	30.0
30572	28.0	38.0	30.0	32.0	10.0	12.0	—	11.0	38.0
50395	18.0	28.0	18.0	21.3	9.0	11.0	12.0	10.0	24.0
30337	24.0	25.0	26.0	25.0	10.0	13.0	13.0	12.0	—
60506	14.0	40.0	20.0	24.7	10.0	10.0	10.0	10.0	20.0
4(2)1443	32.0	36.0	36.0	34.7	10.0	10.0	14.0	11.3	24.0
4(2)0763	28.0	34.0	28.0	30.0	9.0	12.0	10.0	10.3	12.0
60444	16.0	14.0	14.0	14.7	4.0	6.0	6.0	5.3	8.0
X̄	*23.3*	*27.9*	*25.9*		*9.3*	*11.3*	*11.4*		*25.3*
*t-test**	*a*	*a*	*a*		*b*	*a*	*a*		
S.E.	*1.46*	*2.59*	*4.94*		*0.64*	*0.68*	*0.69*		*2.84*

chikwange yield according to root size. For *gari*, the small roots gave less yield.

This study showed no difference in the quality of *gari* from different sizes of cassava roots. However, the quality of *chikwange* from the small roots was not as good as *chikwange* from medium and large cassava roots.

Detoxication of cassava roots by fermentation in water

N.M. Mahungu, S.K. Hahn

Cassava contains cyanogenic glycosides which release HCN on hydrolysis. This HCN poses a health hazard in areas where cassava is a staple food and where fermentation is a common practice in preparing cassava for food. This study investigated the rate of detoxication of cassava roots after fermenting in water.

Fresh cassava roots were harvested from 4 IITA improved clones TMS 30572, TMS 30395, TMS 50395 and TMS 30001, as well as from 2 Nigerian checks 60506 and Isunikankiyan.

Ten roots were randomly selected from each clone and divided into 2 sets of 5 g each. They were then peeled and soaked in 10 liters of water 28° to 30°C, and pH 6.8. Samples were taken daily for HCN analysis by the enzymatic assay method.

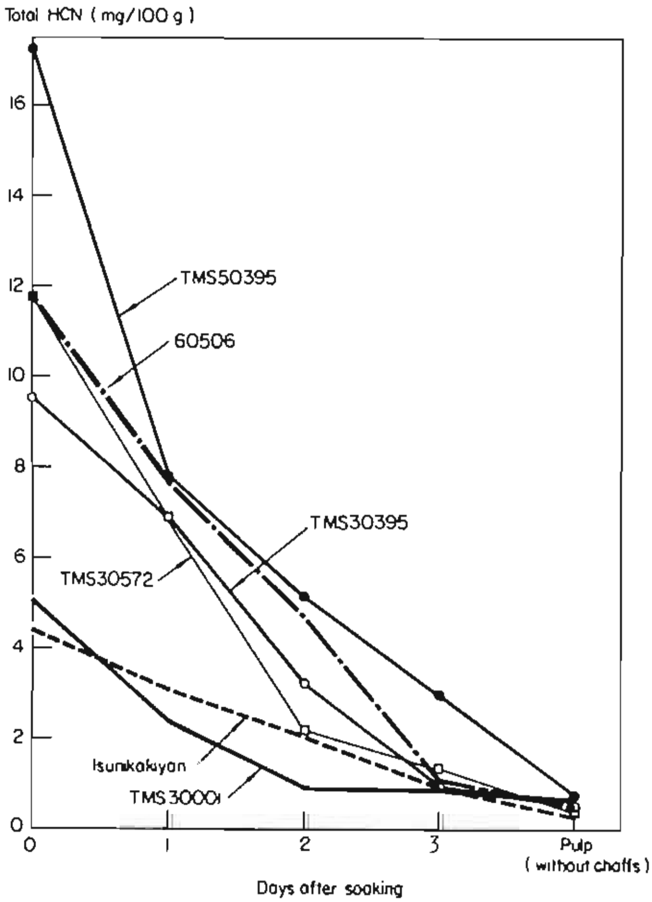


Fig. 14. Total cyanide reduction following cassava root fermentation in water.

Total HCN in fresh roots ranged from 4.45 to 17.25 mg/100g of fresh weight (Fig. 14). On the third day, after complete fermentation and chaff removal, total HCN ranged from 0.13 to 0.60 mg/100g of fresh weight. Almost 95 percent of total HCN in the roots was hydrolyzed. Free HCN increased in the first 2 days but decreased on the third day. The increase in free HCN was due to total HCN being converted to free HCN.

Tissue Culture and the Distribution of Disease-Free Material

E.A. Frison and S.Y.C. Ng

To satisfy as many as possible of the requests received during 1981 for IITA improved clones, plants from 14 clones of cassava were obtained through meristem and shoot tip culture. These methods as described in IITA Annual Report 1979 offer the opportunity to eliminate diseases from infected material which makes international movement of clonal material feasible.

Of the 14 cassava clones produced from meristem culture, 8 were certified and a phytosanitary certificate issued. During 1981, disease-free cassava was distributed to 13 African countries: Cameroon, Gabon, Gambia, Guinea Bissau, Kenya, Liberia, Rwanda, Senegal, Seychelles, Sudan, Uganda, Zanzibar and Zimbabwe.

Feedback information so far received from 9 countries showed that the success rate of transplanting tissue culture material ranged from 0 to 100 percent.

Removing tissue cultured cassava plantlet from test tube.

Cameroon National Root Crops Improvement Program (CNRCIP)

Cassava: genetic improvement

S. Nzietchueng, S. Lyonga

Cassava seedlings were raised at Babungo, 1,300 m elevation; Garoua-Boulay, 1,000 m (CGM infestation); Meiganga, 900 m (CMD infection); Nkolbisson, 750 m; and Njombe, 80

m. Seedling clonal evaluations and yield trials were carried out.

LM, a local check variety, was identified as a vigorous, high yielding variety in moderate CMD and CBB conditions.

In a preliminary yield trial, it gave a fresh yield of 18.9 t/ha (Table 24). Only 2 clones, 7804 and 7839, gave higher yields of 20 or more t/ha.

In an advanced yield trial, LM gave a fresh yield of 40.5 t/ha while 5 selected clones gave less than 20 t/ha each (Table 25).

COLLECTION AND EVALUATION OF LOCAL CASSAVA CLONES. A total of 54 acccessions of local clones have been collected throughout Cameroon. They are maintained at Njombe and have been evaluated for disease resistance, branching habit and yield. Cross breeding is planned with outstanding local clones from IITA selected material to create a new genetic pool.

Table 24. Yield of selected clones of cassava in preliminary yield trials.

Clone	Fresh yield (t/ha)	% of check Var. LM	Dry yield (ta)
7802	13.5	71	5.4
7804	20.5	108	6.6
7806	4.4	23	—
7807	12.4	66	4.8
7810	15.1	80	4.2
7825	6.1	43	—
7830	12.5	66	4.9
7838	12.3	65	3.2
7839	22.6	120	8.8
7840	10.5	56	—
7844	15.2	80	5.2
LM	18.9	100	7.4
LN	13.3	70	5.9
LSD (.05)	6.0		

Table 25. Yield of selected clones of cassava clones in advanced yield trials.

Clone	Fresh yield (t/ha)	% of check var. LM	Dry yield (t/ha)
7641	15.4	38	5.9
7649	18.3	45	7.3
7673	16.3	40	6.5
7722	19.7	49	7.1
7734	19.0	47	6.5
LM	40.5	100	16.2
LN	16.8	41	6.7
LSD (.05)	4.0		

Pathology

S. Nzietchueng

CMD, CBB and AD were recorded regularly every other month throughout the season on 129 clones in preliminary yield trials at Meiganga and Mbankomo. The highest incidence for CMD, CBB and AD was observed from October to December. Figure 15 gives the distribution of the clones infected by both CMD and CBB at Meiganga, where the incidence of CMD and CBB is normally very high. Disease

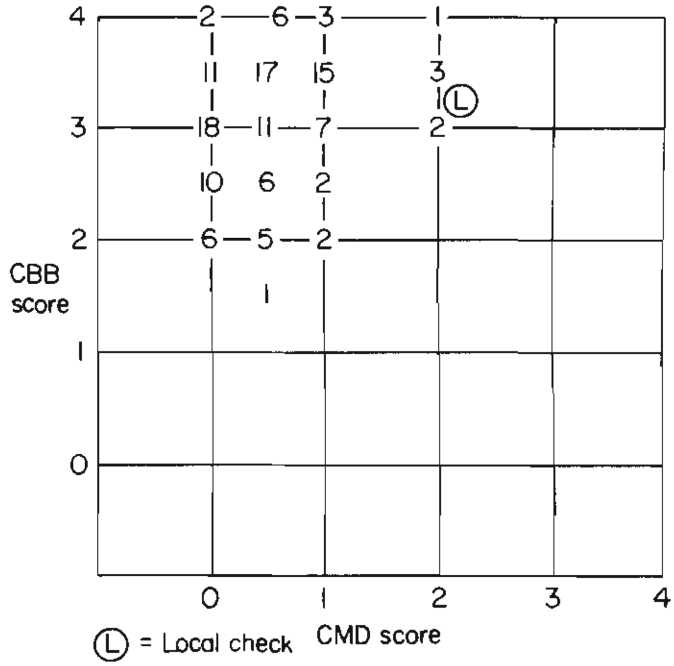


Fig. 15. Distribution of CMD and CBB infected clones in PYT (MEIGANGA).

infection was based on a scale of increasing severity from 0 to 4.

Most of the clones were severely infected by CBB and none of them were free of symptoms. But about one-third of the 129 clones were free of CMD symptoms. Fifteen clones were free or showed a low incidence of CMD and CBB.

The same clones were planted at Mbankomo. A majority of the clones was fairly low in both diseases (Fig. 16) and about one-half of the 129 clones rated below 1 for both of them.

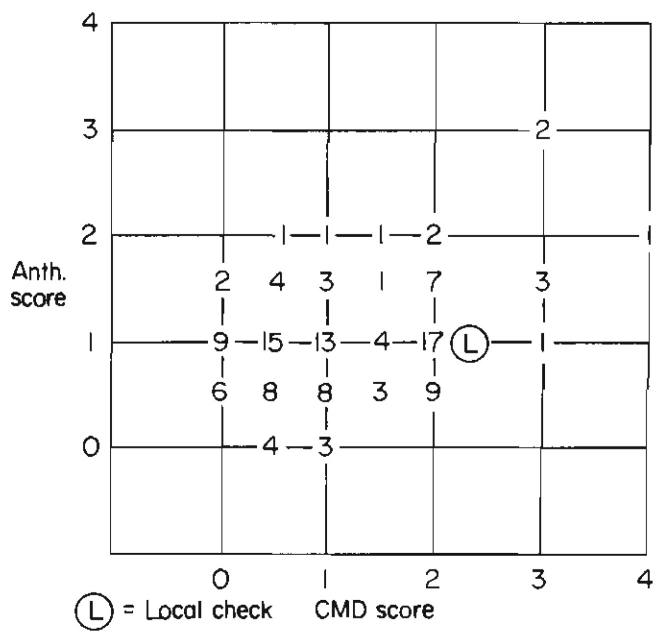


Fig. 16. Distribution of CMD and anthracnose infected clones in PYT (MBANKOMO).

Zairean National Manioc Program (PRONAM)

Genetic improvement

T.P. Singh
Seedling and clonal evaluations of cassava were carried out, and 5 promising varieties were identified. They were judged not only for their yields, but also for their food tasting quality. *Fufu* and *Chikwange*, local dishes perepared from the varieties were acceptable. *Pondu*, a leaf vegetable prepared from 85/28 was liked, and that from 179/2 was disliked. 85/28 is resistant to stem die back. A56, though the highest yielder, is susceptible to CBB.

The multiplication program of these improved PRONAM varieties has been initiated. During the year, improved material was multiplied on 9.4 ha, and variety 02864 was multiplied on 8.92 ha. From this multiplication, planting material sufficient to cover 56 ha was supplied to farmers and used to establish demonstration trials on farmers' fields.

Entomology

R. Hennessey, T.P. Singh
Research to identify sources of resistance to CM was initiated in 1976. Efforts were strengthened in 1978 when a seedling nursery was artifically infested and screened.

More than 6,500 seedlings of cassava were raised and 120 promising clones selected. In 1981, 13 clones with a low CM score were tested in fields and greenhouses. Initial observations of CM resistance on clone TMS 70453 were followed by more detailed observations of this clone against TMS 02864, a check variety highly susceptible to CM.

Each shoot of TMS 70453 and TMS 02864 was infested with 3 adult CM. About 4-5 days after infestation, CM on the cassava plants were counted and missing CM were replaced.

Results obtained show differences in terms of CM establishment and multiplication (Table 26). About 4-6 days after infestation, 56.4 pecent of the CM placed on clone TMS 70453 and 7.8 percent of those placed on variety TMS 02864, was not on the plant. On TMS 70453, CM was not concentrated near the growing point. One month after infestation, the number of CM present on each shoot was counted.

Table 26. Number of adult CM found on the cassava plants of clones under test 4-6 days after infestation.

Clone	Number of CM			
	Placed	Observed	Lost	% loss of mealybugs
TMS 70453	39	17	22	56.4
TMS 02864	51	47	4	7.8
TMS 71550/2	33	26	7	21.2

**3 adults were initially placed on each per shoot.*

The results show a highly significant difference in CM population on the 2 cassava varieties (Table 27). The multiplication rate of CM was significantly lower on clone TMS 70453 than on variety TMS 02864. Furthermore, the development rate of CM from young to adult was slower on TMS 70453 than on TMS 02864. The percentage of CM population in the adult stage was only 9.2 for TMS 70453 compared to 24.0 for TMS 02864.

Table 27. Average CM counts per shoot on a resistant clone 70453 and the susceptible check variety 02864.

Clone	Immature CM	Pre-ovipositing adults	Ovipositing adults	Total
70453	16.3**	0.5**	1.0**	17.8**
02864	195.1	29.8	17.0	241.9

Yam

Studies on yam production show that a new minimum staking method where the yam vines are grown on nylon netting about 50 cm above ground may be less expensive than conventional staking. The efficiency of producing minisets as planting material in yam production appears promising.

Genetic improvement

Varietal trials

M. Alvarez, S.K. Hahn
STAKED ADVANCE TRIALS. Data were obtained from 9 genotypes of *D. rotundata* and 6 genotypes of *D. alata* grown in the field in 1980 and 1981. Plot sizes were 11 m long with 1 m between rows and 1 m spacing on the row. A randomized complete block design with 3 replications for *D. rotundata* and 6 replications for *D. alata* was used. The plants were subjectively evaluated for virus, and the tubers for nematode damage using a scale of increasing severity from 1 to 5. For yield evaluation, only the inner 10 plants were harvested.

Results are shown in Table 28 for *D. rotundata*. Only 1 hybrid line, RB6-114-1052, exceeded the yield of the check clone Nwapoko. TDr 819, a local collection, also yielded more than Nwapoko and had the lowest virus score, but RB6-114-1052 showed high susceptibility to nematode damage. Figure 17 shows the relationship between virus score

Table 28. Yield, virus and nematode scores of *D. rotundata* advance yield trials (1980 and 1981).

Clone	Mean for 2 years		
	Yield t/ha	Virus score*	Nematode score
TDr 819	31.9a	2.0	2.8
RB6-114-1052	27.9a	2.8	3.5
Nwapoko (ck)	27.3a	2.2	1.5
W 512	25.4a	2.7	3.0
TDr 148	24.5a	2.3	2.5
TDrs-4001-C226	22.2a	3.0	3.1
TDrs-4002-9	19.9a	2.8	2.3
R16-215-16	17.5	3.3	2.5
W4-B58	14.2	3.3	3.3
Mean	23.5	2.7	2.7
SE	3.1	0.3	0.6
LSD	13.7	1.2	2.4

**Subjective score from 1-5; 1 = no damage; 5 = severe damage.*

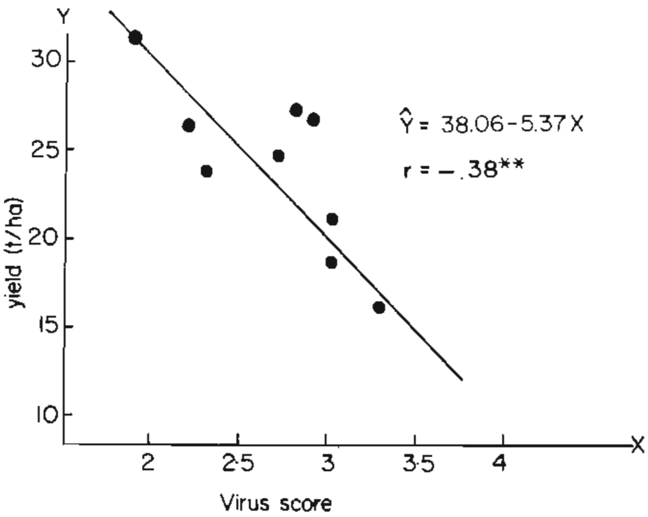


Fig. 17. The relationship between yam virus complex (x) and yield (y).

and yield in white yam. The correlation coefficient was highly significant (r = −.38). This relationship indicates that reduction in tuber yield is associated with this virus complex.

For *D. alata*, the advanced yield trial results are shown in Table 29. There was no relationship between yield and scorch score. Analysis of variance and means showed a significant difference between years for yield and scorch, and significant interaction was found for year x genotype for both species. There was no significant difference between years for virus and nematode scores.

Table 29. Yield, scorch score and number of tubers of *D. alata* advance yield trials (1980 and 1981).

	Mean for 2 years		
Clone	Yield t/ha	Scorch score*	No. of tubers
TDa 251	34.8	3.7	13.9
TDa 204	34.0	4.0	14.3
TDa 5	27.2	3.5	13.1
TDa 310	22.1	2.3	11.2
TDa 297	21.8	1.5	9.9
TDa 291	18.5	1.4	12.5
Mean	26.4	2.8	12.5
SE	2.4	.2	1.2
LSD	10.9	.9	4.4

**Subjective score from 1-5; 1 = no damage; 5 = severe damage.*

STAKED INTERMEDIATE AND PRELIMINARY TRIALS. Intermediate and preliminary yield trials, which consisted of 20 lines each, were evaluated for the same characters as in the advanced yield trial. The trials were not replicated.

In the intermediate yield trial, there was no line that exceeded the yield of the Nwapoko check line. More than 80 percent of these lines representing 17 families showed high susceptibility to the virus like complex. It is possible that this condition could have contributed to the low yields. For the preliminary yield trial, 15 percent of the lines yielded more than the check line.

NO STAKING/MINIMUM STAKING TRIALS. Some lines were also evaluated under conditions of no staking and minimum staking (height of vine above ground not more than 1 m).

The response of yam lines of both *D. alata* and *D. rotundata* grown without staking at IITA is shown in Table 30. In the moderate and high rainfall areas, higher yields are produced by *D. alata* than *D. rotundata*. Response of lines to minimum staking conditions is shown in Table 31.

Table 30. Yem yields without staking (1981).

Clone	Yield (t/ha)	Scorch* score	Nematode* score
D. alata			
TDa 5	26.3	2	—
TDa 297	18.2	2	—
TDa 291	18.0	2	—
TDa 251	13.0	5	—
D. rotundata		Virus* score	
RI6-210-1399	8.8	2	2
M108-1	8.6	3	2
RI6-215-5	7.8	3	3
RI8-24-330	7.4	3	3
RI8-60-300	5.8	3	3
Nwapoko (ck)	5.2	2	3
RI7-76-367	3.2	4	4
TDr 821	1.9	4	4
RI6-213-425	1.8	4	4
Mean	9.7		3.1
SE	3.0		.78

**Subjective score from 1–5; 1 = no damage; 5 = severe damage.*

Table 31. Yam yield and nematode score with minimum staking (1981).

Clone	Yield (kg/plot)	Nematode* score
TDa 291	69.3	—
Nwapoko (ck)	67.4	1
RI 7-167-531	53.4	4
TDrs/4001-C226	35.4	3
TDr 830	35.0	1
W4-B58	30.8	3
RI6-215-182	30.8	3
TDr Ekpe	28.6	3
TDr 148	27.4	3
Boki	25.0	2
Okunmodu	24.8	2
Mean	38.9	2.2
SE	16.5	1.9

**Subjective score from 1-5; 1 = no damage; 5 = damage.*

Producing minisets

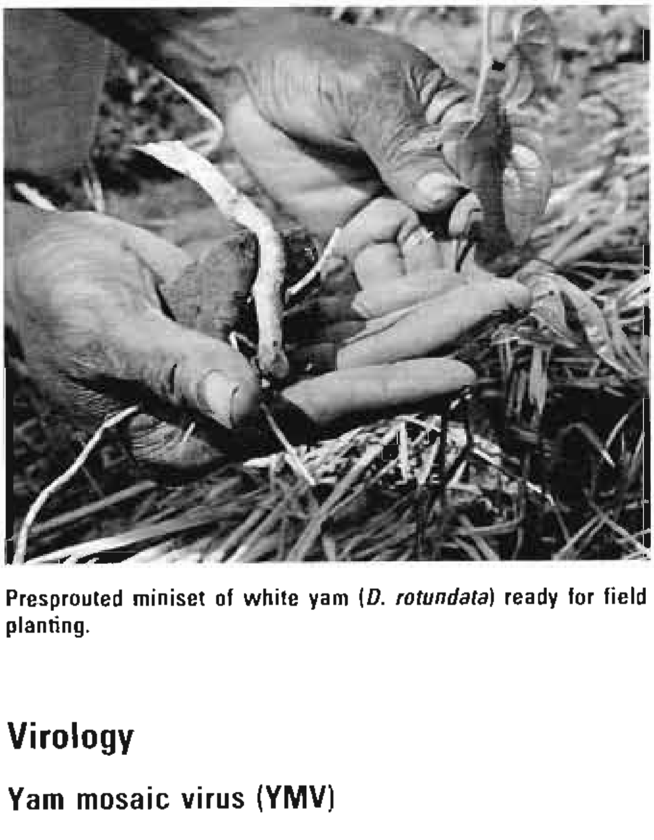
M. Alvarez and S. K. Hahn

Seven *D. rotundata* clones were cut into one-half moon minisets ranging in weight from 50 to 90 gm and treated with a mixture of wood ash and Aldrex T. The pieces were planted in a nursery with washed river sand as a medium. Fifty days after planting, the clones that had sprouted sufficiently were transplanted to the field and planted 1 m between rows and 50 cm within the row. Seven months later they were harvested.

Of the 7 clones of *D. rotundata* planted in the nursery, only 4 yielded enough transplanting material (Table 32). Other clones germinated too late for transplanting. The hybrid clone TDr/4001/C226 gave the highest percentage increase of sets over the original material. The mean tuber weight produced from these minisets was 400 g with a range from 80 to 1,252 g. Except for Okunmodu, which had 30 percent of its tubers weighing more than 500 g, all other clones produced tubers of seed yam size.

Table 32. Response of 7 *D. rotundata* lines to minisets seed-piece propagation.

Clones	% transplanted to field	% increase of original (sets)
TDrs/4001/C226	55	500
TDr 667	44	435
Boki	50	400
Okunmodu	50	300
Rlb-215-148	—	—
TDr 821	—	—
TDr 819	—	—



Presprouted miniset of white yam (*D. rotundata*) ready for field planting.

Virology

Yam mosaic virus (YMV)

G. Thottappilly

D. rotundata and *D. cayenensis*, are often symptomless, but they are always infected with a potyvirus. This sap-transmissible virus is transmitted by aphids in a nonpersistent manner. As reported in IITA 1978 Annual Report, *Nicotiana benthamiana* and N. clevelandii are the only alternate hosts. The symptoms of *N. benthamiana* consist of an initial vein-clearing followed by an inconspicuous green vein banding.

In the field, diseased yam plants usually show different kinds of symptoms such as green vein-banding, strapping, mottling and yellowing. To find out whether all these symptoms are caused by the same virus, isolations were carried out from leaves of plants showing symptoms by means of sap inoculation to *N. benthamiana*. The symptoms expressed by *N. benthamiana* were the same with all isolates.

The virus was purified by the following procedure: Artificially infected *N. benthamiana* leaves were collected and chilled. They were homogenized in 0.1 *M* phosphate buffer, pH 7.7., containing 0.01 *M* EDTA and 0.001 *M* cysteine plus 0.5 percent 2—mercaphtoethanol. The extract was clarified by adding 25 percent chloroform and 25 percent carbon tetrachloride. The extract was put in a centrifuge and run at 8,000 rpm for 10 minutes and then at 20,000 rpm for 90 minutes. The virus preparation was then layered on top of a 10-40 percent sucrose gradient. In all cases, a single peak containing numerous particles typical of viruses in the potyvirus group was visible.

Attempts were also made to purify the virus directly from field-infected samples of *D. rotundata*. Mucilaginous substances in yam leaves make the purification of the virus extremely difficult. However, by diluting the sap with buffer, a small quantity of virus could be purified from different plants showing symptoms and in all cases typical potyvirus particles were observed.

Virus preparations purified from artificially inoculated *N. benthamiana* leaves with the virus from infected *D. rotundata* plants showing mosaic symptoms were injected into a rabbit and an antiserum produced. Further research on serological comparisons is in progress.

Sweet Potato

Genetic Improvement

Varietal trials

M. Alvarez and S.K. Hahn

PERFORMANCE OF 10 SWEET POTATO CLONES. Ten sweet potato lines were evaluated for 2 years at IITA, Jos, Mokwa, Onne and Zaria in Nigeria. Plot sizes were double 10 m long rows with 1 m between rows and 30 cm spacing on the row. A randomized complete block design with 4 replications was used for each test.

Information on the cultivar x location interaction effects was obtained from the analysis of variance on the combined data. A consistency index (CI) provided a measure of consistency resulting from changes in ordering genotypes from one environment to the next.

The highest yielding line over environment and year was TIS 8441 followed by TIS-2498 (Table 33). TIS-2498 was more consistent than TIS-8441 in rank over locations, but they were both consistently higher yielders than the other clones. Tlb-4 has a low consistency index, but was also the lowest yielder in most locations.

Mean square attributable to lines and locations was highly significant with location accounting for 63 percent of total variation. The interaction of line x location, line x year, location x year and line x year x location were all highly significant ($p < 0.01$) and accounted for another 17 percent of variation.

Table 33. Clones, site, year, mean and consistency index of 10 sweet potato clones grown at 5 locations in Nigeria for 2 years.

Clone	Mean yield (t/ha)	CI
TIS-8441	12.1	1.78
TIS-2498	11.5	1.52
TIS-8250	11.3	2.88
TIS-70357	11.2	2.70
TIS-8164	11.1	2.30
TIS-8244	10.9	1.67
TIS-71102	10.3	3.27
TIS-8163	7.8	1.14
TIS-71354	7.2	2.12
Tlb-4	4.4	.88
Mean	9.80	
SE	1.93	
Site		
IITA	23.8	
Zaria	9.4	
Mokwa	6.3	
Jos	4.9	
Onne	4.6	
Year		
1980	9.6	
1981	9.9	

Evaluation of sweet potato clones for SPVD

M. Alvarez and S.K. Hahn

Sweet potato lines were evaluated for SPVD in the nursery and in the field. Disease ratings were based on subjective evaluation on a scale of increasing severity from 0 to 5 (Table 34). Sweet potato at different stages in the nursery throughout the year provided a good source of incoculum for the plants tested.

Table 34. Schedule for SPVD evaluation in sweet potato.

Activity	Month	Season
Nursery planting	August	End of rain
1st field planting	November	Dry
Nursery (Multiply)	March	Beginning of rain
2nd field planting (SPVD evaluation)	May	Rain
Nursery (SPVD evaluation)	Nov.-Mar.	

The seedlings in the initial field virus evaluation showed a range of 0-5 with a high rate of plants showing no symptoms (Fig. 18). Many of these plants from the field showed severe symptoms 30 days after planting in the nursery.

Thirty-six of the 49 lines selected for the second field virus evaluation had no symptom. Forty-two percent of these remained symptomless and 10 percent showed moderate to severe symptoms in the field.

Many lines that might have escaped in the field were identified in the nursery evaluation and greatly reduced the number of susceptible plants for the next field test.

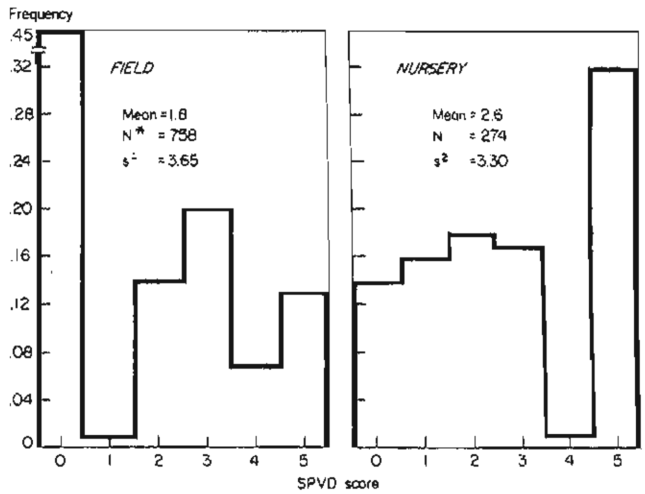


Fig. 18. Distribution of SPVD scores among sweet potato lines in the field and in the nursery. (**N = number of lines evaluated.*)

Evaluation of sweet potato clones for flood stress

M. Alvarez and S.K. Hahn

Root formation and development in sweet potato under flood stress conditions were studied in a screenhouse and in the field. In the screenhouse, the performance of stressed and unstressed plants was compared.

In the field, clones were planted in hydromorphic conditions with 1 m between rows and 30-cm spacing in the row. The 5 clones planted for sampling were in 4 replications while all other lines were in 2 replications. Seventy-eight days after planting, the plants were sampled, and fresh and dry weight recorded for leaves, vines, roots and tubers. Four samples were taken at 7-day intervals from each plot of 14 plants.

In addition, 73 lines were planted as above in the field but with only 7 plants per line. These plants were allowed to grow until harvest.

Epinasty, chlorsis, stunting, wilting of lower leaves and formation of adventitious fibrous roots were characteristic symptoms of flood stress in the screenhouse. Table 35 shows the relative growth of tops and roots as influenced by flooding for 90 days.

All plants survived in the field under hydromorphic conditions. As in the screenhouse response, plants produced a large number of adventitious roots and the characteristic chlorosis of lower leaves was noticeable. Some of the tubers deteriorated in waterlogged conditions.

Table 35. Effect of 90 days of flooding on top growth and root growth of 4 sweet potato clones.

Clone	Relative top growth*	Relative root growth*
TIB-4	.15	.42
TIS-2498	.36	1.14
TIS-2534	.55	1.87
TIS-3017	.54	.85

**Expressed as ratio of flooded/control.*

The efficiency of partitioning of accumulated photosynthate to the tuber was measured as harvest index (HI). The HI in hydromorphic conditions is shown in Figure 19. Changes in efficiency of top dry weight production are given in Figure 20. There was always a characteristic peak followed by decline. The rapid decline could be attributed to unfavorable conditions for sink demand. This, in turn, caused a reduction in photosynthetic efficiency and reduction in HI.

Of the 73 lines planted under the same conditions only 10 produced tubers of good size. Some lines that produced tubers rotted under these wet conditions. Others had very encouraging top growth with very little leaf chlorosis.

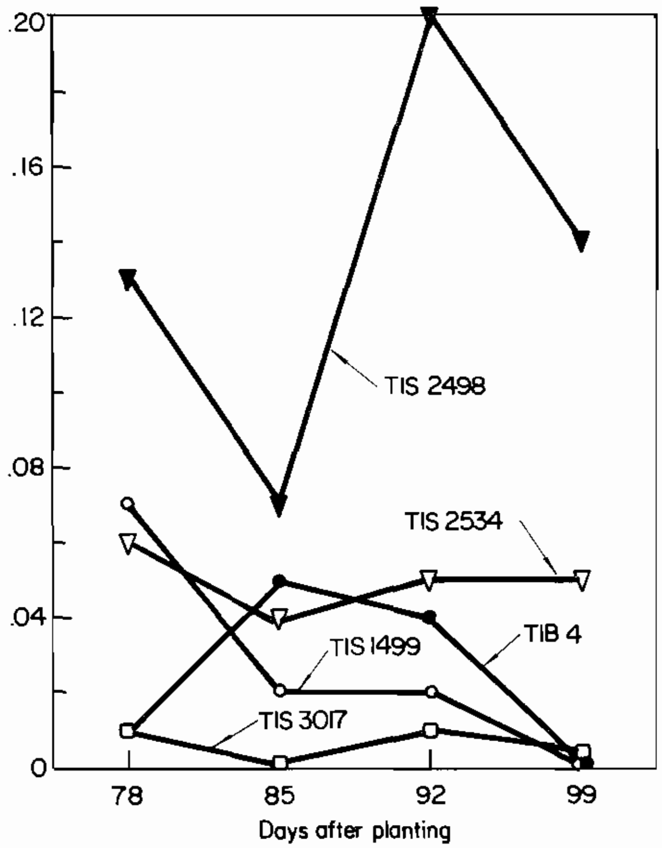


Fig. 19. Variation of harvest index with time after planting of 5 sweet potato clones grown in field hydromorphic soil.

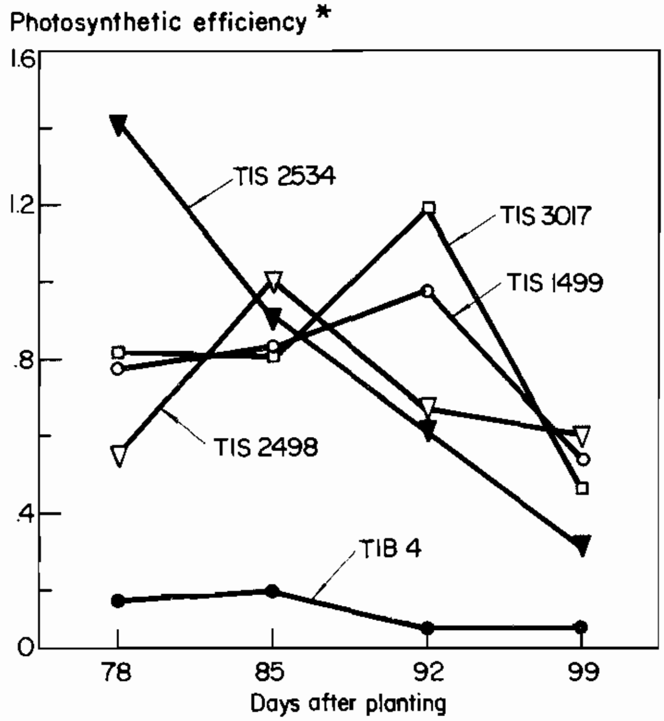


Fig. 20. Variation of photosynthetic efficiency with time after planting of 5 sweet potato clones grown in field hydromorphic soil.

Table 36. Summary of biological data of *C. puncticollis*.

	Range	Mean ± S.E.
Egg incubation (days)	3-4	3.3 ± 0.4
Larval period (days)	11-12	11.1 ± 0.3
Pupal period (days)	5-7	6.2 ± 0.9
Pre-oviposition period (days)	3-4	3.6 ± 0.5
Oviposition period (days)	41-91	71.4 ± 14.3
Longevity of female (days)	44-95	80.5 ± 14.4
Longevity of male (days)	46-69	54.8 ± 6.7
No. of eggs laid per female	201-496	329.8 ± 78.5

Entomology

Survival of the sweet potato weevil on some promising sweet potato clones

T. Anota, K. Leuschner

The biology of immature stages as well as the fecundity and longevity of *C. puncticollis* were studied in the laboratory on Tlb 4 at 25°-30°C and 79 percent relative humidity.

Table 36 shows that the development period from egg to adult of *C. puncticollis* averaged 20.2 days, the preoviposition period 3.6 days and the oviposition period 71.4 days. A female lived an average of 80.5 days and laid an average of 329.8 eggs. The male lived an average of 54.8 days.

To study the survival pattern of different stages of the weevil, tubers of resistant clones TIS 2532, TIS 2534, TIS 3017, TIS 3030 and TIS 3053 and a susceptible clone TI64, were infested with eggs and kept in the incubator at 25°-30°C and 70 percent relative humidity. For each clone, the mortality at each stage was recorded.

The survival of the successive stages of *C. puncticollis* on various clones (Table 37) was highest on the susceptible clone Tlb 4. Apart from TIS 2532, survival was significantly lower on all other varieties at all stages of development. Survival, therefore, seems to be a better criterion for evaluating the level of resistance of sweet potato clones under laboratory conditions.

Table 37. Survival percent[1] of different stages of *C. puncticollis* on various sweet potato clones.

Clone	Instar I	Instar II	Instar III	Pupal	Adult
Tlb 4	80.4a	80.3a	79.7a	79.1a	79.1a
TIS 2532	73.7a	72.3a	71.9a	70.8a	68.9a
TIS 2534	55.6b	53.2b	52.6b	51.5b	52.0b
TIS 3017	54.5b	53.8b	50.9b	50.7b	50.5b
TIS 3030	51.8c	51.3c	50.8b	49.4c	48.9c
TIS 3053	44.5c	44.2c	41.2c	40.8c	40.5c

Means followed by the same letter are not significantly different at 5% level.
[1]Means of 10 replicates.

Table 38. Effect of temperature on the development period and survival of *C. puncticollis*.

Temperature °C	Development period (days)* Range	Mean[1]	% adult emergence*
20	(27-38)	33.6 ± 3.16a	10.5b
23.5	(26-40)	33.6 ± 3.33a	73.3a
27	(19-22)	22.2 ± 1.23b	79.8a
34	(16-22)	16.8 ± 0.61b	81.1a

**Means followed by the same letter are not signficantly different at the 5% level.*
[1]Means of 12 replicates.

Effect of temperature on the development of the sweet potato weevil

S.K. Hahn, T. Anota

The effect of temperature on the development period of the sweet potato weevil was studied on Tlb 4 tubers kept at 4 constant temperatures, 20°C, 23.5°C, 27°C and 34°C. Eggs laid by actively ovipositing females were observed for adult emergence and immature stage survival.

Table 38 shows a significant delay in the development period of the insect at 20°C and 23.5°C (33.6 and 33.6 days, respectively). At 27°C and 34°C, the development period is shortened (22.2 and 16.8 days, respectively). High mortality (89.5 percent) occurred at 20°C. These results suggest that low temperature extends the development period and drastically affects its survival. With the increase in temperature, the development period shortens and survival rate (immature stages) increases. Therefore, low temperature should be used in sweet potato storage to avoid severe weevil infestation.

Effect of water treatment on the survival of sweet potato weevil

S.K. Hahn, T. Anota

The effect of immersing sweet potato weevils in water was studied as a method that could be applied to tubers to prevent weevil infestation during storage.

Meshed nylon bags containing 100 individuals (adults or larvae) were immersed in the water at different temperatures. Weevils were kept for 12, 24, 48 and 72 hours in a basin filled with tap water at 23°C while they were immersed for 10, 20, and 30 minutes in an oven bath with controlled temperature at 42°, 52° and 62°C.

After the required time, the bags were removed, and the weevils were transferred to a screened paper cup or petri dish for larvae for 12 hours. The number of dead individuals was then recorded. Two hundred individuals in 2 replications were used in the experiment.

Table 39 shows that the adult weevil does not survive long in water at 52°C and 62°C, and dies within 10 minutes of immersion. The insect can withstand immersion for up to 30 minutes in water at 42°C. While at 23°C the insect died after 48 hours of immersion. All the larvae died after 10 minutes in hot and after 12 hours in tap water.

Mortality pattern of weevils buried in soil at different depths

S.K. Hahn, T. Anota

Underground storage may be a cheap and satisfactory method of storing sweet potato and may also reduce the weevil problem. This experiment, therefore, was initiated to study the behavior of weevils buried in soil at different depths.

Meshed nylon bags containing 100 adults were buried at 0, 1, 2, 3, 4, 5, 10, and 20-cm depths. Daily mortality of weevils was monitored by digging out 1 bag from each depth and counting in the laboratory the number of dead insects. Two hundred weevils in 2 replications were used for each depth.

Table 40 shows that quick death occurred mostly in the first 5-cm layer. After 3 days, all the insects kept at soil surface were dead probably because of being directly exposed to the sun. After 5 days, up to 90 percent of the insects in the first 5-cm depth were dead. This could be explained essentially by the high temperature (41.9°C in the afternoon) to which this layer was subjected. At 10, 15 and 20 cm where temperature was quite low (27°C), the insects survived longer, but from the sixth day, the mortality increased considerably up to the eighth day when most of the weevils were dead.

Table 39. Mortality pattern of sweet potato weevil immersed in water at different temperatures.

Av. No. weevil dead[1]	Tap water 23°C Time (hours) 12	24	48	72	Hot water 42°C Time (min) 10	20	30	52°C Time (min) 10	20	30	62°C Time (min) 10	20	30
Adult	0	0	100	100	0	0	0	100	100	100	100	100	100
Larvae	100	100	100	100	100	100	100	100	100	100	100	100	100

[1]Average of 2 replicates.
N = 200

Table 40. Mortality (%) pattern of weevil at different soil depth.

Soil depth (cm)	12 hours	Time (days) 1	2	3	4	5	6	7	8
Soil surface	0	2	35	98.5	100	—	—	—	—
1	0	0	0	97.5	100	—	—	—	—
2	0	0	0	93	100	—	—	—	—
3	0	0	0	61	95.5	100	—	—	—
4	0	0	0	37.5	82.5	100	—	—	—
5	0	0	0	35.5	79.5	98.5	100	—	—
10	0	0	0	3	15.5	30	75.5	100	—
15	0	0	0	2	28.5	68	88	96.5	99.1
20	0	0	0	4	18.5	43.4	80.7	99.8	100

Virology

Sweet potato virus disease (SPVD)

W.H. Rossel

The 2 component nature of the sweet potato virus disease (SPVD) was further investigated by using the single component pre-infected test and indexing clone Tlb8 c19 (IITA Annual Report 1980). Various types of aphid-transmitted components as well as white fly-transmitted components seem to occur. Various isolates of these components express considerably different symptoms when in various combination inoculated to sweet potato.

In order to get an impression of the epidemiology and geographic distribution of the SPVD components in Nigeria, symptomless sweet potato was collected from different regions in the country, Port Harcourt, Enugu, Yandev and Kaduna, and indexed on Tlb8 c19—aphid component pre-infected and on Tlb8 c19—white fly component pre-infected.

In all cases, symptomless sweet potato contained an aphid-transmitted component. On 1 occasion, however, symptomless material collected from a farmer's field near Enugu (eastern Nigeria) indexed positively on both the aphid as well as the white fly component preinfected Tlb8 c19 test plants. Symptomless sweet potato with both components may be considered highly tolerant but only to the prevalent combination of component types and not necessarily to others.

This finding may have implications for the SPVD resistance breeding program since materials selected for resistance to certain component combinations may not be resistant to others.

In further attempts to characterize the white fly vectored agent, host range studies were carried out in order to identify *Ipomoea* species or other test plant species, which would become infected and develop characteristic symptoms with this component. *Ipomoea aquatica*, a common weed species in swampy areas, was found to develop characteristic white vein network symptoms on approach grafting to sweet potato containing both components. No virus particles of the aphid transmitted component (Poty-virus) were seen in this species in the electron microscope. The symptom-showing plants are presently being tested back to the Tlb8 c19 indexing clones in order to find out the component with which it had become infected.

Also, further host range studies were carried out with disease samples from other regions in order to obtain further information as to whether possibly other viruses are occurring in sweet potato in Nigeria.

So far, however, all evidence obtained from survey and virus indexing work indicates that only 1 virus—the aphid-transmitted poty component—occurs widely and possibly in all sweet potato in Nigeria. This virus on its own appears to be fully latent in all genotypes of sweet potato.

SPVD, a result of complex infection of that virus with a white fly vectored agent, may be considered, thus, solely the result of occurrence and infection with the white fly vectored agent. Only with the infections are there the symptoms in sweet potato seen in farmer's fields in all earlier mentioned regions of Nigeria though only at very low incidence.

Indexing for absence of this component in tissue cultured improved sweet potato materials meant for export is very important. Since this component could not be propagated and purified from a suitable host plant so far, a specific antiserum for serological indexing is still lacking. However, indexing for this component by means of approach grafting to aphid component preinfected Tlb8 C19 has proved very reliable. By approach grafting sweet potato to sweet potato, escapes as a result of unsuccessful grafts are extremely rare.

Tissue culture and the distribution of disease-free sweet potato material

E.A. Frison, S.Y.C. Ng

Plants from 58 clones of sweet potato were obtained through meristem and shoot tip culture. Serological Specific Electron Microscopy (SSEM) and graft tests to *I. setosa* provide a very high degree of assurance that the material is virus-free. SSEM considerably reduces the time required for virus indexing.

Of the 58 clones of sweet potato successfully produced from meristem tip culture, 10 have been certified by the Plant Quarantine Officer and phytosanitary certificates issued. During 1981, disease-free sweet potato was distributed to 20 countries throughout the world. Among these countries, 15 are in Africa: Cameroon, Gabon, Gambia, Ghana, Guinea Bissau, Ivory Coast, Kenya, Liberia, Rwanda, Senegal, Seychelles, Sudan, Togo, Uganda and Zanzibar, and 5 are in Asia, Latin America and the Pacific: Indonesia, Taiwan, Argentina, Brazil and Samoa.

Feedback received from 13 countries showed that the success rate of transplanting tissue culture material of sweet potato ranged from 0 to 100 percent.

In addition, 400 clones of sweet potato germplasm are now maintained in tissue culture. With the combinations of a slow growth medium and low temperature, the germplasm can be maintained in the test tubes for 8-24 months depending on the variety.

Screening sweet potato for both source potentials and sink capacities

S.K. Hahn, M.T. Dahniya

In sweet potato, the roots, which accumulate assimilates, are the predominant sink while the shoots, mainly leaves, which produce assimilates are the source. In previous studies, the relationships between source and sink of sweet potato were investigated quantitatively through the use of reciprocal grafts of a set of varieties in all possible combinations, and the responses of source to sink and of sink to source were examined. The varieties with large sink capacities showed greater response of sink to source while the varieties with large source potentials showed greater response of source to sink.

It is easier for a plant breeder to identify, evaluate and select for sink capacity (yield) than for source potential (photosynthetic capacity). In a previous study, test clones were grafted on 4 tester varieties as stock, and source potentials of the test clones were measured by their average scion effects. Sweet potato clones with high source potentials were then selected. In the present study, each of 26 clones of sweet potato was grafted on 1 tester variety, TIS 2498, as both stock and scion as well as the clones were evaluated simultaneously for their source potentials and sink capacities.

The 26 clones included in the advanced yield trials were used as the test clones and the high yielding variety, TIS 2498, was used as the tester variety. To evaluate source potential, each of the test clones as scion was grafted on the tester variety, TIS 2498, as stock. To evaluate sink capacity, the tester variety, TIS 2498, as scion was grafted on each of the test clones as stock. The grafts were planted in the field at 1 m between rows and 50 cm in the row in August and harvested 4 months after planting to screen for source potentials and at 5 months after planting to screen for sink capacities. A randomized complete block design was used with 4 replications. Each plot consisted of 3 plants. Data for the average dry root yield were analyzed. Source potentials and sink capacities of clones were measured by the average scion and average stock effects, respectively, of the test clones.

The source potentials measured by average scion effects of the test clones on yield of the tester variety and the sink capacities measured by average sink effects of the test clones when grafted with the tester variety TIS 2498 as scion and stock are summarized in Table 41. There were significant differences among the source potentials and sink capacities of the tested clones at 5 percent and 1 percent levels, respectively. The source potentials of the clones tested ranged from 35.5 g/plant to 651.3 g/plant, and their sink capacities ranged from 17.9 g/plant to 314.3 g/plant. Clone TIS 70995 showed the largest source potential and was followed by clones TIS 71139, TIS 70209, TIS 71244, TIS 70150 and TIS 70882. Clone TIS 70683 showed the largest sink capacity and was followed by TIS 71102, TIS 70357, TIS 71139, TIS 71104, TIS 70209 and TIS 70150.

The correlation (r) of source potential and sink capacity in sweet potato was estimated for the tested clones, and the relation of source potential and sink capacity with root yield was also estimated. The correlation coefficients were all significant. The multiple regression equation of source potential

Table 41. Screening sweet potato for source potentials and sink capacities.

No.	Lines	Source potential (X_1) (g/plant)	Sink Cap. (X_2) (g/plant)	Dry Yield (Y) (t/ha)
1	TIS 70054	86.3	86.6	3.4
2	TIS 70263	95.8	48.8	1.4
3	TIS 70995	651.3	120.2	3.6
4	TIS 70691	122.6	64.3	2.3
5	TIS 2534	72.3	121.1	—
6	TIS 70388	276.5	147.2	4.5
7	TIS 71354	369.6	136.0	6.2
8	TIS 70683	337.6	314.3	6.2
9	TIS 70399	250.6	130.9	5.9
10	TIS 71307	60.4	17.9	2.7
11	TIS 70882	381.6	132.4	6.9
12	TIS 70357	300.0	202.4	6.4
13	TIS 70209	495.3	175.0	4.7
14	TIS 70150	385.4	173.9	5.3
15	TIS 70189	35.5	44.6	0.9
16	TIS 70314	328.3	99.4	4.7
17	TIS 71139	522.6	197.2	3.2
18	TIS 70297	54.7	92.7	2.1
19	TIS 71244	450.0	150.5	6.7
20	TIS 71104	75.0	175.5	3.1
21	TIS 71102	280.2	248.6	4.6
22	TIS 71202	244.1	71.1	5.0
23	TIS 70906	388.1	167.6	5.1
24	TIS 70799	65.1	143.3	1.5
25	TIS 70163	198.3	25.6	2.9
26	TIb 4	180.5	168.5	4.5
Mean		257.99	132.90	4.25
SE		57.05	48.40	0.55
LSD		160.98	136.57	1.56

(X_1) and sink capacity (X_2) on root yield (Y) was obtained as $Y = 1.7581 + 0.0047\ X_1 \div 0.0086\ X_2$. The R value was 0.6780. This indicates that both source potential and sink capacity significantly affect root yield. The standard partial regression of source potential and sink capacity on root yield was also estimated to find out the effect of source potential and sink capacity on root yield and the relative importance of these in determining yield. Figure 21 shows that the source potential has a standard partial regression coefficient 0.45

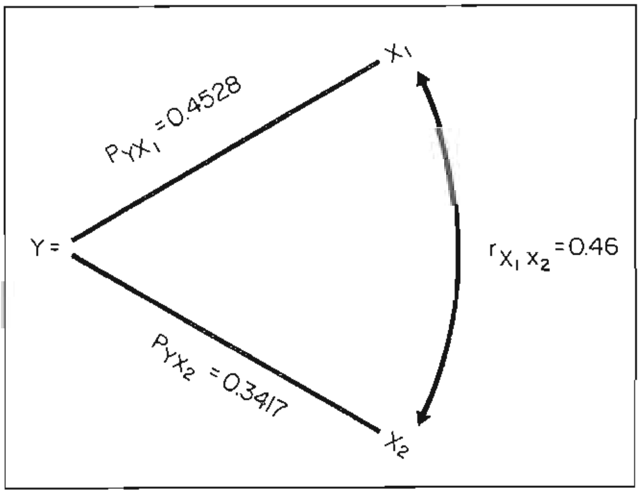


Fig. 21. Source potential against sink capacity.

against that of 0.34 for sink capacity. The standard partial regression coefficients are not significantly different from each other.

Total dry matter yield of sweet potato roots depends on photosynthesis of the leaf canopy, the capacity of the plant to translocate assimilates from the leaf source to the root sink and the capacity of the roots to accept assimilates. Limitations of any of these factors will affect yield.

The results show that both source potential and sink capacity are interdependent and lead to higher root yield. It would be possible to select for both traits at the same time. Selection for sink and source individually could ultimately be misleading. Further progress could be made by selecting sweet potato breeding material for both source potential and sink capacity at the same time in a coordinated way.

The clones with relatively larger source potential, sink capacity and high root yield are TIS 70683, TIS 71354, TIS 70882, TIS 70357, TIS 70150, TIS 71244 and TIS 70906.

The broad sense heritabilities were estimated for source potential and sink capacity as H = 0.50 and H = 0.89, respectively. The heritability estimates are relatively high indicating that selection for source potential and sink capacity individually is possible. Further studies need to be made to know if selection for both traits at the same time is possible.

Cocoyam

Pythium myriotylum has been identified as the principal causal agent in cocoyam root rot complex (CRRBC). The disease has now assumed economic importance, eliminating commercial production in some areas and becoming the most limiting factor in cocoyam production throughout the humid tropics. Cocoyam propagation by vegetative means through the use of corms and cormels has, in the past, restricted genetic variability. However, since flower induction has been established, producing genetic variability is now practicable.

Genetic Improvement

Evaluation of cocoyam clones for CRRBC

M. Alvarez, S.K. Hahn

Several cocoyam lines from seedling crosses between Nigerian and Caribbean collections were grown in a hydromorphic area at IITA. Six months after planting, the lines were subjectively evaluated for visible symptoms of CRRBC. The evaluation was based on a scale of increasing severity from 0 to 5. Nine months after planting, selections from this evaluation were harvested, multiplied and further field and screenhouse testing carried out.

Growing cocoyam under different levels of soil moisture at IITA had a marked influence on cocoyam reaction to CRRBC. The plants were more severely affected when grown under low-elevation, high soil moisture conditions than under high-elevation, low soil moisture conditions.

Cocoyam plants naturally infected with CRRBC developed chlorotic leaves. These leaves show brown blight developing from the periphery and later extending toward the petiole. The petioles droop, the leaves dry up and are shed prematurely. Infected plants remain stunted with necrotic shrivelled leaves.

The root system is greatly reduced due to decay. In advanced stages, the cortical tissue turned brown and disintegrated leaving a nonfunctional vascular skeleton. The corm is usually small and may be brown when cut with little or no cormel formation. The fungi associated with the disease include *Pythium myriotylum, Rhizoctonia solani* and *Fusarium* spp with *P. myriotylum* as the main causal organism.

Figure 22 shows the frequency distribution of plants showing varying degrees of symptoms in a population of seedlings grown in a hydromorphic soil at IITA. Twenty-eight percent of the plants were selected for further evaluation.

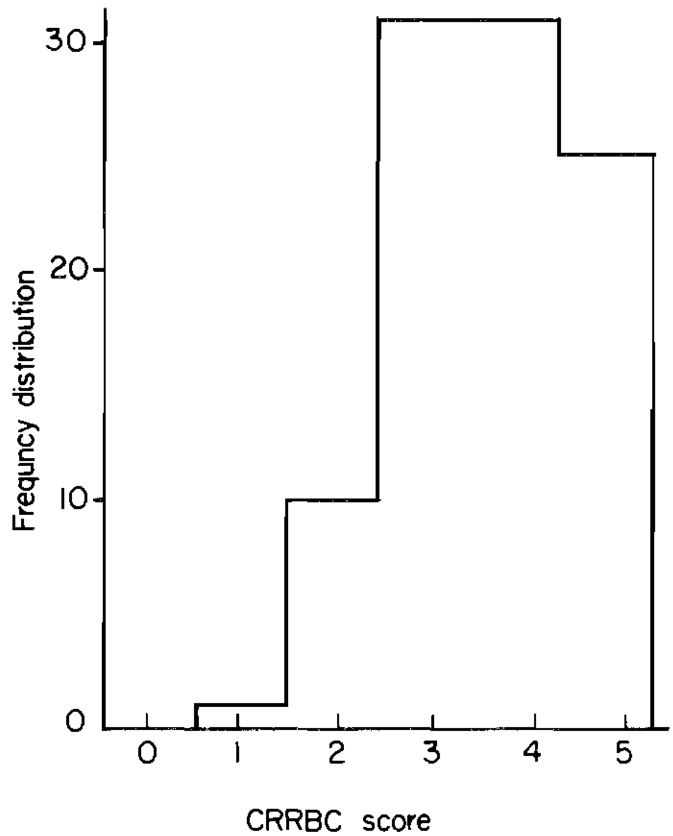


Fig. 22. Distribution of CRRBC score among cocoyam lines.

Varietal trials

M. Alvarez, S.K. Hahn

Sixteen lines were evaluated in an unreplicated intermediate yield trial. The highest yielding clone was not necessarily the one with the highest harvest index (Table 42). Also, 33 lines were evaluated in 3 replications in a preliminary yield trial. Table 43 shows the range, mean and broad sense heritability estimates of various characters of these clones. These estimates imply that improvement by selection can be made for the various traits measured. The correlation coefficient among these traits is shown in Table 44.

Healthy roots of wild yellow type tetraploid cocoyam resistant to CRRBC (left) and susceptible type (right).

Table 42. Variation in yield, harvest index (HI) number of leaves and leaf area per plant among cocoyam lines.

Line	Yield (t/ha)	HI	No. of leaves	Leaf area* per plant (m^2)
XI9-9-287	15.12	.24	5	.74
XI9-9-452	13.86	.20	6	.68
XI9-9-284	11.52	.25	7	1.10
TXS-17	9.72	.19	7	.82
XI9-9-454	9.54	.28	5	.54
XI9-9-281	9.36	.39	7	.74
XI9-9-426	9.00	.22	7	.79
XI9-9-419	9.00	.25	7	1.17
XI9-9-423	8.10	.13	5	.84
XI9-9-453	7.56	.15	5	.75
XI9-9-299	7.38	.22	7	1.03
XI9-9-288	3.78	.19	5	.53
XI9-9-427	3.42	.19	6	.89
XI9-9-429	3.42	.10	7	.85
TXS-18	2.88	.27	7	47
XI9-9-421	2.70	.46	6	.57
Mean	7.87	.23	6.1	.78
SE	3.83	.09	.91	.20

**Leaf area expressed in square meters.*

Crossing cocoyam

M. Alvarez, S.K. Hahn

Seven lines were Pro-Gibbed at the first 3-5 leaf stage with 1,500 ppm gibberellic acid (GA) to induce flowering. When the stigmas were receptive, usually before the pollen shed, they were selfed and cross pollinated reciprocally where possible.

Pollen mother cells (PMC) were stained with acetocarmine for study of microsporogenesis and chromosome counts. Pollen fertility was estimated by establishing the percentage stainable pollen grains in 1 percent acetocarmine. Total

Table 43. Broad sense heritability estimates of measurements taken on 32 cocoyam lines.

Characters	Range	Mean	Heritability 3 plant mean basis
Plant	.33-4.06	2.35	.47
Harvest index	.15-.46	.25	.67
Biological yield	2.0-18.8	9.6	.73
No. of leaves	3-7	5	.63

Table 44. Correlation coefficient among traits in cocoyam.

	BY	PH	NL	HI
Yield	.60*	.31	.28	.54*
Biological yield (BY)	1	.54*	.28	−.24
Plant height (PH)		1	.34	−.19
No. of leaves (NL)			1	.02
Harvest index (HI)				1

**Significant at $P < .05$.*

number of florets per spadix was counted and from a random sample of 25 florets from each spadix the number of seeds per floret or ovary was counted.

The crossing study showed that cross incompatability prevented seed set in some cross pollinations (Table 45). In compatible crosses, many pollen tubes penetrated into the ovarian cavity about 24 hours after pollination. Table 46 shows the mean seed set resulting from crossing and selfing.

Almost all clones had a high percentage of viable pollen (Table 47). One clone, TXS 18, had only 17 percent fertile pollen. In this clone, meiotic division is normal indicating that low pollen viability was not necessarily caused by chromosomal irregularity. Chromosomal counts in PMC confirm that $2n = 26$.

Table 45. Crossing cocoyam lines.

♂	TXS-17	TXS-18	427	422	426	284	418
♀							
TXS 17	+		±	−	−	−	
TXS 18	+				+		
X19-9-427	+		+	−	+	±	
X19-9-422	−		−			−	
X19-9-426	+				+		
X19-9-284			+			+	
X19-9-418	−						

Table 46. Results of clone selfing and crossing.

Clones crossed	Mean seed set	Range	Mean no. of ovarites/spadix
471[1]xTXS 17	14.3	3-33	413
426xTXS 17	7.1	1-18	209
TXS 17x426	7.9	2-16	411
TXS 18xTXS 17	9.8	5-14	204
427x418	7.4	2-20	98
TXS 17 (x)	3.8	0-13	305
427 (x)	4.8	1-10	85
426 (x)	6.1	3-10	—
427x426	7.9	1-17	433

[1]*Except for TXS 17 and 18 all clone numbers are preceeded by X19-9-*

Table 47. Percentage stainable pollen of *X. sagittifolium*.

Clone #	Stainable pollen %
TXS 17	86
TXS 18	17.5
X19-9-418	76
X19-9-422	79.5
X19-9-426	71.7
X19-9-427	93.7
X19-9-284	89.4

Agronomy

H.J. Pfeiffer

Agronomic trials were planted in the Njombe, Hondole and Mbomhomo in Cameroon regions to determine the cultural practices that slow down CRRBC.

SPACING. Foliar symptoms of the disease were reduced by wider spacing, 1.5 m or more, compared to closer spacing. Cormel yields were identical in the 1 x 1.5 m and 1.5 x 1.5 m spacing despite the very high disease incidence from July onward.

INTERCROPPING. During 1980-81, cocoyam and taro (*Colocasia* spp.) were intercropped. CRRBC is specific to cocoyam so that taro could be used as a barrier. Two trials were laid out in the highly infected area of Hondole (1980-81) and 1 trial in the lightly infected area of Mbankomo (1980) in randomized complete block designs with 4 replications for each trial.

No significant differences were observed either for the cormel yield of white cocoyam per plant or the combined cocoyam and taro cormel yield per unit area in Hondole or Mbankomo. Only total cormel yield at Hondole in 1981 was significantly higher in the cocoyam/taro treatment because of excellent taro production.

The more resistant red cocoyam was no more effective than the resistant taro in slowing the spread of the disease. Wider spacings between cocoyam (2 x 2 m) in Treatment 6 did not have any positive effect.

PLANTING TIME AND TYPE OF PLANTING MATERIAL. In the past, the disease incidence increased drastically in August at Hondole. Therefore, trials were planted early to overcome the disease incidence which was especially severe on weak plants.

Planting was done every 2 weeks from mid-March to May. Big corm heads (±700 g) and big medium parts (±700 g) were planted in a randomized complete block design with 6 replications. A spacing of 1 x 1 m was used, and plant development was recorded monthly. Table 48 shows the mean cormel yield and type of planting material used. Leaf area is reported for June, July, August, September and October.

The second treatment was low yielding because of a severe dry period at the end of March which led to a bad start. Early planting gave signifiantly higher yields for each type of planting material used. Disease incidence was at a lower level in the well developed, early planted crops. The mean cormel yield from corm heads was significantly higher than the yield obtained from the middle parts of the corms.

From the disease area at Hondole, 5 different types of planting material were selected to study how *Myriotylum*, the causal agent of the CRRBC, is carried by planting material or present on the remaining plants in the soil. Even after a 10-year fallow, cocoyam plants will emerge after clearing and burning.

Half of each selection was pregerminated in the dry season in a swampy location. Planting was done at the end of March at a spacing of 1 x 1 m in a randomized complete block design with 6 replications.

The yield of cormel harvested in mid-December and the corresponding leaf area per plant in June, July, August, September and October are shown in Table 49. Development of the number of leaves per plant is presented in Figure 23. Pregerminating cormels in the dry season depressed the yield significantly ($P = 0.05$). Aerial plant development during the early season as well as general plant vigor were lower than for the nonpregerminated planting material.

Corm heads produced higher yields than the 3 middle parts of the corm, but the weight of the planting material did not

Table 48. Time of planting effect on mean cormel yield.

Time of Planting / Planting Material		13/3/81	27/3/81	9/4/81	22/4/81	7/5/81	Mean
Corm Heads Cormel Yield (t/ha)		3.73	1.44	3.69	1.78	0.48	2.22 a
Corm Medium Parts Cormel Yield (t/ha)		3.11	1.82	1.56	0.86	0.17	1.50 b
Mean Cormel Yield (t/ha)		3.42 b	1.63 a	2.63 a	1.32 a	0.33 a	
	June	6.9	4.1	3.5	2.2	0.9	3.5
	July	5.7	5.0	4.7	4.0	1.4	4.2
Mean Leaf Area	Aug.	4.6	4.5	4.8	3.8	1.9	3.9
per Plant	Sept.	2.9	2.5	3.2	2.7	1.7	2.6
	Oct.	1.9	1.7	2.6	2.0	1.2	1.9

Mean leaf area per plant by 2 types of planting material (t/ha). Figures followed by the same letters are not significantly different at 0.05 level (Newman-Keuls Test).

Table 49. Cormel yield (t/ha) and leaf area corresponding to the number of large leaves per plant of different planting materials.

Material	Corm Heads (700g)	Corm Med. parts (700g)	Corm Heads (350g)	Corm Med. parts (350g)	Cormels (100g)	Corm Heads (700g)	Corm Med. parts (700g)	Corm Heads (350g)	Corm Med. parts (350g)	Cormels (100g)
Cormel Yield (t/ha)	1.57 a	0.29 a	1.68 a	0.50 a	8.02 b	1.68 a	0.14 a	1.78 a	0.22 a	1.01 a
Leaf Area										
June	5.9	2.7	5.7	2.5	3.9	2.6	1.8	3.3	1.2	0.7
July	4.2	3.0	3.6	2.6	6.5	2.4	1.6	2.3	1.0	1.0
August	4.2	5.2	3.4	2.8	6.3	2.5	2.1	2.6	1.1	1.1
September	3.3	2.2	1.7	1.6	4.9	2.0	1.1	1.7	0.6	0.6
October	1.9	1.3	1.4	1.3	4.3	1.7	0.9	1.3	0.4	0.7

Figures followed by the same letters are not significantly different at 0.05 level (Newman-Keuls).

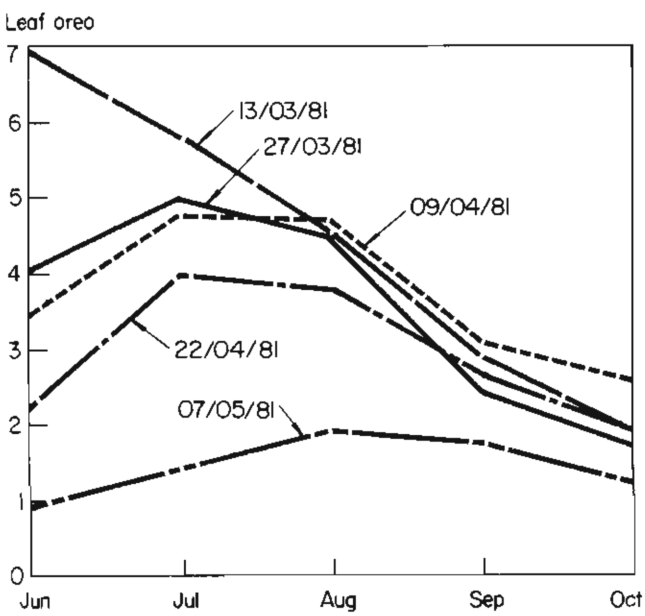


Fig. 23. Effect of time of planting on the average leaf area as number of large leaves per plant.

have significant influence on the final cormel yield in both types of planting material. Nonpregerminated cormels produced a significantly higher cormel yield. This planting material, despite slower growth at the start compared to the corm heads, maintained a high number of leaves per plant up to the end of the season and effectively survived the heaviest attack period (Fig. 24).

N.P.K. FERTILIZATION. A factorial NPK trial at 3 levels in 4 replications was laid out in a newly cleared 10-year old fallow. Plots of 30m^2 were planted at the end of March and fertilized as shown in Table 50 at mid-June. No significant differences could be observed at any level since the disease was spreading out from spots within the field. No treatment significantly altered the disease incidence.

PHYTOSANITARY MEASURES. No insecticide (Hondole 1979-80), nematicide (Nyombe 1980, Hondole 1979-80) or antibiotic (Nyombe 1979-80) has been found to have any effect on the development of the disease. A systemic fungicide (Ridomil) was found effective against root rot in Hondole in 1979-80 at 1 g/plant/2 weeks. Lower application rates and longer periods were tried in 1980-81 to reduce application costs and toxicity risks. The different treatments and cormel yields are shown in Table 51.

No significant differences could be observed between "diseased" and "disease-free" planting material in this highly infested plot (2 crops in 2 years). Also, planting material from the "disease-free" area produced significantly higher cormel yield during the first year.

Differences between treatments were significant at the 0.001 level. A comparison of means shows that the 1 g/plant/2-week treatment is best. Reducing the application dose or lengthening the application period would cause significant cormel yield reduction. Ridomil seems to have a curative and preventive effect against root rot at 1 g/m^2/15 days of application in this highly infested area. At the current prices and with the distribution difficulties, no farmer can afford to use this chemical.

Treatment 8 has to be considered with care since it was located on soil which had a Ridomil treatment and probably benefitted from less infection. Severe phytotoxicity symptoms on the plants from treatments 2 and 8 and treatments 3 and 4 sometimes showed medium or low symptoms.

Galben, another systemic fungicide from the same family, was tried in an observation trial at a 1 g/m^2/15 days. This fungicide did not have any effect at all.

Table 50. NPK fertilization levels and type of fertilizer used.

Treatment	Rate of application (kg/ha) 1	2	3	Fertilizer used
N	0	60	120	Urea
P	0	60	120	Bicalcic phosphate
K	0	90	180	Potassium chloride

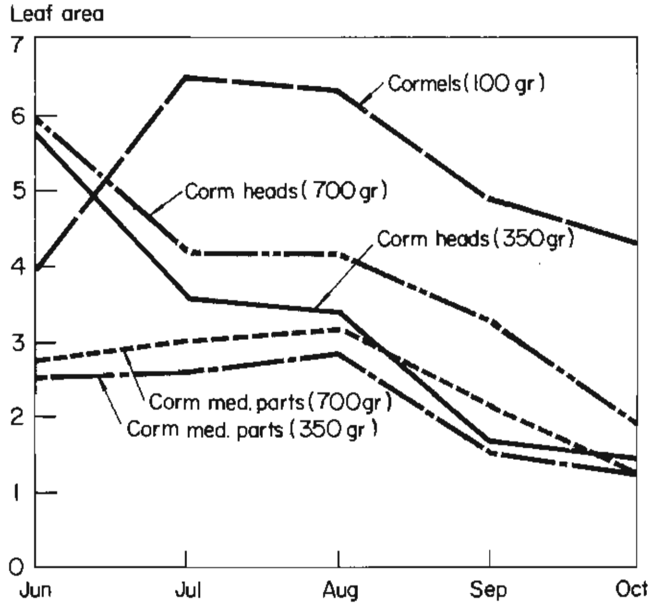


Fig. 24. Leaf area evolution for different types of non-pregerminated planting material.

Table 51. Ridomil treatments and corresponding cormal yields (kg per plot of 20m^2).

Treatment: Dose gr/m^2	Period in days	"Disease free" planting material: Cormel yield (kg/20m^2)	"Diseased" planting material: Cormel yield (kg/20m^2)	Mean: Cormel yield (t/ha)
—	—	0.40 a	0.15 a	0.14 a
1.0	15	6.45 b	6.58 c	3.26 d
1.0	30	3.15 ab	3.08 ab	1.56 bc
1.0	60	2.71 ab	3.00 ab	1.43 bc
0.5	15	3.2 ab	2.44 ab	1.41 bc
0.5	30	2.05 a	1.39 a	0.86 ab
0.5	60	1.95 a	1.40 a	0.84 ab
1 gr	End of June +	4.45 ab	5.38 bc	2.46 cd
0.5	60			

Beginning of application : End of June
End of application: End of October
Mean results of 4 replications.
Figures followed by the same letter are not significantly different at 0.05 level (Test Newman-Keuls).

Cereal Improvement Program

Introduction

IITA has, since its earliest days, included work on maize and rice, 2 of the most important cereal crops in Africa. The demand for both maize and rice is increasing continuously. Maize is the basic staple food in many parts of the continent. It is also used widely as animal feed, especially in the expanding poultry industries. Rice is not grown yet in large areas but the demand is increasing in the urbanized areas.

The major emphasis of the Cereal Improvement Program is to develop stable, high yielding, consumer acceptable maize and rice varieties with resistance to diseases and insects. IITA scientists are seeking solutions to problems such as maize streak virus (MSV), downy mildew, stem borers and drought in maize and blast, panicle discoloration, rice yellow mottle virus (RYMV), Fe toxicity and drought in rice.

Improved germplasm developed by other International Institutes such as the Centro International de Mejoramiento de Maiz Y Trigo (CIMMYT), International Rice Research Institute (IRRI), as well as the Institut de Recherches Agronomiques Tropical (IRAT), is being widely used by this program. All the 3 institutes have posted scientists with IITA who are actively participating in the program's research efforts.

IITA scientists also execute the regional maize program of the Semi-Arid Food Grains Research and Development Project (SAFGRAD) and participate in the international rice program of the West Africa Rice Development Association (WARDA). An IITA scientist is posted with WARDA in Liberia.

The program also cooperates directly with national programs by sending breeding materials and experimental varieties for testing, upon request. Two new rice varieties, FARO 26 (TOs 78) and FARO (TOs 103), have been officially released in Nigeria as a result of this cooperation. Encouraging results were obtained in 1981 by testing the newly developed experimental rice varieties in Nigeria and several other West African countries, as well as in Brazil and Panama.

Multilocational full-sib family trials of late-maturing white and yellow streak-resistant populations were initiated with maize. Six different countries in Africa participated in the testing program, and a number of streak-resistant experimental varieties were developed. A late maturing streak-resistant experimental variety trial will be conducted throughout Africa during 1982. IITA scientists also participated in the USAID-supported National Cereal Research and Extension project (NCRE) in Cameroon, which was started toward the end of 1981.

Maize

The major objective of the maize improvement program is to develop stable, high yielding varieties adapted to the different ecologies in Africa. The main emphasis is on varietal stability through resistance breeding for the major diseases and insect pests in Africa. Population improvement combined with multilocational testing and, when possible, artificial infesting and screening techniques, are used as major breeding strategies. Resistance breeding for MSV was emphasized during 1981 as in previous years.

Research is being done also on hybrid maize. The major objective is to develop inbred lines adapted to the tropics, resistant to major diseases and insect pests, with good vigor and combining ability. The lines will be available to national programs upon request.

Genetic Improvement

International testing of TZSR-W-1 and TZSR-Y-1

M. Bjarnason, Y. Efron, S.K. Kim, J. Singh

TZSR-W-1 and TZSR-Y-1 are 2 newly developed populations with good levels of streak resistance. In 1980, about 380 half-sib families from each population were yield tested at 5 locations in Nigeria. Fifty families from each population were selected for a new cycle of selection and planted in the 1980 third season. These families were recombined by developing 250 full-sibs through reciprocal plant to plant crosses among the families.

The 250 full-sibs were yield tested along with 6 local checks in 6 different countries in West Africa, using a 16 x 16 simple lattice design with 2 replications. The cooperating countries were Benin, Cameroon, Ghana, Ivory Coast, Nigeria and Upper Volta. Table 1 outlines the future steps to improve these populations.

Table 1. Maize breeding sequence in population improvement of TZSR-W-1 and TZSR-Y-1.

Season						
	Within-family improvement (S.) *streak pressure*					
81 III	Make selfs in about 75 across site selected F.S. families. Save 3 selfs from each selected family.					
	Family improvement and recombination (H.S.) *streak pressure*					
82 I	Plant 210-240 sub-families. Select one or two best sub-families from each selected F. S. family. Select best plants from each selected sub family and bulk pollinate. Save about 240 H. S. ears.					
	Progeny regeneration (F.S.) *streak pressure*					
82 II	Plant 240 half sibs. Make reciprocal plant to plant crosses to generate 250 F.S. families for second cycle of improvement.					
	Progeny trials (250 F.S. with 6 checks) No artificial streak pressure					
83 I	Loc. 1	Loc. 2	Loc. 3	Loc. 4	Loc. 5	Loc. 6

Seed multiplication at IITA of the late-maturing, streak-resistant maize variety, TZSR-W-1, for the Nigerian Green Revolution project.

Between 8 and 12 families were selected for the formation of of an experimental variety in cooperation with the national breeders at each location. The results from 3 locations were obtained early enough so that these families could be planted from remnant seed in the 1981 third season. The performance of the selected families is shown in Tables 2 and 3. They were 28-47 percent higher yielding than the population mean, similar in days to 50 percent silking to the population mean, and superior in root lodging tolerance to the population mean. Most selections were somewhat taller than the population mean. These families were screened for streak resistance, and resistant plants were recombined. They will be tested in Africa in variety trials during 1982.

The data from all the locations where the trials were successfully grown are being analyzed in a combined analysis to select families for the next cycle of recombination and develop an experimental variety based on across site data. The selected families will undergo family improvement for streak resistance and agronomic characters before recombination.

Population improvement

S. K. Kim, J. Fajemisin, Y. Efron

Two maize varieties, TZB and TZPB, developed by IITA are presently grown widely in Nigeria and also, to some extent, in neighboring countries in West Africa. In Nigeria, TZB is named FARZ 34. TZPB is named FARZ 27. TZPB is well adapted to the forest areas in Benin, Cameroon, Gabon, Nigeria and Sierra Leone. TZB is well adapted to the savanna areas. Approximately 80 percent of the maize grown in the savanna of Nigeria is TZB. Small farmers as well as commerical farmers with up to 1,000 hectares are adopting this variety.

Although TZB and TZPB have been subjected to several cycles of population improvement, they still show wide genetic diversity for flowering date, plant height and ear height. It was observed that the root system of TZB is rather poor, and the plants are liable to lodging. Recently family testing trials were conducted in the populations at different ecological zones to extract some uniform experimental varieties composed of a limited number of selected families in each location.

TZB. At 2 savanna locations in Nigeria, Gusau and Mokwa, 250 half-sib families were tested with 3 replications of single row plots, 5 m long. Since TZB is segregating for grain texture, 10 families were selected for the development of experimental varieties for each of the flint and semi-flint types. Table 4 shows grain yield at 15 percent moisture content of the selected 10 families in Mokwa. Mean yield of the selected families was 7.5 t/ha, 45 percent higher than the population mean. The same 250 half-sib families with a check variety at every 20 rows were tested at Gusau (Table 5). Mean yield of the selected 10 families was 5.4 t/ha, 38 percent higher than the population mean. As noticed previously, the yield of TZB was better than TZPB at Gusau.

The 5 experimental varieties (2 from Mokwa, 2 from Gusau and 1 from Across) will be tested at several different locations in the savanna zone in 1982. Based on the results of these trials, the best varieties will be further tested and

Table 4. Grain yield (t/ha) and agronomic traits of the selected TZB semi-flint maize families from Mokwa (1981).

Family	Yield (15% moist)	% Pop. mean	Rank	Plants harv.	Moist % at harv.	Ear aspect (1-5)
4	6.7	130	25	13	29	1.8
17	5.8	112	84	12	30	2.1
39	7.0	135	11	13	26	1.9
44	6.6	127	30	14	29	1.7
52	9.2	177	1	15	24	1.8
95	8.3	160	4	15	23	1.8
105	8.0	154	6	12	29	1.8
132	8.7	167	2	18	28	1.8
150	5.9	132	17	13	27	1.6
246	8.2	159	5	16	30	1.5
Sel. mean	7.5	145	—	13	28	1.8
Pop. mean	5.2	100	—	10	27	2.1
Check mean (TZPB)	4.7	90	—	10	29	2.4
LSD (.05)	1.19			2.53		0.37

Table 2. Performance of maize families from TZSR-W-1 selected for experimental variety formation at 3 locations in West Africa.

	Yield			Difference to pop. x̄ in:				
Country/Location	t/ha	rel. to pop. x̄(%)	rel. to best check (%)	DS	PH (cm)	EH (cm)	RL (%)	CV (yield)
Benin/Sekou	6.1	133	174	0	+6	+5	− 4.3	18.0
Ivory Coast/Ferke	7.3	128	124	0	+2	0	− 0.4	14.1
Nigeria/Ikenne	6.1	130	102	0	+7	+3	−15.0	16.9

DS: Days to 50% silking; PH: Plant height; EH: Ear height; RL: Root lodging; CV.: Coefficient of variation.

Table 3. Performance of maize families from TZSR-Y-1 selected for experimental variety formation at 3 locations in West Africa.

	Yield			Difference to pop. x̄ in:				
Country/Location	t/ha	% to pop. x̄	% to best check	DS	PH (cm)	EH (cm)	RL (%)	CV (yield)
Ivory Coast/Ferke	7.1	143	114	0	+14	+12	+ 7	22.5
Nigeria/Ikenne	6.0	143	88	−1	+ 3	− 2	−11	17.8
Upper Volta/Farako-Ba	9.3	147	123	−1	+15	+ 7	− 4	25.8

DS: Days to 50% silking; PH: Plant height; EH: Ear height; RL: Root lodging; CV: Coefficient of variation.

if proved to be adapted, then seed will be multiplied for distribution.

TZPB. At Onne, 250 half-sib families were tested in acid and lime strip soils. Details of the strips were described in the 1980 Annual Report.

Twelve families tolerant of acidity were selected for the formation of an experimental variety. Grain yields and fresh plant weights of the selected families compared to the TZPB check bulk planted in every 20 rows are summarized in Table 6. Mean yield of the selected families grown in the lime strip was 4.0 t/ha, 67 percent higher than the mean of the same families in the acid strip but only 4 percent higher than the mean of the check (TZPB) in the lime strip. Mean of fresh plant weight of the selected families was higher in the lime strip (12.2 t/ha) than in the acid strip (9.2 t/ha).

Plant height and days to silk (flowering) of the selected TZPB families are also presented. Mean plant height of the selected 12 families in the lime strip was 212 cm compared to 182 cm in the acid strip.

Difference of days to silk between means of selected families from the acid and lime strips was 4 days compared to 7 days of difference between TZPB (check) when grown in the 2 strips. This indicates that some of the selected families were tolerating the acid conditions and having almost normal growth development.

The same 250 half-sib families of TZPB were also tested at Suakoko, Liberia. Twelve families were selected and grown during the 1981 dry season for the formation of an experimental variety.

In 1982, these 2 experimental varieties (1 from Onne and 1 from Liberia) will be tested in international testing trials in Africa.

TZUT. The major objective of TZUT (US x tropical) is to transfer the efficient agronomic characteristics of the U.S. corn belt material into tropical varieties with relatively high levels of disease resistance to *Puccinia polysora* and *Helminthosporium maydis*. Two hundred and fifty full-sib families were tested at 4 locations in Nigeria: Gusau, Ikenne, Ilorin and Mokwa. Three replications were used in all locations, except Mokwa where only one replication was used because of land shortage.

Table 5. Grain yield and agronomic traits of the selected TZB semi-flint maize families from Gusau (1981).

Family	Yield* t/ha (15% moist)	% Pop mean	Rank	Days silk	Ear ht.	Plants harv.	Moist % at harv.	Ear aspect (1-5)
16	6.6	168	3	64	107	16	26	1.9
50	5.7	144	6	61	95	15	30	2.1
86	6.8	173	1	65	117	16	21	1.8
99	5.2	133	13	62	92	17	28	2.0
102	4.5	115	56	63	83	14	29	1.9
103	5.2	133	12	62	90	14	20	2.0
119	5.4	138	9	61	98	17	31	2.2
135	5.0	128	25	66	82	17	26	1.9
144	5.0	127	29	62	100	14	26	1.8
166	4.7	121	41	61	85	18	23	1.8
Sel. mean	5.4	138	—	63	95	16	27	1.9
Pop. mean	3.9	100	—	64	93	12	26	2.2
Check mean (TZPB)	3.4	87	—	66	95	13	26	2.5
LSD (.05)	0.8	—		3.6	22.7	1.9	0.8	0.3

Relatively high selection intensity was used. Twenty-two families out of 250 were selected commonly from both Ikenne (forest) and Ilorin (derived savanna) and designated as south selections (S). Only 16 families with high yield and hard kernels were selected commonly from Gusau (savanna) and Mokwa (savanna) and called northern selections (N). Mean yields of TZUT population (250 families) at Ikenne and Ilorin were 5.2 and 5.5 t/ha (15% moisture), respectively (Table 7). Differences among families were significant for yield at the 5-percent level. Mean yields of the selected families were 16 and 25 percent higher than their population means.

Yields were slightly higher at Ilorin than Ikenne. In Gusau and Mokwa, the mean yield of the population (4.1 t/ha) was not significantly different from the check, TZE_4. However, mean yield of the selected 16 families (5.3 t/ha) was significantly higher than the check (2.9 t/ha), and it was 29 percent higher than the population mean. Remnant seeds of the selected 36 families (22S and 16N) were planted at IITA during the 1981 dry season, and about 40-50 plants were

Table 6. Grain yield, fresh plant weight (t/ha) and agronomic trials of the selected maize families from TZPB grown in lime and acid strips (Onne, 1981).

Family	Grain yield		Fresh plant weight		Plant height (cm)		Days to silk	
	Lime	Acid	Lime	Acid	Lime	Acid	Lime	Acid
50	4.7	1.7	10.9	7.5	188	163	60	66
65	4.1	2.8	14.1	10.1	220	165	57	60
93	4.3	1.9	13.3	8.0	187	163	56	63
143	5.1	3.6	12.8	10.7	225	198	57	62
148	3.6	1.3	10.7	8.5	218	178	58	62
151	3.8	3.0	10.7	8.5	225	183	58	60
176	3.4	2.3	13.6	7.7	208	118	56	61
179	4.1	2.3	13.3	10.7	215	228	57	60
207	2.8	1.9	10.7	6.9	234	180	58	63
211	4.3	3.0	10.7	10.4	200	198	55	59
219	3.4	2.6	13.1	13.1	203	205	57	58
223	2.8	2.3	12.3	8.0	215	210	56	60
Mean	4.0	2.4	12.2	9.2	212	182	57	61
TZPB (check)	2.6	1.3	9.9	4.5	206	174	57	63
LSD (.05)	0.6	0.7	1.7	2.5	11	23	2	12

Table 7. Summary of TZUT family testing (1981).

	South		North	
	Ikenne	Ilorin	Gusau	Mokwa
No. families tested	250	250	250	
No. selected families	22*	22*	16	
Selected fam. mean (t/ha)	6.2	6.9	5.3	
Range of selected fam. (t/ha)	7.1-4.3	9.0-5.1	6.1-4.4	
Population mean (t/ha)	5.2	5.5	4.1	
Check mean (t/ha)	3.4	2.8	2.9	

Selected families (south) were common across Ikenne and Ilorin.

selfed from each family. The purpose of selfing is to separate grain color into white and yellow.

Bulk seed of TZUT was also tested at 5 locations in Nigeria and 15 locations in the SAFGRAD countries in 1981. In Nigeria, yield of the TZUT was the top of the early-medium maturing varieties (34 percent higher than the TZE_4 check. In the SAFGRAD countries, TZUT was also the top yielding variety (3.3 t/ha) in RUVT-1 trials.

In conclusion, medium-maturing (100 days), high-yielding, white and yellow maize varieties with disease resistance and good agronomic characteristics are expected to be developed from this TZUT population. International testing trials of TZUT full-sib families will be proposed for 1983.

Line development

S. K. Kim, J. Fajemisin, Y. Efron

Although there is a considerable area under hybrid maize production in East and Central Africa, notably Kenya, Malawi, Zambia and Zimbabwe, there has been little effort to develop hybrids for the West African lowland areas. Lack of adapted lines, particularly those with reliable resistance to the prevailing diseases and pests, is a major restraint in initiating and/or strengthening the hybrid maize program at the national level. Such lines can also be used for population improvement. During 1981, attempts were made to advance and classify available inbred lines according to maturity (late vs. early), grain color (white vs. yellow) and grain texture (dent vs. flint).

Approximately 2,000 S_3 lines were advanced into the next generation during 1981 with special emphasis for resistance to streak, blight, and rust (Table 8). New introductions were also made to diversify the germplasm base. Most segregating families were planted in an ear-to-row basis, and the 5-8 best plants in each row were selected and selfed.

During the dry season, test crosses were made between selected lines and open-pollinated counterparts of different grain textures for higher hybrid vigor, e.g., dent line x flint variety. Selected late, white dent lines were test-crossed to a late, white flint variety, TZB, while selected late, white flint lines were test-crossed to a late, white dent variety, Poza Rica 7843. An average of 10 individual plants of the open-pollinated variety were crossed with a bulk pollen from 5-8 plants of the selected lines. At the same time, 5-8 selected plants in each line were selfed for the next generation. Line selection was made under severe streak infestation.

Test crosses were also made for yellow lines: selected yellow dent lines were test-crossed to a semi-flint, streak-resistant variety, TZSR-Y-1, while yellow flint lines were test-crossed to a yellow dent variety, Milo Maya Brazil.

Table 8. Number of maize S_3 lines from different maturity, grain texture, and their respective testers (1981).

Maturity	Grain color/ texture	No. of S_3 lines	Tester
Late	White dent	560	TZB
	White flint	96	Poza Rica 7843
	Yellow dent	232	TZSR-Y-1
	Yellow flint	32	Milo Maya Brazil
Early	White dent	140	Pop. 30
	White flint	160	Pool 16
	Yellow dent	96	Poza Rica 7931
	Yellow flint	50	TZESR-Y
Streak & Downy Mildew resistance		96	Pop. 49
Streak, rust & blight resistance		280	Pop. 49, TZESR-Y
Total		1,742	

Similar attempts were made for the early-maturing lines, both white and yellow grain color with 2 different grain textures.

Significant progress was made in the development of lines resistant to both MSV and downy mildew. The segregating lines were screened for downy mildew at Owo and for MSV at IITA. Another set of multiple resistance was to combine resistant genes against MSV, *Puccinia polysora* and *Helminthosporium maydis*. White lines were test-crossed to Population 49 from CIMMYT and yellow lines to TZESR-Y. Visual selection for rust and blight under artificial disease infection, plant vigor, lodging tolerance, etc., can be done prior to test crossing at the S_3 stage. Major selection criteria in maize line development programs are listed in Table 9.

Table 9: Major selection criteria in maize line development program.

Combining ability	GCA (early generations) SCA (late generations)
Disease resistance	Streak, *Polysora maydis*, ear rot, etc.
Plant vigor	*1*, 2, 3, 4, 5
Uniformity	*1*, 2, 3, 4, 5
Pollen production ability	*1*, 2, 3, 4, 5
Silk emergence, nicking (low barreness)	*1*, 2, 3, 4, 5
Stalk & root lodging tolerance	*1*, 2, 3, 4, 5
Ear aspect	*1*, 2, 3, 4, 5
No. of kernels	Over 200.

*Rating: 1 = good; 5 = bad.

Variety yield trials

S. K. Kim, Y. Efron, J. Fajemisin

The yield trials consisted of 3 sequential types: elite, advanced and preliminary trials. Within each type, there were 2 variety trials of different maturities, late (120 days) and early (90-100 days). In the elite yield trials, 4 open-pollinated varieties and 3 elite top-crosses (for each of late and early maturities) were tested at 5 locations of 6-row plots.

In the advanced yield trials, 35 varieties of late maturity and 20 varieties of early maturity, including top-crosses, were tested at 4 locations with 4 replications of 4-row plots. In the preliminary yield trials, 50 varieties of late maturity and 50 varieties of early maturity, including top-crosses, were tested at 2 locations with 3 replications of single-row plots.

Grain yields of the late maturing elite yield trial at 5 locations are summarized in Table 10. In the forest zone (IITA and Ikenne), yields of TZPB (4.1 t/ha at 15% moisture) and Poza Rica 7843 (3.9 t/ha) were significantly higher than 4 other varieties tested. However, in the savanna zone (Gusau, Ilorin and Mokwa), there were no significant differences among varieties. Average grain yields of TZSR-W-1 and TZSR-Y-1 were similar to the TZPB check in the savanna zone. Poza Rica 7843 scored better than any other varieties in root and stalk lodging tolerance. Except for Gusau, all other yield trials might have been affected by the heavy incidence of lodging. Planting was delayed for 1 month at IITA and Ikenne due to late seed production.

In the future, more emphasis will be given to the improvement of root and stalk lodging tolerance.

Grain yields of the early maturing elite yield trial at 5 locations are summarized in Table 11. In the forest zone, yields of 2 top-crosses, TZE_4 x 95 (4.0 t/ha) and TZE_{17} x 95 (3.9 t/ha), were significantly higher than the TZE_4 check. In the savanna zone, yields of the same 2 top-crosses and TZUT (5.9 t/ha) were significantly higher than the TZE_4 check. Average yield of TZUT across 5 locations in the previous year was 42 percent higher than TZE_4.

Table 11. Grain yield (t/ha at 15% moisture) of early maize varieties from elite yield trial (1981).

	Forest			Savanna			
Pedigree	Ibadan	Ikenne	Mean	Ilorin	Mokwa	Gusau	Mean
TZUT	4.3	2.7	3.5	6.0	6.0	5.6	5.9
Sps	4.6	2.6	3.6	5.5	5.1	4.1	4.9
Poza Rica 7930	4.4	2.4	3.4	5.8	4.5	4.3	4.9
TZE_4 (check)	3.8	2.0	2.9	5.0	3.5	3.8	4.1
TZE_4 x 174	4.4	2.7	3.6	5.5	5.2	4.1	4.9
TZE_4 x 95	4.9	3.0	4.0	6.3	4.7	4.5	5.2
TZE_{17} x 95	4.8	2.9	3.9	5.4	5.7	5.0	5.4
LSD (.05)	0.5	0.4	0.5	0.8	1.0	0.7	0.8

Results of the advanced yield trials for the late and early maturing open pollinated varieties and 5 top-crosses are summarized in Tables 12 and 13, respectively. Yields in the forest zone were significantly lower than in the savanna. For the late maturing trial, TZSR-W x 189, TZSR-W x 95, TZPB and TZB gave the highest average yields in the forest zone while 105 x 95, TZB, TZPB x 279 and TZSR-W x 95 gave the highest average yields at the 3 locations in the savanna zone.

For the early maturing trial, TZUT x 276, TZE_3 x 95, TZE_4 x 276 and TZE_3 x 174 were the highest yielding entries in the forest zone while TZE_3 x 174, TZE_3 x 95, TZUT x 276 and TZE_{17} were the highest yielding entries in the savanna zone.

Table 12. Grain Yield (t/ha at 15% moisture) of late maize varieties from advanced yield trial (1981).

	Forest	Savanna			
Pedigree	Ikenne	Ilorin	Mokwa	Gusau	Mean
105 × 95	3.3	7.0	6.2	5.4	6.2
TZB	3.5	6.4	6.9	4.9	6.1
TZPB × 279	3.6	5.7	6.4	5.8	6.0
TZSR-W × 95	3.8	6.0	6.5	4.8	5.8
Across 7729	2.8	5.9	6.0	5.2	5.7
TZB × 168	3.6	6.2	4.9	5.3	5.5
La Maquina 7843	3.4	5.2	5.9	5.0	5.4
Western Yellow	2.9	5.9	5.4	4.5	5.3
Ferke (1) 7622	3.1	5.1	6.7	4.0	5.3
TZSR-W × 189	3.9	6.0	5.3	4.7	5.3
Across 7728	2.9	4.9	5.7	4.4	5.0
TZPB	3.5	5.4	5.2	3.9	4.8
Sn. Andres 7823	2.8	4.8	4.1	5.5	4.8

Table 13. Grain yield (t/ha) of 10 early maize varieties from advanced yield trial (1981).

	Forest	Savanna			
Pedigree	Ikenne	Ilorin	Mokwa	Gusau	Mean
TZE_3 × 174	3.4	5.7	5.0	5.2	5.3
TZE_3 × 95	3.8	6.2	5.0	4.2	5.1
TZE_{17}	2.9	5.7	4.9	3.6	4.7
TZUT × 276	3.9	6.1	3.9	4.1	4.7
TZE_4 × 276	3.7	6.2	4.2	3.4	4.6
TZESR-W	2.8	5.2	4.9	3.1	4.4
TZESR-Y	2.4	4.6	5.0	3.2	4.3
TZE_3 × 276	3.3	5.9	4.6	2.5	4.3
TZE_{14}	3.0	4.8	3.6	3.8	4.1
Suwan 7726	2.9	5.5	2.9	3.9	4.1
Pool 16	2.6	4.6	2.8	4.3	4.0
TZE_4	2.3	5.3	3.3	3.0	3.9
Ferke (2) 7635	2.7	5.1	3.5	3.0	3.9
Tocumen 7835	2.9	4.7	2.8	3.0	3.5
Poza Rica 7931	2.2	3.8	3.1	2.4	3.1
LSD (.05)	0.9	1.1	1.5	1.4	1.3

Table 10. Grain yield (t/ha at 15% moisture) of late maize varieties from elite yield trial (1981).

	Forest			Savanna			
Pedigree	Ibadan	Ikenne	Mean	Ilorin	Mokwa	Gusau	Mean
TZSR-W-1	3.8	2.6	3.2	5.4	5.6	4.0	5.0
TZSR-Y-1	4.4	2.5	3.5	4.5	5.8	4.2	4.8
TZPB (check)	5.0	3.1	4.1	4.8	5.9	4.4	5.0
Poza Rica 7843	4.8	2.9	3.9	6.2	6.2	4.1	5.5
LM 7422 x 167	3.8	2.5	3.2	4.9	6.5	5.1	5.5
TZPB 1808 x 189	3.1	3.1	3.1	5.7	5.7	4.4	5.3
TZSR-W x 174	3.8	2.7	3.3	5.9	6.7	4.1	5.6
LSD (.05)	0.6	0.4	0.5	1.1	—	—	—

The top-crosses were usually a few days later in flowering compared with the open pollinated early varieties. Yields of the 2 early streak-resistant populations, TZESR-Y and TZESR-W, were equal to those of other open pollinated entries. These 2 populations are currently under international population improvement programs.

Some promising results were obtained in the preliminary yield trial grown at Gusau. Four top-crosses, TZSR-Y-1 x B73, -XVa35, -X105 and -X239, gave significantly higher yields than the TZPB check (4.4 t ha). Guanacaste 7729 ranked first in yield of the open pollinated varieties (Table 14).

In the preliminary early maturing variety trial, 4 top-crosses, TZE_3 x 276, TZUT x 276, MMB x 13 and MMB x CM109, gave significantly higher yields than the TZE_4 check (Table 15).

Table 14. Grain yield (t/ha) and grain moisture at harvest from preliminary yield trial, late maize at Gusau (1981).

Pedigree	Yield (15% moist.)	% of check	Moist. % at harv.
TZSR-Y-1 x B73	6.9	156	22
TZSR-Y-1 x Va 35	6.6	152	19
TZSR-Y-1 x 105	6.4	146	21
TZSR-Y-1 x 239	6.3	143	24
Guanacaste 7729	5.7	129	26
Poza Rica 7824	4.9	112	22
Across 7643	4.7	107	22
Ominita 7643	4.7	106	26
Poza Rica 7822	4.6	105	24
Los Banos 7632	4.5	103	22
La Maquina 7827	4.5	102	23
TZPB	4.4	100	30
Across 7721	4.0	92	25
Sete Lagoas 7728	3.4	77	22
LSD (.05)	1.7	—	—

Table 15. Grain yield (t/ha) and grain moisture at harvest from preliminary yield trial, early maize at Gusau (1981).

Pedigree	Yield (15% moist.)	% of check	Moist. % at harv.
TZE_3 x 276	7.6	162	24
TZUT x 276	7.2	153	20
MMB x 13	7.4	157	24
MMB x Hi29	7.6	162	22
Prisabak (1) 7930	4.8	102	21
Ferke (1) 7635	3.3	70	27
Pichilingue 7726	4.8	102	23
TZE_4	4.7	100	22
LSD (.05)	2.2		

Entomology

Stem borer resistance breeding

S.K. Kim and Y. Efron

Three stem borers, *Sesamia calamistis*, *Eldana saccharina* and *Busseola fusca*, are the major insect pests of maize in West Africa. Severe epibiotics of *Sesamia* and *Eldana* are often observed in southeastern and western, Nigeria, respectively. *Sesamia* attacks mainly young maize plants while *Eldana* attacks maize at a late flowering stage causing stalk lodging and ear damage. In southeastern Nigeria, farmers do not grow maize during the second season due to heavy infestation of *Sesamia*.

Two hundred and fifty half-sib families were tested at Umudike for *Sesamia* and at IITA for *Eldana*. Plantings were

Promising half-sib family of stem borer resistant population, TZBR, under severe *Sesamia calamistis* epibiotics at Umudike, Nigeria.

made on 2-4 August and on 1 June at IITA and Umudike. A randomized complete block design with 3 replications was used.

Ratings of *Sesamia* damage at Umudike were made twice, first at a young stage (knee high) and second at a maturing stage (3 weeks after flowering), based on number of dead hearts and plants surviving. Field performance was also considered at maturity. Ratings of *Eldana* damage at IITA were made at the late growing stage and at harvest time and were expressed as stalk lodging and ear aspect ratings (Table 16).

Table 16. *Sesamia ratings (1-5) of selected half-sib families from TZBR population at Umudike (1981).**

Family	Young stage	Maturing stage
31	2.7	3.3
81	2.3	2.3
84	2.7	3.2
106	3.3	2.8
114	2.7	3.4
138	3.0	3.4
149	2.7	2.7
163	3.0	2.9
234	3.0	3.1
240	3.0	3.2
248	3.3	3.3
249	3.3	3.4
LSD .05	1.4	1.0
Mean	2.9	3.2
Population	3.5	3.9
Check (TZPB)	3.8	4.2

* *Borer ratings: 1 = resistant, 5 = susceptible.*

Severe infestation of *Sesamia* occurred at Umudike. The best 12 half-sib families scored for borers were chosen for the formation of an experimental variety. *Sesamia* ratings of the selected families selected at young and maturing stages are summarized in Table 16. The mean rating of the selected families at the young stage was 2.9 based on a 5-point scale, not significantly different from the check mean, 2.8. However, the mean rating of the selected families at maturity was 3.2, significantly different from the check mean, 4.2. The good performance of these families was clear during harvest time. Remnant seeds of the selected families were planted at IITA during the dry season and about 40 plants per family were randomly interpollinated to form the experimental variety.

Further population improvement will be carried out based on the result obtained from the trials grown in 1982. Most of the families tested at IITA were heavily infested by *Eldana* due to delayed planting. Grain yield, ear aspect, stalk lodging, and plant stand at harvest of the selected families from TZBR population are summarized in Table 17. Only 11 families were selected for their outstanding grain yield and ear aspect considering borer damage. Mean grain yield of the selected families was 4.0 t/ha, 38 percent higher than the TZPB check. Ear aspect rating of the selected families was 2.3 compared with a rating of 3.0 for the check variety. Only 2 out of the 11 selected lines scored well against both *Sesamia* at Umudike and *Eldana* at IITA.

Although the progress of building up stem borer resistance is much slower than that of disease resistance, i.e, MSV, there is a justified optimism for breeding against stem borers,

Table 17. Grain yield, ear aspect and stalk lodging ratings* of selected families from TZBR population at IITA (1981).

Family	Yield (t/ha)	Ear aspect (1-5)	Stalk lodging (1-5)
15	4.0	2.3	2.3
75	4.4	2.3	2.6
106	3.9	2.5	2.5
107	3.9	2.0	2.8
110	3.6	2.3	2.8
114	3.7	2.3	2.7
115	4.4	2.5	2.3
172	4.0	2.5	2.5
228	3.6	2.2	2.5
231	3.7	2.3	2.8
244	4.4	2.5	2.7
LSD .05	1.6	0.8	0.8
Mean	4.0	2.3	2.6
Population Mean	3.0	3.2	2.8
Check Mean	2.9	3.0	2.6

**Ratings: 1 = good; 5 = bad.*

especially *Sesamia calamistis*. Genetic advancement could be speeded up by expanding testing of breeding materials and developing a uniform articifical infestation technique for stem borers. The experimental variety selected for tolerance to *Sesamia* will be tested under natural and artificial infestation of larvae conditions in 1982.

Rearing of maize borer

L.E.N. Jackai

DIET MODIFICATION AND EVALUATION. The development of an artificial rearing medium for the maize borers, *Sesamia calamistis* and *Eldana saccharina*, was as described in IITA Annual Report 1980. In 1981, a number of modifications to improve the base diet were made, and these were evaluated for larval development, pupal size and oviposition.

The modifications consisted of the following:

1) Addition of a bulking agent (corn cob grits) to the base diet (soy wheat germ) to improve consumption.
2) Replacement of soy flour with cowpea flour.
3) Addition of various amounts of corn leaf powder (13, 25 and 49 g, representing approximately 11, 22 and 43 percent w/w of the amount of wheat germ) to the base diet.

The results are shown in Tables 18 and 19. Neither the addition of corncob grits to the diet nor the replacement of soy flour with cowpea flour improved larval performance or pupal size for *Eldana*. The results, nonetheless, suggest that addition of corncob grits was as good as the soy wheatgerm diet alone (Table 20). However, when the bulking agent is added, more diet is obtained (by volume), and, therefore, a greater number of larvae can be reared on the same amount of soy flour. This is an obvious advantage. In the case of *Sesamia*, the addition of 25 g of corn leaf powder and corncob grits to the diet gave pupal weights comparable to those obtained from soy wheatgerm diet alone. However, a shorter developmental period was obtained from the base diet with 25 g corn leaf powder added. This means that more genera-

Table 18. Development of *Eldana saccharina* on soy wheatgerm (SWG), corn cob grits (CC) and cowpea diets (CP).

Parameter	Diet SWG alone	SWG + CC	CP
Pupal weight (mg) ± sd			
Male	124.1 ±39.09 (122)	130.38 ±39.08 (79)	87.35 ±18.69 (133)
Female	168.79 ±37.87 (120)	154.48 ±37.34 (63)	138.89 ±26.19 (155)
Days to pupation ± sd			
Male	20.63 ±2.66 (122)	20.63 ±3.17 (79)	30.59 ±5.11 (133)
Female	21.63 ±2.81 (120)	21.59 ±3.01 (63)	32.4 ±5.19 (155)
Days to emergence ± sd			
Male	8.25 ±3.28 (122)	9.95 ±2.11 (79)	9.80 ±2.88 (133)
Female	9.20 ±3.03 (120)	10.40 ±2.84 (63)	10.61 ±2.40 (155)
Total development time (days)			
Male	28.88	30.58	40.39
Female	30.83	31.99	43.01

tions of the borer can be reared on the soy wheatgerm and corn leaf powder diet than on the other diets in any given time.

EFFECT OF TEMPERATURE IN LARVAL DEVELOPMENT. The maize borers have a very wide geographical and ecological distribution. There are wide environmental variations across this distribution range—particularly with respect to termperature, humidity and rainfall. Therefore, it is important to know which of these factors may be limiting in determining the distribution of a particular species in a given ecological zone. This information is also important in insect rearing since similar environmental conditions such as occur in nature should be provided for artificial rearing. Three temperature regimes were selected, viz: 22, 27 and 32°C. Humidity was uncontrolled, but it varied between 70 and 80 percent.

The results obtained indicate that *Eldana* produces bigger pupae at 22°C than at the other 2 temperatures while larger *Sesamia* pupae are obtained at 32°C, but not statistically different from those obtained at 22°C (Table 21). The total development time is shortest at 32°C and is remarkably longer at 22°C for both species.

Oviposition data (for *Eldana* only) indicate that more eggs are laid at 22 and 27°C than at 32°C, with the best results obtained from larvae reared at 22°C and adults made to oviposit at 27°C, followed by 22°C (larvae) and 22°C (oviposition) and then 27°C (larva) and 27°C (oviposition) etc., (Table 22). Also, both male and female moths lived longer at lower temperatures.

Table 19. Development of *Sesamia calamistis* on soy wheatgerm, corn leaf factor and corn cob grits diets.

Parameter	Diet SWG alone	SWG + CLF-13	SWG + CLF-25	SWG + CLF-49	SWG + CC
Pupal weight (mg) (± sd)					
Male	164.4 ±27.80 (119)	139.89 ±23.48 (38)	164.49 ±21.92 (114)	134.07 ±21.40 (19)	168.42 ±28.31 (120)
Female	242.9 ±40.56 (118)	193.00 ±46.48 (47)	204.56 ±33.01 (141)	150.92 ±30.29 (11)	239.29 ±46.23 (129)
Days to pupation ± sd					
Male	23.79 ±2.50 (119)	22.47 ±2.11 (38)	20.32 ±2.16 (114)	24.36 ±2.61 (19)	25.32 ±3.27 (120)
Female	24.99 ±2.24 (118)	22.85 ±2.11 (47)	21.48 ±1.77 (141)	26.0 ±2.53 (11)	26.66 ±3.34 (129)
Days to emergence ± sd					
Male	13.51 ±1.92 (118)	13.31 ±0.93 (38)	12.93 ±1.86 (114)	14.92 ±1.61 (19)	13.53 ±1.99 (120)
Female	13.04 ±1.94 (117)	13.04 ±1.04 (47)	13.17 ±1.12 (139)	13.63 ±1.43 (11)	12.86 ±2.07 (129)
Total development period (days)					
Male	37.30	35.78	33.25	38.78	38.85
Female	38.03	35.89	34.65	39.63	39.52

Number in parentheses = number of insects. *CLF = 13, 25, and 49g corn leaf powder.*
SWG = Soyflour wheatgerm diet. *CC = corncob grits*

Table 20. Effect of temperature on larval development, pupal size and adult emergence. Larvae were reared on SWG diet.

	Temperature (°C)					
	22°		27°		32°	
Parameter	Eldana	Sesamia	Eldana	Sesamia	Eldana	Sesamia
Pupal weight (mg) ± sd						
Male	122.92 ±19.03 (93)	157.13 ±33.60 (36)	111.31 ±15.95 (158)	146.11 ±29.63 (83)	112.11 ±20.50 (103)	166.56 ±17.78 (38)
Female	196.60 ±36.34 (86)	219.79 ±40.88 (33)	181.90 ±30.29 (122)	191.18 ±47.39 (53)	165.99 ±22.43 (103)	247.42 ±48.05 (29)
Days to pupation ± sd						
Male	32.49 ±3.85 (93)	44.89 ±4.35 (36)	21.04 ±3.45 (158)	26.89 ±5.84 (83)	17.94 ±2.01 (103)	21.82 ±2.40 (38)
Female	34.65 ±2.97 (86)	43.48 ±3.77 (33)	22.88 ±3.60 (122)	28.60 ±5.04 (53)	19.12 ±1.78 (103)	23.59 ±1.97 (29)
Days to emergence ± sd						
Male	14.04 ±1.57 (93)	16.25 ±2.66 (36)	8.49 ±1.56 (158)	12.63 ±4.42 (83)	7.91 ±1.31 (103)	10.34 ±1.28 (38)
Female	14.49 ±1.45 (86)	15.55 ±2.25 (33)	9.22 ±1.33 (122)	12.57 ±3.62 (53)	8.04 ±1.10 (103)	10.24 ±1.02 (29)
Total development time						
Male	46.53	61.14	29.53	39.52	25.85	32.16
Female	49.14	59.03	32.1	41.17	27.16	33.83

Numbers in parentheses = number of insects.

Table 21. Longevity and oviposition of *Eldana saccharina* reared as larvae in 3 different temperatures (L) and allowed to oviposit at 3 different temperatures (A).

	Temperature (°C)								
	L-22°			L-27°			L-32°		
Parameter	A-22°	A-27°	A-32°	A-22°	A-27°	A-32°	A-22°	A-27°	A-32°
Mean longevity (days)									
Male	6.9	10.3	3.0	8.6	7.5	5.6	6.2	7.5	4.8
(SE)	(0.69)	(1.59)	(0.32)	(0.68)	(0.45)	(0.75)	(0.45)	(0.69)	(0.12)
Female	8.8	9.2	3.3	9.2	6.8	6.8	6.2	8.0	4.6
SE	(0.58)	(0.58)	(0.18)	(0.66)	(0.49)	(0.20)	(0.80)	(1.92)	(0.40)
Mean oviposition	790.0	905.6	326.2	617.2	744.4	502.8	87.8	297.2	234.4
(SE)	(42.76)	(76.15)	(55.45)	(77.12)	(46.75)	(190.72)	(32.11)	(114.04)	(57.07)

Table 22. Longevity and oviposition of *Eldana saccharina* reared as larvae in 3 different temperatures (L) and allowed to oviposit at 3 different temperatures (A).

	Temperature (°C)								
	L-22°			L-27°			L-32°		
Parameter	A-22°	A-27°	A-32°	A-22°	A-27°	A-32°	A-22°	A-27°	A-32°
Mean longevity (days)									
Male	6.9	10.3	3.0	8.6	7.5	5.6	6.2	7.5	4.8
(SE)	(0.69)	(1.59)	(0.32)	(0.68)	(0.45)	(0.75)	(0.45)	(0.69)	(0.12)
Female	8.8	9.2	3.3	9.2	6.8	6.8	6.2	8.0	4.6
(SE)	(0.58)	(0.58)	(0.18)	(0.66)	(0.49)	(0.20)	(0.80)	(1.92)	(0.40)
Mean Oviposition	790.0	905.6	326.3	617.2	744.4	502.8	87.8	297.2	234.4
(SE)	(42.76)	(76.15)	(55.45)	(77.12)	(46.75)	(190.72)	(32.61)	(114.04)	(57.07)

Pathology

Screening for stalk and ear tolerance.

J.M. Fajemisin

In the tropics, stalk and ear rots contribute to huge losses in maize production. Stalk rots cause lodging while ear rots cause a reduction in both the quantity and quality of grain. Both stalk and ear rots are caused by various pathogens, the most prevalent of which are fungi belonging to the genera *fusarium, Diplodia* and *Macrophomina*. An efficient inoculation technique is necessary, therefore, to evaluate ear and stalk rot as an integral part of efforts to develop stable, high yielding varieties.

TECHNIQUES FOR STALK ROT INOCULATION. An experiment was carreid out at IITA in the 1981 first season to determine the most vulnerable plant age for artificial inoculation. Eight types of inoculum treatments and 4 times of incoculation were tested using a split-plot design with time as main plot treatments and pathogens as sub-plot treatments. The maize line 276 (S_4) was used. All treatments were applied through infected toothpicks except for the soil treatment, which was dispensed by injecting the suspension in water.

There were differences among both times of inoculation and types of inoculum used in the severity of rotting (Table 23). The highest rot scores were obtained for the 8-week inoculation; whereas, at 4 weeks after planting, the plants were not vulnerable to stalk rot. All the pathogens and pathogen combinations tested induced higher rot scores than the check.

The experiment was repeated in the 1981 second season with 2 maize types, line 276 and population TZUT, more pathogen combinations and with 4-week inoculation excluded. A split-split plot design was used with maize types as the main plot treatments and pathogens as the sub-sub-plot treatments. The 8-week inoculation produced the greatest rotting, but low stalk rots were obtained with the 10-week inoculation (Table 24).

Although a combination of *diplodia, Macrophomina* and *Fusarium moniliforme* gave the highest rot scores, this was not significantly different from that obtained by inoculating with *Fusarium* seed isolate alone. The maize entry TZUT was generally more susceptible than line 276. It would appear from the results obtained that the most reliable time for stalk rot inoculation in both the wet and dry seasons is between 6-8 weeks after planting. Inoculation at 10 weeks after planting gave differential results only during the first (wet) season and not in the second (dry) season.

TECHNIQUES FOR EAR ROT INOCULATION. Three techniques of inoculation (spray silk with spore suspension, insert infected toothpick through the middle of the ear and through the shank) and 5 inoculum treatments were tested using 2 maize types (line 276 and population TZUT). A split split-plot design was adopted with maize types as main plot treatments, inoculation techniques as sub-plot treatments and pathogens as the sub-sub plot treatments.

There were significant differences among inoculation techniques and among pathogens (Table 25). Inoculation with infected toothpicks was the most reliable method for the 3 pathogens, *Diplodia, Macrophomina* and *Fusarium*. Spraying of silk was found to be reliable only for *Fusarium* while toothpick through the shank was the least efficient for all the pathogens.

Early maturing, streak-resistant populations

S.K. Kim, Y. Efron, J. Singh

Risk of MSV epidemic increases with time after the beginning of the rain due to a vector population (leafhoppers) buildup and increased source of inoculum in the fields. Cultivation of MSV-susceptible maize during the second season in the forest zone of West Africa is risky. Because of shortness of the second season, early maturity is also required, and, therefore, it is especially important to develop early maturing, streak-resistant varieties. They are also important when MSV spreads to the savanna areas such as the northern part of Cameroon; therefore, 2 new, early maturing (90 days), streak-resistant populations, TZESR-W (white) and TZESR-Y (yellow), were developed.

Their pedigrees are summarized in Table 26. In the 1977 third season, 4 early maturing maize varieties, TZE3, TZE4,

Table 23. Effect of time of inoculation on the severity of stalk rot in maize (line 276) using different pathogens and pathogen combinations (IITA 1981 first season).

Pathogen(s)	Time of inoculation (weeks after planting) 4	6	8	10	Pathogen mean
Diplodia	0.0[a]	1.0	1.9	2.1	1.3
Macrophomina	0.1	1.2	2.1	1.4	1.2
Fusarium (stalk isolate)	0.1	1.1	2.2	1.8	1.3
Fusarium (seed isolate)	0.1	2.1	2.2	2.3	1.7
Diplodia + *Fusarium*[b]	0.1	2.0	2.7	2.5	1.8
Macrophomina + *Fusarium*[b]	0.1	2.2	2.5	2.5	1.8
Soil[c]	0.0	0.8	2.4	2.2	1.4
Check (uninfested toothpick)	0.0	0.8	1.5	1.3	0.9
Time of inoculation mean	0.1	1.4	2.2	2.0	

5% LSD (1) Main effects (a) Time of inoculation (T) = 0.4.
(b) Pathogen (P) = 0.3.
(2) Interactions (a) Difference between two P means at the same T = 0.6.
(b) Difference between two T means for the same or different P = 0.7.

[a]*Figs. are on a rot scale of 0-6 where 0 = no rot and 6 = rot spreading to two or more internodes.*
[b]*Fusarium* used in the mixture is the stalk isolate.
[c]Soil is from a farm site of 3 years of continuous maize cropping.

Table 24. Effect of time of inoculation on the severity of stalk rot in 2 maize types using different pathogens and pathogen combinations (IITA 1981 second season).

Pathogen(s)	Maize type	Time of inoculation (weeks after planting) 6	8	10	Maize type mean	Pathogen mean
Diplodia	TZUT	1.5[a]	1.9	0.5	1.3	
	Line 276	1.7	1.8	0.3	1.3	1.3
Macrophomina	TZUT	2.2	1.8	0.5	1.5	
	Line 276	1.8	1.3	0.4	1.2	1.3
Fusarium	TZUT	2.1	1.2	0.8	1.4	
(*stalk isolate*)	Line 276	1.8	1.1	0.1	1.0	1.2
Fusarium	TZUT	3.4	1.6	0.7	1.9	
(*seed isolate*)	Line 276	2.6	1.7	0.1	1.5	1.7
Diplodia +	TZUT	2.4	2.4	0.4	1.7	
Macrophomina	Line 276	2.1	2.1	0.6	1.6	1.7
Diplodia +	TZUT	2.0	2.0	0.5	1.6	
Fusarium[b]	Line 276	2.0	2.0	0.1	1.4	1.5
Macrophomina +	TZUT	2.7	2.4	0.6	1.9	
Fusarium[b]	Line 276	1.8	1.7	0.3	1.3	1.6
Diplodia +	TZUT	2.7	2.5	0.7	2.0	
Macrophomina +	Line 276	2.9	2.2	0.5	1.9	2.0
Fusarium						
Soil[c]	TZUT	1.5	1.4	0.5	1.1	
	Line 276	1.7	1.0	1.0	1.2	1.2
Check (uninfested	TZUT	0.7	1.0	0.3	0.5	
toothpick)	Line 276	1.4	0.6	0.1	0.7	0.6
Time of inoculation mean		2.1	1.7	0.5		

5% LSD (1) Main effects (a) Maize type (V) = 0.07; (b) Inoculation time (T) = 0.15; (c) Pathogen (P) = 0.21.
(2) Interactions VT = 0.22; TP = 0.38; VP = 0.29; VTP = 0.55.
[a]*Figs are on a rot scale of 0-6 where 0 = no rot and 6 = rot spreading to 2 or more internodes.*
[b]*Fusarium used in the mixture is the stalk isolate.*
[c]*Soil is from a farm site of 3 years of continuous maize cropping.*

Table 25. Effect of different methods of inoculation and different pathogens on the severity of ear rot in two maize types (IITA, 1981 second season).

Methods of inoculation	Maize type	Pathogens[a] D	M	F_s	F_d	C_k	Maize	Pathogen
Spray silk	TZUT	1.0[b]	1.0	1.0	1.3	1.0	1.1	
	Line 276	1.0	1.0	1.4	1.3	1.0	1.1	1.1
Toothpick mid-ear	TZUT	1.7	1.7	1.1	1.3	1.1	1.4	
	Line 276	1.1	1.2	1.4	1.2	1.0	1.2	1.3
Toothpick shank	TZUT	1.1	1.1	1.0	1.2	1.0	1.1	
	Line 276	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Pathogen mean		1.2	1.2	1.2	1.2	1.0		

5% LSD (1) Main effects (a) Maize type (V).
(b) Inoculation method (I) = 0.1; (c) Pathogen (P) = 0.1.
(2) Interactions: VI = 0.1; IP = 0.1; VIP 02.
[a]*Pathogens: D =* Diplodia, *M =* Macrophomina; *F_s =* Fusarium *(stalk isolate); F_d =* Fusarium *(seed isolate); C_k = Check.*
[b]*Figs are on a rot scale of 1-4 where 1 = no rotten kernels, 2 = 1-10 rotten kernels; 3 = 11-100 rotten kernels; and 4 = more than 100 rotten kernels.*

Table 26. Pedigrees of TZESR-W and TZESR-Y populations.

Year Season	Generation	Testing site
1977 III	Cross TZE3, TZE4, TZE14, and TZE15 xTZSR-W, and TZSR-Y	Field
78 I II	F_1	Field
79 I	S_1 (1,000 plants)	Screenhouse
79 II	S_2 (215)	Screenhouse
80 I	S_3 (256)	Field Screenhouse
80 II	Half-sib recombination (136) TZESR-W 42 TZESR-Y 94	Field
81 I	TZESR-Y. Half-sib testing at 2 locations	Ikenne, Gusau
81 II	TZESR-W Full-sibtesting at 2 locations	Ibadan, Ikenne
81 III	Full-sib production for 1982 International Trial	

Promising S_3 maize lines with uniform and low ear placement.

TZE14 and TZE15, were crossed to 2 late maturing, streak-resistant populations, TZSR-W and TZSR-Y. Two hundred and fifty-six sleak-resistant S_3 lines were developed by the 1980 first season. Forty-two selected white lines were combined by the half-sib method during the 1980 second season to develop the TZESR-W population. A second selected set of 94 yellow lines was also combined to obtain the TZESR-Y population.

These 2 early maturing, streak-resistant populations were further improved by recurrent selection. In the 1981 first season, 250 half-sib families of TZESR-Y were tested at 2 locations in Nigeria: Gusau and Ikenne. Also, 250 full-sib families of TZESR-W were developed at IITA in the 1981 first season with special emphasis given to the selection of root lodging tolerance, grain type (white flint) and other agronomic traits. These ful-sib families were tested at 2 locations in Nigeria, IITA and Ikenne, during the 1981 second season. Seventy-four families for TZESR-W and 44 families for TZESR-Y were finally selected, and all will be used for the development of full-sib families for international testing in 1982.

Grain yield of TZESR-W and TZESR-Y at 15 percent moisture is summarized in Table 27. Results of the 2 population trials show the potential for further yield improvement of these populations through the recurrent selection method. These 2 populations will flower in about 50 days, similar to the early maturing check, TZE4. Grain texture of TZESR-W is flint and that of TZESR-Y is semi-flint. Average yield of the selected TZESR-W families from 2 locations was 5.01 t ha—82 and 16 percent higher than the check and population means, respectively. Yield of the selected 44 TZESR-Y families from Ikenne (Gusau data were taken only for observation) was 5.4 t ha, 95 percent higher than the check mean.

Table 27. Grain yield (t/ha) of early maturing streak-resistant maize populations, TZESR-W and TZESR-Y, in progeny testing at 2 locations in Nigeria (1981).

	TZESR-W			TZESR-Y
	Ikenne	Ibadan	AV	Ikenne
No. of families tested	250	250	250	250
Yield of population (t ha)	4.3	4.4	4.4	4.2
Yield of selected families	5.1	5.0	5.1	5.4
TZE4 (check)	3.1	2.4	2.8	4.4
LSD (.05)	1.5	2.0	1.8	1.7

Screening of resistant maize plants against maize streak virus under artificially infested conditions at IITA.

Bulk seeds of these 2 populations were also tested at 4 different locations in Nigeria in 1981 (Table 28). Grain yields of both TZESR-W and TZESR-Y at these locations were similar to the nonstreak resistant check, TZE4. IITA has nominated the 2 populations for the 1982 international family testing trials, especially in the savanna area and forest zone during the second season.

Table 28. Grain yield (t/ha) of early maturing, streak-resistant maize populations—TZESR-W and TZESR-Y, at 4 locations in Nigeria, 1981.

	Forest	Savanna			
Variety	Ikenne	Ilorin	Mokwa	Gusau	Av.
TZESR-W	2.8	5.2	4.9	3.1	4.0
TZESR-Y	2.4	4.6	5.0	3.2	3.8
TZE4 (check)	2.3	5.3	3.3	3.0	3.5
LSD (.05)	0.9	1.1	1.5	1.4	1.2

Mid-altitude, streak-resistant populations

S. K. Kim, J. Fajemisin, Y. Efron

MSV, leaf blight (*Helminthosporium turcicum*) and rust (*Puccinia sorghi*) are the major maize foliar diseases in mid-altitude ecology thorughout East and Central Africa. Selected high yielding varieties and hybrids from East and Central African countries have been tested at IITA for MSV reaction. Unfortunately, the varieties and hybrids tested are very susceptible. The development of streak-resistant populations for East African mid-altitude ecology has been attempted at IITA since 1978.

One hundred and ninety half-sib families, the TZMSR population (East African Highland materials x IITA streak-resistant TZSR), were tested at Jos, Nigeria, (1,200m above sea level) under severe natural epiphytotics of *H. turcicum* and *P. sorghi*. Each family was planted with 2 replications of single-row plots, 5 m long. Thirty-eight families were selected based on yield, agronomic traits and good levels of resistance to streak, *H. turcicum* and *P. sorghi*. Mild streak infestation was also observed in this nursery. Data were taken at 3 weeks after flowering for agronomic traits and disease ratings.

Grain yield at 15 percent moisture and disease ratings are summarized in Table 29. Mean grain yield of 190 families of the TZMSR population was 4.3 t/ha, 34 percent higher than the mean of 2 check varieties, S123 and TZPB. However, mean grain yield of the selected 38 families of the TZMSR population was 5.4 t/ha, 69 percent higher than the mean of S 123 and TZPB. Disease resistance levels of the selected families were also superior to the population and the check means.

Remnant seeds of the selected families were planted under severe artificial streak infestation at IITA during the 1981-82 dry season. Selected streak resistant plants were selfed for further population improvement. Selected white grain S_1 lines will be further tested at Jos in 1982, and full-sibs will be developed there among the selected lines in 1982.

Table 29. Grain yield, — disease and ear aspect ratings of TZMSR families at Jos, Nigeria (1981).

	Yield (t/ha)	Ratings (1-5) Streak	Blight	Rust	Ear aspect
Selected families (38)	5.4	1.7	2.0	1.8	2.1
Population mean	4.3	2.3	2.5	2.2	2.7
Check mean	3.2	3.3	3.0	3.0	3.1
LSD .05	1.9	0.8	0.4	1.4	1.0

Rating 1-5: 1 = highly resistant or excellent; 5 = highly susceptible or very poor.

Streak-resistant, back-up populations

S.K. Kim, J. Fajemisin, Y. Efron

The major purpose of this back-up population is to develop better streak-resistant populations by introducing new improved materials. The deficiencies of the present 2 late maturing, streak-resistant populations, TZSR-W-1 and TZSR-Y-1, are relatively poor root and stalk quality and poor tip cover. Varieties involved in this back-up are newly developed varieties from IITA, CIMMYT (EVT 12, EVT 13, ELVT 18A and ELVT 18B), SAFGRAD (RUVT 1 and RUVT 2), African national programs, and the Asian Regional Maize Program (ARMP). ARMP materials were introduced as downy mildew resistant sources.

A total of 1,287 S_2 lines were tested at 4 different locations in Nigeria, Gusau, Ikenne, Ilorin and Mokwa, to select for adaptation and disease resistance. Observational ratings were made based on a 1-5 rating scale for plant vigor, ear height, disease resistance, stalk and root lodging tolerance and ear aspect, etc. Approximately 400 lines were selected. One replication each of all back-up lines was planted at IITA under artifically infected conditions with MSV and leaf diseases, rust, blight and *Curvularia* leaf spot. Selected individual plants from the selected lines were selfed for the development of more homozygous resistant lines to MSV, *P. polysora*, *H. maydis*, *Curvularia* spp. and lodging. New materials, especially from commercial tropical hybrids, were introduced and crossed with streak-resistant TZSR-W-1 or TZSR-Y-1 populations.

Table 30 summarizes the testing of the back-up lines. Selection was based on agronomic traits and ear aspect. Three hundred and ninety-eight lines were selected for different maturity (late and early), grain color (white and yellow) and grain texture (dent and flint). Each group of selected lines will be recombined by the half-sib method for the creation of new back-up populations.

Downy mildew, streak-resistant populations

J. Fajemisin, S.K. Kim, Y. Efron

Downy mildew (*Peronosclerospora sorghi*) is a major threat to successful maize production in parts of Bendel, Kwara and Ondo States of Nigeria. The disease has also been reported in other countries in Africa, Sudan, Uganda and Zaire. In these areas, MSV and downy mildrew coexist. A program was initiated in 1979 in collaboration with the National Cereals Research Institute (NCRI), Nigeria, to develop adapted varieties with combined resistance to downy mildew and

Effectiveness of streak-resistant, early maize, TZESR-W (right) and TZESR-Y (left), compared to susceptible variety, TZE4 (center) at IITA.

Table 30. Number and origins of back-up lines tested in 1981.

Maturity/Grain color	Number of lines tested	Number of lines selected	Populations involved
Late white	631	227:LWD:138	TZPB, CIMMYT pop. 21, 22, 27, 28, 29, 43, 44.
		:LWF: 89	TZB, Pop. 27, 29, 32, 33.
Late yellow	233	49:LYD: 22	TZSR-Y-1, CIMMYT pop. 28, 35, 36, 38, 43.
		:LYF: 27	Pop. 27, Suwan 1.
Early white	190	63:EWD: 23	CIMMYT Pop. 33, 34, 44, 45.
		:EWF: 40	TZESR-W, Pop. 33, 34, Suwan 4, Suwan S.9.
Early yellow	233	59:EYD: 36	TZESR-Y, CIMMYT pop. 33, 34, 44, 45.
		:EYF: 23	Pop. 33, 34, Suwan S.9.
Total	1,287	398	

A farmer's field in Nigeria highly infested with downy mildew.

Promising downy mildew resistant materials at Owo, Nigeria (IITA/NCRI Cooperative Project).

MSV using downy mildew resistance sources from Indonesia, Philippines and Thailand, and streak resistance sources from IITA.

During the 1981 first season, the 4 maize populations being developed for downy mildew resistance, with and without streak resistance, DMR-W, DMR-Y, DMRSR-W and DMRSR-Y, were compared to elite tropical maize varieties from IITA and CIMMYT and downy mildew resistant populations from Asia at Owo, Nigeria. The trial was carried out under artificial and natural epidemics. The artificial epidemic was generated by planting and inoculating susceptible spreader rows, TZPB, prior to planting the test entries.

The buildup of downy mildew was faster under artifical than natural epidemic. Susceptible entries were observed beginning at 3 weeks after planting under artificial epidemic but 6 weeks after planting under natural epidemic. TZPB and other elite varieties/populations were severely affected under both artificial and natural disease pressures (Table 31). On the other hand, DMR-W and DMR-Y had low infection, comparable with the Asian downy mildew resistant varieties. Yields of DMRSR populations are still highly depressed by downy mildew because they have undergone only 1 cycle of improvement compared to 2 cycles for DMR populations.

Both the DMR and DMRSR populations were subjected to further improvement during the year. One hundred and eighty-six and 206 half-sib families of DMR-W and DMR-Y, respectively, several S_2 lines, and some bulked half-sib families of DMRSR populations were evaluated under mild and severe artificial infection levels during the 1981 early season at Owo (Table 32). Full sibs were developed among selected disease-free plants under the 2 levels of disease pressure.

In the 1981 second season, a set of 250 full sibs from each of the populations, DMR-W, DMR-Y and DMRSR-Y, and a set of 150 families for DMRSR-W were planted at Owo. Only families with less than 10 percent downy mildew were selected for further improvement. In the DMRSR populations, selected families were also segregating for streak resistance. Selected families in the 4 populations are being recombined under irrigation.

Conversion of selected experimental varieties to streak resistance

M. Bjarnason, S.K. Kim

Through its international testing program, CIMMYT has developed many populations with wide adaptation and good yield potential in collaboration with national programs around the world. Presently, 29 populations are undergoing international testing. The best available experimental varieties from 9 of these populations are used as recurrent parents in a conversion program to streak resistant sources available at IITA as donors.

The newest and best performing experimental variety of each of the 9 populations is used every time a new backcross is made in this conversion program. In this manner, the program takes advantage of the continuous progress

Table 31. Downy mildew infection and yield in 16 maize entries under artificial and natural epidemics (Owo, Nigeria, 1981 first season).

		Artificial epidemic			Natural epidemic		
Maize entry	Origin	% DM	No. of cobs/ha ('000)	Yield (kg/ha)	% DM	No. of cobs/ha ('000)	Yield (kg/ha)
DMR-W	IITA-NCRI	38[a]	27	3016	20	33	3073
DMR-Y	IITA-NCRI	33	33	2805	25	37	3393
DMR SR-W	IITA-NCRI	54	23	1214	28	22	1797
DMRSR-Y	IITA-NCRI	59	12	648	38	25	1064
Suwan 1 C_6	Thailand	14	35	2969	10	37	3207
Thai Comp. ¾	Thailand	26	28	3382	17	44	3370
Caripeno DMR	Thailand	23	35	3046	10	36	2861
MIT Syn F_3	Philippines	21	42	3329	10	32	3157
TZPB	IITA	92	6	508	88	33	290
TZSR-W-1	IITA	99	1	74	72	7	818
TZSR-Y-1	IITA	92	4	435	85	5	435
TZUT	IITA	88	5	406	80	8	623
Western Yellow	IAR&T	91	5	429	82	8	762
NCC	NCRI	82	5	264	82	6	328
Across 7728	CIMMYT	86	10	591	88	9	657
La Maquina 7843	CIMMYT	84	10	754	65	9	940
LSD (.05)		4	4	505	3	4	753

[a]*Each figure represents a mean of 2 replicates with a plot size of 40 plants.*

Table 32. Downy mildew infection in 6 maize populations under artificial and natural epidemics (Owo, Nigeria, 1981 first season).

Maize Population	Disease pressure[a]	No. of families with % infection of 0-25	26-50	51-75	76-100	Total no. of families
DMR-W	Mild artificial	36	87	44	19	186
	Severe artificial	33	48	72	32	186
DMR-Y	Mild artificial	90	88	21	7	206
	Severe artificial	10	45	91	60	206
DMRSR-W (HS)	Mild artificial	1	3	1	0	5
DMRSR-Y (HS)	Mild artificial	5	13	1	0	19
DMRSR (S_2)-W	Severe artificial	2	15	26	88	131
DMRSR (S_2)-Y	Severe artificial	14	28	39	125	206

[a]*Mild and severe pressures refer to infection levels of 51-75 percent and 91-100 percent, respectively, on susceptible spreader entry.*

being made in the recurrent selection of each of the parent populations. A list of these populations is shown in Table 33. After each backcross, the BC_n-F_1 generation is advanced to BC_n-F_2 under artificial streak screening. The BC_n-F_2 generation is again screened for streak resistance, and highly tolerant segregants are used as parents for the next backcross generation. In addition to the selection for streak tolerance, selection pressure for the plant and grain type and maturity group of the recurrent parents is exerted in each generation.

The initial crosses with the streak-resistant donors, TZSR-W-1 and TZSR-Y-1 for the late-maturing varieties and TZESR-Y for the early-maturing varieties, were made in 1980. During 1981 these crosses were advanced and backcrosses were made to the recurrent parents. From 6 of the varieties under conversion, the BC_2-F_1 generation has now been advanced to F_2. Three of the varieties are still in the BC_1-F_1 stage. Good segregants with high level of tolerance to MSV were obtained in the F_2 generations of these conversions.

Table 33. Parent populations of experimental varieties undergoing conversion to streak resistance.

Parent population*	Pop. No.	Description
Mezcla Tropical Blanca	22	Late, white semi-dent
Amarillo Dentado	28	Late yellow dent
Tuxpeno Caribe	29	Late white dent
Blanco Cristalino-2	30	Early white flint
Amarillo Cristalino-2	31	Early yellow flint
Antigua x Republica Dominicana	35	Intermediate yellow dent
White QPM	40	White semi-flint
La Posta	43	Late white dent
A.E.D. x Tuxpeno	44	Late white dent

**All the parent populations are adapted to the lowland tropics except A.E.D. x Tuxpeno, which is adapted to the mid-altitude and subtropical areas.*

Improvement of streak resistance and agronomic characters of La Posta (Population 43)

M. Bjarnason and Y. Efron

The population La Posta (Pop. 43) has undergone 4 cycles of recurrent full-sib selection in international progeny testing organized by CIMMYT in cooperation with various national programs in Africa, Asia and Latin-America. This is a tropical, late, white dent population and is well accepted in areas of Africa where streak virus can be a threat to production. Experimental varieties from La Posta have been released in several countries, and various selections from this population are commercially grown in Africa. These varieties lack streak resistance. Therefore, it was decided to shift the base of population improvement of La Posta to IITA with the objective to continue the improvement of agronomic characters and to build up streak resistance through population improvement and conversion to streak resistance by backcrossing.

The recurrent selection is based on progeny testing of full-sib families, which are tested in a 16 x 16 simple lattice design in 6 different countries every 2 years. The seasons between the international progeny trials are used to screen the families for streak resistance and to select plants with superior agronomic characters within each family. In addition, a backcrossing program for the transfer of streak resistance to La Posta, using TZSR-W-1 as a donor, has been initiated.

Data from the international progeny trials in 1980 were received early enough from 4 locations out of 6 to be used for selection. Based on these data, 86 families were selected to initiate the next cycle of selection. Within these families, agronomically desirable plants were selfed in the 1980 second season. In addition, these families were screened for streak tolerance; whereby only a few plants survived. Three sub-families from each original family were planted in the 1981 season. The best 1 or 2 subfamilies from each group of 3 were selected, and these families were recombined by bulk-sibbing among all selected families. In the 1981 second season, 3 sub-families (half-sibs) from each originally selected full-sib family were planted, and again the best 1 or 2 sub-families were selected.

Among these families, reciprocal plant-to-plant crosses were made to generate 250 full-sib families for the next cycle of improvement. These families will be tested in 1982 in international progeny testing trials in 6 different countries in Africa, Asia and Latin-America.

In addition to these efforts within La Posta *per se*, the selected full-sib families were crossed with TZSR-W-1 in the 1980 second season. These crosses were advanced to F_2 under streak pressure in the 1981 first season, and the F_2 generation was planted and screened for resistance or tolerance to maize streak virus in the 1981 second season. The first backcross to the population La Posta was made by bulking pollen of selected plants in La Posta and pollinating segregants highly tolerant to maize streak virus in (La Posta x TZSR-W-1)-F_2.

Virology

Maize mottle/chlorotic stunt (MMCS)

G. Thottappilly

Maize mottle/chlorotic stunt (MMCS) has been recognized in experimental fields at IITA and in farmers' fields throughout the major maize growing areas of Nigeria. It manifests itself in progressively shortening internodes resulting in marked stunted growth (IITA Annual Report, 1978). This condition is usually accompanied by an inconspicuous chlorosis and/or vague chlorotic mottle in newly developing whorl leaves.

To further elucidate the etiology of this disease, attempts were made to purify the virus. Maize was artificially inoculated with infective *Cicadulina triangula* which is an efficient vector of this disease (IITA Annual Report 1980). Several methods of purification were tried, and the following procedure yielded small quantities of virus: Infected leaves were homogenized in 0.1 *M* phosphate buffer (2 ml/g leaf), pH 6.0, containing 1 percent driselase and 0.1 percent 2-mercaptoethanol.

The homogenate was incubated at 25-30°C, for 1 hour and then emulsified in 0.5 volume of chloroform. The emulsion was broken by centrifugation at 6,600 *g* for 10 minutes. After 2 cycles of low and high speed centrifigation, the partially purified preparation was layered on top of a sucrose gradient. A small but single peak was observed, which was collected and concentrated. Electron microscopic examination of the preparation revealed spherical particles. When the purified preparations were fed to healthy leaf-hoppers, they acquired and transmitted the virus to healthy maize seedlings producing the original mottle symptoms.

The virus concentration in infected maize plants appears extremely low and inadequate to produce an antiserum through purification.

Serological studies of purified MMCS virus were carried out using an antiserum produced against MSV. Negative results were obtained both in the agar gel diffusion and the enzyme-linked immunosorbent assay (ELISA) technique, indicating that MMCS is not a manifestation of MSV. Further attempts to purify the virus in sufficient quantities are underway.

Detection of a new spherical virus in *Roettboellia exaltata*

H.W. Rossel, G. Thottappilly

Regular surveys were carried out to detect viruses in *Roettboellia exaltata*, an alternate host for maize viruses. During one survey in September 1981, a few plants showed stunt and chlorotic symptoms. On electron microscopic examination many spherical particles were observed. Since rice yellow mottle virus (RYMV) is another virus in cereals having spherical particles, samples were first tested using an antiserum against RYMV. The tests were negative indicating that RYMV was not involved.

On mechanical inoculation to healthy *Roettboellia* seedlings as well as to maize seedlings, the virus was found to be readily transmitted. The symptoms in maize were characterized by a vague banding chlorosis and stunted growth, very similar to MMCS infection.

The virus was purified and an antiserum produced for future reference. In an agar gel diffusion test, the antiserum has a titer of 1/1024. When it was tested against 12 randomly collected maize plants from IITA's field showing symptoms suspected to be caused by this virus, none proved to be infected by this virus from *Roettboellia*.

Cooperative Research with the University of Ife

M.A.B. Fakorede, S.K. Kim, Y. Efron

The purpose of the line development project of IITA is to make lines available upon request to national programs. A possible model of cooperation between national programs and IITA has been developed for the production and testing of top-crosses (variety X line hybrids). According to the model, lines developed at IITA are grown as females (detasseled) with the best available local variety as male by the national program in isolated fields. The lines are evaluated for adaptation, and, at the same time, experimental top-crosses are produced for evaluation in the next season.

The model has been tried for the first time in cooperation with the University of Ife, Nigeria. Fifty-eight S_3-S_4 lines from IITA were grown in an isolated field as females using FARZ 27 (TZPB) as the male parent. The inbred lines were detasseled and top-crossed hybrid seeds were harvested from most of the lines. The experimental top-crosses will be tested in the first season of 1982 by both the University and IITA.

Two trials of early and late maturing top-crosses were also conducted at the University of Ife. The top-crosses in these trials were produced at IITA during the maize production training course in 1980 as part of the experimental work of the trainees.

EARLY MATURING TOP CROSS TRIAL. Twenty entries in three replications were tested at 2 locations. Grain yield (t/ha) and shelling percentage of the selected eight top-crosses are sumarized in Table 34. The highest yielding top-cross, Suwan 4 x 276, yielded almost twice as much as the check variety, TZE_4. Other selected top-crosses exceeded the control by more than 50 percent. There were no significant differences in yield among the top-crosses. Five of the selected top-crosses showed significantly higher shelling percentage than the control.

Table 34. Grain yield and shelling percentage of the selected early top crosses from the University of Ife (1981).

Variety	Yield t/ha	Yield index	Shelling %	Days silk
Suwan 4 x 276	4.5	196	76.7	55
SR-Y-E-57 x 276	4.2	183	74.9	53
TZUT x 276	4.1	178	76.6	55
SR-Y-E-58 x 276	4.0	174	75.2	52
SR-Y-E-268 x 276	3.7	161	78.4	54
TZE_4 x 276	3.6	156	78.4	52
TZE_{15} x 276	3.5	152	78.2	51
SR-W-E-202 x 276	3.5	152	75.4	54
Check (TZE_4)	2.3	100	70.0	51
SE ($\bar{x}$)	0.7	—	2.9	0.6

LATE MATURING TOP-CROSS TRIAL. Thirty entries in 3 replications were tested in 2 locations. Grain yield and shelling percentage of 6 selected top crosses are presented in Table 35. The best top-cross yielded 50 percent higher than the control variety, FARZ 27. The yield index of the other 5 selected top crosses was 143-125 percent. There were also significant differences in shelling percentage between the top-crosses tested. FARZ-27, the check variety, showed the lowest shelling percentage.

Table 35. Grain yield and shelling percentage of the selected late top crosses from the University of Ife (1981).

Variety	Yield t/ha	Yield index	Shelling %	Days silk
TZPB 1838 x TZSR-Y-1	4.2	150	76.3	59
159 x TZSR-Y-1	4.0	143	74.2	62
95 x TZSR-Y-1	3.8	138	76.2	59
189 x TZSR-Y-1	3.8	138	68.3	59
TZPB 1808 x TZSR-Y-1	3.8	138	76.7	60
177 x TZSR-Y-1	3.5	125	68.2	58
FARZ 27 (check)	2.8	100	65.7	59
SE ($\bar{x}$)	0.9	—	4.4	1.0

Participation in International and National Trials

M. Bjarnason, S.K. Kim

The National Cereals Research Institute (NCRI) Moor Plantation, Ibadan, Nigeria, evaluated promising late and early varieties in zonal trials throughout Nigeria. SAFGRAD and CIMMYT offered different variety trials and progeny trials to national programs. In order to strengthen testing these materials and to help identify promising materials for Nigeria, IITA planted some of these trials on its sites.

The variety trials were tested in a randomized complete block design with 4 replications and 4-row plots. The progeny trials were tested in a simple lattice design.

Zonal trials of late varieties were conducted in Gusau and Ilorin (Tables 36 and 37). In Ilorin, Poza Rica 7843, TZSR-W-1 and TZPB gave the highest yields, and in Gusau, TZPB, Poza Rica 7843 and Western Yellow gave the highest yields.

Table 36. Summary of Nigerian National Zonal Trial, late maize varieties at Ilorin (1981).

Variety	Yield (t/ha at 15% moist.)	% of check	Moist. % at harv.
Poza Rica 7843	5.6	140	35
TZSR-W-1	5.6	140	31
TZPB	5.6	139	35
096EP6	5.2	130	34
TZSR-Y-1	5.2	129	35
Local check	4.0	100	28
LSD (.05)	1.5		

Table 37. Summary of Nigerian National Zonal Trial, late maize varieties at Gusau (1981).

Entry	Yield (t/ha at 15% moist.)	% of check	Days silk	Ear ht. cm	Moist. % at harv.
TZPB	4.5	143	66	118	24
Poza Rica 7843	4.3	136	59	118	25
Western Yellow-1	4.1	131	65	141	24
TZSR-W-1	3.6	113	65	115	27
RSPH-W	3.3	105	59	106	22
Local	3.1	100	62	130	28
LSD (.05)	1.5				

Both trials had high coefficients of variation, and in Gusau, plant stand was poor. Zonal trials of early varieties were conducted in Gusau. The highest yielding entries were TZUT, Kewesoke-Y, TZESR-Y and the check (Table 38). The yield differences were not significant at 5% probability level.

Two variety trials from the SAFGRAD Project were conducted in Gusau. RUVT-1 (Table 39) is composed of early-maturing varieties. The highest yields were obtained from HVB-1, TZESR-W and Early Yellow. The earliest entries were Pool 27, Comp. 77 and TZE_4. The coefficient of variation for yield was high (27 percent) and differences among most of the varieties were not significant. RUVT-2 (Table 40) consisted of medium-maturing varieties among which IRAT 100 and Poza Rica 7822 produced the highest yield.

Several variety trials from CIMMYT were conducted by IITA in 1981. In Gusau, ELVT 18B (1981), which consisted of early to medium-maturing varieties, showed Poza Rica 7926, Pirsabak (1) 7930 and Across 7726 as the highest yielding experimental varieties (Table 41). TZE_4x 174 ranked second for grain yield. This top-cross hybrid, however, was the tallest and latest maturing entry in the trial.

In ELVT 18A, (1980) conducted in Gusau in 1981 (Table 42), the top yielding varieties were Sete Lagoas 7728, San Andres (2) 7530 and Ferke (1) 7622. However, the yields of these varieties were not significantly different from the best check, TZPB.

In Jos (1,300 m above sea level), ELVT 20 was planted as 2-row plot with 3 replications (Table 43). The varieties in these trials were mostly derived from populations formed by crossing tropical and temperate materials. These varieties are well adapted to subtropical and mid-altitude areas. Here, all entries were higher yielding than the best check, TZPB. However, TZPB is not adapted to the mid-altitude ecology and lacks resistance to *P. sorghi* and *H. turcicum*. The highest yielding variety was Across 7844 (7.5 t/ha).

Results from ELVT 18A (1981) from Ikenne are summarized in Table 44. The highest yielding entries were Cotaxtla 7822 (6.3 t/ha), Poza Rica 7921 (6.2 t/ha) and La Maquina 7843 (6.1 t/ha). The best check was TZPB (5.3 t/ha).

The most promising varieties from these trials will be further tested in the Nigerian Zonal Trials.

A progeny trial from CIMMYT (IPTT 49) was conducted in the 1981 second season at Ikenne. The progenies in this trial are from Population 49, Blanco Dentado-2, a new population with white dent grain and intermediate maturity. This population is derived from selection for reduced plant height in Tuxpeno Crema 1, Cycle 17. In this trial, 8 families were visually selected based on good yield, earliness and short and uniform plant type. The performance of these families is summarized in Table 45. These families will be recombined using remnant seed at CIMMYT to give rise to an experimental variety called Ikenne (1) 8149.

Breeding maize for semi-arid regions

V.L. Asnani

Semi-arid regions of Africa with an annual rainfall of 700-1100 mm. are marginal for cultivation of full season maize varieties (e.g. TZB) which are grown in subhumid and humid zones. Biotic stresses (leaf diseases, streak and borers) are milder than and different from what they are in the humid zone; and, further, the crop is exposed periodically

Table 38. Summary of Nigerian National Zonal Trial, early maize varieties at Gusau (1981).

Entry	Yield (t/ha at 15% moist.)	% of check	Days silk	Ear ht. cm	Moist. % at harv.
TZUT	5.8	102	54	96	24
Kewesoke-Y	5.4	95	55	103	23
TZESR-Y	5.1	89	55	93	23
TZESR-W	4.8	84	54	91	21
TZE_4	4.6	81	52	76	21
Check - TZB	5.7	100	58	131	26
LSD (.05)	1.4				

Table 39. Summary of SAFGRAD RUVT-1 (early) at Gusau, Nigeria (1981).

Entry	Yield (t/ha at 15% moist.)	% of check	Days silk	Ear ht. cm	Moist. % at harv.
HVB-1	4.8	107	58	88	32
Early Yellow	4.1	91	57	86	34
NH2	4.0	90	59	91	34
TZE_4	3.9	88	50	76	23
Pool 16	3.9	86	53	64	28
TZPB	3.7	83	65	95	41
Comp. 77	3.7	83	49	89	24
Pool 18	3.7	82	54	56	27
Pool 27	3.6	80	48	64	24
TZUT	3.4	75	58	86	36
Mexican 17E	3.1	70	64	85	41
Check - TZESR-W	4.5	100	56	90	29
LSD (.05)	1.5				

Table 40. Summary of SAFGRAD RUVT-2 (late) at Gusau, Nigeria (1981).

Variety	Yield (t/ha at 15% moist.)	% of check	Days silk	Ear ht. cm	Moist. % at harv.
IRAT 100	5.9	133	63	91	18
Poza Rica 7822	5.3	120	62	81	23
Golden Crystal	4.9	112	63	88	20
Composite 4	4.9	110	67	115	30
Comp. Y	4.7	108	62	103	19
Check - TZB	4.4	100	65	88	27
LSD (.05)	1.2				

Table 41. Performance of the 5 highest yielding experimental varieties plus 3 checks in ELVT 18B, Gusau, Nigeria (1981).

Rank	Variety	Yield (t/ha at 15% moist.)	% of check	Days silk	Ear ht. cm	Moist. % at harv.
1	Poza Rica 7926	5.4	105	55	67	20
3	Pirsabak (1) 7930	5.0	96	48	57	19
4	Across 7726 RE	4.8	93	55	68	21
7	Juliapa(1) 7930	4.2	81	48	52	16
8	Across 7835	4.2	81	51	55	18
2	TZE_4 x 174 (check)	5.2	100	58	113	21
5	TZE_4 (check)	4.6	89	56	73	18
6	TZE17 x 95 (check)	4.5	88	55	92	21
	LSD (.05)	1.2				

Table 42. Performance of the 5 highest yielding experimental varieties in ELVT 18A, 1980 Gusau, Nigeria (1981).

Rank	Variety	Yield (t/ha at 15% moist.)	% of check	Days silk	Ear ht. cm	Moist. % at harv.
1	Sete Lagoas 7728	5.5	114	59	89	25
2	San Andres(2) 7530	5.1	105	62	89	26
3	Ferke(1) 7622	4.9	102	63	59	30
4	Across 7721	4.9	101	62	66	27
6	Poza Rica 7822	4.7	97	62	68	27
5	TZPB (check)	4.0	100	66	99	33
20	TZSR-Y-1 (check)	3.1	64	63	93	27
	LSD (.05)	1.3				

Table 43. Performance of 5 highest yielding experimental varieties in ELVT 20, Jos, Nigeria (1981).

Rank	Variety	Yield (t/ha at 15% moist.)	% check	Moist. % at harv.
1	Across 7844	7.5	167	27
2	Across 7842	6.3	131	25
3	Across 7734	6.3	131	23
4	Chucquisaca(1) 7842	6.2	129	23
5	Sids 7844	6.2	129	28
9	TZPB (Mokwa) (check)	4.8	100	29
10	S 123 (check)	4.2	88	22
	LSD (.05)	1.5		

Table 44. Performance of the highest yielding experimental varieties from ELVT 18A, Ikenne, Nigeria (1981).

Rank	Variety	Yield (t/ha at 15% moist.)	% of check	Days silk	Ear ht. cm	Moist. % at harv.
1	Cotaxtla 7822	6.3	119	52	131	27
2	Poza Rica 7921	6.2	117	52	124	30
3	La Maquina 7843	6.1	115	53	138	28
4	Across 7843	5.9	112	54	136	29
5	Across 7822	5.9	110	53	123	26
6	Poza Rica 7843	5.7	108	53	136	27
7	La Maquina 7928	5.7	108	53	133	26
13	TZPB (check)	5.3	100	56	141	20
23	TZSR-Y-1 (check)	4.2	79	55	141	26
24	TZSR-W-1 (check)	3.9	73	56	129	26
	LSD (.05)	0.8				

Table 45. Performance of eight visually selected families from IPTT 49 (Ikenne, Nigéria, second season, 1981)

		Yield (t/ha)	Days silk	Plant ht. (cm)	Ear ht. (cm)
Selected families:	range	5.6-6.5	50-52	170-188	78-90
	mean	6.0	51	178	85
TZSR-W-1 (check):	mean	4.7	58	265	150

to drought stress which is accentuated by the poor water holding capacity of the soils. A separate breeding program is, therefore, necessary to evaluate available germplasm for adaptation to dry regions and to improve the performance of promising materials by recurrent selection.

In Upper Volta, the breeding program is implemented at 4 locations—Kamboinse, Loumbila, Saria and Farako-Ba which represent different rainfall regions.

The following are the salient findings:

1) HVB, a hybrid from Senegal, gave the highest yields in the uniform variety trial RUVT-1, but took a week longer to mature. TZE_4 and Pool 16 were found promising from the standpoint of duration and yield. Experimental varieties from these composite SAFITA-1 and SAFITA-2 have been developed by full-sib recurrent selection.
2) A full-sib recurrent selection program was initiated in 8 populations—bearing TZE numbers 7, 8, 9, 12, 14, 15, 16 and 17. About 1600 progenies were tested in two locations and the experimental varieties are being developed.
3) Two populations—TZSR-1 (Y) and TZSR-1 (W) are being improved for adaptation to semi-arid environments.
4) Local varieties from Kamboinse, Laye, Tougouri, Mamonou Koudougou and Nedego have been hybridized with the more productive and early maturing varieties.

Regional program for maize breeding

V.L. Asnani

The regional program for maize breeding functions as a collaborative research network of scientists in a number of countries. The program is jointly planned by the cooperators who also participate in monitoring tours to different locations. The Semi-Arid Region Maize Adaptation and Testing Program (SARMAT) includes uniform variety trials (RUVT-1 & 2) and full-sib family testing trials (RFTT-1V2). Salient results from the trials are given in Table 46.

Management of maize in semi-arid tropics

M.S. Rodriguez

In the semi-arid regions, maize is grown around the family compound in the low-rainfall (700-800 mm) belt and as a field

Table 46. Promising maize varieties in the SARMAT trials.

Country (location)	Trial	Promising varieties	Remarks
Senegal (Nioro)	RUVT-1	Mexican 17-E TZUT, TZE_4, Pool-16	Significantly better than local check
Togo	RUVT-1	TZPB, DMR-YE, TZSR-(Y), TZUT	Significantly outyields local.
Cameroom (Maroua)	RUVT-1	TZUT	Significantly better than local.
Mali	RUVT-2	Poza Rica 7822 Comp. 4 TZSR-1(Y)	—
Cameroon (Touboro)	RUVT-2	IRAT-100, SAFITA-102 TZSR-1(Y) TZPB	Significantly outyields local.
Republic of Benin	RUVT-2	TZPB, SAFITA-102	Significantly outyields local.
Togo	RUVT-2	TZPB Comp. 4 TZSR-1 (Y)	Significantly outyields local.

crop in the higher-rainfall (1000-1200 mm) belt. Intensive agronomic research on several aspects of tillage, influence of toposequence, plant density, timing of fertilizer application, residue management and moisture conserving techniques has been conducted at two locations in Upper Volta: Kamboinse and Saria.

Both locations are characterized by 800-mm annual rainfall and ferruginous tropical soils that tend to crust and compact; the soils are also low in organic matter and major nutrients. Erratic distribution of rainfall and incidence of drought spells further compound the stresses experienced during the crop growing season.

The concept is to determine a maize production package for low management (low crop density at 44,000 plants/ha and low fertilizer at 37 kg.N/ha) and high management (59,000 plants/ha and 100 kg. N/ha) levels. Because of the evapotranspiration demand of a 90-day maize in the test locations with 500-600 mm of water, such low rainfall locations, in general, need to manage the rain water most efficiently for crop production.

The following are salient observations:

1) Optimum plant density depends on the duration of the variety, soil fertility and time of planting.
2) Deep tillage is beneficial and zero-till farming gave consistently low yields.
3) The practice of earthing up the maize plants around 4 weeks after sowing and tying the ridges is an effective moisture conservation technique that prevents the negative impact of drought and improves nutrient uptake. Yields were improved by 20-100 percent over flat beds.
4) Toposequence has a big influence on maize yields which are low on the ridges, particularly when tied ridging is not practiced (Fig. 1). In the hydromorphic region of the toposequence, tied ridges help the maize crop in dry years, but can lower the yields in wet years.
5) Mulching with crop residues at 4 t/ha of dry matter is beneficial; but this quantity can be expected when the yields are more than 3 t/ha. Such a yield level is possible only when fertilizers are used. Leaving the crop residue on the ground helps maize in two ways: the moisture conservation effect of the mulch and increased water infiltration due to termites.
6) The negative impact of drought spells on maize yields can be prevented by deep plowing, tied ridging, repeated intercropping, choice of lower slopes in the toposequence, use of crop residues as mulch, choice of early maturing varieties and proper time of sowing.

Rice

The major objective of the rice improvement program is varietal improvement of free draining, upland (dryland), near-saturated valley bottoms (hydromorphic) and irrigated/shallow flooded (swamp) conditions. This is pursued through active participation and cooperation with international and national organizations. In 1981, the natural occurrence of rice yellow mottle virus (RYMV) infested plants was rather wide-spread in Nigeria. Resistance breeding for RYMV is being given more emphasis.

Considerable progress has been made in dryland rice varietal improvement by incorporating drought and blast resistance into short and intermediate cultivars. International trials conducted by the International Rice Research Institute (IRRI) indicate that IITA cultivars were found to be superior outside the continent. They were rated high for drought tolerance, recovery from drought and phenotypic susceptibility based on their performance in 19 locations in Asia. In addition, ITA 116, ITA 117, ITA 118, ITA 225 and ITA 235 showed improved vigor in an acid soil nursery at David, Chiriqi, Panama, where most other materials showed very poor growth.

In 1981, coordinated dryland rice trials were conducted by the West Africa Rice Development Association (WARDA) Liberia. Among 174 cultivars tested from various national and international programs, only ITA 233, ITA 234 and ITA 235 were found to have the least or no sterility of grains. Interestingly, ITA 233 and ITA 234 are improved lowland types while ITA 235 is an improved dryland rice type. Additional emphasis in varietal improvement for dryland rice is to develop high yielding semi-dwarf plant type culitvars. The seedling stage selection for short height and thick root system appears to be a particularly suitable approach for this objective. The performance of F_4 progenies of TOx 936 developed from such an approach supports this view.

In the 1981 coordinated irrigated rice trials of WARDA, ITA 230 for the Sahel zone and ITA 212 for the moist zone were among the top yielders. In an Initial Evaluation Trial comprising 216 entries, ITA 240 was one of 7 that yielded above 12 t/ha.

The National Cereals Research Institute (NCRI), Nigeria, released TOs 78 and TOs 103 as FARO 26 and FARO 27, respectively, for cultivation in irrigated lowlands.

Crop physiology studies were conducted to understand the effect of climatic conditions and cultural practice management on crop growth and production in West Africa. Grain yields of rice varieties tested were high when they ripened under high solar radiation (September/October and March) and low when they ripened under low solar radiation (June/July and December). The highest yield levels obtained in the trials are comparable to those obtained in other countries. Thus, the data suggest that the climate in West Africa will not be the yield limiting factor if the cropping season is carefully chosen.

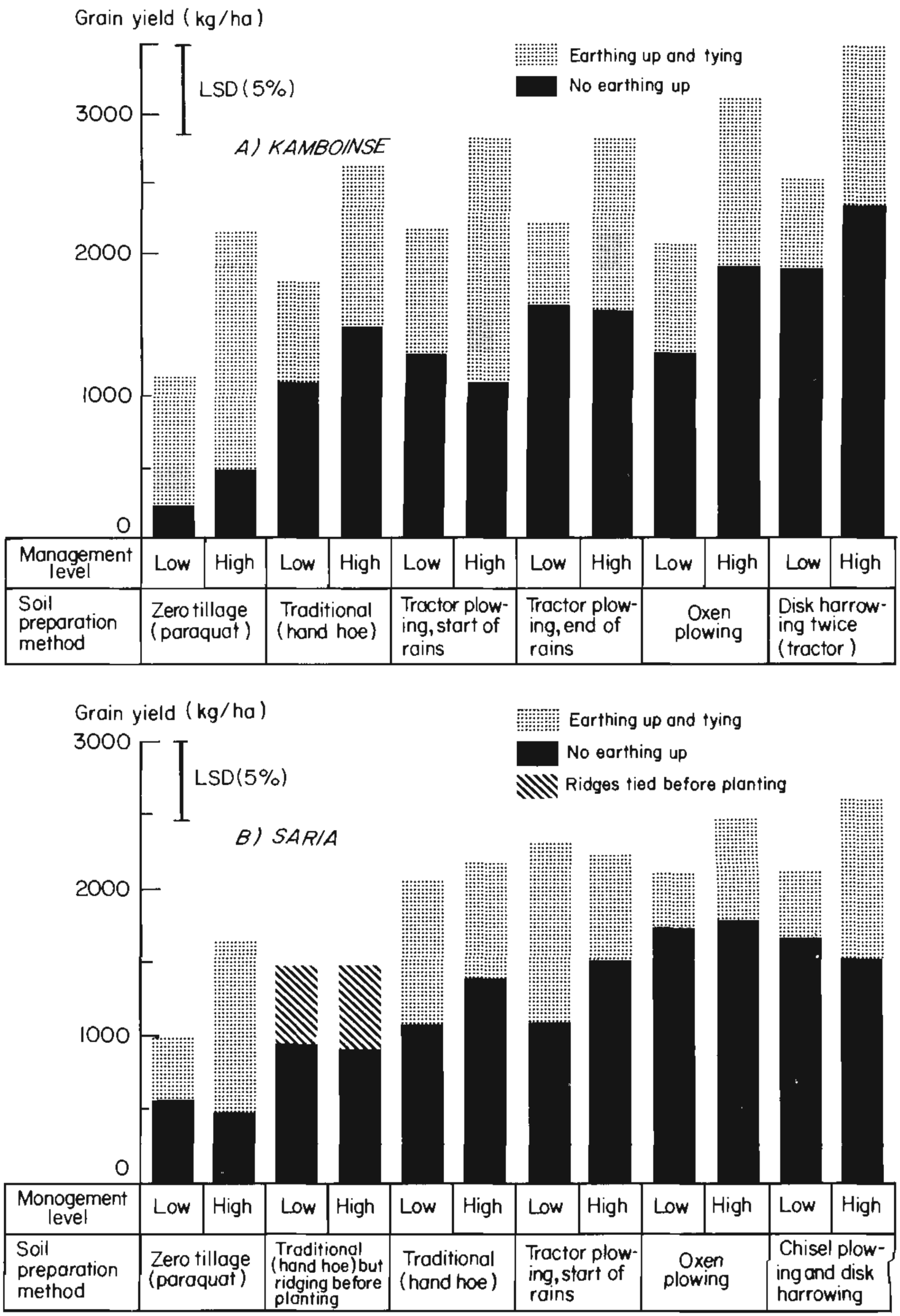


Fig. 1. The effect of different soil preparation methods and of earthing up and tying on the grain yield of maize in Kamboinse and Saria, 1981.

Evaluating the N response of improved irrigated lowland rice cultivars developed at IITA showed that their yield potential is generally comparable to those high yielding varieties released from Asia.

Plant density studies in dryland showed that the grain yield of all types of cultivars tested responds positively to increased plant densities under favorable moisture regimes. The grain quality of rice was very poor at higher densities in lowland cultivars and less affected in dryland cultivars. However, improved dryland cultivars, ITA 118 and ITA 235, responded well to the highest density of 100 plants/m^2 tested.

These results indicate that in the absence of severe drought, the optimum plant density with improved dryland cultivars is likely to be similar in drylands to that in irrigated lowland.

Studies on the resistance to the stalk eyed fly (*Diopsis thoracica*) and rice stem borers have been reactivated, with the arrival of an entomologist late in the year.

Genetic Improvement-Dryland Rice

Varietal trials

S. Sarkarung

The main objective of the dryland rice improvement program is to develop high yield potential rice varieties with improved plant type, resistant to or tolerant of the major stress such as drought, blast, *Rynchosporium,* and sheath blight and also with wide adaptability under different climatic conditions. The major emphasis during 1981 was to determine yield potential of breeding materials under different agro-climatic conditions and to evaluate their performance for different stresses.

Several crosses were made with different donors. The early generation materials were grown mainly at Ibadan but some of them were also grown at Onne, Ikenne, Ubiaja and Ilorin, all in Nigeria, which represent different agroclimatic conditions. F_2 seeds were very lightly drilled at a row spacing of 40 cm. Check varieties (IRAT 112 for short height and early, 6850, 6906, ADNY 11 for semi-dwarf tillering and OS6 for local check), including parents, were also planted across the field. Tall F_2 plants were rouged as soon as they were recognized. Selections were made at the ripening stage to insure that only clean grain, semi dwarf plants were kept.

Observational trials were conducted in three different locations, Onne, Ikenne and Ilorin in Nigeria. Each entry consisted of 4 rows 5 meters long with two replications. Spacing between rows was 30 cm. One hundred entries were tested both in Onne and Ikenne; 84 at Ilorin. Maturity period of these entries ranged between 90-135 days. Test entries of observational trials were mainly from IITA, IIRI and the International Rice Testing Program (IRTP), but some entries were also from IRAT and Brazil.

Three different yield trials: Preliminary, Advanced and Elite Trials were conducted in 3 to 5 different locations within Nigeria representing different environmental conditions and stresses. Preliminary Yield Trials were carried out at Ibadan, Ikenne and Onne with 25 entries of early and medium maturity groups. Each entry consisted of 5 rows, 5 meters long with spacing 30 cm between rows. A randomized complete block design was used with three replications.

Advanced yield trials were conducted in the same three locations. These trials consisted of 28 entries with two groups of maturity, early and medium. Each test entry consisted of 6 rows, 5 meters long with a spacing of 30 cm between rows. A randomized complete block design was used with four replications.

Elite Yield Trials consisted of 11 most promising lines with uniformity in plant height, maturity date and reaction to diseases. Trials were conducted at Ibadan, Ikenne, Ubiaja, Onne and Ilorin in Nigeria. Test material was planted in 6 rows, 5 meters long with 30 cm between rows. The experimental design was a randomized complete block with four replications.

A total of 100 crosses were made and 2043 early generation materials were grown in 1981 (Table 47). F_2 populations from crosses involving improved upland cultivars and high yielding semi-dwarfs were planted at Ikenne. Several hundred single plant selections were made (Table 48) and these selected materials will be tested against blast at Onne. F_3 families from TOx 1858, 1922 and 1805 will be screened for RYMV resistance. F_3 and F_4 families of TOx 1871 were outstanding. They have sturdy culm, upright leaves and an early maturity period (ca. 90 days). Plant height was about the same as IRAT 112. Some families had dense panicles with intermediate grain size. All these selected materials will be evaluated further.

Table 47. Early generation materials grown at different locations in Nigeria (1981).

	No. planted					
Generation	IITA	Onne	Ikenne	Ubiaja	Ilorin	Total
F_1	100	—	—	—	—	100
F_2	120	10	6	—	—	136
F_3	500	314	109	74	30	1027
F_4 onward	300	480	—	—	—	780

Table 48. F_3 single plant selections* from different F_2 populations in dryland at Ikenne (1981).

Designation	Parentage	No. of selections
TOx 1858	TOx 504-14-1/6810	99
TOx 1861	TOx 95/6811	2
TOx 1805	Coll. 6852/IAC 435	3
TOx 1922	TOx 494/TOx 711/6805	22
TOx 1815	Coll. 6852/TOx 475 SLR	52
TOx 1871	ITA 212/TOx 1192-16	150

**The selections are generally intended for moist zones, while TOx 1871 selection could be useful also in subsavanna regions.*

Most of the materials from the observational trials were discarded due to severe leaf and neck blast, *Rynchosporium*, dirty grain and also for tallness and lodging.

Several early and medium duration entries performed well at Ilorin. Entries having a growth cycle beyond 125 days were severely affected by drought at the end of the rain season. Semi-dwarf types from IRTP were most affected. All the IRTP materials performed poorly at Ilorin (sub-savanna ecology) except M/133/6/1/2 which performed fairly well there. IITA lines, TOx 1012-12-3-1, TOx 1011-4-1, ITA 154, TOx 1010-25-16, TOx 1369-23-10 and TOx 1369-24-5 also performed well at Ilorin.

Based on reaction to diseases and on other agronomic characters, 15 cultivars, ITA 154, ITA 207, TOx 1010-25-16, TOx 1010-27-1, TOx 1012-12-3, TOx 1011-4-1, TOx 1127-2-1-1, TOx 1177-17-1-1, TOx 1369-23-10, TOx 1369-24-5, IRAT 13, IRAT 112, LAC 25, M 133/6/1/2 and Khao 10/IR 8 were found promising cultivars at all locations and will be re-evaluated.

In preliminary yield trials, most entries performed well under intermediate level management at Ikenne. Early duration varieties TOx 10114-1 and TOx 10114-1-2 gave a higher yield than the check varieties. The performance of many medium cultivars was also good. Outstanding yield was obtained from TOx 718-1-24, ITA 143, TOx 1789-19-18 and TOx 718-1-23.

At Onne, several superior entries were identified. Entries having high yielding ability and clean grains were TOx 718-1-23, TOx 718-1-24, ITA 143 and ITA 145. TOx 1012-12-3-1 also performed fairly well. It has very clean grain, intermediate strong culm, and a high level of blast resistance.

Among the test entries, TOx 1011-4-1 and IR 5931-110-1 gave the highest yield at Ibadan. TOx 1011-4-1 is an early duration variety which can mature within 90 days. Moreover, its grain quality is also acceptable. Other promising entries were ITA 143, TOx 1369-17-1, ITA 182 and TOx 1785-19-18. On an average, the yield of selected entries was 18-35 percent higher than the check variety OS 6. Relative yield, growth duration and reaction to blast of 5 superior entries and the check variety OS 6 are shown in Table 49.

In advanced yield trials, cultivars ITA 141, ITA 165, ITA 182, ITA 235 and IRAT 13 performed well at all test locations. All the selected varieties gave 21-33 percent higher yield than the standard check variety OS 6. Due to absence of leaf and neck blast, semi-dwarf cultivars IR 6669 and IR 9575 were superior in yield at Ibadan. IR 9575 also performed fairly well at Ikenne. But these entries were severely affected by blast at Onne. ITA 235, ITA 141 and ITA 142 were holding their good performance across the environments. Only a few entries performed well at Onne. Pressure from leaf and neck blast and *Rynchosporium* was high at this location. Many entries were severely infected by blast at both vegetative and reproductive stages.

Results of elite trials (Table 50) show that ITA 118 and ITA 235 are stable across the environments. ITA 235 performed well in preliminary and advanced yield trials. Average yield of ITA 118 and ITA 235 was 31 percent higher than the standard check variety OS 6. ITA 118 is erect with sturdy

Table 49. Characteristics of selected materials from preliminary yield trial (1981).

Cultivar	Parentage	Relative yield[a]	Maturity (days)	Reaction to blast[b]
TOx 1011-4-1	(IRAT 13/Donrado Precose No. 689/TOx 490	121	88-92	R
TOx 718-1-23	IRAT 13/OS 6	118	105-113	R
TOx 718-1-24	IRAT 13/OS 6	123	106-112	R
(TOx 1785-19-18) (ITA 235)	OS 6 mutant/OS 6	123	106-112	R
ITA 143±	63-83/Vijaya, Juma-1 Dourado Precose	135	103-110	R
OS 6 check		100	119-121	R

[a] *Average of three locations.*
[b] *Based on visual grading, R = resistant.*

Table 50. Grain yield (t/ha) of promising rice cultivars in elite variety trials at 5 locations in Nigeria (1981).

Cultivar	Ubiaja	Ibadan	Ikenne	Onne	Ilorin	Av.	% of check
ITA 235	5.2	4.8	4.9	3.5	2.7	4.2	131
ITA 118	5.8	5.5	3.9	3.6	2.4	4.2	131
ITA 135	5.1	5.3	4.1	3.5	2.4	4.1	128
ITA 162	6.0	5.8	4.2	2.5	1.9	4.1	128
ITA 132	5.1	5.4	4.1	3.2	2.1	4.2	116
ITA 164	4.9	4.9	4.1	2.6	1.9	3.7	116
ITA 173	5.9	4.6	3.8	2.5	1.6	3.7	116
ITA 116	5.1	4.6	3.7	2.5	2.4	3.6	113
ITA 117	4.3	4.5	3.7	3.6	1.8	3.6	113
ITA 119	4.5	4.0	4.2	2.4	2.8	3.6	113
ITA 130	4.3	3.9	4.0	2.6	1.8	3.3	103
OS 6 (check)	4.9	3.7	3.5	2.4	1.5	3.2	100
	5.1	4.7	4.0	2.9	2.1	3.8	

	CV	SE	L.S.D.
Variety	14.962	126.357	0.353
Location	16.555	90.244	0.279
Variety × Location	14.962	282.543	0.790

culms, less tendency to lodge and is less vulnerable to diseases. ITA 119 is also a short variety and performed well at Ilorin, but it is highly susceptible to *Rhynchosporium* and dirty grain.

Other cultivars—ITA 116, ITA 132 and ITA 135—also performed well at sub-savanna zone at Ilorin. Though the yield of ITA 162 and ITA 173 was good, these varieties are too tall for the high rainfall zone and too late in maturity for the sub-savanna zone. General performance of elite cultivars was good at Ubiaja. This indicates that maximum yield can be obtained in this favorable forest zone. This may be due to abundant rainfall, sufficient solar radiation and absence of major diseases.

Genetic Improvement—Hydromorphic and Shallow Swamp Rice

Variety trials

K. Alluri

OBSERVATIONAL TRIALS. Observational yield trials were carried out at different locations in Nigeria with 50 entries. The trials were unreplicated. Among the 50 cultivars evaluated, 6838, ITA 238, ITA 212, ITA 240 and ITA 250 along with the check variety FARO 15 averaged 6.7-7.0 t/ha. But when the same set of cultivars was tested under moderate Fe toxicity conditions in Uzo-Uwani, Nigeria, ITA 212 still was among the top yielders (3.7 t/ha). Several TOx 711 (IR 5/Suakoko 8) lines such as ITA 244, ITA 249 and ITA 255 yielded 3.6-3.8 t/ha.

ADVANCED TRIALS. Advanced yield trials were carried out at different locations in Nigeria with 15 entries. A randomized complete block design with 3 replications was used. ITA 247 was the top yielder in most of the locations tested (Table 51). ITA 247 and ITA 239 were developed by crossing IR 5 and Suakoko 8 to incorporate Fe toxicity tolerance and long, nonchalky grain characters. Most varieties, including ITA 247, grew very leafy and lodged at Uzo-Uwani, where the fertility was high.

Physiology

Evaluation of climate on growth and grain yield

J. Yamaguchi

Plant growth and grain yield of rice plants as well as other crop species are dependent on genetic as well as environmental factors. Among the climatic factors, solar radiation and temperature give predominant effects, showing seasonal fluctuations. Thus, planting should be timed to take maximum advantage of the seasonal variation.

This experiment was carried out with periodic plantings using 2 different varieties in 2 irrigated and hydromorphic conditions to (1) evaluate the climatic effect on the plant growth and grain yield with special attention given to solar radiation and (2) provide fundamental data to estimate the favorable growing season.

IRRIGATED LOWLAND. TOs 103 and ITA 212 with short and medium-growth duration, respectively, were grown in irrigated lowland conditions at IITA with periodic plantings, every 4 weeks from 24 November, 1980 to the end of 1981

Rice breeding at IITA emphasizes thick root systems and good grain filling characteristics in making the right selections for dryland rice.

(planting Nos. 1-14). Eight-plant samples for dry weight, leaf area index (LAI) and light transmission ratio (LTR), etc., were taken every 2 weeks at successive growth stages.

This was a sampling study where 200 hills ($9m^2$) were harvested at maturity for yield determination. Grain yields of both cultivars were high when plants ripened under high solar radiation and low under low solar radiation conditions (Fig. 2). For example, when ITA 212 was planted in June/July (planting Nos. 8 and 9) and December (planting No. 1), the ripening period coincided with September October and

A typical hydromorphic valley developed for rice cultivation at IITA.

ITA 212, a derivative of BG 90-2, developed for irrigated lowland conditions. It is superior to BG 90-2 in its grain quality and resistance to blast.

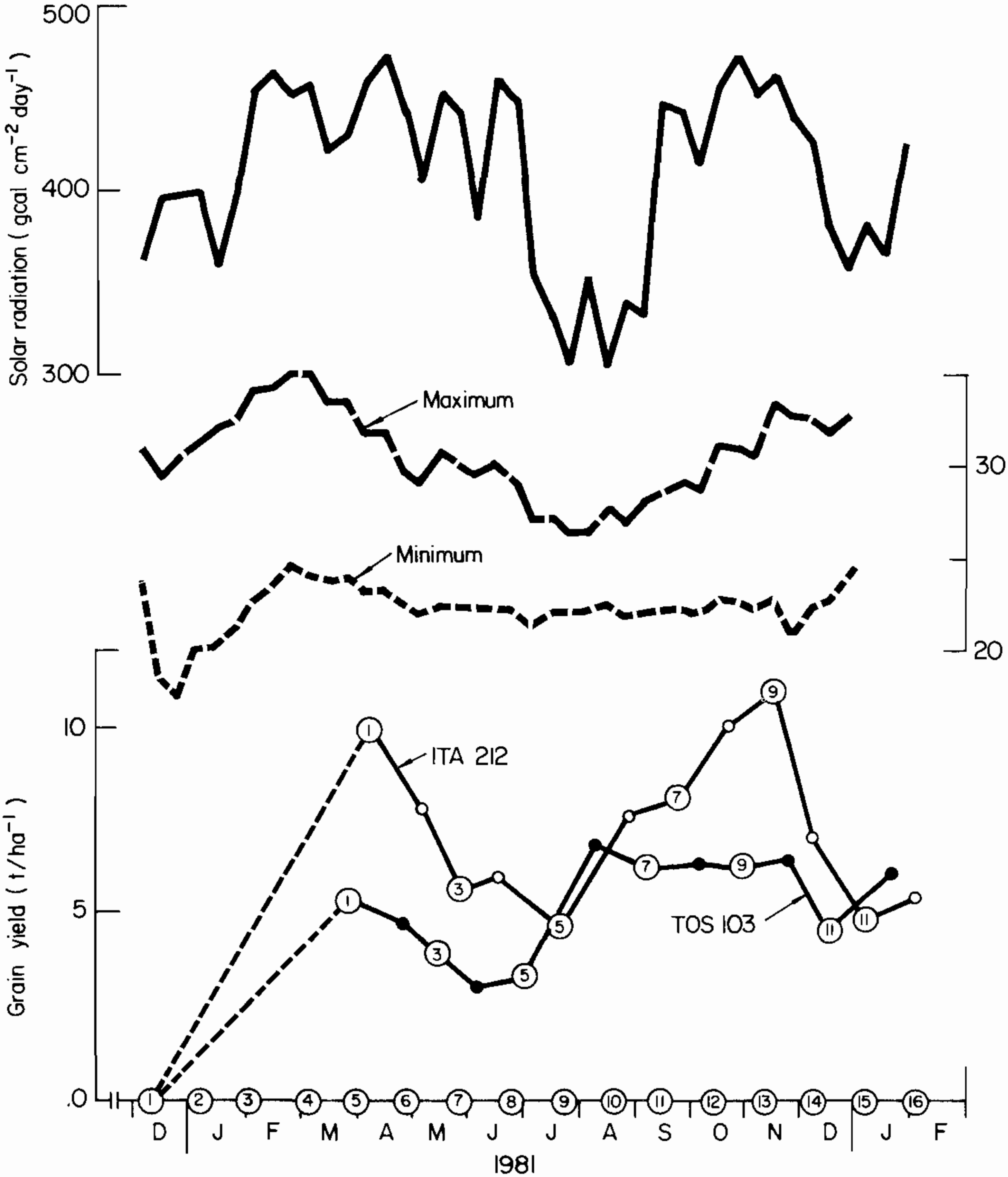


Fig. 2. Climatic effect on the grain yield of rice plants under irrigated lowland condition. *(The numbers in the circle indicate the dates of transplanting and full maturity at successive plantings.)*

Table 51. Grain yield in kg/ha, plant height and growth duration of the cultivars tested in 1981 swamp rice multilocational yield trial, Nigeria.

Variety	Ibadan	Amaeke	Ndi Ojugwu	Uzo Uwani (West)	Uzo Uwani (South)	Mean	Plant height (± 10 cm)	Growth duration (± 10 days)
ITA 247	4916	7555	8610	7738	2873	6838	140	150
IET 6279	5307	6747	7523	7313	3509	6080	130	145
IR 5 (check)	5031	6629	6820	6563	2786	5566	125	145
ITA 239	4051	7082	6208	6714	3606	5532	135	145
FARO 15 (check)	4270	6370	6864	6590	3885	5496	140	145
ITA 121	4655	6531	6495	5352	4186	5444	110	125
ITA 212	5068	5553	7320	4724	3582	5249	110	130
IET 5854	4600	5582	7013	5280	3497	5194	130	140
BG 90-2 (check)	4540	6348	7038	4658	3290	5175	110	130
ITA 245	4443	6050	6146	6155	2977	5154	125	140
ITA 123	4783	6942	6941	3917	2521	5021	110	120
IET 4865	4574	5724	6049	5806	2701	4971	130	135
ITA 222	5222	4269	2566	4902	3823	4216	115	130
ITA 231	3870	4752	4671	3274	1631	3640	115	125
IR 36	2246	3659	3827	2773	2115	2924	100	110
LSD (.05)	718	1165	1082	1192	895			

March, respectively, and the yield reached 10-11 t/ha because of favorable radiation (about 450 gcal M^{-2} day^{-1}). In contrast, when ITA 212 was planted in March (planting Nos. 4 and 5) and September (planting No. 11), the ripening period coincided with June/July and December, respectively, and the yield only reached 5 t/ha because of unfavorable radiation (300-350 gcal cm^{-2} day^{-1}).

Yields were reduced more during the ascending periods of solar radiation (i.e. from January to February in planting No. 1 and from August to September in planting Nos. 8 and 9) than during the descending periods of solar radiation (i.e., from May to June in planting Nos. 4 and 5 and from November to December in planting Nos. 10 and 11). (Fig. 3).

The highest yield levels obtained in this trial are comparable to those in other countries, e.g. Philippines. Thus, climate is not a yield-limiting factor in West Africa if the cropping season is carefully chosen.

Growth duration was affected by temperature and solar radiation (Fig. 4). Growth duration from sowing to 50 percent flowering was longer in the period of lower temperature and shorter in the period of higher temperature. The ripening period also fluctuated nearly 10 days among plantings; there seemed to be an optimum ripening period to produce high yield: not very short, but also not very long.

Maximum production per year with multiple plantings could be estimated using the results obtained: about 21 t/ha with 2 plantings (July and December) of ITA 212, about 19 t/ha with 3 plantings (April, August, and December) of ITA 212 and about 26 t/ha with 2 plantings (July and December) of ITA 212 plus 1 planting (April) of TOs 103. The latter 2 cases are quite rigid for successive plantings, since only a short period is afforded between 3 plantings. Optimum growth duration in irrigated lowland rice is well studied, being about 130 days. Thus, it is better to take advantage of seasonal changes of yields and yield potentiality of medium growth duration varieties; grain production greater than 20 t/ha from the same field in a year is feasible without a particularly intensive management.

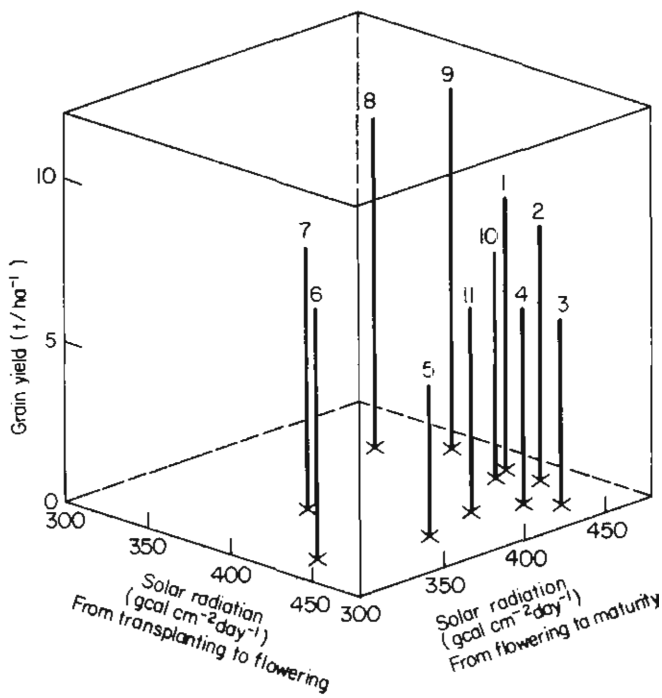


Fig. 3. Relationship between grain yield and solar radiation at vegetative growth and ripening stages. *(ITA 212 in irrigated lowland)*

HYDROMORPHIC. Three traditional upland rice varieties (LAC 23, OS 6 and Dourado Precoce) 4 improved upland ones (IRAT 13, ITA 117, ITA 120 and ITA 173), and 3 improved irrigated lowland varieties (TOs 103, ADNY 11 and ITA 212) were grown in hydromorphic conditions at IITA. Periodic plantings were made every 4 weeks from March 20 to November 2, 1981 (Nos. 1-8) with 2 replications.

The soil moisture content was maintained at 21-26 percent until the middle of July, dropped to 14 percent at the end of July because of less rainfall, recovered and maintained at 21-27 percent until the middle of November, and then gradually decreased toward January (Fig. 5). Since rain stopped earlier in 1981 than in previous years, supplemental irrigation

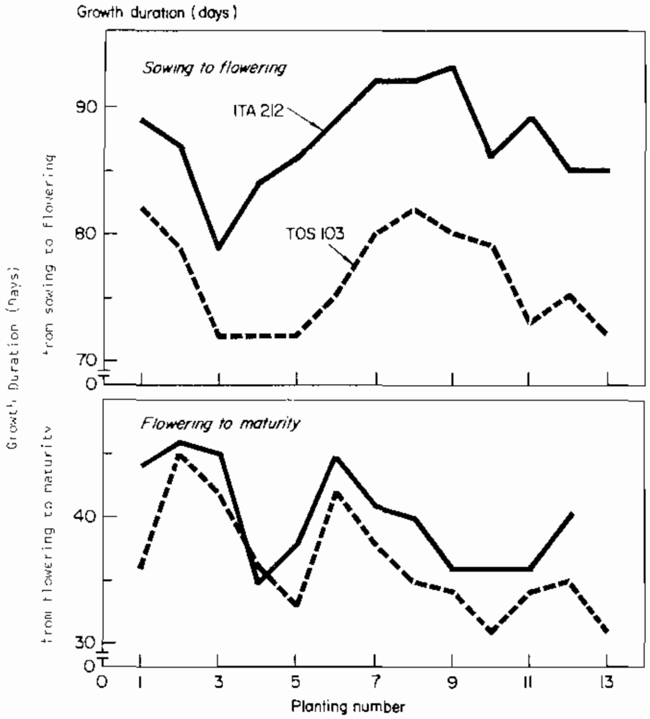


Fig. 4. Changes of growth duration at successive plantings of rice plant in irrigated lowland.

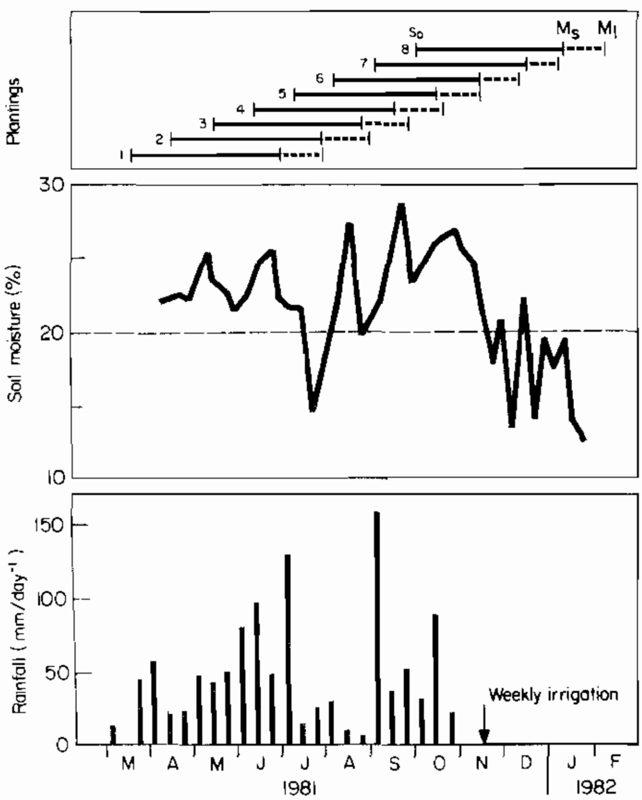


Fig. 5. Annual changes of soil moisture and rainfall and sequence of successive plantings in hydromorphic conditions. (So, Ms, and Me: Dates of sowing and full maturity of shortest and longest growth durations cultivars.)

was given to the plants at minimum levels for a few hours once a week.

LAC 23, OS 6 and ITA 173 were taller. Late planting reduced the plant height more in LAC 23 and ADNY 11 (Table 52). Panicle number was larger in irrigated lowland than in upland cultivars, and late planting decreased the panicle number of most cultivars. Growth duration became a few days shorter with late plantings.

Several cultivars gave yields and similar trends at successive plantings so that cultivars were pooled in 3 groups (Figs. 6 and 7).

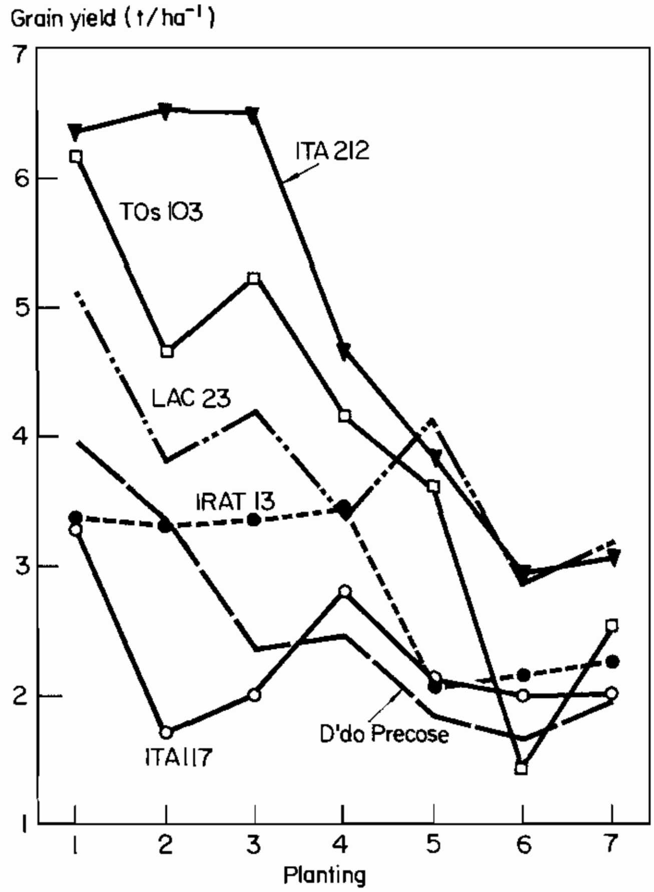


Fig. 6. Grain yield of rice cultivars at successive plantings in hydromorphic conditions.

Yield was higher in irrigated lowland than upland cultivars with early plantings : 5.5-6, 4-4.5 and 2.5-3.5 t/ha in irrigated lowland, traditional upland and ITA 173, and the other entries of improved upland cultivars, respectively, for the first 3 plantings. Grain yields decreased with the delay of plantings, and all cultivars reached 2-3 t/ha level at the final planting.

These results demonstrate that improved lowland cultivars perform better than any entries of upland cultivars in hydromorphic conditions as far as the moisture is available, they are characterized with short stature (100 ± 10 cm), medium to high tillering ability (300 ± 50 panicles/m^2), medium growth duration (130 ± 5 days from sowing to full maturity) and larger harvest index. Ideoplant type of hydromorphic rice is essentially similar to that of improved lowland rice. Higher

Table 52. Plant height, panicle number and growth duration of rice cultivars with periodic plantings in hydromorphic conditions.

Cultivar	Plant height* (cm)		Panicle no.*		Growth duration*		Harvest index*	
	P_{1-2}	P_{7-8}	P_{1-2}	P_{7-8}	P_{1-2}	P_{7-8}	P_{1-2}	P_{7-8}
LAC 23	175	144	85	97	134	128	35	33
OS 6	160	146	130	114	118	118	43	45
Dourado Precoce	124	125	132	94	102	102	35	47
IRAT 13	121	121	150	133	117	113	44	46
ITA 117	97	93	204	162	108	109	39	43
ITA 120	112	115	128	100	101	99	39	48
ITA 173	143	136	147	118	128	121	44	43
TOs 103	85	76	338	237	121	117	41	43
ADNY 11	115	90	238	207	129	125	48	44
ITA 212	104	90	266	261	136	128	46	40

*P_{1-2} and P_{7-8}: Average of planting Nos. 1 and 2 and planting Nos. 7 and 8, respectively.

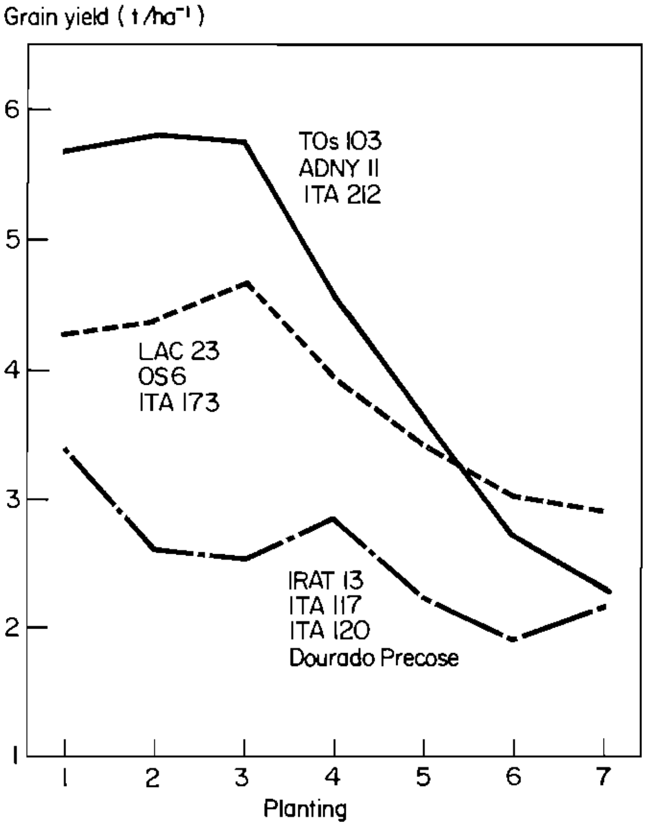


Fig. 7. Changes of grain yield with group of cultivars at successive plantings in hydromorphic conditions.

yields were produced in upland cultivars with tall statures (140 cm above) including traditional cultivars, than short statures. Upland cultivars with short stature have a short growth period (100-110 days) and probably this is why they yield less.

Thus, similar yields are produced of 1 crop of medium duration, improved irrigated lowland cultivars (about 6 t/ha) and 2 crops (e.g., planting Nos. 1 and 5) of short duration upland cultivars. From these aspects, it is recommended that 1 planting with high yielding lowland cultivars is more feasible in hydromorphic conditions even if the moisture is available for 7 months or so. Also a single planting can be free from the uncertainty of yearly rainfall fluctuations.

Transpiration coefficient of rice cultivars

J. Yamaguchi

Adaptability of crop plants to limited water conditions can be evaluated by the following physiological characters:

1) Capability of water absorption by plant roots in a given moisture regime in the soil.
2) Utilization efficiency of absorbed water by plants.

The latter can be determined as a transpiration coefficient (water requirement), which is expressed as the amount of water required to produce a unit amount of plant dry matter, while the former is closely associated with root development and activity.

Various characters related to the evaluation of drought tolerance such as the stomata resistance, leaf water potential, dessication and heat tolerance can be described by 1 character, i.e. the transpiration coefficient because the transpiration coefficient is the result of plant growth through all aspects of water metabolism.

This experiment is to explain the diversity of rice cultivars in transpiration coefficents by using various rice cultivars along with maize and soybean. The results are discussed in relation to different crops.

Cultivars were selected from upland and irrigated lowland rice, while maize and soybean were added for comparison. Seeds were sown in pots containing 3 kg soil with 3 g compound fertilizer (15-15-15). Number of plants per pot was 1 each for maize and soybean and 2 for rice after thinning. Pot weight with soil was measured daily for each pot and the amount of water lost through transpiration added to maintain the original water retention at 0.1 bar in the soil. To get the transpiration coefficient, pots were covered with aluminum foil and plastic sheets to prevent evaporation from the soil surface. To estimate the transpiration coefficient (transpiration/dry matter production) the amount of transpiration was the sum of daily water added and dry matter production was the balance of plant dry weight between initial and final days of the experiments.

TRIAL 1. Seeds were sown on 26 February, and the experimental period was from 23 March to 5 April (14 days) for maize and soybean, and from 6 April to 20 April (15 days) for rice. The experiment was duplicated.

Transpiration during the experimental period was larger in 2 entries of lowland rice and maize followed by upland rice and was smallest in soybean (Table 53). Dry matter production was largest in maize followed by 2 entries of lowland rice and TOx 515 selection (Tough C24) and was smallest in soybean. Thus, the transpiration coefficient was smallest in maize (176) followed by rice (262-334) and was largest in soybean (682).

Table 53. Estimate of transpiration coefficient (Trial 1).*

Entry No.	Crop/ Rice cultivar	Transpiration (g/pot)	Dry matter production (g/pot)	Transpiration coefficient
1	Maize (IB32 × 495)	2448	13.94	176
2	Soybean	903	1.32	682
3	OS 6	2139	7.45	287
4	IRAT 13	1633	6.23	262
5	ITA 119	1587	4.11	387
6	TOx 515 selection	2278	8.54	267
7	IR 5	2785	8.33	334
8	IR 1416-131-5	2777	8.64	322

Upland rice: Entry Nos. 3-6
Lowland rice: Entry Nos. 7 and 8

TRIAL 2. Seeds were sown on 15 May, and the experimental period was from 11 to 25 June (14 days) for maize and soybean, and from 25 June to 8 July (13 days) for rice. There were 4 replications.

The transpiration coefficient was smaller in LAC 23, OS 6, ITA 119, ITA 162 and TOs 103 (155-190) than in the other entries of rice and maize (206-219) and was largest in soybean (373) (Table 54).

Table 54. Estimate of transpiration coefficient (Trial 2).*

Entry No.	Species/ Rice cultivar	Transpiration (g/plant)	Dry matter production (g/plant)	Transpiration coefficient
1	Maize (IB 32 × B68)	2662	12.91	206
2	Soybean	2149	5.77	373
3	LAC 23	1096	6.48	169
4	OS 6	1193	6.27	190
5	ITA 119	959	6.21	155
6	ITA 141	1128	5.26	215
7	ITA 162	1057	5.59	189
8	TOx 711-3-204	1357	6.20	219
9	TQs 103	1179	6.36	185
10	ITA 212	1349	6.52	206
11	IR 5	1404	6.47	217

Upland rice: Entry Nos. 3-8
Lowland rice: Entry Nos. 9-11

Because transpiration coefficients were greatly influenced by humidity in the atmosphere, the values obtained in both trials did not correspond with each other. In general, values were larger in Trial 1. Nevertheless, differences were likely to exist among crop species and also between upland and lowland rice cultivars. Mean values averaged over 2 trials were about 190 in maize, 530 in soybean, 245 in upland rice and 270 in lowland rice (Table 55). Water use efficiency of upland rice seems to be about 10 percent higher than that of lowland rice, but not as high as maize plants.

Hence, improvement of rice cultivars to adapt to dryland conditions may be possible through the improvement of water use efficiency but not beyond 10 percent.

Table 55. Summary of transpiration coefficient (T.C.).*

Species/ Rice group	T.C.	Relative value
Maize	191	71
Soybean	528	196
Upland rice	245	91
Lowland rice	270	100

Mean of trials 1 and 2

Nutritional disorder of a highly leached acidic soil (Onne)

J. Yamaguchi

Suppression of adverse factors in problem soils by manipulating nutrient supply is essential for improving crop productivity.

At Onne in eastern Nigeria under high rainfall, rice plants often suffer from dirty panicle (glume discoloration). So far, several fungi have been identified as causal agents. It is, however, thought that the cause is closely related to a nutritional disorder in the soil because the cation exchange capacity is very low and nutrient availability in these soils is also poor.

This experiment was carried out to identify the cause of nutritional disorders that occur when rice plants are grown in Onne soils with various remedial treatments such as chemical and water treatments.

Rice variety ITA 122 was grown in pots containing 3 kg of Onne soil with 14 chemical treatments as listed in Tables 56 and 57, both under flooded and free-drained conditions. Soils were soaked with demineralized water in flooded treatments while demineralized water was occasionally supplied through the holes of the bottom of the pots in free-drained

Table 56. Quantity of chemicals used.

Element	Quantity (mg/kg soil)	Salt
N	300*	$(NH_4)_2SO_4$
P_1	100	$Ca(H_2PO_4)_2\ H_20$
P_2	500	$Ca(H_2PO_4)_2\ H_20$
K_1	100	K_2SO_4
K_2	300*	K_2SO_4
Ca.Mg.	50 each	$CaCO_3$, $MgCO_3$
Lime	2000	Dolomatic limestone
$Ca(SO_4)$	342	$CaSO_4.2H_20$
$Mg(SO_4)$	162	$MgSO_4.7H_20$

* *3 splits application.*

Table 57. Chemical treatment to Onne soil.

No.	Treatment	No.	Treatment
1	Control	8	NK_2.CaMg
2	N	9	NP_1K_1.CaMg
3	P_2	10	NP_2K_2.CaMg
4	K_2	11	Lime
5	NP_1K_1	12	NP_1K_1.Lime
6	NP_2K_2	13	NP_2K_2.Lime
7	NP_2.CaMg	14	NP_2K_2.Ca Mg SO_4

treatments using saucers to protect run-off. The experiment was carried out in screen houses. Seeds were sown on 29 January, and 2 plants per pot were established.

Data on mechanical analysis show that the soil used was composed of 81 percent sand, 5 percent silt and 14 percent clay. Organic C content was 0.98 percent while total N was 0.12 percent. Effective CEC was 3.0 me/100 g soil which was the sum of exchangeable bases, Ca, Mg, K and Na (1.05, 0.41, 0.16, and 0.18 me/100 g, respectively) and the Kcl-exchangeable Al and H (1.18 me/100 g). The original pH (soil: water = 1:2.5) was 4.0, and lime requirement was determined by the incubation method using ground dolomatic limestone (Fig. 8). Lime was used to adjust soil pH to about 5.5.

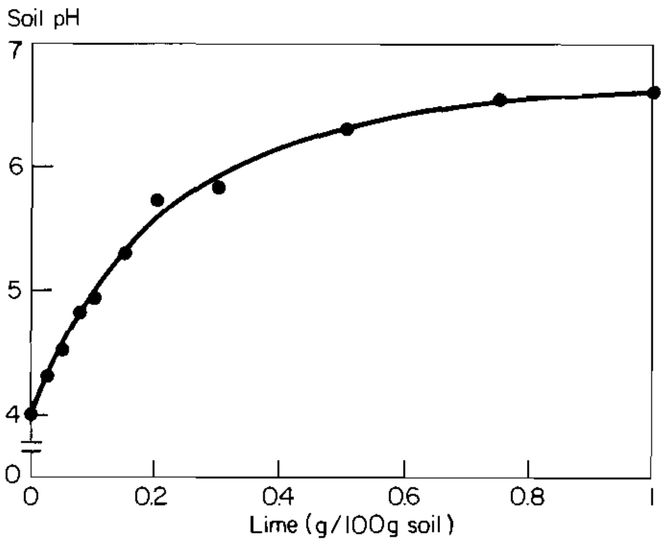


Fig. 8. Lime requirement in Onne soil. *(Soil pH was determined after 1 week incubation with soil = water = 1 ÷ 2.5).*

Samples were taken at the vegetative growth stage (54 days after sowing) and full maturity (117 days), and the dry weight and chemical content were determined.

Severe symptoms of Fe toxicity, bronzing in the leaves and reduction in plant height were observed in most low nutrient treatments (Control, N, P, K, NPCaMg, Lime) throughout the growth stages. Symptoms were generally less severe under free-drained conditions even in the control. Slight symptoms were observed in P, NPK, NPCaMg and NPKCaMg (SO_4) treatments. Symptoms of dirty panicles (glume discoloration) were not observed. Generally, the percentage of sterile spikelets was more than 50 percent in most treatments.

Plant height and number of panicles per plant at maturity were less in low nutrient treatments (control, N, P, K, etc) than in high nutrient treatments (N P K Ca Mg/Lime) under flooded conditions (Table 58). Plant height in low nutrient treatments was greater under free-drained than under flooded conditions while panicle number in all chemical treatments was larger in flooded than in free-drained soils.

Total dry weight at maturity in control, P, K and lime treatments was less under flooded than under free-drained conditions. It was greater in all other chemical treatments under flooded conditions (Table 59). These trends were not significant at the vegetative growth stage most likely because plant nutrient requirement was still low so that the soil was able to supply nutrients to such small plants.

Table 58. Plant height and panicle number at full maturity under various chemical and water treatments in highly leached acidic Onne soil.

Chemical treatment		Plant height (cm) Flood	Plant height (cm) Free-drain	Panicle No. per plant Flood	Panicle No. per plant Free-drain
1	Control	51	75	3	1
2	N	60	72	11	3
3	P_2	69	90	4	2
4	K_2	62	90	3	1
5	NP_1K_1	80	72	11	4
6	NP_2K_2	95	92	12	3
7	NP_2Ca Mg	73	80	9	5
8	NK_2 Ca Mg	105	79	9	3
9	Np_1K_1 Ca Mg	92	83	10	4
10	NP_2K_2Ca Mg	100	90	12	5
11	Lime	75	91	5	1
12	NP_1K_1 Lime	102	86	7	4
13	NP_2K_2 Lime	94	67	14	4
14	NP_2K_2 Ca Mg So_4	98	86	12	5
	SE	5.5	7.0	0.8	0.4

Table 59. Total dry weight (g/plant) under various chemical and water treatments in highly leached acidic Onne soil

Chemical treatment		Vegetative growth stage Flood	Vegetative growth stage Free-drain	Full maturity Flood	Full maturity Free-drain
1	Control	2.6	2.6	8	13
2	N	3.3	2.9	28	21
3	P_2	2.0	3.2	9	16
4	K_2	2.8	2.9	7	18
5	NP_1K_1	7.0	3.7	46	19
6	NP_2K_2	2.9	2.9	60	29
7	NP_2Ca Mg	3.1	3.9	29	23
8	NK_2 Ca Mg	4.6	4.0	63	23
9	Np_1K_1 Ca Mg	5.1	3.7	43	28
10	NP_2K_2Ca Mg	7.8	3.0	62	52
11	Lime	2.3	2.8	12	19
12	NP_1K_1 Lime	6.1	3.8	69	35
13	NP_2K_2 Lime	2.9	3.6	74	42
14	NP_2K_2 Ca Mg So_4	2.8	2.9	50	34
	SE	1.5	0.5	6.7	4.8

Panicle dry weight under flooded conditions was less in control than in high nutrient treatments (Table 60). A significant increase was obtained with a combination of all nutrients N, P, K, Ca and Mg, either under flooded or free-drained conditions. Panicle weight in high nutrient treatments was greater under flooded than under free-drained conditions. Liming together with N, P and K showed no signficant effect in comparison to Ca + Mg treatments. In the same manner, calcium and magnesium sulfate treatments did not cause signifiant reduction of panicle weight despite maintaining or decreasing original soil pH.

Phosphorus content in plants was below critical levels in N, NK_2CaMg and NP_1K_1CaMg for the two water treatments.

Table 60. Panicle dry weight (g/plant) under various chemical and water treatments in highly leached acidic Onne soil.

Chemical treatment		Flood	Free-drain
1	Control	0.4	1.1
2	N	2.4	2.5
3	P_2	0.9	1.0
4	K_2	0.8	1.5
5	NP_1K_1	5.8	1.7
6	NP_2K_2	7.2	3.8
7	NP_2Ca Mg	4.6	5.2
8	NK_2 Ca Mg	8.6	2.8
9	Np_1K_1 Ca Mg	10.3	6.4
10	NP_2K_2Ca Mg	7.0	5.7
11	Lime	1.1	1.0
12	NP_1K_1 Lime	5.5	3.4
13	NP_2K_2 Lime	5.5	7.3
14	NP_2K_2 Ca Mg So_4	9.2	5.7
	SE	1.8	1.2

The level of K was low for N and NP_2CaMg treatments under flooded conditions while the level of Ca and Mg was low for N and NP_1K_1 treatments under flooded conditions (Table 61). The content of iron was above critical levels in most low nutrient treatments. Neither manganese nor zinc was in the normal range. The content of copper in plants was very low which may be the major cause of high sterility in spikelets and a low harvest index.

These results show that there is interaction between nutrients, so that balanced fertilizer application is important.

Agronomy

Grain yield of hydromorphic rice under various nitrogen levels with and without bund treatment.

J. Yamaguchi

To maximize yields, rice culture under hydromorphic conditions should consider: (1) the fluctuation of water supply and (2) the loss of N. This experiment was conducted as a part of studies to elucidate the N nutrition of hydromorphic rice and to develop a cultivation method that would obtain higher yields through various cultural practices.

Cultivars, ITA 139 and ITA 162, were selected from upland entries, which were assumed to perform well under hydromorphic conditions, and 3 cultivars, ITA 231, IR 42 and ITA 212, of irrigated lowland rice were included.

They were grown in hydromorphic sites which had been fallowed for several years. Three N levels, 0, 60 and 120 kg N/ha using ammonium sulfate, and treatments with and without bund were set up.

The treatments were arranged in a split-split-split-plot design with 3 replications where bund treatments were the main

Table 61. Contents* of some mineral elements in stem at maturity under various chemical and water treatments in highly leached acidic Onne soil.

Chemical Treatment		P (%)		K (%)		Ca (%)		Fe (ppm)	
		F	D	F	D	F	D	F	D
1	Control	0.6	0.3	2.9	2.3	0.12	0.07	1540	392
2	N	0.1	0.1	0.7	1.2	0.03	0.31	1660	250
3	P_2	0.6	0.8	2.1	2.3	0.13	0.18	1031	470
4	K_2	0.5	0.2	4.8	3.5	0.09	0.07	1618	335
5	NP_1K_1	0.2	0.2	1.0	1.5	0.04	0.06	1028	317
6	NP_2K_2	0.4	0.8	2.2	3.6	0.08	0.28	628	248
7	NP_2Ca Mg	0.6	0.6	0.6	1.3	0.13	0.24	1213	349
8	NK_2 Ca Mg	0.1	0.1	2.4	2.0	0.05	0.06	959	717
9	Np_1K_1 Ca Mg	0.1	0.2	1.8	1.9	0.09	0.07	647	280
10	NP_2K_2Ca Mg	0.4	0.7	2.1	3.4	0.08	0.09	614	757
11	Lime	0.3	0.3	1.7	1.7	0.12	0.09	608	332
12	NP_1K_1 Lime	0.2	0.3	1.1	1.6	0.07	0.09	684	391
13	NP_2K_2 Lime	0.4	0.6	2.1	2.7	0.11	0.10	689	475
14	NP_2K_2 Ca Mg So_4	0.4	0.6	2.4	2.5	0.06	0.08	427	258

**Underlines: values either lower or higher than critical levels.*

Table 62. Grain yield (t/ha) in bund x nitrogen x cultivar trial in hydromorphic rice.

	With bund Nitrogen (Kg N/ha)				Without bund Nitrogen (kg N/ha)				
Cultivar	0	60	120	Mean	0	60	120	Mean	Mean
ITA 139	3.1	3.9	3.8	3.6	3.7	3.6	4.1	3.8	3.7
ITA 231	4.6	4.8	4.7	4.7	4.1	4.7	4.9	4.6	4.6
ITA 162	4.4	5.4	5.4	5.0	4.9	5.3	4.9	5.0	5.0
IR 42	5.1	5.4	5.1	5.2	4.3	5.2	5.3	5.0	5.1
ITA 212	6.2	6.0	6.9	6.4	5.9	6.2	5.8	6.0	6.2
Mean	4.7	5.1	5.2	5.0	4.6	5.0	5.0	4.9	4.9*

**SE: 0.24 t/ha.*

Table 63. Major plant characteristics of 5 cultivars grown in hydromorphic averaged over 3 nitrogen levels and bund treatments.

Cultivar	Growth duration* (days) So-F	F-M	So-M	Plant height (cm)	Panicle number (per m^2)	Harvest Harvest Index	Leaf No. on main culm	LAI at flowering	1000 Grain wt. (g)
1 ITA 139	83	29	113	141	158	0.39	12.9	2.9	33.3
2 ITA 231	101	34	135	107	237	0.39	13.8	5.2	30.4
3 ITA 162	89	37	126	136	155	0.48	13.1	3.4	30.4
4 IR 42	120	29	150	111	309	0.33	13.1	5.0	20.6
5 ITA 212	105	34	139	104	324	0.46	14.5	5.6	25.5
SE	0.4	0.5	0.3	2.2	10.4	0.01	—	0.28	0.35

So-F: From sowing to 50% flowering.
F-M: from 50% flowering to full muturity.
So-M: from sowing to full maturity.

plots, N levels were sub-plots and cultivars were sub-sub-plots. Sowing was on 15 April, 1981.

Grain yield ranged from 3.1 to 6.9 t/ha, and differences were statistically significant only among varieties, not among N levels nor between bund treatments (Table 62).

The experimental site was hydromorphic, but the rainfall was less during the crop season than in previous years; thus, the water table never reached the ground level even with bund conditions. Actually, there was no difference in soil moisture between bund treatments. The experimental site selected was kept under fallow for several years; thus, soil fertility, in general, seemed to be higher while organic carbon and total N in soil were not necessarily higher than those in the adjacent dryland plots.

ITA 212 was the highest yielder at 6.2 t/ha, a yield similar to typical higher yielding short stature varieties with medium tillering ability and medium growth duration (Table 63). ITA 139 was the lowest yielder, mainly attributable to low harvest index and small LAI caused by short growth duration, low tillering ability and tall plant stature.

Cultivars derived from upland rice, ITA 139 and ITA 162, and from lowland rice, ITA 231, possess large grain size in comparison with 2 other higher yielders. It may be important to analyze how much an increase of the grain size contributes to yield improvement.

Plant density response of rice cultivars under dryland conditions

J. Yamaguchi

Some rice cultivars exhibit their potential productivity under specific environments where high yields are often produced; others may produce relatively stable but relatively lower yield over a wide range of cultural and climatic conditions.

Among cultural practices, plant density and fertilizer are 2 key manipulations.

High yields in irrigated lowland have been achieved by selecting the variety with medium tillering ability grown under high plant density with sufficient supplies of mineral nutrients. Optimum number of tillers or panicles per unit area is suspected to be lower in dryland than in lowland conditions, since in the former the soil moisture and mineral nutrients are less available. Thus, improvement of dryland cultivars is directed toward selecting a low tillering ability. Optimum plant density for dryland rice cultivation is yet unknown, especially in relation to the tillering ability of cultivars. This experiment was conducted to estimate the optimum plant density under dryland conditions with special attention to tiller or panicle number and leaf area index.

Ten cultivars covering a wide range of genetic backgrounds (Table 64), were grown in dryland conditions at IITA and Ikenne. Five spacings were established, i.e., 10 x 10 cm, 15 x 15 cm, 20 x 20 cm, 30 x 30 cm, 50 x 50 cm, designated as D10, D15, D20, D30 and D50, containing 100, 44.4, 25, 11.1 and 4 plants per m^2, respectively. Treatments were arranged in a split plot design with 3 replications where plant densities were the main plots and cultivars were sub plots. Because of frequent appearances of Fe and N deficiencies at higher densities (D10 and D15), iron chelate and ammonium sulfate (60 kg N/ha total) were applied on several occasions. Sowing was 1 April and 3 June, 1981, at IITA and Ikenne, respectively.

Table 64. Cultivars used for response to plant density under dryland conditions at IITA and Ikenne.

Entry No.	Cultivar	Cross (Origin)
1	LAC 23	Reselection from traditional African
2	OS 6	Improved traditional
3	IRAT 112	IRAT 13/Dourado Precoce
4	ITA 117	13A-18-3-1-3//OS 6/IR 154-61-1-1
5	ITA 118	IR 154-61-1-1/OS 6//63-83
6	ITA 141	LAC 23/(TOx 7, IET 1444)
6′	ITA 162	Moroberekan/(ROK 1, TOx 7)
7	ITA 173	LAC 23/(IR 528,TOx 7)
8	ITA 235	OS 6 Mutant/OS 6
9	ADNY 11	IR 665-23-3-1/Tetep
10	ITA 212	BG 90-2^4/Tetep

1, 2, 3, 4, 5, 6, 7, 8, 9, 10: Entries at IITA. Entry No. 6 was replaced by Entry No. 6′ at Ikenne. Entry Nos. 1 and 2: Traditional upland cultivars; Entry Nos. 3 to 8: Improved upland cultivars; Entry Nos. 9 and 10: Lowland cultivars.

Grain yield of all cultivars used at IITA increased with an increase of plant densities between 4 and 25 plants/m^2 (Table 65 and Fig. 9). At higher densities, cultivars such as LAC 23, IRAT 112, ITA 173 and ADNY 11 decreased yields while ITA 117, ITA 118 and ITA 235 increased yields. Yields of lowland cultivars, ADNY 11 and ITA 212, were higher than dryland cultivars at the lowest density. Highest yields (more than 6 t/ha) were obtained at the highest plant density with ITA 118 and ITA 235.

Most cultivars responded to an increase of plant densities in Ikenne (Fig. 10). Average yield was slightly higher in Ikenne than in IITA. The highest yield was obtained at the highest plant density with lowland cultivar ITA 212. These results are likely due to a better moisture condition at Ikenne than at IITA (200-300 mm rainfall more in Ikenne).

Grain yield measured as paddy rice increased with an increase in plant densities even under dryland conditions; yield of lowland cultivars was not necessarily lower. However, the quality of rice produced became very poor at higher densities, especially in lowland cultivars (Table 66). Discoloration of glume, pericarp layers and endosperm as well as chalkiness were serious at higher densities and with lowland culitvars.

Milling return, particularly percentage of whole rice in polished rice, was also lower at higher density as well as in lowland cultivars (Table 67). Thus, yield as polished whole rice became low: most cultivars produced the highest yield at 25 plants/m^2 (D20) (Fig. 11). Nevertheless, ITA 118 and ITA 235 responded well to the highest density tested, 100 plants/m^2. These results demonstrate that the optimum plant density does not differ between dryland and lowland unless there are serious drought and fertility problems in dryland.

Plant height decreased with an increase in plant density, which was caused by the shortage of moisture and mineral nutrients (Table 68). Although lodging was observed at near full maturity because of a storm, none of the tall cultivars lodged seriously. However, the low yielding ability of LAC 23 at higher density is likely due to the nature of tall stature and excessive growth (larger LAI and dry matter production), resulting in low LHI (Tables 65 and 68).

Growth duration of IRAT 112 was shortest so that LAI and dry matter production were smallest, resulting in low yielding ability. Harvest index (ratio of panicle weight to total dry

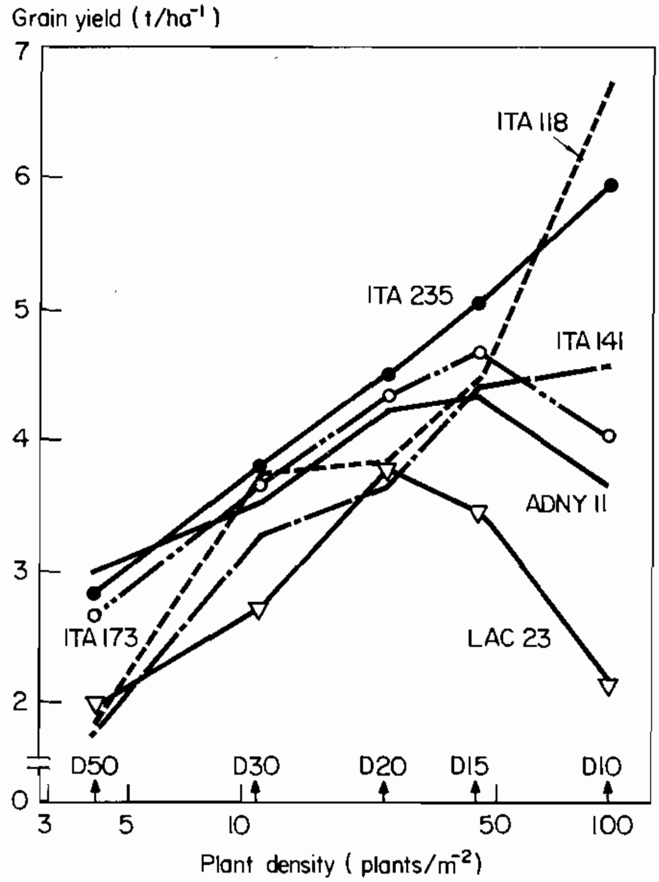


Fig. 9. Response of grain yield to plant density in dryland (Ibadan, 1981).

Table 65. Grain yield and yield components of rice cultivars under different plant densities in dryland conditions (IITA).

	Grain yield (kg/ha)	Panicle no. per m^2	Spikelet no. per panicle	Sterility (%)	Grain no. ('000 /m^2)	Grain Size (mm) Length	Width	Thickness	1,000 grain weight (g)
Plant density									
D10	4490	355	96	16	14.2	7.3	2.55	2.00	31
D15	4100	245	121	12	12.8	7.2	2.53	1.97	32
D20	3970	167	153	12	12.5	7.3	2.59	1.98	33
D30	3270	131	164	12	10.4	7.1	2.55	1.95	32
D50	2320	84	192	12	7.5	7.1	2.55	1.96	32
Cultivar									
1. LAC 23	2810	116	194	12	9.5	6.6	2.66	1.94	30
2. OS 6	4100	163	149	9	11.8	7.1	2.69	2.02	35
3. IRAT 112	2650	185	128	15	7.6	7.4	2.65	2.09	35
4. ITA 117	3070	241	110	9	9.9	7.5	2.44	1.92	31
5. ITA 118	4120	144	134	11	10.0	7.5	2.95	2.15	41
6. ITA 141	3530	169	148	12	11.6	7.5	2.43	1.89	30
7. ITA 173	3870	159	150	14	11.2	6.7	2.87	2.08	35
8. ITA 235	4430	181	136	8	13.3	7.4	2.53	1.97	33
9. ADNY 11	3740	293	152	15	14.5	7.2	2.13	1.80	26
10. ITA 212	3950	314	152	23	15.4	6.9	2.22	1.86	26
Standard error									
Density	344	12	6.7	0.8	1.0	0.02	0.01	0.01	0.3
Cultivar	259	12	6.7	1.4	0.7	0.04	0.02	0.01	0.3

Table 66. Score of discoloration and chalkiness of rice cultivars grown at different plant densities in dryland conditions (IITA).

	Discoloration[1) Paddy rice	Hulled rice	Polished rice	Chalkiness[1) of endosperm
Plant density				
D10	4.1	7.4	5.8	4.1
D15	3.4	6.3	4.1	4.1
D20	3.1	5.0	3.6	3.8
D30	2.2	4.2	3.8	3.8
D50	2.5	3.7	3.5	4.3
Cultivars				
LAC 23	2.7	5.4	5.1	3.8
OS 6	2.3	4.8	2.4	3.2
IRAT 112	1.0	5.2	3.9	3.1
ITA 117	1.6	4.9	2.8	4.8
ITA 118	1.8	5.9	3.4	3.0
ITA 141	3.6	4.2	3.2	2.3
ITA 173	1.0	4.6	4.8	6.6
ITA 235	1.6	2.9	3.1	2.3
ADNY 11	7.5	7.5	5.6	4.0
ITA 212	7.5	7.8	7.0	7.0
Standard error				
Density	1.1	2.2	1.3	0.3
Cultivar	1.7	1.0	1.0	1.2

1) 0 to 9 scale; 0: None, 9: severe/large.

Table 67. Milling return and yield of polished whole rice of rice cultivars grown at different plant densities in dryland conditions (IITA).

	Milling Out-turn (%) Hulled to paddy	Polished to hulled	Whole rice in polished	Yield of whole rice (kg/ha)
Plant density				
D10	76	82	68	1900
D15	78	83	75	1980
D20	78	82	71	1840
D30	80	81	74	1540
D50	81	81	71	1070
Cultivar				
LAC 23	79	85	80	1480
OS 6	81	85	72	2000
IRAT 112	75	87	77	1320
ITA 117	75	85	75	1450
ITA 118	81	81	67	1830
ITA 141	80	78	71	1530
ITA 173	81	83	77	1990
ITA 235	80	84	78	2340
ADNY 11	78	77	56	1250
ITA 212	78	75	65	1490
Standard error				
Density	0.3	0.1	0.03	0.0005
Cultivar	0.2	0.3	0.5	0.0003

Table 68. Some plant characteristics of rice cultivars grown at different plant densities in dryland (IITA).

	Plant height (cm)	Growth duration[1) (days) So-F	F-M	So-M	Total dry weight[2) (g/plant) Veg.	Flow.	Mat.	HI (%)	LAI at flow.	Leaf no. per m^2 flow.
Plant density										
D10	98	93	33	126	149	860	1440	36	4.0	920
D15	108	92	32	124	95	780	1380	40	3.2	650
D20	113	93	30	123	71	770	1110	41	3.0	420
D30	121	98	30	128	27	607	940	41	2.2	330
D50	119	100	33	132	11	410	630	43	1.5	220
Cultivar										
1. LAC 23	147	114	30	144	73	940	1290	27	3.3	250
2. OS 6	141	95	31	126	79	710	1100	40	3.1	380
3. IRAT 112	99	75	28	103	75	360	860	38	1.4	620
4. ITA 117	87	84	29	113	75	450	900	39	2.1	800
5. ITA 118	107	90	31	121	67	540	890	45	2.0	350
6. ITA 141	109	93	32	124	62	530	1060	46	2.0	370
7. ITA 173	125	97	34	131	73	780	1170	43	3.1	370
8. ITA 235	117	89	34	122	65	580	1070	44	2.6	430
9. ADNY 11	96	105	33	138	80	980	1270	38	3.6	740
10. ITA 212	89	110	35	145	60	990	1400	40	4.4	790
Standard error										
Density	1.4	0.8	0.6	0.6	8.5	43	26	1.1	0.2	47
Cultivar	1.8	0.8	1.0	0.8	7.0	37	44	1.2	0.2	58

1) So-F: From sowing to 50 percent flowering; F-M: From 50 percent flowering to full maturity; So-M: From sowing to full maturity.
2) Flow: 50 percent flowering, Mat: Full maturity.

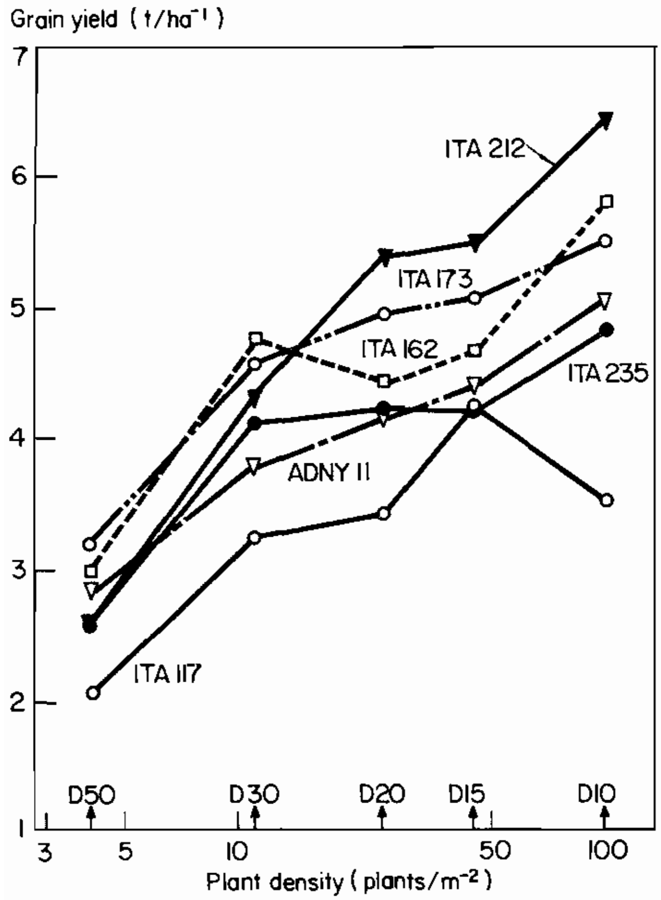


Fig. 10. Response of grain yield to plant density in dryland (Ikenne, 1981).

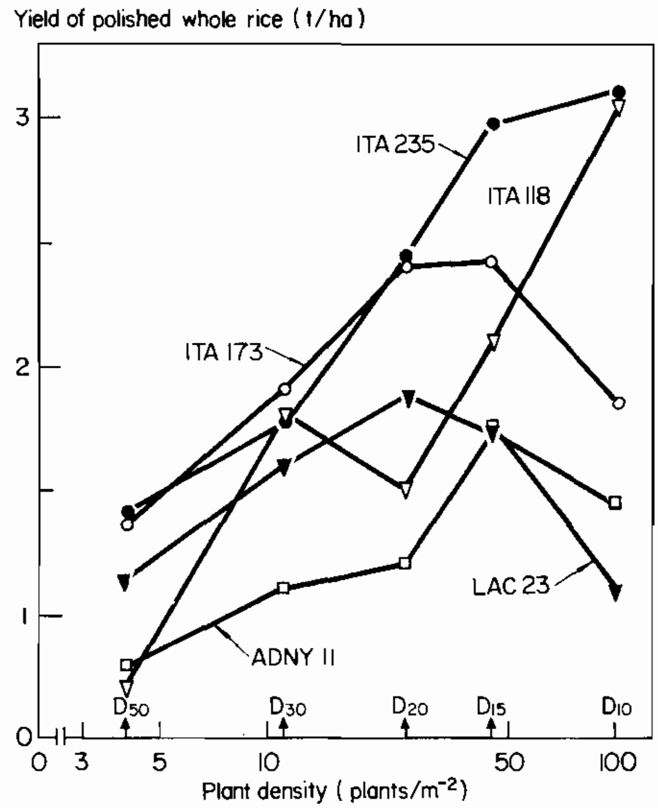


Fig. 11. Response of yield of polished whole rice to plant density in dryland (Ibadan, 1981).

weight at full maturity) decreased with an increase in plant density, and was 5-10 percent lower than lowland cultivars grown under lowland ecology.

Panicle number, total number of green leaves and LAI increased, and larger dry matter was produced with an increase in plant density; larger dry matter production contributed to the higher yield.

In view of yield components, the higher yielding ability of ITA 118 and ITA 235 was derived from larger grain weight, not from larger panicle size (spikelets per panicle) or panicle number. Tillering ability is distinguishable between dryland and lowland cultivars. Sterility percentage of spikelets was higher in lowland cultivars grown in dryland. Grain length and thickness of filled grains were even larger at higher densities. However, there was no significant difference of 1,000 grain weight among plant densities.

Nitrogen response of irrigated lowland rice varieties

J. Yamaguchi

The concept of ideoplant type for high yielding variety was established nearly 20 years ago: short stature, medium tillering ability and medium growth duration with high N response. IR 8 is an example. Varieties with such plant traits produce the expected high yields only when they are grown under intensive management, dense planting, heavy fertilizer and weed and pest control.

Many countries in Africa have now begun to develop large-scale irrigation schemes to overcome rice shortages. To respond to these trends, IITA has developed several cultivars adapted to irrigated lowland or shallow swamps. This experiment was conducted to evaluate the N response of cultivars from IITA along with some IRRI lines.

Seven ITA-numbered cultivars, 2 varieties from IRRI and TOs 103, an IRRI line, selected at IITA in the early 1970s, were grown under irrigated lowland conditions (Table 69). Five levels of N-0, 30, 60, 120 and 240 kg N/ha using ammonium sulfate—were set up. Treatments were arranged in

Table 69. Cultivars used and their parentage.

No.	Variety	Parentage
1	ITA 121	Moroberekan/ (SE 363G, Ikong Pao)
2	ITA 123	OS 6 dw mutant
3	ITA 212	BG 90-2*4/Tetep
4	ITA 222	Mahsuri/IET 1444
5	ITA 231	IR 262/Bahagia
6	ITA 237	LAC 23 (red)/Soavina
7	ITA 239	IR 5/Saukoko 8
8	TOs 103 (IR790-35-5-3)	Peta//Peta*3/TN 1////IR 8/H 105// DGWG///B589A4-18-1*2/TN1
9	IR 36	CR94-13//IR1561/IR 1737
10	IR 42	IR 156-228//IR 24*4/O.niv.///CR 94-13

a split plot design with 2 replications where N levels were the main plots and varieties were sub-plots. Plot size was 1.5 x 3.3 m (5 x 23 hills), and 40 hills were harvested.

Seeds were sown in the nursery on 23 September, while seedlings were transplanted on 15 October, 1981. Neither lodging nor any serious pest damage was observed in all the varieties used throughout the growth stages.

Grain yield increased significantly with an increase of N levels in all varieties used. Mean yield was 3.7 and 6.3 t/ha at 0 and 240 kg N/ha, respectively (Fig. 12 and Table 70). At 240 kg N/ha level, ITA 121, ITA 212, ITA 222 and ITA 237 yielded about 7 t/ha, while ITA 123, ITA 239, TOs 103 and IR 36 yielded about 5.5 t/ha. At 0 kg N/ha level, ITA 212 and ITA 237 yielded about 5 t/ha while ITA 121, TOs 103 and IR 36 yielded about 3 t/ha. Under both low and high N conditions, ITA 212 and ITA 222 were higher yielders, and TOs 103 and IR 36 were lower yielders.

Low yielding ability of TOs 103 and IR 36 is due to fewer leaves and LAI. Thus, there was less dry matter production from short growth period (about 110 days from sowing to full maturity) (Table 71). High yield potential of ITA 212, ITA 222 and ITA 237 may also be attributed to a longer ripening period (35 days and more). Grain production from sowing to maturity was higher in medium growth duration varieties such as ITA 212 and ITA 222 (45 kg/ha/day) than in short growth duration varieties such as TOs 103 and IR 36 (37-39 kg/ha/day). This result demonstrates the superiority of medium-duration varieties even in aspects of production rate per day, although short-duration varieties are likely to produce higher yields under higher density.

N response of grain yield was higher in ITA 121 and ITA 237 and lower in ITA 123, ITA 239, TOs 103 and IR 42. (Fig. 12)

Harvest index was about 0.5, except for a few varieties; thus, it can be said that potentiality of most varieties released from IITA breeding program is comparable to that of high yielding varieties released from other major rice producing

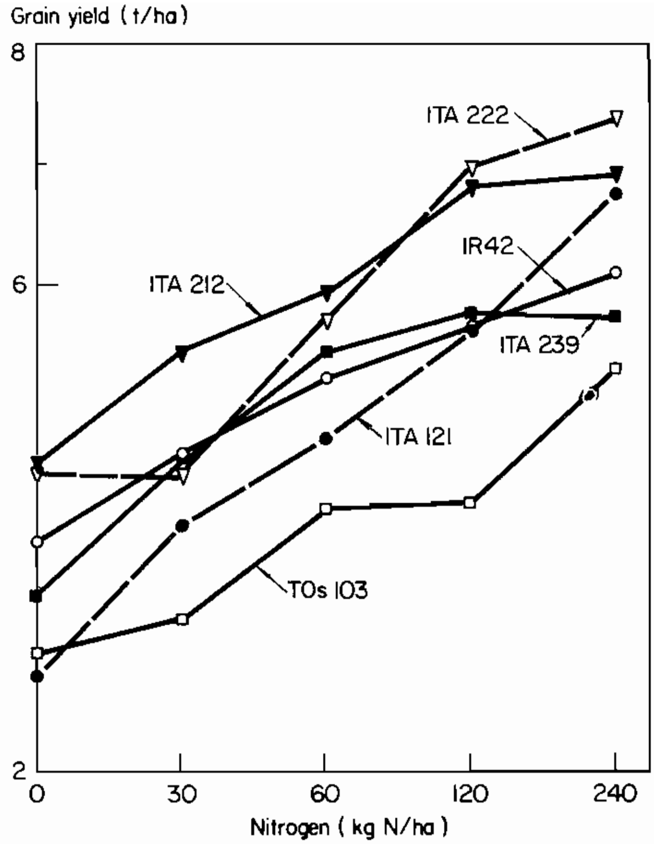


Fig. 12. Grain yield under different nitrogen levels.

Table 70. Grain yield and yield components of rice varieties grown under different nitrogen levels.

	Grain yield (kg/ha)	Panicle No. per m^2	Spikelet No. per panicle	Sterility (%)	1,000 grain weight (g)	Grain No. (,000 per m^2)
Nitrogen (kg N/ha)						
0	3670	179	138	12	24.3	15.3
30	4230	184	137	10	23.9	17.9
60	5090	207	133	9	24.2	21.3
120	5810	238	149	7	24.4	24.0
240	6250	249	161	12	23.8	26.5
Variety						
1 ITA 212	5930	236	140	8	25.4	23.3
2 ITA 121	4800	177	178	14	23.9	20.1
3 ITA 123	4790	185	166	13	24.8	19.4
4 ITA 222	5790	197	157	14	27.4	21.2
5 ITA 231	5120	194	145	16	26.6	19.4
6 ITA 237	5250	217	157	6	19.7	26.6
7 ITA 239	4990	255	118	13	24.7	20.2
8 TOs 103	3990	184	128	8	25.2	15.8
9 IR 36	4330	223	115	6	23.3	18.8
10 IR 42	5110	246	131	6	20.2	25.3
Standard error						
Nitrogen	242	6	2.4	0.4	0.1	0.9
Variety	167	8	4.6	0.6	0.2	0.7

countries in terms of efficiency of photosynthate allocation (Table 71). IR 42 showed a low harvest index, but yields were not very low because of high dry matter production. ITA 239 had a large LAI at flowering, causing serious mutual shading which resulted in a low harvest index under high N condition. Thus, N. response became smaller beyond 60 kg N/ha level.

ITA 121 and ITA 222 produced higher yields due to larger grain size, and ITA 212 and ITA 237 due to a larger number of grains produced per unit area (Table 70). Number of panicles was fairly small—less than 300 per m^2 in all varieties used. It is worthwhile to try to improve the yield potential of cultivars through an increase in panicle number and grain number per unit area.

It is worth mentioning here that ITA 222 is highly susceptible to blast, especially under dryland conditions, although few lesions were observed under irrigated conditions in this trial. It is, however, moderately tolerant of iron toxicity being a derivative of improved Mahsuri.

Root thickness of rice cultivars under different ecologies

J. Yamaguchi

Root thickness of rice cultivars is most likely associated positively with drought resistance (IITA Annual Report 1980). It seems that root length is directly involved in drought resistance and root thickness and length are highly correlated.

However, precise determination of root length in the field is tedious and hardly applicable to a large-scale trial. In contrast, scoring the root thickness is very simple and even applicable to the selection of segregating breeding lines.

This experiment was conducted by using rice cultivars with a wide range of genetic backgrounds. They were grown under different ecological conditions to evaluate (1) the genetic variation of root thickness among rice cultivars with visual scoring and (2) the feasibility of improvement of upland rice through this character, considering several other characters measured.

Two hundred and seventy cultivars were selected to cover a wide range of original ecologies and plant types from all over the world: 29 traditional uplands, 77 improved uplands, 17 traditional lowlands, 137 improved lowlands, 6 floatings and, in addition to these cultivars of *O. sativa*, 4 collections of *O. glaberrima*.

Seeds were directly sown on 28 September, 12 October, and 2 October, 1981, in irrigated lowland hydromorphic, and dryland, respectively. Irrigation was given to dryland twice and to hydromorphic once a week after November until full maturity.

Root thickness was based on a score from 1 to 9: 1 = all root thinner than 1 mm and 9 = all roots thicker than 2 mm. Several other plant traits, such as plant height, tiller/panicle number, leaf size and panicle exertion, etc., were also measured to characterize the plant type at vegetative growth and full maturity.

The root was thicker in traditional upland followed by improved upland and floating and was thinner in irrigated lowland cultivars (Table 72). *O. glaberrima*, as a group, possessed thinner root characteristics than *O. sativa*, in general.

Root thickness was similar between the plants grown in irrigated lowland and dryland conditions (Fig. 13). Root thickness was positively correlated with plant height (r = 0.66) (Fig. 14). Taller cultivars tended to have less number of

Tabla 71. Plant height, growth duration, total dry weight, harvest index, grain production rate of rice varieties grown under different N levels.

	Plant height (cm)	Growth duration[1)] (days) So-F	F-M	Total DW[2)] (g/m^2) Flow.	Mat.	HI (%)	(Grain[3)] production rate (kg/ha/day)	LAI[2)] at flow.	No. of[4)] green leaves (per m^2)
Nitrogen (kg N/ha)									
0	90	90	32	568	770	50	30	2.00	821
30	92	90	32	602	860	51	35	1.95	828
60	98	91	33	739	1060	49	41	2.89	1013
120	102	92	33	835	1250	49	47	3.65	1202
240	109	93	33	995	1410	47	50	5.01	1382
Variety									
1 ITA 121	104	88	32	750	960	50	40	3.00	923
2 ITA 123	96	87	31	664	910	54	41	2.55	893
3 ITA 212	98	96	37	766	1150	53	45	2.67	1082
4 ITA 222	98	93	35	791	1200	51	45	3.43	1055
5 ITA 231	102	91	33	769	1050	53	41	3.06	963
6 ITA 237	102	93	38	748	1130	48	40	3.53	1088
7 ITA 239	108	105	30	857	1390	40	37	4.25	1377
8 TOs 103	83	80	28	638	820	51	37	2.39	840
9 IR 36	92	81	31	674	900	48	39	2.72	997
10 IR 42	98	100	30	820	1200	43	39	3.36	1274
Standard error									
Nitrogen	0.1	0.8	0.4	19	48	0.3	2.1	0.06	28
Variety	0.8	0.4	0.6	27	45	1.0	1.3	0.18	65

1) So-F: From sowing to 50% flowering; F-M: From 50% flowering to full maturity.
2) Flow: 50% flowering, Mat: Full maturity.
3) Average over sowing to full maturity.
4) At 50% flowering.

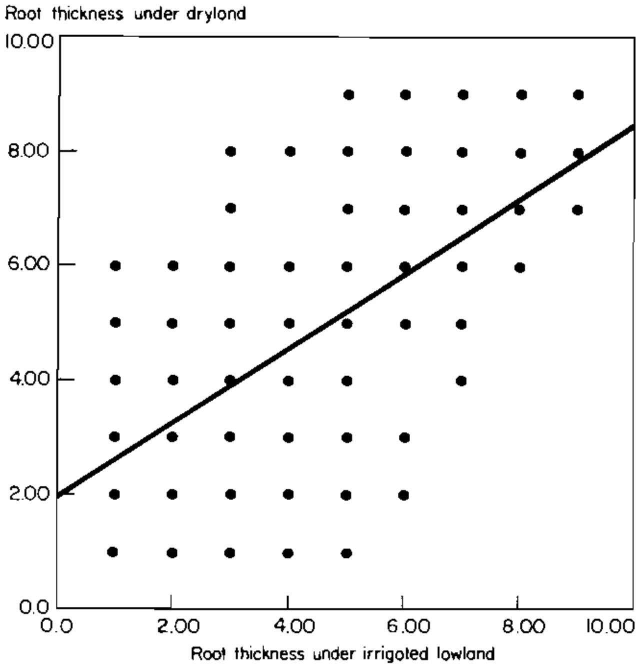


Fig. 13. Comparison of root thickness between irrigated lowland and dryland at vegetative growth stage (Root thickness in 1-9 score: 1 = thinnest, and 9 = thickest).

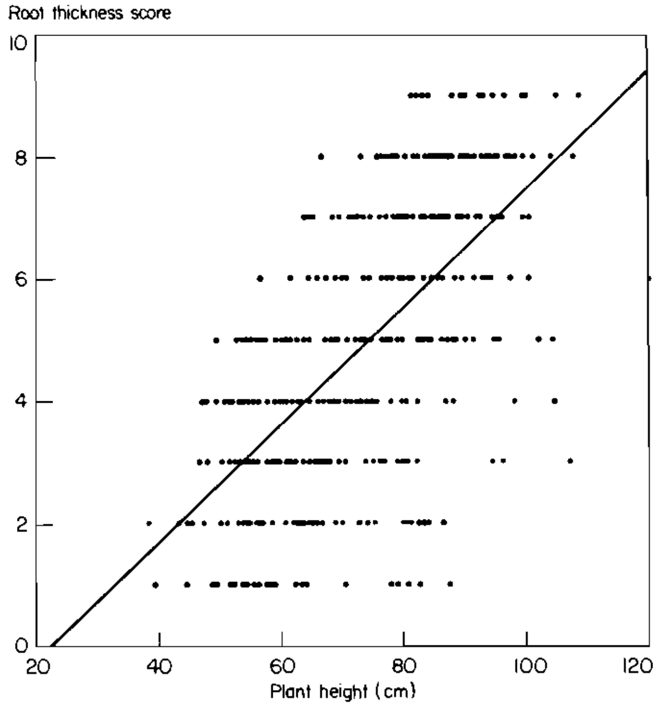


Fig. 14. Relationship between plant height and root thickness at vegetative growth stage (55 days) over irrigated lowland, hydromorphic and dryland conditions.

tillers; thus, high tillering cultivars tended to have thinner roots, although the correlation coefficient was low (r = 0.19).

Tiller number was larger in dryland than in irrigated lowland conditions (Table 72). This result confirms 1980 observations. Roots were thinner in hydromorphic than in irrigated lowland and dryland conditions; this was found to contradict the previous year's result. It might be due to the fact that hydromorphic conditions in this experiment were drier than the ordinary dryland condition in the rain season.

Importance of root thickness in relation to drought resistance will be analyzed when the final harvest has been completed.

Virology

Rice yellow mottle virus (RYMV)

H.W. Rossel, G. Thottappilly, K. Alluri

Rice yellow mottle virus (RYMV) reported in Nigeria in 1978 (IITA Annual Report, 1978) was found in 1981 in important rice growing areas in eastern and central Nigeria where it was not found in earlier surveys in 1977.

In both areas, the virus was noticed in experimental as well as in farmers' fields on recent and old introductions. Also, in both areas the virus occurred under conditions whereby infected ratoon plants stood a good chance of survival throughout the dry season.

RYMV, which is found in various countries in West and East Africa, is probably endemic to tropical Africa although it has never been a problem in traditional farmers' rice crops. In most cases, so far, it has come to the foreground in newly established, large-scale irrigated rice development schemes and/or experimental fields. Growing new, highly susceptible introductions and maintaining higher crop intensity without dry season gaps are among the factors governing the per-

Table 72. Root thickness, plant height and tiller number at vegetative growth stage (55 days after sowing) under irrigated lowland (L) hydromorphic (H) and dryland (D) conditions.

	Root thickness* (Score)			Plant height (cm)			Tiller number (per plant)		
Group	L	H	D	L	H	D	L	H	D
Lowland									
Traditional	4.3	4.0	4.3	62	50	69	24	21	38
Improved	3.6	3.2	4.2	63	44	64	21	19	36
Dryland									
Traditional	6.6	4.8	7.1	85	69	90	11	8	15
Improved	5.7	5.5	7.1	77	64	84	15	11	19
Floating	7.0	5.0	6.0	91	66	94	21	24	28
O. glaberrima	3.3	4.0	2.8	81	54	82	22	23	30

**1-9 Score: 1 = thinnest, 9 = thickest.*

sistant occurrence and steady increase of this virus disease. Resistance breeding to RYMV has started at IITA. Rice production in Africa will undoubtedly increase under conditions that favor carry-over, reoccurrence and gradual build-up of this virus.

The use of ELISA for detection of rice yellow mottle virus in tolerant lines

G. Thottappilly

After inoculation of RYMV, several rice lines remained symptomless, indicating that they are probably resistant or immune to the virus. Preliminary tests using the agar gel diffusion test gave negative results, and, therefore, the ELISA technique was applied as a quick and sensitive method to detect small quantities of virus and to classify these lines as tolerant, highly resistant or immune. Several rice lines were inoculated with RYMV at the 4-leaf stage. One week later, they were reinoculated to prevent escapes. Samples were taken 3 and 5 weeks after the last inoculation. They were tested by ELISA using serial dilutions of the sap.

In several lines, LAC-23, TOx-494-1011 and Diwani, the virus could be detected only up to a dilution of 1/5; whereas, in many other lines classified as fairly tolerant, e.g., OS-6, the virus could be detected up to a dilution of 1/3125, indicating that the earlier mentioned lines are highly resistant to RYMV. Also, 2 *Oryza glaberrima* lines, TOg-5674 and TOg-5681, showing little or no symptoms after inoculation with RYMV, were tested using the ELISA technique. Although the virus could be detected in undiluted sap, the test was negative in further dilutions, indicating that these 2 lines are highly resistant to the virus.

Further research is in progress to compare different methods for their sensitivity and reliability to detect the presence of the virus and to test the inoculated plants individually to make single plant selections.

A new virus disease in rice

G. Thottappilly, K. Alluri, J.W.M. van Lent

Approximately about 20 percent of TOx-959-111 and a few plants of TOx-959-107, TOx-959-108 and TOx-959-110 showed characteristic chlorosis and mottle at IITA. Infected plants were considerably stunted. Agar gel diffusion tests were carried out using an antiserum against RYMV and results showed that the disease is not caused by this virus. Electron microscopic examination of infected leaves revealed filamentous particles.

Attempts were made to purify the virus from infected leaves. After 2 cycles of low and high speed centrifugations, samples were examined by the electron microscope which again revealed numerous filamentous particles. It is reported that maize dwarf mosaic virus, a filamentous virus, can infect rice plants after artificial inoculation. Therefore, healthy maize seedlings were inoculated with sap from infected leaves, but, so far, investigations have been unsuccessful.

Further research is in progress to transmit and to identify the virus as well as its vector.

International Trials

K. Alluri, S. Sarkarung, K. Zan

IITA selected some of the promising upland materials from IRTP nurseries at IRRI and from the Initial Evaluation Test (IET) of WARDA. The objective of IITA's participation in these international trials was to determine the performance of IITA materials under different agroclimatic conditions. At IRTP there was the Eighth International Upland Rice Yield Nursery (IURYN) and the Seventh International Upland Rice Observational Nursery (IURON).

The IURYN consisted of 26 entries from Burma, India, Indonesia, Philippines, IRRI and IITA. The entries were mostly semi-dwarfs, but some were intermediate. A trial was laid out as a randomized complete block design with 3 replications. The IURON consisted of 104 entries which included semi-dwarf, intermediate, tall and early as well as medium. The entries were from Bangladesh, Brazil, Burma, India, Indonesia, Philippines, IRRI, IITA and IRAT. Tests were conducted in Bangladesh, India, Philippines, Thailand and Vietnam.

Out of the 104 entries, 15 were from IITA. They are ITA 116, ITA 117, ITA 118, ITA 119, ITA 141, ITA 142, ITA 158, ITA 162, ITA 164, ITA 173, ITA 175, ITA 183, ITA 186, ITA 225 and ITA 235. WARDA's Initial Evaluation Test consisted of 174 entries tested in 11 locations in Africa.

In the 10 locations where IURYN trials were conducted, ITA 116 and 118 performed well at Khajura in Nepal. Five IITA entries—ITA 116, ITA 117, ITA 118, ITA 225 and ITA 235—were rated good against blast at IRRI. For IURON, 6 parameters were considered: phenotypic acceptability, drought tolerance, drought recovery, reaction to herbicides and diseases. Thirteen entries were selected as superior for phenotypic acceptability. Among them were ITA 141, ITA 164, ITA 175, ITA 183 and ITA 235. Sixteen entries were selected as promising for drought tolerance. Of these are ITA 119, ITA 141, ITA 164, ITA 173, ITA 175, ITA 183, ITA 186 and ITA 235. Among the 16 entries ITA 164 and ITA 173 received the best scores. Included in the 28 entries selected for better drought recovery were ITA 164, ITA 173, ITA 175, ITA 183, ITA 186, ITA 225 and ITA 235.

There were 8 entries selected for both tolerance of and recovery from drought. These included ITA 164, ITA 173, ITA 175, ITA 183, ITA 186 and ITA 235. Nursery materials were also screened for their reaction to the herbicide Butachlor. ITA 118, ITA 119 and ITA 162 were included amo g the 8 selected entries as tolerant of this herbicide. Test entries were also screened for their reaction to major diseases. For blast, the 18 entries rated as good included ITA 117, ITA 118, ITA 142, ITA 164, ITA 175, ITA 225 and ITA 235. Two entries were selected as promising against brown spot and ITA 142 was one of them. ITA 141 and ITA 142 were among the best 11 entries for their reaction to bacterial leaf blight.

THE INITIAL EVALUATION TEST. WARDA's Initial Evaluation Test in upland trials consisted of 174 entries tested in 11 locations. ITA 233 gave the highest yield (3.5 t/ha) and ITA 132, ITA 135, ITA 183, ITA 208, ITA 233, ITA 234 as well as ITA 235 were highly resistant to neck blast. ITA 233, ITA 234 and ITA 235 were the only varieties with least or no grain sterility among the good yielders.

RELEASE OF NEW VARIETIES IN NIGERIA. The National Cereals Research Institute (NCRI) at Ibadan, Nigeria, released 3 new rice varieties found suitable under irrigation in Nigeria. These were previously known as TOs 78, TOs 103 and FAROX 188A, but they are now named FARO 26, FARO 27 and FARO 28, respectively. FARO 26 and FARO 27 were, at IITA, among the superior cultivars introduced from IRRI. Their characteristics are presented in Table 73.

Table 73. Characteristics of FARO 26 (TOs 78) and FARO 27 (TOs 103 released in Nigeria for irrigated conditions).

Cultivar	Cross	Plant height (± 10 cm)	(± 10 days)	Reaction to blast	Grain type
FARO 26	TN1/Blue belle	110	105	MR*	Long, slender, translucent
FARO 27	IR400-5-12-10-2/IR662	90	110	MR	Medium long, slender, translucent

MR: Moderately Resistant.

EVALUATION OF ELITE SELECTIONS UNDER HYDROMORPHIC AND IRRIGATED PADDY CONDITIONS. The purpose of this trial was to evaluate superior varieties at IITA under irrigated paddies with bunds compared to hydromorphs without bunds or leveling. The data show that the hydromorphs were as productive as irrigated paddies (Table 74).

Table 74. Evaluation of elite selections under hydromorphic and irrigated paddy conditions.

	Grain yield (t/ha)		Plant height	Days to maturity
	Hydromorphic plot	Paddy	(± 10 cm)	(± 10 days)
ITA 121	5.36	6.79	105	118
ITA 123	7.31	7.36	101	125
ITA 212	6.86	7.51	98	128
ITA 231	—	7.77	100	120
IR 36	7.72	5.03	103	110

Evaluation of elite selections in Benin Republic

S. Vodouhe (Department de la Recherche Agronomique, Cotonou, Benin) and K. Alluri

An evaluation of elite selections was carried out in an irrigated trial at Sagbovi Dome, Benin Republic, with 6 promising cultivars. A randomized complete block design with 5 replications was used. ITA 121 was the top yielder (Table 75). ITA 222 was found to be susceptible to blast.

Table 75. Performance of 6 selections in Benin Republic.

Cultivar	Grain yield (t/ha)	Plant height (cm)	Days to maturity	Blast score
ITA 121	4.05	87	115	1
ITA 123	2.49	90	113	3
ITA 222	1.97	92	115	7
ADNY 11	2.58	93	113	3
IR 42	2.82	83	124	1
IR1416-131-5	3.55	90	124	1

Evaluation of elite selections in Malawi

A.S. Kumwenda (Lifuwu Rice Research Station, Malawi) and K. Alluri

An irrigated trial of elite selections was carried out at the Lifuwu Rice Research Station, Malawi, with both dryland and hydromorphic shallow swamp rice that matures in 140-145 days and has good yield potential with long, slender grains. The check variety, Blue Bonnet, has the desirable grain type, but its maturity is delayed under low temperatures. The trial was not only intended to assess agronomic traits, but also to multiply seed. Based on days to flowering and grain yield, ITA 121, ITA 231 and IR 13429 among the shallow swamp cultivars were found to be desirable. Several dryland rice cultivars matured earlier. Among them ITA 135, ITA 164 and ITA 183 were superior. However, none of them has the preferred long, slender grains.

International trials in Nigeria

K. Zan, K. Alluri

IITA actively participated in the International Rice Testing Program (IRTP) of IRRI as well as in the Coordinated Variety Trials (CVTs) and the Initial Evaluation Trials (IETs) of WARDA. Participation was through trials to identify or develop superior cultivars. IRTP trials included material from the International Rice Yield Nurseries (IRYN), the International Upland Rice Yield Nursery (IURYN) and the International Upland Rice Observational Nursery (IURON). All the trials, except for IURYN, were conducted at IITA. IURYN material was evaluated at Ikenne. A randomized complete block design with 3 replications was used and the number of entries varied between 15 and 30. IETs and IURON were not replicated.

IRYN—VERY EARLY. The local check FARO 27 (TOs 103) and the international check, IR 50, yielded 4.6 t/ha and 4.9 t/ha, respectively. Among the entries, BKNLR 750091-B3-CNT-B4-RST-47-1 (6.2 t/ha) and BG 367-4 (6.0 t/ha) were superior in grain yield. FARO 27 matured in 118 days while the other three matured in 110 days.

IRYN—EARLY. ITA 123 (5.9 t/ha) was the local check and IR 36 was the international check with 5.4 t/ha. BPT 1235 (6.5 t/ha) and Taichung Sen Yu 285 (6.2 t/ha) were the top yielders. However, BPT 1235 and ITA 123 matured in 120 days while IR 36 matured in 115 days and Taichung Sen Yu 285 in 110 days. The latter is of intermediate (125 cm) stature.

IRYN—MEDIUM. Twenty-seven entries were evaluated together with ITA 212 as the local check and IR 42 as the international check. None of the entries was superior to the checks. However, Cisdane and IR 17488-2-3-2 were the 2 top yielders.

IURYN. The trial included 6 entries from IITA and ITA 141 was included as a local check. None of the entries was significantly superior to ITA 141. However, IR 52 with 4.3 t/ha yielded 24 percent higher than ITA 141 as in the previous 2 years. IR 5931-110-1 performed well again this season. IR 52 is a semi-dwarf type with good medium-long grains and is moderately resistant to blast. It is being used in IITA's breeding program.

WARDA CVT MOIST, IRRIGATED, SHORT DURATION. This trial evaluated 15 entries. The cultivars, Kn 144 (7.3 t/ha), Bouake 189 (6.2 t/ha), IR 2042-178-1 (6.1 t/ha) and MRC 505, (6.0 t/ha) significantly outyielded the trial check IR 36 (4.4 t/ha). However, all superior yielders were 10 to 15 days later in maturity than IR 36 which matured in 110 days.

WARDA CVT MOIST, IRRIGATED, MEDIUM DURATION. This trial evaluated 15 entries. The cultivars, ITA 212 and

ITA 123 with 6.8 t/ha and 6.3 t/ha respectively significantly outyielded the local check ITA 222 which yielded 4.5 t/ha.

WARDA CVT SAVANNA, UPLAND, SHORT DURATION. This trial included 9 entries from IRAT and 2 from IITA. Local check ITA 235 matured in 120 days and yielded 3.2 t/ha. Several IRAT lines that matured 10-20 days earlier than the local check, escaped drought and yielded higher than ITA 235.

WARDA CVT MOIST, UPLAND, SHORT DURATION. This trial was conducted along with the previous trial so that it also suffered from drought stress. IRAT 144, the top yielder, produced 4.6 t/ha compared to 3.9 t/ha for ITA 118, the local check.

Performance of short-duration cultivars in Nigeria

K.A. Ayotade, S.O. Fagade (NCRI, Nigeria) and K. Alluri

This trial was carried out by NCRI at its substations in Abakaliki, Badeggi, Bendel and Edozhigi with 12 promising cultivars that mature in 115-130 days. A randomized complete block design with 3 replications was used. ITA 212, BR51-46-5 and ITA 121 were the 3 top yielders (Table 76).

Screening under Fe toxicity in Liberia

A.O. Abifarin, F. Sumo (Central Agricultural Experiment Station, Suakoko, Liberia) and K. Alluri

SCREENING OF SEGREGATING POPULATIONS. Nine segregating populations resulting from crossing parents known to be tolerant of or resistant to Fe toxicity were screened. Four populations were from mutation breeding. The segregating materials were in the F3 generation and the mutant populations were in the M_1 generation. All available seeds were planted and 46 selections were made. The mutant populations originated from Gissi 27. Many of the lines selected from these populations were non-sensitive and more resistant to toxicity than Gissi 27.

OBSERVATIONAL TRIALS OF PROMISING CULTIVARS. Forty-seven collections previously found tolerant of or resistant to Fe toxicity were screened in 5 rows, 2 m long. The replicated plots had Suakoko 8 as the check variety. Most entries outyielded the check. They were also more uniform and shorter in height than Suakoko (Table 77). The resistance noted in earlier screening has been confirmed by most of the entries that were moderate to highly resistant to Fe toxicity.

PRE-WARDA-IET SCREENING. In 1981, 40 entries were screened in 3 rows, 5 m long with 25 cm between rows and 15 cm on the row. The replicated plots had Suakoko 8 as the check variety. Table 78 shows that 9 entries outyielded the resistant check, Suakoko 8.

Table 77. Days to maturity, height and grain yield per plot of top entries in an observational yield trial at Suakoko, Liberia (1981).

	Cultivars	Days to maturity	Height (cm)	Grain yield per plot (gms)
1	TOx 711-16-1	150	109	970
2	TOx 711-18-7	145	81	890
3	TOx 711-18-15	150	94	872
4	TOx 711-18-181	150	100	823
5	TOx 711-18-8	150	77	818
6	TOx 711-15-5	150	73	780
7	TOx 711-15-4	153	100	772
8	TOx 711-2-6	142	85	730
9	TOx 711-18-2	155	79	685
10	TOx 711-17-8	155	79	622
11	Suakoko 8 (check)	145	110	420

International trials in Liberia

A.O. Abifarin, F. Sumo

FE TOXICITY SCREENING. Twenty entries, including IR 5 and Gissi 27 as the susceptible and resistant checks, respectively, were screened in 1981 at Suakoko, Liberia, for Fe toxicity. The most promising entries were IR4625-269-4-2, IR4683-54-2-3 and BW 100.

INTERNATIONAL RICE OBSERVATIONAL NURSERY. Two hundred and fifty-four entries from 11 countries and IRRI were screened in 1981 at Suakoko for agronomic characters, disease incidence and grain yield.

Table 76. Mean grain yield (t/ha), grain type and growth duration of short duration rice cultivars at different locations in Nigeria — 1981, NCRI Zonal Trials.

Varieties	LOCATIONS Edozihigi	Badeggi	Abakaliki	Bende	Mean	Grain type	Growth duration (± 10 days)
1 ADNY 11	3.8	6.9	5.2	4.4	5.1	A	126
2 ITA 212	4.5	6.5	6.2	5.5	5.7	B	127
3 BIPLAB	3.7	6.2	5.2	3.6	4.7	B	128
4 ITA 123	4.2	6.2	5.2	4.1	4.9	A	122
5 IR 790-35-5-3	3.8	4.2	4.3	3.4	3.9	A	116
6 IET 2938	3.6	3.7	3.9	3.6	3.7	B	113
7 BPI 76/Dawn	3.8	4.0	4.5	5.1	4.3	B	125
8 ITA 121	4.5	5.4	6.1	5.4	5.3	A	129
9 BR 51-46-5	4.6	6.5	5.8	4.8	5.4	B	128
10 IR 934-450-1	2.9	4.5	3.3	2.7	3.3	A	115
11 IR 30 (check)	3.7	3.1	4.2	2.9	3.5	A	118
12 FARO 27 (check)	4.2	4.9	4.8	3.9	4.4	A	
LSD (.05)	N.S.	1.5	—	—	—	—	

Table 78. Grain yield per plot of top entries in a pre-IET trial at Suakoko, Liberia (1981).

	Entries	Grain yield per plot (gms)
1	ITA 249	890
2	ITA 240	810
3	ITA 241	782
4	ITA 253	738
5	ITA 247	725
6	ITA 252	695
7	ITA 255	685
8	6902	642
9	ITA 248	630
10	Suakoko 8 (check)	618
11	ITA 254	617
12	ITA 245	595
13	ITA 238	549
14	ITA 244	534

The materials were seeded on 7 August and transplanted on 22-23 September. Each entry consisted of 4-m long rows. The trial was unreplicated. The most promising entries were AD 9246, IR 13538-48-2-3-2, IR 13540-56-3-2-1, IR 15324-12-2-3-3-2, IR 19575-85-2-2-3, BR 51-315-4, RPW 1064-14-2-1 and Suakoko 8.

FE TOXICITY SCREENING OF GERMPLASM COLLECTIONS FROM IITA AT SUAKOKO, LIBERIA. Samples of IITA's *O. sativa* and *O. glaberrima* germplasm collection were screened under Fe toxicity conditions at Suakoko with a soil pH of 4.8, Fe content of 8,200 ppm and Mn content of 59 ppm.

The unreplicated plots had both a resistant check, Suakoko 8, and a susceptible check, IR5. Fe scores were made at vegetative, panicle initiation and dough stages. Other observations and data collected were days to first flowering, 50 percent flowering, complete flowering and maturity, as well as grain color, grain quality, grain discoloration, uniformity and maturity, height at maturity, neck blast, lodging and grain weight per plot.

There was a high death rate due to Fe toxicity among *O. sativa* lines. By the first score, only 88 cultivars survived. Most of the test varieties were more susceptible to Fe toxicity than the resistant variety at both the vegetative and panicle initiation stages. Exceptions were TOs 7725, TOs 7726, and TOs 7769, which were as resistant as or more resistant to Fe toxicity than Suakoko 8 at all growth stages. The findings reveal that the cultivars reacted differently to the toxic conditions at different growth stages. Higher scores were obtained at early growth stages than at the late growth stages for almost all the cultivars.

Out of the 91 *O. glaberrima* cultivars planted, only 34 were not wiped out before the maximum tillering stage. Therefore, 65 percent of the collection screened was highly susceptible. None of the cultivars was as resistant as the resistant check. They were all equally or more susceptible at the tillering or panicle initiation stage.

FE TOXICITY SCREENING OF GERMPLASM FROM GHANA AND NIGERIA, AT SUAKOKO, LIBERIA. Six collections from Ghana as well as 6 each from Benue and Sokoto in Nigeria were planted using the same design as above and data were collected on the same variables. Four collections from Benue, 5 from Ghana and 3 from Sokoto matured. Some of the cultivars were moderately resistant. TOs 5532 and TOs 5354 from Sokoto were as resistant as or more resistant than Suakoko 8 the resistant check.

Grain Legume Improvement Program

Introduction

The Grain Legume Improvement Program at IITA consists of cowpea and soybean improvement and microbiology research. The cowpea program has an international mandate for the improvement of the crop. At present, a major effort is under way to develop cowpea varieties with desirable seed quality, with resistance to pests and diseases and with different maturity periods to suit the different ecological zones.

To more effectively cover a large part of the tropics a cowpea breeder is based in Brazil who is developing cowpea varieties suitable for Brazil and other Latin American countries. Also, the Upper Volta food legume project, which has support from the International Development Research Center (IDRC) and the Semi-Arid Food Grains Research and Development project (SAFGRAD), develops cowpea varieties for the semi-arid region in Africa.

The major objective in the improvement of soybeans is to develop varieties that combine good seed storability, compatability with African rhizobia and yield capability. Poor seed storability and incompatibility with indigenous rhizobia are the 2 principal factors that have prevented the development of soybeans as a commercial crop in Africa.

Genetic improvement in cowpeas and soybeans is reinforced by parallel research on symbiotic N-fixation. There have been few studies of the population of rhizobia in tropical soils, and, therefore, little is known about their diversity, survival in adverse environments, host range or effectiveness in symbiosis with selected crop hosts in terms of N-fixation. With the cost of N fertilizer escalating, the importance of studying these topics is clear.

Two tons of TVx 3236 cowpea seeds at IITA ready for delivery to Kano State Agricultural Development Project for seed multiplication and distribution.

Cowpea

Advanced breeding lines of cowpea were evaluated in multilocational trials to identify widely adapted, high yielding varieties. Concerted efforts were made to develop large, white, rough seed varieties preferred in West Africa and to breed insect and disease resistance into high yielding backgrounds.

White, rough seed lines developed through hybridization were included in international trials, and 2 lines, TVx 3236 and TVx 4262-09D, had significantly higher yields than other cultivars. IITA lines were included in regional cowpea variety trials conducted by the Upper Volta food legume project at various locations in the semi-arid tropics of Africa. The top 3 yielders, VITA-7, TVx 1999-01F and TVx 3236, were from IITA.

TVx 3236 is also moderately resistant to thrips and was tested by the Agricultural Projects Monitoring, Evaluation and Planning Unit, Federal Department of Rural Development, Nigeria, under a minimum insecticide regime. TVx 3236 gave about 2 to 3 times more yield than standard checks. Based on the performance of TVx 3236, the Kano State Agricultural Development Project, Nigeria, has procured 2 tons of seed for seed multiplication, demonstration and distribution. If the project produces as planned, Kano State should have sufficient seed for planting 0.5 million ha in 1984.

In Tanzania, 2 cowpea cultivars, TVx 9-11D and TVx 1948-01F, were released under local names 'Tumaini' and 'Fahari' meaning 'Hope' and 'Pride', respectively. In Togo and the Republic of South Yemen, VITA-5 was released and multiplied for large-scale cultivation.

In Upper Volta, VITA-7 released as KN-1, was further multiplied and distributed to farmers. In Nicaragua where leafhopper is a serious pest, leafhopper resistant VITA-3 was released, multiplied and distributed to grow 700 ha. In Brazil, VITA-3, VITA-6, VITA-7, TVx 309-1G, TVx 1836-013J and 4R-0267-01F were released, multiplied and distributed to farmers.

Crosses from bruchid resistant TVu 2027 have now reached the F_6 stage and combine disease and bruchid resistance with desirable agronomical characters, including large, white, rough seed. Seed of these lines should be ready for distribution by the end of 1982.

In addition, programs were initiated to develop extra-early maturing varieties (60-65 days) and to develop "bush" type, vegetable cowpeas with long, fleshy and tender pods which stand without any extra support.

In recent years, there has been a high demand for an early maturing cowpea in the sahel and sub-sahel regions because of short rains or irrigation. A number of early maturing germplasm lines and individual plants from various segregating populations were selected in the 1981 second season. These were multiplied in the 1981 dry season and about 65 lines will be evaluated in a preliminary yield trial in 1982. A number of these lines have large, white seeds.

A crossing program was also initiated to develop high yielding, early maturing breeding lines combining disease and insect resistance with good seed quality.

In the past, research on vegetable cowpea was given low priority. However, 8 lines are now available at the F_6 stage that are bush type and do not need support as the traditional vegetable cowpeas do. They have long fleshy vegetable pods held upright on long peduncles which do not touch the ground. These will be further evaluated for yield potential and quality characteristics in 1982.

Genetic Improvement

Variety trials

R.J. Redden, B.B. Singh

PRELIMINARY TRIALS. Preliminary trials consisted of newly developed breeding lines combining acceptable seed quality and good agronomic characteristics and disease resistance. Thirty-eight large, white seed lines developed for West Africa were included in Preliminary Trial-1, and 23 breeding lines with other colors suitable for different regions were included in Preliminary Trial-2. VITA-5 and VITA-7 were included as checks in both trials. These trials were conducted at IITA (1981 second season) and Mokwa in Nigeria. The yield performance of the top 5 breeding lines in each trial is presented in Tables 1 and 2.

ADVANCED TRIALS. Sixty-nine newly developed breeding lines were evaluated in 3 different advanced trials each having 25 entries including VITA-5 and VITA-7 as check varieties. These trials were conducted at 3 different locations in Nigeria, at IITA (1981 first and second seasons), Gusau and Mokwa. The yield performance of the top 5 breeding lines in each trial is presented in Tables 3, 4, and 5.

INTERNATIONAL TRIALS. Based on their previous performance, 23 promising breeding lines were grouped into 3 classes on the basis of seed color and included in 3 international trials with appropriate checks, including local varieties. International Trial-1 had 10 varieties, all with white seeds; International Trial-2 had 10 varieties, all with tan seeds; International Trial-3 had mixed colors, including red and black. One-hundred-and-eighty sets of international trials and 106 sets of observation nurseries (unreplicated international trials) were sent to cooperators in 52 countries. So far, only data from locations within Nigeria and Upper Volta are available.

Data for International Trial-1 are presented in Table 6. Among the white seeded lines commonly preferred in West Africa, TVx 3236 gave consistently higher yields at most of the locations and appeared superior to all other entries, including VITA-4 and VITA-5 (Table 6). TVx 3236 is derived from a cross involving TVu 1509 (a thrips resistant line) and Ife Brown (a popular variety in Nigeria). Therefore, it combines thrips resistance, acceptable seed quality and high yield potential. Another line, TVx 4262-09D, also appeared promising.

Data from International Trial-2 and Trial-3 indicated no significant differences in the yield potential of new breeding lines compared to VITA-6 or Ife Brown (Table 7.) However, TVx 1948-01F yielded consistently better at most of the locations and showed good levels of resistance to major diseases. This variety was also the highest yielder in the 1980 International Trial and showed wider adaptability in several countries.

Table 1. Cowpea Preliminary Trial-1—seed yield (kg/ha) of the top 5 lines (1981).

Variety	IITA (second season)	Mokwa	Mean
VITA-5*	1150	991	1071
VITA-7*	1161	1278	1220
TVx 5052-07C	1278	1376	1327
TVx 5048-013C	1267	1361	1314
TVx 5041-014C	1181	1207	1194
TVx 5049-01C	1200	1185	1193
TVx 5054-010C	1064	1310	1187
LSD (.05)	345	462	

*Check varieties.

Table 2. Cowpea Preliminary Trial-2—seed yield (kg/ha) of the top 5 lines (1981).

Variety	IITA (second season)	Mokwa	Mean
VITA-5*	1131	1311	1221
VITA-7*	1622	1506	1564
TVx 5592-OC	1651	1716	1683
TVu 2115	1569	1742	1656
9R-86-OC	1619	1661	1640
TVx 5623-OC	1687	1522	1604
9R-77-OC	1710	1438	1574
LSD (.05)	331	394	

*Check varieties.

Table 3. Cowpea Advanced Trial-1—seed yield (kg/ha) of the top 5 lines (1981).

Variety	IITA (First season)	IITA (Second (season	Mokwa	Gusau	Mean
VITA-5*	1008	702	1219	1917	1212
VITA-7*	1232	626	1244	1866	1242
TVx 4661-07E	1489	833	1400	2043	1441
8-43-01E	1399	861	1428	1816	1376
TVx 4262-026D	1142	965	1328	1892	1332
TVx 4726-01E	1136	861	1467	1891	1339
TVx 3337-03J	1221	627	1425	2068	1335
LSD (.05)	435	378	397	402	

*Check varieties.

Table 4. Cowpea Advanced Trial-2—seed yield (kg/ha) of the top 5 lines (1981).

	IITA (first season)	IITA second season)	Mokwa	Mean
VITA-5*	1373	606	1400	1126
VITA-7*	1343	1054	1456	1284
TVx 3381-02F	1380	915	1744	1346
TVx 4072-5C-02D	1499	1321	1117	1312
TVx 3410-02J	1279	984	1561	1275
TVx 3627-023F	969	852	1600	1120
TVx 3627-03G	970	871	1489	1110
LSD (.05)	425	374	418	

*Check varieties.

Top, left to right: TVx 4031-6B-1C-1G-1H and TVx 6332-3B-17C-7D-1E. Bottom, left to right: Ife Brown, TVx 4417-8B-1C-2D-2E and VITA-7.

Breeding for bruchid resistance

S.R. Singh, R.J. Redden, B.B. Singh

Several lines are now available in the F_8 stage that combine bruchid and disease resistance with good seed quality (more than 18g/100 seeds) and include cream, tan, red and white colors. Some have large, white seeds with rough testa (Table 8). These lines will be further tested for agronomic characters and bruchid resistance in cooperation with the Tropical Products Institute, England.

Breeding for thrips resistance

S.R. Singh

THRIPS POPULATION STUDIES. TVx 3236 and VITA-7 were evaluated for comparative thrips resistance and yield in a monocrop and mixtures of 2:2, 3:3 and 4:4 plants. Thrips populations per raceme were recorded at 38, 45 and 48 days after planting (Table 9). TVx 3236 had comparatively low thrips population, an average of about 2.5 thrips per raceme, compared to 10.1 thrips on VITA-7 when planted either in a monocrop or mixtures.

TVx 3236, VITA-6, VITA-7 and Ife Brown were evaluated for comparative thrips resistance and yield. Insecticide endosulfan was applied against pod bugs at 56 and 60 days after planting.

Thrips populations were recorded at regular intervals on racemes and flowers along with the number of flowers per plants (Table 10). TVx 3236 had comparatively less number of thrips per raceme and flowers and produced more flowers than other cultivars. TVx 3236 also had the highest yield under this insecticide regime.

Table 5. Cowpea Advanced Trial-3—seed yield (kg/ha) of the top 5 lines (1981).

	IITA (first season)	IITA (second season)	Mokwa	Gusau	Mean
VITA-5*	664	960	1875	2346	1461
VITA-7*	1519	823	2744	2119	1801
TVx 4571-08D	1597	659	2733	1362	1588
TVx 4262-013D	793	1008	2806	1589	1549
TVx 3928-02G	1016	778	2544	1816	1539
TVx 4255-02G	1003	1052	2600	1412	1517
TVx 5984-02D	1148	1315	2080	1261	1451
LSD (.05)	415	600	390	578	

**Check varieties.*

Field evaluation of thrips resistant TVx 3236—(University of Ife)

A.E. Akingbohungbe (University of Ife, Nigeria), S.R. Singh

In cooperation with the University of Ife, Nigeria, TVx 3236, VITA-5 and Ife Brown were evaluated for comparative thrips resistance and yield. Trials were conducted at the University

Table 6. International Trial-1—seed yield (kg/ha) of promising lines (1981).

Variety	IITA (first season)	IITA (second season)	Mokwa	Gusau	Kamboinse	Ayangba	Dekina	Mean
VITA-4	1069	859	706	873	1200	1127	430	895
VITA-5	1265	731	873	615	871	1188	818	1020
TVx 3236-01G	1907	761	1148	1029	2267	1334	831	1325
TVx 3516-09D	574	787	881	873	1547	1522	868	1007
TVx 3627-12F	1136	768	797	597	1247	1182	651	911
TVx 3671-3C-4D	1501	640	789	615	1182	1046	567	905
TVx 3671-14C-01D	866	628	931	725	1011	1075	454	813
TVx 4072-1C-01D	495	962	418	817	1411	900	534	791
TVx 4262-09D	1399	822	1019	909	1367	1557	776	1120
Local check	476	471	964	785	8*	1090	622	734
LSD (.05)	382	237	229	282	287	334	388	

Kamboinse Local was destroyed by Fusarium *wilt.*

Table 7. International Trial-2 and Trial-3 seed yield (kg/ha) of promising lines (1981).

Variety	IITA (first season)	IITA (second season)	Mokwa	Gusau	Mean
		International Trial-2			
VITA-7	1435	693	1219	1841	1191
Ife Brown	1279	797	1290	2069	1359
TVx 1948-01F	1484	737	1578	2106	1476
TVx 2724-01F	1546	716	1081	1746	1272
LSD .05	303	310	306	434	
		International Trial-3			
VITA-6	986	807	1046	1670	1127
TVx 1836-013J	1382	1029	1148	1537	1274
TVx 2394-02F	1297	976	889	1688	1213
TVx 4577-02D	1360	669	1086	1537	1163
LSD (.05)	243	293	378	528	

Table 8. Percent bruchid emergence in some selected breeding lines with large white seed and rough testa, IITA (1981).

Line	Percent adult emergence Day 41	Day 56
TVu 2027 (Res. check)	10	18
TVx 6332-7D-2E	22	31
TVx 6332-7D-3E	18	32
TVx 6332-19D-2E	23	33
TVx 6332-48D-2E	20	33
TVx 6332-3D-1E	19	36
TVx 6332-7D-1E	19	36
TVx 6332-4D-3E	18	37
Ife Brown (Sus. check)	99	100
LSD (.05)	24	21

Table 9. Flower thrips populations on TVx 3236 and VITA-7, IITA (1981 first season).

Cultivar	Planting pattern*	Thrips/raceme**
TVx 3236	Mono	2.09 ± 1.38
TVx 3236	Mix 2:2	2.78 ± 1.14
TVx 3236	Mix 3:3	2.39 ± 0.78
TVx 3236	Mix 4:4	2.59 ± 0.88
VITA-7	Mono	10.15 ± 2.40
VITA-7	Mix 2:2	9.88 ± 2.23
VITA-7	Mix 3:3	10.08 ± 2.05
VITA-7	Mix 4:4	10.23 ± 1.97

**TVx 3236 and VITA-7 were planted in a monocrop or mixtures as indicated.*
***Average of 3 readings at 38, 45, 48 days after planting.*

Table 10. Flower thrips populations in TVx 3236, VITA-6, VITA-7 and Ife Brown, IITA (1981 first season).

Cultivar	Days after planting (35) Th/Ra	(48) Th/Ra	(48) Th/Fl	(48) Fl/Pl	(50) Th/Fl	(50) Fl/Pl	Yield* (kg/ha)
TVx 3236	7.7	2.3	21.3	20.3	41.2	14.5	1703.7
Ife Brown	16.9	7.8	69.9	9.8	128.1	8.2	925.0
VITA-6	10.9	8.6	53.4	5.6	112.2	7.5	443.5
VITA-7	10.0	6.7	60.2	7.0	97.9	7.2	689.2
LSD .05	1.42	3.07	25.4	5.6	39.4	4.3	176.3

*Endosulfan applied at 56 and 60 days after planting.
Th = Thrips, Ra = Raceme, Fl = Flower, Pl = Plant.

Table 11. Evaluation of TVx 3236 for thrips resistance and yield in Nigeria (1981).

Cultivar	Days after planting (43) Th/Ra	(51) Th/Fl	(51) Fl/Pl	Yield* (kg/ha)
		Aroko Village		
TVx 3236	1.0	12.7	7.4	2186
Ife Brown	2.9	28.0	4.7	1266
VITA-5(LS)11	2.8	19.4	3.0	578
LSD (.05)	1.5	11.7	2.0	333
		Aganran Village		
TVx 3236	1.8	19.6	9.3	999
Ife Brown	2.1	28.9	3.7	613
VITA-5(LS)11	4.2	54.3	2.7	404
LSD (.05)	1.6	13.0	1.9	86
		University of Ife		
TVx 3236	0.7	31.6	8.0	910
Ife Brown	1.3	70.9	5.3	526
VITA-5(LS)11	0.5	80.9	4.5	270
LSD (.05)	0.8	28.3	2.4	208

**Endosulfan applied at 56 and 60 days after planting.*
Th = Thrips, Ra = Raceme, Fl = Flower, Pl = Plant.
Trial conducted by University of Ife, Nigeria.

of Ife and on farmers' fields in 2 nearby villages, Aroko and Aganran. Insecticide was applied against pod bugs at 56 and 60 days after planting. Thrips populations and yield were recorded (Table 11). Thrips populations were significantly low on TVx 3236 which also had significantly more flowers and higher yield than the other 2 cultivars.

Federal evaluation of thrips resistant TVx 3236—(Federal Department of Rural Development)

G. Quin (Agricultural Projects Monitoring, Evaluation and Planning Unit, Nigeria)

The Agricultural Projects Monitoring, Evaluation and Planning Unit, Federal Department of Rural Development, Nigeria, conducted 2 cowpea observation trials to compare the yield of TVx 3236 to TVx 7-5H and Ife Brown under partial and full pest protection. The trials were conducted at Ilorin in southern Nigeria and Ayangba in northern Nigeria. At both locations, TVx 3236 gave higher yields both under partial and full protection (Table 12). There was also not much difference in the yield of TVx 3236 under the 2 protection levels.

Table 12. Evaluation of TVx 3236 for yield under 2 insecticide protection regimes in Nigeria (1981).

Location	Cultivar	Insecticide* applications	Yield (kg/ha)
Ilorin	TVx 3236	2	1500
	Ife Brown	2	956
Ayangba	TVx 3236	2	1144
	TVx 7-5H	2	300
Ilorin	TVx 3236	4	1589
	Ife Brown	4	1667
Ayangba	TVx 3236	4	1156
	TVx 7-5H	4	383

**2 = Endosulfan applied at 35 and 60 days after planting.*
**4 = Endosulfan applied at 30, 40, 50 and 60 days after planting. Trial conducted by Agricultural Projects Monitoring, Evaluation and Planning Unit, Federal Department of Rural Development, Nigeria.*

Evaluation of advanced thrips tolerant lines

R.J. Redden, S.R. Singh

Lines that indicated less thrips damage in thrips screening trials or regular agronomy trials in previous years were evaluated for thrips resistance in replicated trials at IITA and Mokwa in 1981. TVx 3236 gave the highest yield in the agronomy trial and least thrips damage in the screening trials (Table 13). Two other cultivars, TVx 6011-01E and TVx 6015-03E, were not significantly different than TVx 3236 either in yield or thrips damage, but they both have poor seed quality.

Cowpea lines included in the International Trial No. 1 were screened for thrips resistance (Table 14). None of the lines except TVx 3236 had any resistance to thrips.

Table 13. Evaluation of 16 cowpea lines for thrips resistance and yield, IITA and Mokwa (1981).

Cultivar	Mean* damage rating	Yield** (kg/ha)
VITA-7	3.3	1578
TVx 3236	1.7	1928
TVx 3410-02J	2.9	1433
TVx 3343-01J	3.6	1383
TVx 3747-03E	4.3	56
TVx 3777-04E	4.5	1778
TVx 4257-03F	5.0	1334
TVx 4661-012E	4.6	1422
TVx 4838-01E	4.5	1428
TVx 4862-01E	4.3	1106
TVx 5995-02E	1.8	906
TVx 6011-01E	1.8	1594
TVx 6015-03E	1.9	1450
TVx 6017-02E	1.8	1100
TVx 5992-013E	2.0	1161
TVx 5992-107E	1.8	628
LSD (.05)	0.59	550

**Data from IITA* ***Data from Mokwa*
Damage rating is based on a 1-5 scale: 1 = Resistant, 5 = Susceptible.

Field screening tests at IITA in 1981 for cowpea resistance to flower thrips.

Table 14. Evaluation of 9 cowpea lines for thrips resistance, IITA (1981 first season).

Cultivar	Mean damage rating
VITA-4	3.8
VITA-5	4.2
TVx 3236	1.8
TVx 3516-09F	4.6
TVx 3627-012F	4.6
TVx 3671-3C-04D	4.8
TVx 3671-14C-01D	4.7
TVx 4072-1C-01D	4.8
TVx 4262-09D	4.5
LSD (.05)	0.58

Damage rating is based on a 1-5 scale: 1 = Resistant, 5 = Susceptible.

Breeding for *Maruca* resistance

L.E.N. Jackai, B.B. Singh

Reciprocal crosses were made between TVu 946 and TVu 2027, TVu 1 and Kamboinse Local. TVu 946 has *Maruca* resistance but unacceptable seed type and plant type. On the other hand, TVu 2027 has acceptable seed type, TVu 1 has acceptable plant type and Kamboinse Local not only has acceptable seed type but also moderate *Maruca* resistance.

Single plant selections of the F_2 progeny were made under field conditions during the 1981 second season. There were 64 F_2 populations each with a minimum of 100 plants. About 1,500 selections were made. Nine-hundred-and-thirty-one F_3 progenies were planted in unreplicated rows and evaluated for *Maruca* resistance during the 1981-82 dry season. Evaluation was made on a progeny row basis, and single plant selections were made from rows with *Maruca* damage of 8 percent or less.

The *Maruca* population is several times higher during the normal growing season than during the dry season, and the level of selection is ≤25 percent pod damage. This is the maximum damage generally observed on the resistant check. Of the 931 progeny rows evaluated, about 250 were selected for testing at F_4. Single plant selections were made from these rows. They will be exposed to high *Maruca* populations during the first and second seasons, and evaluation will be made using field screening methodology developed at IITA. Work on the development of a bioassay for screening is still in progress. F_3 progeny of those selections that could not be planted during the dry season will be planted and evaluated during the growing seasons in 1982.

Breeding for disease resistance

R.J. Redden and B.B. Singh

Preliminary and international trials were screened for cowpea yellow mosaic virus (CYMV) resistance at IITA under artificial epidemic and for web blight, bacterial blight, anthracnose and pod blotch resistance at Mokwa under natural epidemic.

In general, lines from the trials were resistant/moderately resistant to most of the diseases (Table 15). Except for VITA-5, which was susceptible to bacterial blight, and Wuse local, which was susceptible to anthracnose, all the lines from the International Trial-1 appeared resistant to web blight, bacterial blight, anthracnose and pod blotch. Only VITA-4, TVx 4072-1C-01D and TVx 4262-09D were resistant to CYMV. Also, resistance to CYMV was higher in Preliminary Trial-2 (colored seeds) than Preliminary Trial-2 (white seeds).

Table 15. Evaluation of 10 cowpea lines for disease reaction, IITA (1981 first season).

	Disease score*				
Variety	CYMV	Bact. blight	Web blight	Anthra-nose	Pod blotch
VITA-4	1.0	1.0	1.25	1.0	1.0
VITA-5	3.0	4.0	1.75	1.0	1.0
TVx 3236-01G	5.0	1.0	1.0	1.0	1.0
TVx 3516-09F	5.0	1.0	1.0	1.0	1.0
TVx 3627-012F	4.0	1.5	2.0	1.25	1.0
TVx 3671-3C-09D	8.0	2.0	2.0	1.0	1.5
TVx 3671-1G-01D	3.0	2.5	2.25	1.0	1.5
TVx 4072-1C-01D	1.0	1.25	1.75	1.0	1.0
TVx 4262-09D	2.0	1.5	2.5	1.0	1.5
Wuse Local	7.0	1.25	2.75	5.0	1.0
LSD (.05)		1.2	.95	.80	.78

**Disease score is based on a 1-9 scale: 1 = Free, 9 = Very severe.*

Entomology

Thrips populations and yield loss

S.R. Singh, R.J. Redden, B.B. Singh

Thrips populations per raceme per plant were recorded at 38, 45 and 48 days after planting on individual plants in plots treated with different levels of monocrotophos. The average thrips population per raceme was calculated and multiplied by the number of racemes per plant to calculate the total number of thrips per plant. Individual plants were separately harvested, and the yield per plant was plotted against the total thrips per plant.

Data indicate a negative relationship between yield and total thrips (Fig. 1). VITA-7, which averages 20 racemes per plant, gave significantly less yield when it had more than 1 thrips per raceme or 20 thrips per plant.

The yield and total thrips per plant were plotted against the insecticide dosage, and regressions were drawn (Fig. 2). Data indicate that with each increase in insecticide dosage, there was an increase in yield and a reduction in the number of total thrips.

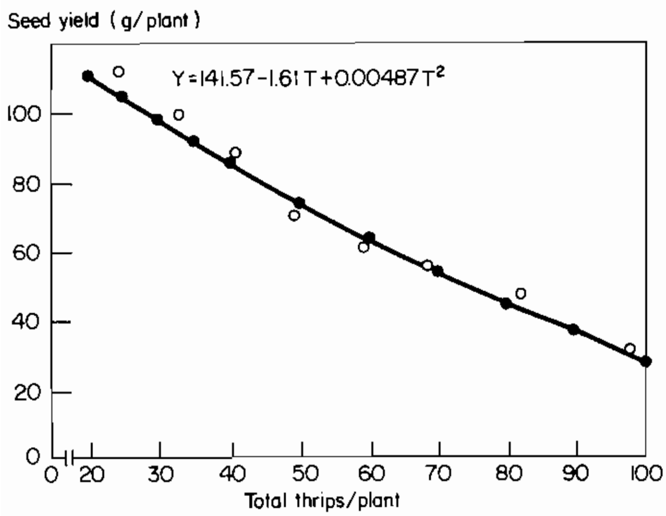


Fig. 1. Relationship between yield and total thrips per plant, IITA.

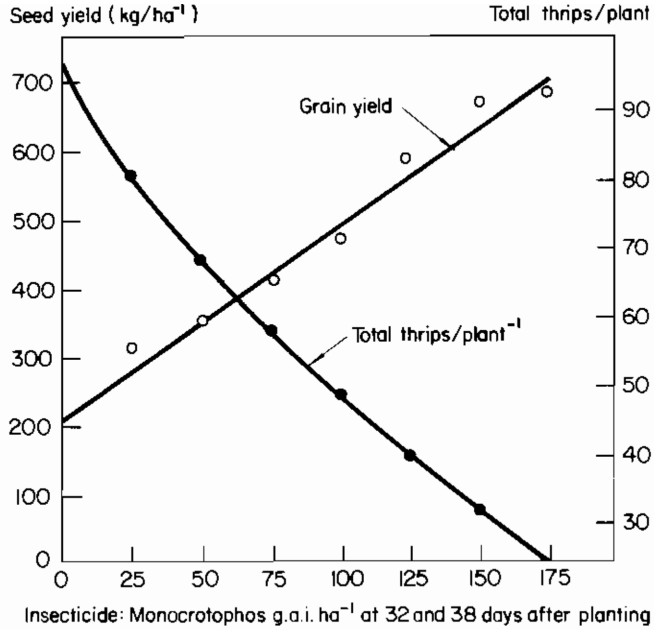


Fig. 2. Effect of insecticide on yield and total thrips per plant, IITA (1981).

Field screening for resistance to *Maruca*

L.E.N. Jackai

Several hundred cowpea varieties from IITA's germplasm collection were screened for *Maruca* resistance at IITA and Mokwa using a field screening method described in IITA's 1980 Annual Report. To monitor the population intensity and distribution of the insect, a susceptible check was planted once in every 10 entries. Flower samples were taken at 49 and 55 days after planting for larval counts.

The insect population was higher at Mokwa than at IITA (Table 16). Out of 400 varieties screened at Mokwa, only the resistant check had less than 25 percent pod damage and only 10 other varieties had less than 50 percent pod damage.

Table 16. Larval population counts on resistant and susceptible checks from 2 testing locations.

	Number of larvae per 10 flowers (mean ± sd)			
	49 DAP*		55 DAP*	
Variety	IITA	Mokwa	IITA	Mokwa
TVu 946 (Resistant check)	8.0 ± 1.61	8.33 ± 1.53	8.0 ± 1.36	7.7 ± 2.65
VITA-6 (Susceptible check)	14.4 ± 11.18	22.4 ± 6.90	26.4 ± 7.99	28.3 ± 1.49

*DAP = Days after planting.

Out of 800 varieties screened at IITA, 74 had less than 25 percent pod damage. A total of 84 varieties were selected and will be screened again as indicated below in the funnel approach to host plant resistance screening.

Step I: Initial field screening (large number of cultivars). Assess stem damage and % pod damage.

Step II: Second field screening of cultivars with ≤25% pod damage from Step I. Evaluate stem, flower, pod and seed damage.

Step III: Behavioral studies/laboratory and/or screenhouse bioassays (best 5-10 cultivars from Step II) effect of host plant on insect.

Step IV: Sprayed versus unsprayed testing (best 5-10 cultivars from Step II) damage assessment in flowers, pods, seeds, and yield.

Use of relative response of cowpea to insecticides as a tool in resistance screening for *Maruca*

L.E.N. Jackai

If a cowpea cultivar is resistant to *Maruca*, it would be expected to show smaller differences in grain yield between protected and unprotected plots than a susceptible variety. To test this hypothesis, an experiment was designed in 1981 using 12 cowpea cultivars, including resistant and susceptible checks.

Planting was staggered to ensure uniform flowering. The entire experiment was sprayed once at bud initiation and once at pod-fill to afford protection against flower thrips and hemipteran pests. Protected plots were sprayed two additional times with decis (15 g.a.i./ha). Three weekly flower samples were collected for larval counts beginning 3 days after the first flower was produced. At the end of the growing period, yields were collected from 3 rows in each treatment. Grain yield is not significantly different between protected and unprotected treatments for TVu 946 (resistant check), TVu 1, TVx 3236, VITA-5, Kamboinse and VICAM-1/SP (Table 17). However, larval count is very different between protected and unprotected treatments for VITA-5, VICAM-1/SP and TVx 3236.

Such results suggest that larval counts in themselves are not adequate in making decisions on the resistance status of any cultivar. It is possible that plant architecture and flower production are important considerations in assessing cultivar response to insecticide applications. Flowers of TVx-3236, for example, are held above the leaf canopy and also this variety flowers profusely. Exposed flowers would increase the efficiency of chemical sprays and damaged flowers may be easily compensated for by the plant. This may be a case of pseudo-resistance but, nonetheless, an important factor in grain production.

Maruca distribution on the cowpea plant

L.E.N. Jackai

To gain some insight into the relationship between plant type and *Maruca* pest damage, a study was initiated to investigate pod borer distribution on the cowpea plant.

A semi-erect improved cowpea variety, VITA-6, was selected for the first phase of the investigation. This was grown at IITA during the 1981 first and second seasons and sampled weekly using destructive sampling. Branches were separated from the main stem in each plant. Plant parts that

Table 17. Comparison of larval infestation and grain yield between protected and unprotected plots of selected cowpea cultivars, IITA (1981 second season).

Cultivar	Av. No. larvae per 20 flowers: Protected	Av. No. larvae per 20 flowers: Unprotected	Av. yield g/5 m-row: Protected	Av. yield g/5 m-row: Unprotected	Significance* (yield)
TVu 946 (check)	.56	4.7	249.8 (11.9)	212.5 (15.9)	ns
TVu 946-1E	1.31	6.8	407.3 (20.4)	309.3 (39.8)	*
TVu 946-2E	1.0	4.4	310.5 (16.2)	180.8 (24.3)	**
VITA-3 (check)	2.7	13.0	573.0 (46.8)	479.5 (41.0)	*
VITA-6 (check)	2.7	10.3	683.3 (61.5)	386.8 (41.1)	**
TVu 1	2.4	8.6	252.0 (27.2)	176.8 (37.7)	ns
TVx 3890-010F	2.1	7.3	424.5 (30.7)	327.0 (23.7)	*
TVx 3236	1.2	9.3	747.0 (102.1)	621.0 (70.2)	ns
TVu 1836	3.9	11.9	545.3 (30.6)	280.0 (91.0)	*
VITA-5	2.0	13.4	582.8 (38.2)	354.7 (125.1)	ns
Kamboinse Local	1.2	6.2	595.0 (27.2)	494.8 (36.5)	ns
VICAM-1/SP	0.4	5.0	255.3 (9.6)	219.5 (23.9)	ns
LSD (.05)	1.4	3.4			

t-test

Numbers in parentheses are standard errors.

serve as feeding sites of the pod borer were counted, and the number of larvae in each assessed.

The branches had a uniformly greater load of plant parts than the main stem (Figs. 3 and 4). An average of more than 80 percent of the reproductive structures was found on the branches. The larval distribution was closely and directly related to the distribution of the reproductive structures which serve as the feeding sites for the insects. The plants were more vegetative in the first season and also had a longer growth period. This may have led to the higher infestation in the first season (Table 18).

These results are still preliminary, but they appear to suggest that profuse branching may lend itself to greater infestation by the pod borer. Since the branches carry most of the flower load, and the flowers have the greatest larval population, yield losses as a result of pod borer damage would be expected to be higher in varieties with profuse branching. The situation is exacerbated by the fact that during the second season, the time when cowpeas are traditionally planted, flowers account for up to 60 percent of the total larval population (Table 18).

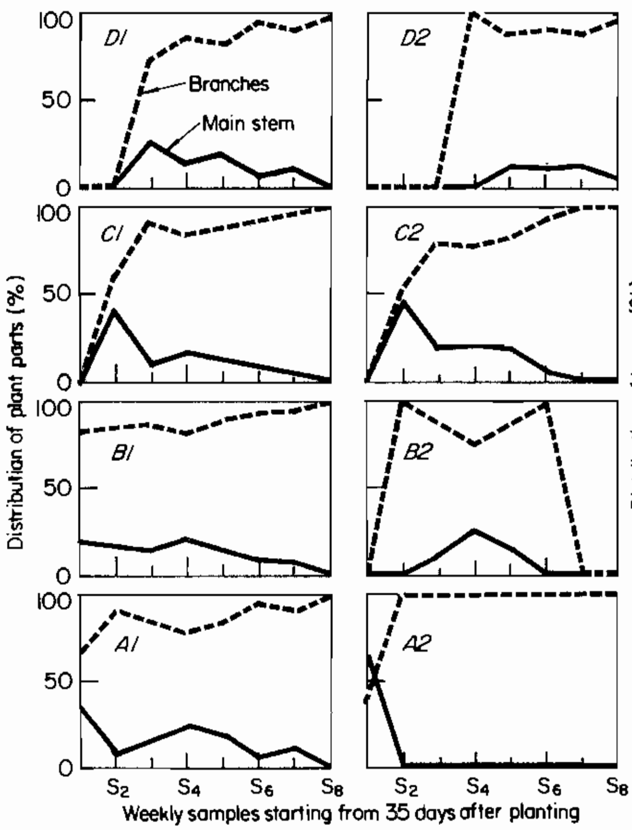


Fig. 3. Distribution of shoots (A1), flower buds (B1), flowers (C1), and pods (D1) and corresponding larval distribution (A2, B2, C2, D2) on these parts on a cowpea plant, IITA (1981 first season).

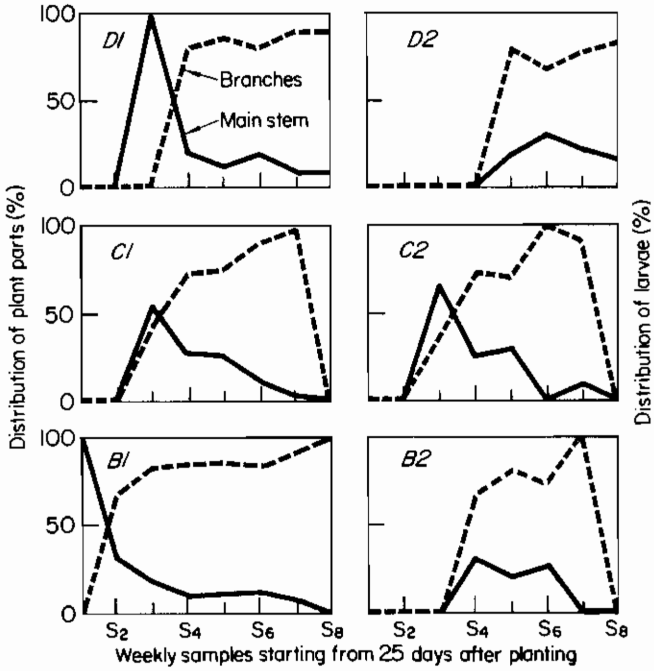


Fig. 4. Distribution of shoots (A1), flower buds (B1), flowers (C1), and pods (D1) and corresponding larval distribution (A2, B2, C2, D2) on these parts on cowpea plant, IITA (1981 second season).

Table 18. Seasonal total larval count and distribution in flowers and pods.

	First season	Second season
Overall larval total	663	303
Mean per plant	132.6	60.6
% of larvae in flowers	49.1	61.4
% of larvae in pods	43.6	24.8

Maruca host range studies

L.E.N. Jackai

The legume pod borer is known to have several alternate hosts, many of them wild leguminous shrubs and trees. Some of these grow well during the dry-season when cowpea is not cultivated.

In 1981, experiments were conducted in the laboratory and screenhouse to study the role these secondary hosts play in pod borer population dynamics, particularly during off season. A few of the most commonly found secondary hosts were selected for the laboratory study on the developmental profile of the pod borer in flowers. These tests were conducted in petri dishes. Flowers were changed daily.

The studies on development indicate that development is greatly prolonged in some species of *Crotalaria*, particularly *C. juncea* and *C. miseriensis*. The latter also gave the lowest emergence. There was complete larval mortality during the early instars on *C. retusa* (Table 19). Prolongation in the larval developmental period was generally accompanied by reduced pupal size except in *Cajanus cajan* which gave pupae of comparable size to those obtained on the principal host. There are a number of these secondary hosts that would appear to be suitable, with respect to development and pupal size, for maintaining the pod borer population when the principal host is not available, and they may be extensively used for this purpose by the insect. The extent to which these hosts are available in the cowpea cropping areas is not fully documented, but it is well known that *C.*

Table 19. **Developmental parameters of** *M. testulalis* larvae on 7 alternate host plants and on cowpea, the principal host plant.

	Host Plant							
Parameter	*Crotolaria retusa*	*C. juncea*	*C. misereninsis*	*C. mocronata*	*C. saltiana*	*C. amazonas*	*Cajanus cajan*	*Vigna unguiculata*
Time to pupation (days)	0	21.0 (±2.74)	19.9 (±1.37)	16.9 (±1.46)	14.0 (±1.51)	13.2 (±1.26)	16.4 (±0.20)	7.3 (±0.24)
Time to emergence (days)	0	11.6 (±0.55)	9.3 (±0.46)	8.4 (±0.76)	7.4 (±0.48)	7.8 (±0.72)	11.1 (±0.12)	5.6 (±0.27)
Pupal weight (mg)	—	27.1 (±3.13)	35.0 (±1.63)	34.6 (±3.23)	36.6 (±1.29)	38.7 (±1.53)	47.8 (±1.33)	48.2 (±0.95)
Percent pupation	0	17.8 (±3.74)	42.0 (±9.68)	78.6 (±6.12)	78.7 (±4.31)	88.0 (±4.26)	80.0 (±0.0)	95.0 (±2.23)
Percent emergence	0	11.6 (±0.90)	38.0 (±7.99)	65.4 (±6.41)	71.9 (±5.19)	77.9 (±4.96)	70.0 (±5.78)	85.0 (±4.99)
Growth index	0	0.84 (±0.34)	2.2 (±0.42)	5.0 (±0.93)	5.9 (±0.70)	6.9 (±0.44)	4.9 (±0.07)	13.2 (±0.56)
Number of insects	100	100	100	50	100	100	60	80

Numbers in parentheses are standard errors.

juncea is widely grown as green manure in parts of South America and for other uses in parts of India. In West Africa, this and other species are known to grow wild.

Previous studies carried out at IITA revealed that *C. juncea* is preferred over cowpea for oviposition by the pod borer, but despite this preference, there is more than 80 percent larval mortality in the flowers. This finding has engendered speculation for using this *Crotalaria* species as a possible trap crop for this insect.

Evaluation of electrodyn sprayer

S.R. Singh

The newly designed electrodyn sprayer operates by batteries and is fitted with a 'bozzle' container. It sprays 60 mu diameter droplets that are attacted to the nearest earth object. The droplets carry a positive charge while the plants carry a negative charge. This system prevents insecticide drift. Half the normally recommended dosage of cypermethrin, cypermethrin plus dimethoate and dimethoate alone were compared using formulations that had 1- and 2-row swaths. The trial was conducted on a 10-ha zero-tillage field planted with VITA-5 in 4 replications.

Effect on thrips populations and yield were recorded (Table 20). All the insecticide treatments gave significant control of thrips. The yield was comparatively higher in the treated than untreated plots. However, the yields were generally low due to poor plant growth and establishment.

Electrodyn sprayer being used on test plots for control of thrips on cowpeas.

Table 20. Comparative performance of electrodyn insecticide formulation against flower thrips and yield of VITA-5, IITA (1981).

Insecticide	Dosage*	Thrips per** flower	Yield (kg/ha)
Cypermethrin (2 row swath)	15	6.0	760
Cypermethrin + Dimethoate (2 row swath)	15 + 25	5.8	712
Cypermethrin + Dimethoate (1 row swath)	15 + 25	3.7	632
Dimethoate 50 (2 row swath)	25	6.8	553
Control		18.9	453
LSD (.05)		5.8	272

**Dosage = g.a.i./ha/application applied at 30, 45 and 55 days after planting.*
***Data collected 50 days after planting.*

Effect of large-scale Cypermethrin ULV application on cowpea pests

S.R. Singh, D. Couper

Based on previous results on the comparative efficacy of insecticides and time of insecticide application in relation to pest infestation and crop phenology, 50 ha of VITA-5 were treated with cypermethrin ULV at 40, 50 and 60 days after planting with battery operated ULV hand sprayers as a preventive insecticide application against thrips, *Maruca* and pod bugs. When the plants were about 20 days old, cowpea aphid, *Aphis craccivora*, infestation was observed.

Cypermethrin ULV applications did not control aphids, but a single pirimicarb ULV application did. Pirimicarb gave 100 percent control of aphids while Cypermethrin later gave 100 percent control of other cowpea pests. On small control plots, which were protected against aphids but not against other cowpea pests, heavy thrips and *Maruca* populations were observed. However, there was no pod bug infestation either on the treated or untreated plots.

Virology

Cowpea yellow mosaic virus (CYMV)

H.W. Rossel

Numerous early and intermediate breeding lines from the bruchid resistance breeding program were screened for resistance to cowpea yellow mosaic virus (CYMV). Only a few lines were identified that combined bruchid resistance with CYMV tolerance. In general, the breeding parents that have been used in this program were found to be at best, only moderately resistant to CYMV. Notably the bruchid resistance donor, TVu 2027, but also the large, white, rough seed breeding parents, used because of the strong preference for these seed characters in the major cowpea growing areas of northern Nigeria, were found to be highly susceptible to CYMV.

To identify potential breeding parents combining the seed characters and CYMV resistance, all large, white, rough seed cowpea introductions in IITA's germplasm collection were screened. So far, no resistance has been found among this material, virtually all of which originates from the major cowpea growing areas of northern Nigeria, where CYMV has never been found. Two introductions that remained symptomless in these tests were further evaluated for type and level of resistance. In back tests to a CYMV local lesion host as well as in agar-gel diffusion tests, no virus could be detected in the inoculated plants of these 2 accessions, TVu 7483 and TVu 5971, which means that these accessions may be immune to CYMV.

Cowpea cucumo virus (CuMV)

H.W. Rossel

Cowpea cucumo virus (CuMV) and cowpea aphid-borne mosaic virus (CAbMV) are the most prevalent aphid-transmitted cowpea viruses in Nigeria. CuMV is a perennial problem at IITA, particularly because of its high seed transmission rate in many advanced breeding lines.

From a germplasm collection of cowpeas grown in the field at IITA, 150 randomly collected samples from severely diseased plants were tested for CuMV and CYMV. All samples were indexed to a cowpea cultivar developing characteristic local necrotic ringspot symptoms with CuMV. Fifty-six percent were infected with this virus, whereas none was infected with CYMV when tested serologically.

Considering the severity of symptoms, most of these possibly also had CAbMV which mostly occurs in mixed infections with CuMV. However, the samples were not specifically indexed for this virus. Elite cowpea breeding material (47 introductions), which had gone through dry-season multiplication and had become massively infected with both CuMV and CAbMV (as concluded from random sampling) were evaluated for seed transmission of these two viruses.

CuMV and CAbMV often occur together since both are transmitted efficiently by *Aphis craccivora*, a common pest of cowpea. In only 15 of these, no seed transmission was observed after 500 seeds each were grown out in an insect-proof screenhouse. All the other introductions showed seed transmission of, surprisingly, only the CuMV.

The seed transmission rates varied from 0.4 percent to as high as 13.6 percent. All lines showing seed transmission rates of more than 2 percent were condemned for export and international testing. Lines showing less than 2 percent seed transmission were still sent for export and testing, but it was left to the local quarantine authorities in the various countries to condemn these lines with low seed transmission rates of CuMV.

During the 1981 growing season, only the lines selected from this set of 47 elite material showing less than 2 percent seed transmission of CuMV were propagated. A northern Nigeria site was used to avoid the high infection pressure of this virus at IITA. No obvious infection occurred in these multiplication plots most likely because of the very low primary infection incidence and as a result of seed transmission in these selected materials. The emerging generation of seed of these lines is likely to be essentially free from seed-borne CuMV infections.

Other materials, non-selected for seed transmission, were simultaneously propagated at the northern site, but separated from the elite materials. They showed epidemic spread of CuMV, which was attributed to a possible high primary infection incidence of seed-borne CuMV in a number of these materials.

Quality Evaluation

Taste and palatability test for TVx 3236

P. Ay

A taste and palatability test on the quality of TVx 3236 was carried out with 165 people in 15 villages in the Ilorin Agricultural Development Project, Nigeria. TVx 3236 was tested along with Ife Brown and local varieties for the quality of their preparation of *ewa*, *akara* and *moin-moin*. Everybody agreed on the very good quality of TVx 3236. For *ewa* and *akara*, TVx 3236 tasted best to the majority of respondents. The local varieties were second, and, in some cases, last. For *moin-moin*, Ife Brown scored best; 56 respondents preferred the taste of Ife Brown *moin-moin* to the other varieties, but TVx 3236 was nearly as good for 50 respondents. A local variety was last.

Seed size and color were important. To nearly all respondents, local varieties scored best in a visual preference test. Local variety grains are white or slightly yellow while Ife Brown grains are brown and TVx 3236 grains are light brown. Grains are largest for the local varieties followed by Ife Brown and TVx 3236. The barrier, because of unfamiliar visual appearance of TVx 3236, was shown to be overcome by a strategy of practical demonstration as the performance of the local dishes is in favor of the new variety. It can be assumed that the good performance and cooking quality of TVx 3236 will be associated with its appearance after a learning period and that the barrier can be overcome in a short time.

Upper Volta Food Legume Program

Genetic improvement

V.D. Aggarwal

VARIETAL TRIALS. Three international yield trials were carried out based on seed color. Trial-1 had 10 white seeded varieties while Trial-2 had 10 tan seeded varieties. One set each of 3 trials was planted at Kamboinse. Out of the 3 trials, only 1 variety, TVx 3236-01G, looked promising for yield (2,269 kg/ha). This variety was also among the highest yielders in 1980 at Kamboinse. It also has a rough seed coat which is a preferred character. However, its seed size needs further improvement.

None of the other lines in the 3 trials looked exceptionally good for high yield and good seed quality. The local check, Kamboinse Local, was completely destroyed by *Fusarium* wilt, yielding between 8 and 23 kg/ha.

Also, an Upper Volta erect variety trial consisting of 20 varieties selected from the previous year's yield trials was planted at Farako Bâ, Kamboinse and Saouga to select early maturing, high yielding varieties.

The yields of selected promising lines are shown in Table 21. The highest mean yield was produced by TVx 4668-28C-1K (1,807 kg/ha), but it was highly susceptible to pod blotch. The second highest yielder was TVx 3236 (1,642 kg/ha) which is not exactly erect and is later in maturity. Among them all, TVx 4659-13C-LK was best in terms of earliness and erect plant type showing no symptoms of lodging. However, it was relatively low yielding and had very small seeds (11g/100 seeds).

Table 21. Yield of selected varieties in the Upper Volta Erect Variety Trial, Upper Volta (1981).

	Location			
Entry	Farako Bâ	Kamboinse	Saouga	Mean
TVx 3404	1081	1583	1343	1336
TVx 2724 = 01F	1444	1763	985	1397
TVx 3404-01J	1588	1842	978	1469
TVx 3236	1653	2093	1181	1642
TVx 4860-6C-1K	1331	1903	1395	1543
TVx 4773-3C-1K	1125	1752	1421	1433
TVx 4659-13C-1K	1306	1688	850	1281
TVx 4680-15C-2K	1338	1833	1154	1442
TVx 4668-28C-1K	1578	2177	1667	1807
TVx 4661-17C-1K	1269	1805	1316	1463
VITA-6	1278	1945	881	1368
Overall mean	1193	1718	1087	1333
LSD (.05)	339	404	461	232

ON-FARM TESTING OF KN-1. In 1981, on-farm testing trials were conducted with KN-1, a variety currently recommended for areas with an annual rainfall of 700 mm or more. A demonstration trial compared yields of KN-1 and local varieties with and without insecticide treatment. The trial was designed as a factorial experiment with insecticide treatments as main plots and varieties as subplots. Fifty-two trials were conducted. Distribution covered most of the central and southern parts of Upper Volta having an annual rainfall of more than 700 mm. Results from 33 locations were received and are summarized in Table 22.

Table 22. Yield of KN-1 and local varieties in the Demonstration Trial, Upper Volta (1981).

	Yield (kg/225 m^2)			
	Treated		Untreated	
Organization/village	KN-1	Local	KN-1	Local
SAFGRAD Farming System's Laboratory Villages:				
Nedogo: mean of 5 trials	11.8	11.1	6.1	8.1
Digre: mean of 5 trials	9.4	9.8	4.2	6.0
Diapongou: mean of 2 trials	6.1	8.2	4.3	2.9
Nyindougou: mean of 3 trials	6.1	8.7	3.8	5.0
ORDS:				
ORD, Ouagadougou: mean of 8 trials	7.3	6.0	1.9	3.4
ORD, Dedougou: mean of 5 trials	18.7	12.9*	5.1	2.9
ORD, Koudougou: mean of 3 trials	9.8	5.9	5.3	3.4
Others:				
ICRISAT: mean of 2 trials	3.5	6.2	1.6	4.1
IITA: mean of 2 trials	9.1	0.0*	4.8	0.0
Overall mean	9.5	8.6	4.2	4.5
KG/ha	422	382	187	200

**Variety did not flower due to early end of rains; excluded from the mean.*

Results show that with insecticide treatment average yields were increased by 100 percent. Yields were not very high, but farmers still seemed to be quite happy. The probable reason for low yields was inadequate insecticide application. Two insecticide treatments recommended were not sufficient. In some cases, the insecticides were not applied properly or in sufficient quantities. In general, yields of KN-1 and local varieties were similar.

According to farmers, KN-1 had an advantage over local varieties in terms of its early maturity. This fact has been demonstrated clearly where late maturing, local varieties were not able to produce anything because rains ended early.

A KN-1/groundnut trial compared yields of KN-1 with improved and local varieties of groundnut to ascertain whether cowpea as a monocrop (with insecticide treatment) can produce higher economic returns. Ten trials were conducted in 1981. Data indicate that it is possible to double the economic returns by growing KN-1 compared to improved or local varieties of groundnuts provided insecticide prices are moderate.

A total of 16 ha in Duapangou, Digre, and Nedogo were planted in KN-1. The minimum plot size was .25 ha. The crop was sprayed twice with Decis. The objective was to know the yield potential of KN-1 on relatively large size plots and demonstrate to the farmers the use of insecticides and other improved cultural practices.

Yields varied significantly (187-528 kg/ha) from location to location due to variations in soil and inadequate and highly variable insect control. Only 50 percent of the land area produced yields exceeding 300 kg/ha, and the highest yield of 528 kg/ha was recorded in a 3-ha plot at Diapangou. There, the soils are good and moisture is not a limiting factor. Despite low and variable yields, farmers seemed to be fairly enthusiastic with the new variety and already its seed is in great demand.

A regional cowpea variety trial, which consisted of 20 varieties, was sent to 33 locations in 18 countries.

Results from 12 locations were received and are summarized in Tables 23a and 23b. TVx 1999-01F (1,765 kg/ha), TVx 3236 (1,542 kg/ha), KN-1 (1,526 kg/ha), Mougne (1,483 kg/ha) and IAR 48 (1,476 kg/ha) gave the best yields over locations.

TVx 1999-01F and IAR 48 gave particularly good yields over a wide range of environments. KN-1 and TVx 3236 performed best at relatively wetter locations while Mougne, Gorom Local, TN 88-63 and 58-57 performed best at relatively drier locations. These yields were obtained with 3-4 insecticide applications beginning at flower initiation. Except TVx 3236, which has moderate thrips resistance, none of the varieties has resistance to major insect pests of cowpea.

TVx 1999-01F, KN-1, Mougne and Tn 88-63 do not have the most preferred seed type across the semi-arid regions. Only Gorom Local and IAR 48, and, to some extent TVx 3236, have the desired seed quality, but IAR 48 is susceptible to pod blotch (*Colletotrichum* spp) which is becoming quite serious and Gorom Local showed virus susceptibility at certain places. TVx 1999-01F, TVx 3236, KN-1, Mougne and Gorom Local will be recommended for on-farm testing in SAFGRAD member countries, including Upper Volta, in 1982. They will be evaluated for their seed acceptability and yield. The exceptionally low yields of Blackeye at almost all the locations and the check variety at Kamboinse were caused by *Fusarium* wilt. Kpodiguegue, VITA-5 (L.S.), Bambey-21 and N'Diambour were highly susceptible to bacterial blight. IAR 48, IAR 355 and TVx 1948-01F showed a high level of susceptibility to brown pod blotch.

BREEDING FOR SEED QUALITY. Seventy F_3 and 154 F_4 families originally developed at IITA were evaluated at Kamboinse. A great variation in plant type, days to flowering, seed size, seed color, texture and yield was recorded. Three lines, TVx 5048-016K, TVx 5050-016K and TVx 5058-03CK have been selected to be crossed with bruchid resistant lines. Other promising lines will be evaluated in replicated trials in 1982.

BREEDING FOR INSECT RESISTANCE. A systematic program has been initiated to incorporate aphid and bruchid resistance in KN-1 and Gorom Local. TVu 36 is the aphid resistant source and TVu 2027 is the bruchid resistant source.

Parent F_1 backcross and F_2 populations derived from crosses involving KN-1 and Gorom Local with TVu 36 were evaluated for aphid resistance in 1981. The results indicated that aphid resistance was a dominant trait and monogenically inherited corroborating earlier findings at IITA. Resistant plants from the backcrosses involving KN-1 and Gorom Local as recurrent parents have been retained for further evaluation.

The F_2 population derived from the cross KN-1 x TVu 2027 and the F_3 population derived from the cross Gorom Local x TVu 2027 were evaluated and desirable plants selected. From the cross Gorom Local x TVu 2027, 425 F_3 families were evaluated at Saouga and Kamboinse which represent different agroclimatic regions. Selected individual plants from different F_3 families were separately harvested and screened for seed quality. A 20-seed sample from each selected plant is currently being evaluated for bruchid resistance.

Some segregating promising materials resistant to bruchids were introduced from IITA and screened for bruchid resistance. All the entries except TVx 4031-6B-1C-2C segregated for bruchid resistance. Seeds without holes were multiplied in the main season and individual plants were separately harvested. These are being retested for bruchid resistance.

Kamboinse Local has shown a moderate level of resistance to *Maruca* in these varieties. F_2 and F_4 populations involving Gorom Local and KN-1, respectively, with Kamboinse Local were evaluated in 1981, and flower samples were taken for *Maruca* count. Data are being evaluated for bruchid resistance.

Efforts are also being made to combine *Maruca* resistance with bruchid resistance by crossing Kamboinse Local and TVu 2072. The F_2 population from this cross was evaluated in 1981 and 130 single plants have been selected.

Semi-Arid Food Grains Research and Development Project (SAFGRAD)

Entomology

Y.S. Rathore

RESISTANCE TO COWPEA APHID. Tests previously conducted indicate that not only are TVu 9836, TVu 9914, TVu 9929, TVu 9930 and TVu 9944 resistant to cowpea aphid mosaic virus, but they are also resistant to cowpea aphids.

Cowpea lines identified as resistant to cowpea aphids were investigated for their mechanism of resistance. At the first trifoliate stage, each plant was infested with 2 last instar nymphs. After 10 days, total number of aphids on each plant was counted (Table 24). The 4 resistant lines tested indicated less progeny production, thus, antibiosis was the mechanism of resistance.

Table 24. Total number of cowpea aphids produced by two last instar nymphs in 10 days, Kamboinse, Upper Volta (1981).

Cultivar	Aphids 10 days after release*	Plant** response	Resistance mechanism
TVu 36	48.5 b	R	Antibiosis
TVu 1037	35.8 b	R	Antibiosis
TVu 2896	51.0 b	R	Antibiosis
TVu 3000	12.4 a	R	Antibiosis
KN-1	235.8 c	S	—

**Mean of 5 replications.*
***R = Resistance, S = susceptible.*

RESISTANCE TO THRIPS. TVu 1509 and TVx 3236, identified as moderately resistant to thrips at IITA, were evaluated for thrips resistance along with TVx 309-1G, VITA-6 and KN-1. The comparisons were made between treated and untreated plots for thrips populations, flower production and yield. The treated plots were protected by monocrotophos

Table 23a. Yield (kg/ha) of varieties included in the Regional Cowpea Variety Trial conducted at various locations in the semi-arid tropics of Africa (1981).

Varieties	Origin	Farako Bâ Upper Volta	Kamboinse Upper Volta	Saouga Upper Volta	Samaru Nigeria	Kano Nigeria	Guering Cameroon
Kpodiguegue	Benin	605	1352	850	2083	1407	1655
Black eye	Botswana	17	279	665	67	46	202
Rhenostar	Botswana	1019	1548	759	2198	1374	1528
IAR 341	Nigeria	1380	465	750	1276	904	1344
IAR 48	Nigeria	1140	1505	1179	1769	2002	2014
IAR 355	Nigeria	783	1114	1120	1400	1708	1440
58-57	Senegal	628	1219	1690	1216	875	858
Mougne	Senegal	729	1431	1503	2179	2353	1835
Bambey-21	Senegal	466	1186	888	1071	428	1428
N'Diambour	Senegal	240	973	934	1105	1134	1207
TN 88-63	Niger	557	1850	1429	1370	1818	1645
TN 13-78	Niger	996	508	934	1533	854	992
TVx 1999-01F	Upper Volta/IITA	1211	1862	1345	2735	2845	2511
TVx 1948-01F	Upper Volta/IITA	927	1284	1002	2072	2365	2242
VITA-4	Upper Volta/IITA	992	1478	794	2647	1979	1904
VITA-5 (L.S)	Upper Volta/IITA	960	1046	805	896	1726	1557
Gorom Local	Upper Volta/IITA	948	1948	1639	1414	1847	1322
KN-1	Upper Volta/IITA	1468	1541	1391	2102	2037	2081
TVx 3236	Upper Volta/IITA	1244	1901	1232	1429	2632	2482
Local Check	—	1227	12	1479	1110	1674	261
Trial mean		877	1225	1120	1584	1605	1526
LSD (.05)		446	385	481	443	555	633
Total rainfall (mm)		1147.6	699.8	363.0	991.1	560.4	710.4

Table 23b. Yield (kg/ha) of varieties included in the Regional Cowpea Variety Trial conducted at various locations in the semi-arid tropics of Africa (1981).

Varieties	Origin	Nyunkpala Ghana	Salibary Mauritania	Sikasso Mali	Sotuba Mali	Seno Mali	Broukou Togo	Overall Mean
Kpodoguegue	Benin	950	1434	202	1325	1297	813	1164
Black eye	Botswana	626	168	10	108	708	215	259
Rhenostar	Botswana	856	1679	521	1855	1263	300	1243
IAR 341	Nigeria	1065	718	981	1583	333	670	956
IAR 48	Nigeria	1294	1536	704	1917	1832	825	1476
IAR 355	Nigeria	731	1267	880	1655	1175	657	1161
58-57	Senegal	1315	2149	524	933	1843	493	1147
Mougne	Senegal	1545	1730	772	1917	1355	442	1483
Bambey-21	Senegal	785	290	480	1263	897	280	788
N'Diambour	Senegal	574	1068	242	883	1460	442	855
TN 88-63	Niger	1336	1379	1083	2105	2177	280	1419
TN 13-78	Niger	1159	1546	490	1875	865	207	1007
TVx 1999-01F	Upper Volta/IITA	1388	1612	479	2648	1240	990	1765
TVx 1948-01F	Upper Volta/IITA	564	1424	890	1488	1268	765	1358
VITA-4	Upper Volta/IITA	626	1583	800	1592	917	1460	1398
VITA-5 (L.S.)	Upper Volta/IITA	825	1288	660	1363	707	958	1066
Gorom Local	Upper Volta/IITA	1420	1450	688	1613	1518	313	1344
KN-1	Upper Volta/IITA	1033	1071	1288	2042	857	1403	1526
TVx 3236	Upper Volta/IITA	898	1762	563	2458	1093	812	1542
Local Check	—	522	734	1738	458	313	520	840
Trial mean		947	1295	717	1554	1151	642	1190
LSD (.05)		383	786	536	660	813	362	344
Total rainfall (mm)		—	346.3	1126.7	771.1	331.7	1026.3	

for control of thrips, *Maruca* and pod bugs. The untreated plots were protected by endosulfan for control of *Maruca* and pod bugs (Table 25.)

There were significantly fewer thrips in TVu 1509, TVx 3236 and VITA-6 than TVx 309-1G and KN-1. Comparatively higher numbers of flowers were produced by TVu 1509, TVx 3236 and TVx 309-1G than VITA-6 and KN-1. TVx 3236 had the highest yield in the protected plot while TVu 1509 and TVx 3236 had highest yields in the unprotected plots.

RESISTANCE TO *MARUCA*. Ten cowpea cultivars, which included material identified as resistant to *Maruca* at IITA and Kamboinse, were evaluated for *Maruca* resistance under protected and unprotected conditions. In protected plots, all insects were controlled, while in unprotected plots, all insects except *Maruca*, were controlled. The percent of infested flowers and pods as well as grain yield were recorded (Table 26). TVu 946, TVx 38 (0-010F), Kamboinse Local and TVx 3236 had least infested flowers in unprotected plots and TVu 946, TVx 3890-010F and TVx 3236 had least infested flowers in protected plots.

RESISTANCE TO POD BUGS. Five cowpea cultivars identified as resistant to pod bugs at IITA were evaluated for pod bug resistance along with Ife Brown (Table 27). The crop was protected against thrips and pod borer by application of Decis at 35 and 45 days after planting. Pod bug population was calculated. There was no significant difference in the pod bug populations on different cultivars. However, the populations were also low. The average number of shrivelled pods dropped on a cloth during sampling was recorded and the average calculated. The number of shrivelled pods was significantly higher for Ife Brown than others. The percentage of shrivelled pods was also recorded at harvest. Ife Brown and 8EN-185-2-1 had significantly higher percentages of shrivelled pods. However, TVu 4600, 8EN-185-2-1 and Ife Brown had higher yields than others.

Table 26. Percent of *Maruca* infested flowers on *Maruca* protected and unprotected cowpea cultivars, Kamboinse, Upper Volta (1981).

Cultivar	Unsprayed	Sprayed	Significance (.05)
VITA-3	29.00	11.67	Dif
VITA-5	20.00	8.67	Dif
VITA-6	19.67	5.33	Dif
TVu-1	15.67	4.33	Dif
TVu 946	4.33	1.33	Same
TVu 946-1E	12.00	4.33	Diff-close
TVu 946-2E	13.33	6.00	Diff-close
TVx 3236	11.00	1.33	Dif
TVx 3890-010F	6.67	3.33	Same
Kamboinse Local	10.33	7.33	Same

Dif = Significant differences exist between sprayed and unsprayed plots.
Diff-close = Significant differences exist between sprayed and unsprayed but differences are very close.
Same = Statistically no difference exists between sprayed and unsprayed.

LOSSES DUE TO BRUCHIDS. To estimate the losses caused by bruchids, grain samples were collected from the market and farmers' storage every month for 1 year. In the market samples, the minimum infestation was in October and July. In the farmers' samples, maximum infestation was in October and November causing more than 50 percent storage loss.

EFFECT OF INTERCROPPING ON THRIPS. TVx 3236 and Ife Brown were intercropped with sorghum. The experiment used a split plot design. Insecticide treatments (protected and unprotected) were the main plots and combinations of cropping systems with varieties (monocrop-Ife Brown, intercrop-Ife Brown, monocrop-TVx 3236 and intercrop-TVx 3236) were the subplots.

Table 25. Flower thrips populations, flower count and yield on thrips protected and unprotected cowpea cultivars, Kamboinse, Upper Volta (1981).

Treatments: Main plot		Sub-plot	Total thrips/ raceme	Total thrips/ flower	Total flowers/ meter	Yield (kg/ha)
TVu 1509		T_I	1.78	2.33	120.75	1089.3
		T_O	11.18	38.10	40.75	199.8
	Mean		6.48	20.21	80.75	644.5
TVx 3236		T_I	1.20	3.30	92.75	1824.3
		T_O	10.05	27.56	22.25	179.5
	Mean		5.63	15.48	57.50	1001.9
TVx 309-1G		T_I	2.45	3.10	101.75	1367.8
		T_O	14.65	60.28	20.00	39.3
	Mean		8.55	31.69	60.88	703.5
VITA-6		T_I	0.50	3.32	90.50	1369.5
		T_O	8.45	39.43	11.25	129.3
	Mean		4.48	21.38	43.88	749.4
KN-1		T_I	1.85	4.58	49.50	1483.5
		T_O	12.45	73.70	9.00	52.8
	Mean		7.15	39.14	29.25	768.1
Sub-plot means		T_I	1.56	3.33	88.25	1426.9
Treatments)		T_O	11.36	47.81	20.65	120.1
LSD (.05) Varieties			N.S.	10.63	20.56	N.S.
Treatment			1.35	7.70	14.50	228.5
Treatment at same variety			N.S.	17.22	N.S.	N.S.
Treatment at different variety			N.S.	16.17	N.S.	N.S.

Table 27. Resistance to pod bug, *Clavigralla tomentosicollis*, field evaluation, Kamboinse, Upper Volta (1981).

Cultivar	Av. no. of pod bugs/ meter row	Av. no. of shrivelled pods/cloth	% shrivelled pods at harvest	Yield (kg/ha)
Ala. 963-8	0.62 a*	0.48 a	13.95 c	1457 d
8 EN-185-2-1	1.26 a	0.67 a	18.70 d	2161 a
TVu 4600	0.85 a	0.25 a	9.35 a	1970 ab
TVx 3878-01C	0.49 a	0.71 a	10.93 bc	1668 cd
TVx 2940-01D	0.20 a	0.42 a	6.75 a	1645 cd
Ife Brown	0.95 a	2.59 b	20.50 d	1745 abc

**Means followed by the same letter(s) are not significantly different from each other at the 5% level of significance. (Duncan's MR test.)*

Table 28. Thrips in racemes and flowers, *Maruca* larvae in flowers, number of flowers per meter in monocrop and mixed cropping of cowpea in treated and untreated plots at Kamboinse, Upper Volta (1981).

Treatments		Total thrips raceme	Total thrips flower	Total *Maruca* larvae/flower	Total no. of flowers
Main plots	Sub-plots				
	Mono Ife Brown	32.78	125.35	3.02	19.13
	Mono TVx 3236	23.58	51.88	2.38	49.38
	Int. Ife Brown	38.33	114.45	2.40	14.63
	Int. TVx 3236	28.15	54.20	2.10	41.13
	Mean	30.71	86.62	2.48	31.06
	Mono Ife Brown	2.73	4.35	1.18	72.13
	Mono TVx 3236	1.58	2.45	0.95	106.75
	Int. Ife Brown	4.60	4.90	1.85	66.23
	Int. TVx 3236	3.00	2.88	1.58	84.75
	Mean	2.98	3.64	1.39	82.47
LSD. (.05)	Mainplot	2.55	15.67	0.58	3.88
	Sub-plot	N.S.	11.89	N.S.	15.00
	Sub-plot for main plot	12.66	16.82	1.19	21.21
	Sub-plot for different main plot	11.23	20.95	1.17	18.73

For number of thrips in racemes, significant differences were found only for insecticide treatments and not for cropping systems with varieties. However, the number of thrips in flowers was significantly higher in Ife Brown than TVx 3236 in both cropping systems, and significantly more flowers were produced in TVx 3236 than Ife Brown (Table 28).

Agronomy

F. Brockman

COWPEA/MAIZE RELAY CROPPING. Trials conducted in 1979 and 1980 indicated that in the Northern Guinea Savanna good yields of both maize and cowpea can be obtained when cowpeas are relay planted in maize. Emphasis in 1981 was placed on defining more precisely the management practices for this cropping system.

The photoperiod sensitive cultivar Logfrousso Local was relay planted on 4 dates in TZE4 at Farako Bâ. The earliest cowpea planting (15 days after maize) caused a slight reduction in maize yield compared to the maize monocrop (Table 29). Later cowpea plantings did not result in any reduction in maize yield. Cowpea yields were highest in the earliest planting and decreased progressively with later plantings.

Table 29. Effect of planting cowpea (cv. Logfrousso Local) as a relay crop in maize on 4 different dates on grain yield of maize and cowpea.

Time of cowpea planting		Maize yield		
Date	Days after maize	(kg/ha)	% of monocrop	Cowpea yield (kg/ha)
12 July	15	3056	93.0	1705
17 July	20	3472	105.7	1292
23 July	26	3613	110.0	993
5 August	39	3385	103.0	676
LSD (.05)		465	14.1	311

Similar results were obtained in another trial with photoperiod sensitive cultivars IAR 1696 and Kaya Local. Thus, the best time for planting photoperiod sensitive cultivars appears to be 2-3 weeks after maize. This will give high cowpea yields and only slightly reduce maize yields. Although results were not obtained this year for nonphotoperiod sensitive varieties, previous results have shown that their response to time of planting in the relay system is markedly different. They should be planted 30 days or less (depending on length of growing season) before maize harvest so that they do not flower under maize and so that they have as long a period as possible to recover after maize competition is removed (IITA/SAFGRAD Report, 1980).

Early maturing (90 days) maize varieties have been utilized in previous relay cropping trials. The possibility of using longer-term varieties was investigated in 1981. POOL 16 (90 days) and IRAT 100 (105 days) were planted on 3 June. The photoperiod sensitive cultivars, Local 337 and IAR 1696, were planted as a relay crop on 10 July. Maize yields were not reduced by relay cropping and the yields of POOL 16 and IRAT 100 were 5,733 and 6,602 kg/ha, respectively. Cowpea yields were 33 percent lower when relay cropped with IRAT 100 than POOL 16 (Table 30). IRAT 100 is taller and leafier than POOL 16, and it may be that differences in maize plant architecture as well as growth duration are responsible for cowpea yield differences.

Table 30. Grain yield of two cowpea cultivars planted as a relay crop in two maize varieties.

Cowpea variety	Maize variety: Pool 16	IRAT 100	Mean
Local 337	1079	547	813
IAR 1696	1058	877	968
Mean	1068	712	890
LSD (.05)			
Maize variety		<0.5	99
Cowpea variety		<0.5	99
Maize variety x cowpea variety		(ns)*	—

**ns: not significantly different.*

TZE3 was planted at densities of 44,444 and 66,666 plants/ha and in rows 75, 112.5 and 150 cm apart. VITA-4 was the only cowpea variety used for relay planting and, as it succumbed to a disease, cowpea data were not obtained. However, maize yield data show that even the most unfavorable (in terms of maize yield) treatment combination (low density, widest row spacing) resulted in a yield that was 81 percent of the most favorable combination (high density, narrowest row spacing) (Table 31). Thus, there appears to be latitude for altering maize population and planting arrangement that might substantially improve the light environment for cowpea during the overlap period.

Previous results have shown that the growth of relay cropped cowpeas is reduced during the period of overlap with maize in comparison with the growth of a monocrop. Differences in growth were found to be still present at the time of pod filling. Thus, it appears that the relay crop, at pod filling, cannot be fully utilizing environmental growth factors when grown at recommended monocrop densities, and it was hypothesized that higher cowpea densities should result in higher yields. IAR 1696 was planted as a relay crop at 4 densities ranging from 22,222 to 155,555 plants/ha and as a monocrop at the recommended density of 22,222 plants/ha.

Table 31. Effect of maize row spacing and density on grain yield (kg/ha).

Density (plants/ha)	Row spacing (cm): 75	112.5	150	Mean
44444	4495	4241	3911	4216
66666	4814	4652	4015	4493
Mean	4655	4446	3963	4355
LSD (.05)				
Density		<0.5%		124
Row spacing		<0.5%		151
Density x row spacing		(ns)*		

**ns: not significantly different.*

There were no differences in maize yield associated with different densities of relay cropped cowpeas (Table 32). Measurement of cowpea growth at flowering showed an increase in biomass per unit area with an increase in density from 21,000 to 62,000 plants/ha, but no further increase in biomass was obtained with higher densities.

Maximum biomass per unit area obtained under relay cropping was only 60 percent of the monocrop. Likewise, cowpea yield increased with an increase in density from 21,000 to 62,000 plants/ha, but increasing density beyond this level resulted in little further increase in yield. The results indicate that the optimum cowpea population for relay cropping is higher than for monocropping, but increasing plant density cannot completely compensate for the reduced growth of relay cropped cowpea.

A trial conducted at Farako Bâ showed no benefit from tied ridges in terms of extending the growing season for a cowpea relay crop. It would appear that the infiltration rate of this soil is high enough that tied ridges do not substantially increase the amount of soil water stored at the end of the rain season.

The possibility of extending the cowpea/maize relay system into the Sudan Savanna was investigated. Maize cultivar Jaune Flint de Saria was planted on 26 June on a lower-

Table 32. Effect of growing cowpeas (cv. IAR 1696) at 4 densities as a relay crop with maize on cowpea growth and grain yield and on maize grain yield and comparison with growth and yield of monocrop cowpeas.

		Experiment 1				
Cropping system	Cowpea density (plants/ha)	Cowpea whole plant fresh wt. (g/plant)	Cowpea whole plant fresh wt. (g/m^2)	Cowpea ground cover (%)	Cowpea grain yield (kg/ha)	Maize grain yield (kg/ha)
Relay	21,354	187	393	41	660	4,981
Relay	62,247	103	692	89	826	5,017
Relay	94,650	62	550	99	840	5,110
Relay	129,821	53	652	82	923	5,004
Monocrop	19,561	523	1,081	96	1,494	—
LSD (.05)	13,566	39	298	27	158	(ns)*

*ns: not significantly different.

Table 33. Effect of land management system and maize harvest method on grain yield of cowpea (cv. Kamboinse rouge) grown as relay crop with maize. (Figures in parentheses are yield as % of yield of monocrop grown on tied ridges).

Land management system	Maize harvest method			
	All green	½ Green ½ Green	All green	Mean
Flat	527 (39%)	542 (47%)	459 (40%)	509 (44%)
Tied Ridges	1415 (123%)	947 (82%)	1040 (90%)	1134 (99%)
Mean	971 (84%)	744 (65%)	749 (65%)	822 (71%)
LSD (.05)				
Land management system (M)			<0.5	305
Maize harvest method (H)			>5.0	—
M X H			>5.0	—

slope hydromorphic soil at Kamboinse either on the flat or on tied ridges. The photoperiod sensitive cowpea cultivar Kamboinse rouge was planted as a relay crop on 30 July. Three methods of maize harvest were used: (1) all harvested for green cobs on 3 September, (2) all was harvested for grain on 22 September, and (3) alternate rows were harvested for green cobs and the remaining rows for grain. For comparison, both crops were grown as monocrops on tied ridges.

Maize yields were 35 percent higher when grown on tied ridges than on the flat (3,904 vs. 2,888 kg/ha) when all was harvested for grain. There was no reduction in yield due to the cowpea relay crop. The use of tied ridges resulted in more than a 50 percent increase in the yield of the cowpea relay crop (Table 33). Harvesting half the maize for green cobs did not result in an increase in cowpea yield over harvesting all the maize for grain, but there was a tendency toward higher cowpea yields when all maize was harvested for green cobs. It should be noted that, due to late coming of the rains, maize planting was about 3 weeks later than is usually possible. With earlier maize planting and subsequent earlier cowpea planting and earlier maize harvest, cowpea yields could be expected to be even higher. From these results, it would appear that the cowpea/maize relay system has potential in the Sudan Savanna on lower slope sites when used in conjunction with tied ridges.

COWPEA/SORGHUM INTERCROPPING. Cowpea cultivar TVx 3236 has been reported to have some resistance to flower thrips. However, under heavy thrips pressure as is often encountered in monocropping, this characteristic may not be displayed. It has been shown, however, that insect pressure is reduced when cowpeas are intercropped with sorghum (IITA/SAFGRAD Report 1979). A trial was conducted to determine if the level of resistance that TVx 3236 possesses could be of value in intercropping. TVx 3236 and its susceptible parent, Ife Brown, were planted both as an intercrop in sorghum and as a monocrop and were grown with and without insecticide protection against flower thrips. Without protection, of the 4 variety x cropping system combinations, only TVx 3236 grown as an intercrop gave any appreciable yield (Table 34). The results indicate that TVx 3236 has some level of thrips resistance, which under intercropping, can result in a substantial yield advantage over susceptible cultivars.

COWPEA/MILLET INTERCROPPING. As only limited information seems to be available on management factors involved in cowpea/millet intercropping in the Sahel, an exploratory trial was conducted at Saouga. Millet was grown at densities of 31,250 and 62,500 plants/ha with and without fertilizer (38-23-14). The cowpea intercrop was planted simultaneously with the millet or two weeks later at densities of 16, 125 or 32,250 plants/ha. Millet growth (fresh weight of stalks) was measured rather than grain yield as the trial was planted too late to obtain reasonable millet yields. Application of fertilizer resulted in a 4-fold increase in millet growth and a small but significant increase in cowpea yield (Table 35). Only when planted simultaneously with millet did cowpea give an appreciable yield. However, simultaneous

Table 34. Grain yield of cowpea (cvs. Ife Brown and TVx 3236) as affected by cropping system and protection against flower thrips.

Variety	Cropping system	Unprotected	Protected	Unprotected as % of protected
Ife Brown	Monocrop	7	1274	1
	Intercrop	39	413	9
TVx 3236	Monocrop	85	2188	4
	Intercrop	310	724	43

Table 35. Main effects of fertilizer, millet density, date of cowpea planting, cowpea density and cowpea insect control on growth of millet and grain yield of cowpea grown as intercrops.

Treatment	Fresh weight millet stalks (kg/ha)	Cowpea grain yield (kg/ha)
Fertilizer	**	*
0-0-0	588	288
38-23-14	2438	384
Millet density	NS	NS
31,250 plants/ha	1580	328
62,500 plants/ha	1446	346
Date of cowpea planting	**	**
At millet planting	748	662
Two weeks after millet	2278	12
Cowpea density	NS	NS
15,125 plants/ha	1568	310
31,250 plants/ha	1456	362
Cowpea insect control	*	NS
no insecticide	1286	290
with insecticide	1741	382
Monocrop	2539	690

**: Significantly different at .05*
***: Significantly different at 0.5*
NS: not significantly different

planting of the two crops resulted in a very large reduction in millet growth. These results indicate a need for further investigation to determine management practices that will result in optimum competitive balance between the two crops.

TIED RIDGES. To determine the effect of using tied ridges on cowpea yield over a range of soil conditions, KN-1 was planted at 5 positions in a toposequence at Kamboinse at two dates (4 July and 1 August) on tied ridges or on the flat. Marked differences in yield, associated with differences in position, were observed (Fig. 5). Overall, yields increased as cowpeas were planted lower in the toposequence. At all positions, yields were much lower in the second planting except at the lowest position where yields of the two plantings were similar. At all positions and with both times of planting, yields were consistently higher where the crop was grown on tied ridges than where grown on the flat. These results and those previously obtained clearly indicate that to obtain the most favorable soil moisture regime, cowpeas should be planted early and/or planted on lower slope soils.

MANAGEMENT AND YIELD POTENTIAL OF PHOTOPERIOD SENSITIVE CULTIVARS. Little genetic improvement or agronomic work has been done to date on photoperiod sensitive cowpea cultivars, but previous results show that some local photoperiod sensitive cultivars have a yield potential close to that of improved varieties and possess certain interesting and perhaps useful characteristics. However, it has been found that the response of photoperiod sensitive cultivars to certain management factors is often different from that of nonphotoperiod sensitive varieties.

Several cowpea varieties collected from different latitudes in Upper Volta and Nigeria were planted at Farako Bâ (7 varieties at 4 dates) and at Kamboinse on upper-slope and lower-slope sites (5 varieties at 3 dates). The improved nonphotoperiod sensitive variety KN-1 was included for comparison. The results confirm earlier observations that photoperiod sensitive cultivars can be high yielding (Fig. 6).

The pattern of maturation of these photoperiod sensitive cultivars is of interest. They tend to flower and produce pods much more synchronously than nonphotoperiod sensitive varieties. The photoperiod sensitive cultivars tend to produce their full yield in one flush while nonphotoperiod sensitive varieties require a series of flushes to reach maximum yield (Fig. 6). Since major field insect problems occur during the reproductive phase, this could possibly be very important in terms of insect control. The period required for insect protection and the time available for insect build up should be significantly less for nonphotoperiod sensitive cultivars. Furthermore, the photoperiod sensitive cultivars can be harvested in fewer pickings than nonphotoperiod sensitive varieties significantly reducing the labor required.

To determine the importance of various agronomic factors in the management of photoperiod sensitive cultivars and their possible interactions, trials were carried out at Farako Bâ and in a farmer's field near Kamboinse.

At Farako Bâ, Logfrousso Local was planted on two dates (18 June and 24 July) at two densities (22,222 and 66,666 plants/ha) and at two fertility levels (0 and 50 kg P_2O_5/ha). The earlier planting gave higher yields than later planting (Table 36). The response to density differed with planting date. The lower density gave highest yield in the first planting while the opposite response was observed in the second planting. Although only maintenance doses of P were applied in previous years, no response to P was observed.

In the farmer's field trial near Kamboinse, the photoperiod sensitive local cultivar, Kamboinse rouge, and the improved nonphotoperiod sensitive variety, KN-1, were planted on two dates (3 July and 24 July) at two densities (22,222 and 66,666 plants/ha) using two land management systems (flat or tied ridges). There was a marked general positive yield response to early planting and to high density (Table 37).

Interesting interaction was observed between variety and P levels. At the low-fertility level, there was no difference in yield of the two varieties, but the improved variety was more responsive to P application giving 50 percent more yield than the local variety at the higher fertility level.

Despite the beneficial effects observed with tied ridges in trials previously discussed, there was no significant difference in yield between the two land management systems in this trial. The trial was situated in the plateau position of the toposequence on a sandy loam with little slope. It would appear that water infiltration rates were high enough so that tied ridges gave no benefit. This indicates a need for testing

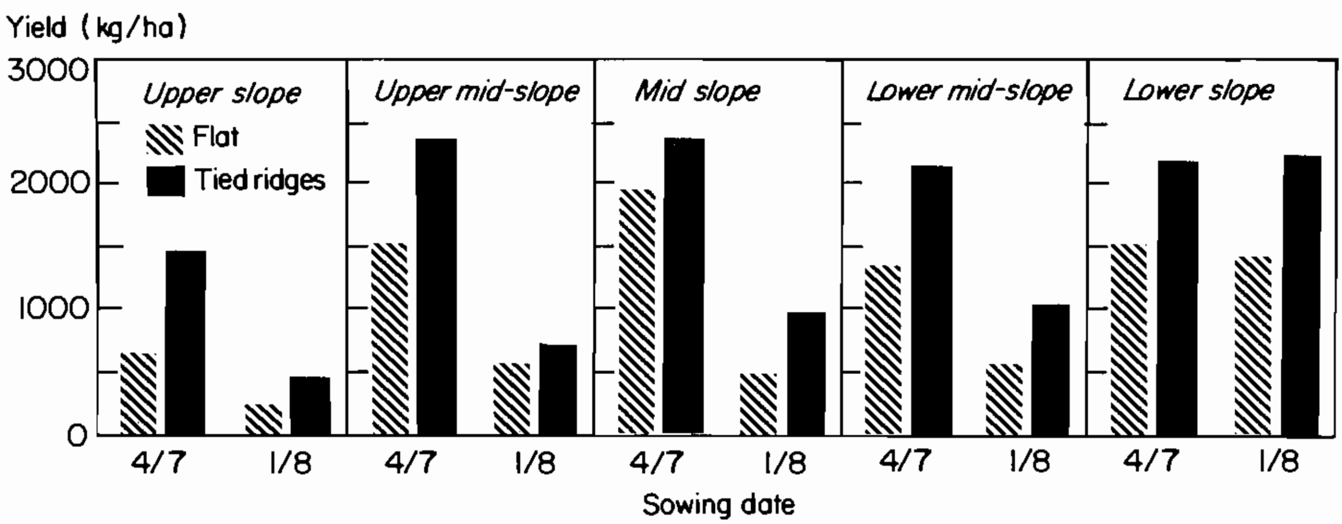


Fig. 5. Effect of position in toposequence and land management system on grain yield of cowpea planted on two different dates.

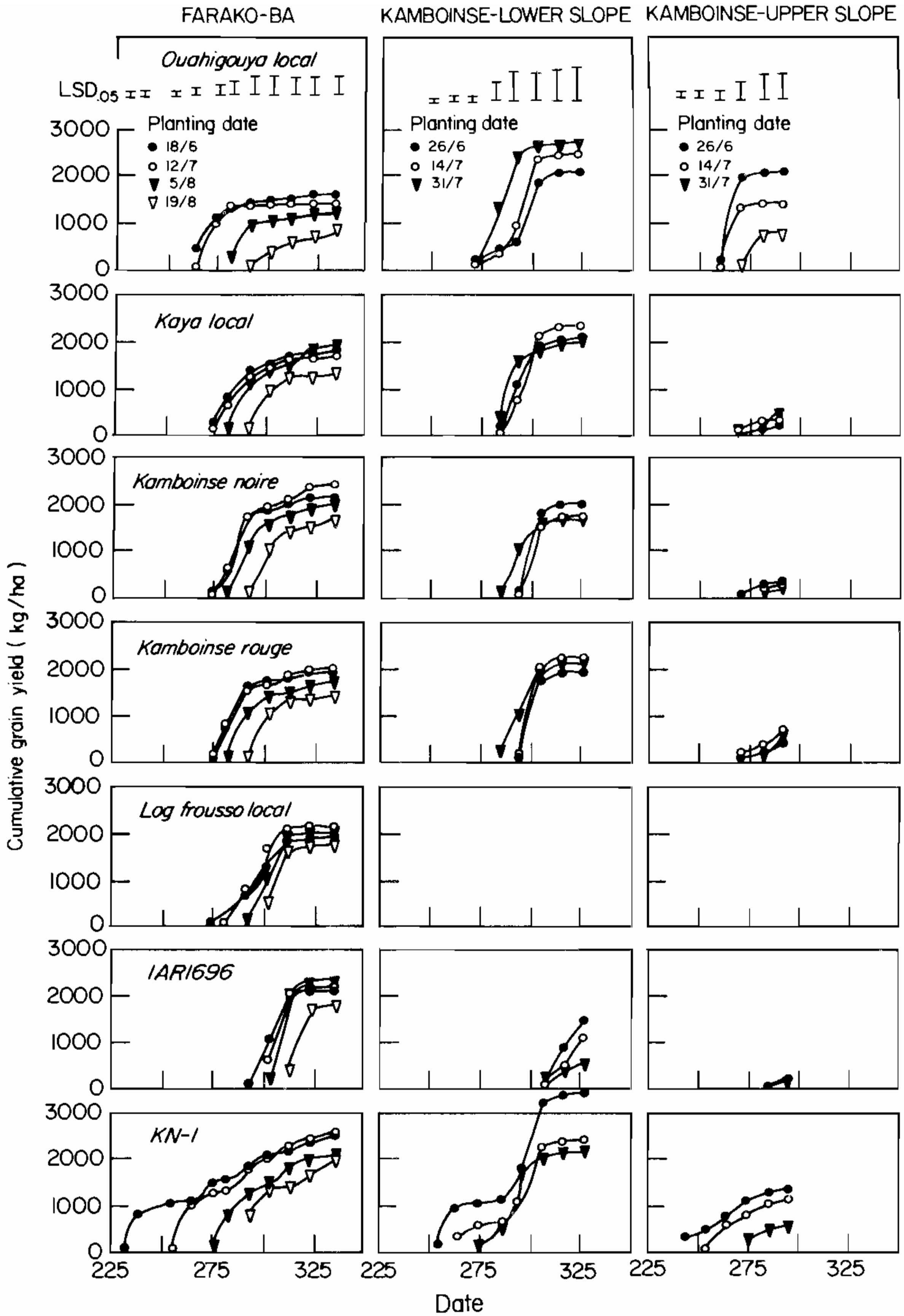


Fig. 6. Cumulative grain yield of several cowpea varieties sown on several dates at three sites.

Table 36. Effect of planting date, plant density and phosphorus application on cowpea grain yield (CV. Logfrousso local).

Phosphorus ($kg\ P_2O_5/ha$)	Density (plants/ha)	Planting date 18 Jun	24 Jul	Mean
0	22,222	2313	1895	2104
	66,666	2181	2151	2166
	Mean	2247	2023	2135
50	22,222	2343	1759	2051
	66,666	2139	1990	2065
	Mean	2241	1875	2058
Density	22,222	2328	1827	2078
	66,666	2160	2070	2115
	Mean	2244	1949	2096
LSD (.05)				
Density			(ns)*	—
Phosphorus			(ns)	—
Planting date			<0.5	135
Density x phosphorus			(ns)	—
Density x planting date			<0.5	190
Phosphorus x planting date			(ns)	—
Density x phosphorus x planting date			(ns)	—

ns: not significantly different

Table 37. Main effects of variety, date of planting, phosphorus, density and land management system on cowpea grain yield.

Treatment	Yield (kg/ha)
Variety	*
Kamboinse rouge	712
KN-1	863
Date of planting	**
3 July	951
24 July	623
Phosphorus	**
0 kg P_2O_5/ha	517
50 kg P_2O_5/ha	1057
Density	**
22222 plants/ha	644
66666 plants/ha	931
Land management system	ns
Flat	762
Tied ridges	813

*: *Significantly different at .01.*
**: *Significantly different at 0.5.*
ns: *Not significantly different.*

the tied ridge system over a wide range of soil conditions.

SCREENING FOR RESISTANCE TO COWPEA STRIGA. In preliminary screening in which 54 varieties were grown in artificially infested plots in two replications, two varieties, Gorom Local and 58-57, were observed to be striga-free in both replications. All other varieties were infested, at least to some extent, in both replications. Further work is planned to determine if these two cultivars do have low susceptibility to striga.

Tanzania Food Crops Research

Genetic improvement

B.B. Singh, M. Price

GERMPLASM COLLECTION, MAINTENANCE AND EVALUATION. More than 1,600 local and introduced cowpea germplasm accessions have now been assembled and the majority evaluated for disease and insect resistance, seed size and color. Also, plant characteristics for these lines have been described. Many of the promising lines have been used in variety trials and as parents in the breeding program. Most of the cowpea germplasm accessions were received from IITA.

A large number of crosses were made and evaluated in 1981. A total of 50 F_1, 100 F_2, 300 F_3, and 30 F_4 populations were evaluated. Individual plants having desirable characters were selected and advanced in the dry season.

TANZANIA COWPEA UNIFORM VARIETY TRIAL. The Tanzania cowpea uniform variety trial consisted of 12 varieties selected on the basis of their superior yield performance and farmer acceptance. This trial was conducted at 9 locations representing the major cowpea growing areas. The mean yield performance of different varieties at 6 locations is presented in Table 38. SVS-3, TKx 14-01D, TVx 1948-01F (Fahari), TKx 9-11D (Tumaini), TKx 179-02D, TKx 169-35D and IET-120-4 comprised the highest yielding group. Their yield levels were consistently superior at most of the

Table 38. Grain yield (kg/ha) of 12 cowpea varieties evaluated in the Tanzanian cowpea uniform variety trial at 6 locations (1981).

S.N.	Variety	Ilonga	Tumbi	Bihawana	Hombolo	Mlingano	Miwaleni	General Means
1	SVS-3	2072	819	904	1879	1770	1120	1427
2	TVx 1193-54D	1635	657	927	373	1345	847	964
3	Tumaini	2017	988	987	1347	1578	1153	1345
4	IET 120-7	2057	777	1067	660	1017	476	1009
5	TVx 2907-02D	2165	911	829	1085	1300	849	1190
6	Fahari	2249	978	901	1585	1478	1077	1378
7	TVx 1850-01E	1942	784	814	999	975	846	1060
8	TKx 14-01D	2212	1079	1136	1397	1391	1097	1385
9	TKx 169-35D	2197	834	838	1087	1158	1176	1215
10	TKx 179-02D	2129	1179	523	1002	1441	1114	1231
11	IET 120-4	2183	945	1344	639	1275	665	1175
12	TVx 2866-04F	1816	610	673	1065	1175	636	996
	LSD (.05)	233	NS	NS	554	175	267	

locations. For the past several years, SVS-3 has consistently yielded higher than the improved varieties, but it is highly susceptible to a number of diseases and is relatively late maturing. Tumaini and Fahari have already been released by the National Grain Legume Program at Ilonga A.R.I. These varieties have resistance to a number of the serious cowpea diseases in Tanzania. TKx 14-01D, TKx 179-02D, TKx 169-35D, and IET 120-4 are resistant to cowpea aphid borne mosaic virus. IET 120-4 matures in about 75 days after planting. Therefore, it could be used in the short rain in bimodal rainfall areas. Additionally, IET 120-4 has extra large seeds and pods and the leaf quality is excellent.

TANZANIA EARLY-MATURING COWPEA VARIETY TRIAL. Two sets of the early-maturing cowpea variety trials were conducted in the 1980-81 season. The first was conducted during the short rains at Ilonga, Mwanhala, Tumbi and Ukiriguru, and the second was conducted during the main rains at Ilonga, Miwaleni, Mlingano and Tumbi. The major objective of these trials was to evaluate extra early-maturing, high yielding varieties with good seed and leaf quality. These varieties would be suitable as a catch crop and may also fit in double and relay cropping systems. Due to drought after planting, the trial failed at Ukiriguru during the long rain season.

During the short rains, M66 TNR yielded the highest followed by TVx 1850-01E, Plot 40, TKx 133-16D-2 and Cross 1-6E-2 (Table 39). TKx 133-16D-2 and Cross 1-6E-2 are resistant to top necrosis and CAMV and mature within 62 days after planting whereas M66 TNR matures in about 70 days after planting. Additionally, Cross 1-6E-2, TKx 133-16D-2 and M66 TNR have synchronous flowering and maturity with completely erect growth habit. Thus, the number of insecticide applications and harvesting costs are greatly minimized.

During the main rains, 4R-0267-1F yielded highest followed by SVS-3, TVx 2907-02D, TKx 133-16D-2 and Cross 3-15E-1 (Table 40). 4R-0267-1F has consistently yielded high in the past, but it has a tendency to lodge and is highly susceptible to most cowpea diseases. Efforts are being made to introduce disease resistance and good agronomic characters into their variety.

TANZANIA COWPEA PRELIMINARY VARIETY TRIALS. Thirty-six newly developed breeding lines and SVS-3 and Tumaini as check varieties were evaluated in 2 different preliminary variety trials at Ilonga, Hombolo, Mlingano and Miwaleni. Due to drought after planting, the trial failed at Ukiriguru. The mean yields of the best 6 varieties from each trial are presented in Table 41. A number of newly developed lines appeared superior to SVS-3 and Tumaini. Some of the lines such as 8R-43-02E, TKx 177-01D-2 and CS-3 have the same yield potential as SVS-3, and they mature about 1-2 weeks earlier and possess resistance to many of the serious cowpea diseases.

Table 39. Grain yield (kg/ha) of 10 cowpea varieties evaluated in Tanzania cowpea early-maturing variety trial at 4 locations in the short rains (1980-81).

S.N.	Variety	Ilonga	Ukiriguru	Tumbi	Mwanhala	General Mean
1	TKx 133-16D-1	1211	1149	543	1057	990
2	SVS 3	491	687	610	1000	697
3	Cross 1-6E-2	963	971	817	1166	979
4	4R-0267-1F	1268	701	850	1067	971
5	TKx 133-16D-2	1136	1191	732	1011	1017
6	M66 TNR	1268	1279	953	1523	1256
7	Plot 40	1217	1205	565	1410	1099
8	Cross 1-6E-1	931	990	720	918	889
9	TVx 1850-01E	1132	1259	950	1190	1132
10	TVx 2907-02D	584	771	715	1164	808
	LSD (.05)	199	117	NS	277	

Table 40. Grain yield (kg/ha) of 14 cowpea varieties evaluated in Tanzania cowpea early-maturing variety trial at 4 locations in the main rains (1980-81).

S.N.	Variety	Ilonga	Tumbi	Mlingano	Miwaleni	General Mean
1	SVS 3	1559	1260	488	1269	1144
2	4R-0267-1F	1756	1010	600	1353	1180
3	TVx 1850-01E	1590	790	488	1104	993
4	TVx 2394-02F	1143	1240	400	782	891
5	TKx 133 16D-2	1650	530	1113	916	1052
6	Cross 1-6E-2	1424	855	713	600	898
7	IET 120-3	1364	1140	350	1056	977
8	IET 120-5	1262	980	275	1196	928
9	TVx 3866-04F	1389	1053	400	980	956
10	TVx 3866-05F	1332	675	725	1166	974
11	TVx 2907-02D	1357	1120	325	1324	1081
12	Cross 3-15E-1	1369	780	225	1541	979
13	Cross 202	1113	—	475	646	745
14	Cross 2-3	1181	785	400	1338	926
	LSD (.05)	2.19	NS	215	157	

Table 41. Grain yield (kg/ha) of the best varieties evaluated in the Tanzania cowpea preliminary trials 1 and 2 at 4 locations (1981).

S.N.	Variety	Ilonga	Hombolo	Mlingano	Miwaleni	General Means
			Prelim. 1			
1	TVx 3384-01E			1439	1339	1389
2	TVx 4677-014D			683	1499	1091
3	TVx 4662-05E			763	1292	1022
4	8R-43-02E			1039	983	1011
5	TVx 4773-01E			772	1191	981
6	TVx 4659-02E			861	1061	961
7	SVS-3			667	1370	1018
8	Tumaini			875	1075	975
			Prelim. 2			
1	CS-3	1598	985	1351	1500	1358
2	TKx 169-25D-1	1934	625	1174	1345	1269
3	TKx 177-01D-2	2225	509	1197	954	1221
4	IET-79	1492	525	1285	1504	1201
5	TKx 177-08D-2	1755	594	1218	1229	1199
6	TKx 3337-02J	657	946	1351	1803	1199
7	SVS-3	1433	1047	956	1237	1167

TANZANIA COWPEA INITIAL EVALUATION TRIAL. Ten newly developed breeding lines and 4 check varieties were evaluated in an augmented design at Ilonga and Miwaleni. Based on their disease reaction and high yield potential, 10 lines have been selected for further testing (Table 42). A number of these lines performed better than the check varieties. Among the varieties that performed best were Cross 3-2 Unin, Cross 3-1 Unin, TKx 43 x TVu 2616-14-4-2 and TKx 43 x TVu 2616-1-6-3. These will be further evaluated in replicated trials at several locations in the coming season.

Table 42. Grain yield (kg/ha) of the best varieties and 3 checks evaluated in the Tanzania cowpea initial evaluation trial at 2 locations (1981).

S.N.	Variety	Ilonga	Miwaleni	General Mean
			(kg/ha)	
1	Cross 3-2 unin	2033	830	1432
2	Cross 3-1 unin	1689	993	1341
3	TKx 43 x TVu 2616-14-4-2	1602	843	1223
4	TKx 43 x TVu 2616-1-6-3	1760	568	1164
5	Cross 3 unin	1602	689	1145
6	TKx 133-16D-01F	1551	711	1131
7	Tumaini	1663	582	1123
8	TKx 169 x TKx 20-1-1-2	1339	827	1082
9	SVS-3	1159	785	972
10	Cross 1-6E-2	1517	587	1052
11	5/8/2/2/-E-3	1249	690	970
12	TKx 44 x TVu 2616-1-1-2	1201	917	1059
13	TKx 133-16D-1	1381	721	1051
14	IET-120-3	1458	609	1034

TANZANIA COWPEA ADVANCED VARIETY TRIAL. Data available from Ilonga, Mlingano and Miwaleni show several lines having high yield potential across locations (Table 43). Cross 3-16E-1 and TVx 46 19-01E had an exceptionally high mean yield of 1,838 and 1,661 kg/ha respectively, for the 3 locations.

Table 43. Grain yield (kg/ha) of 20 cowpea varieties evaluated in the Tanzania cowpea advanced variety trial at 3 locations (1980-81).

S.N.	Variety	Ilonga	Mlingano	Miwaleni	General Mean
			(kg/ha)		
1	Cross 3-16E-1	2256	1898	1361	1838
2	TVx 4619-01E	1726	1802	1454	1661
3	SVS-3	2034	1546	1342	1641
4	TVx 3921-05F	1846	1613	1376	1612
5	Cross 3-13E-1	2143	1379	1296	1604
6	TVx 1843-01C	1729	1557	1435	1574
7	Cross 3-1	1956	1491	1179	1540
8	TKx 528-01C	2042	1669	889	1533
9	Tumaini	1901	1468	1189	1519
10	TVx 3882-05F	1752	1580	1061	1464
11	IET-120-4	1797	1364	1055	1405
12	8R-43-03E	1724	1275	1197	1399
13	TVx 3790-01F	1622	1484	959	1355
14	TVx 3404-01J	1611	1346	1096	1351
15	Cross 2-3	1558	1346	1085	1328
16	IET 120-6	1713	1246	925	1295
17	TKx 169-31D	1816	1424	639	1291
18	TVx 3866-04F	1423	1246	689	1119
19	TVx 3890-09F	1408	1407	637	1151
20	8R-86-01E	1054	1350	709	1038
	LSD (.05)	281	257	165	

Brazil Cowpea Program

Genetic improvement

E.E. Watt

F_2 and F_3 nurseries, 3 preliminary trials, 3 advanced trials, 2 regional trials and a large, white seed observation trial were conducted in northern Brazil to identify high yielding and widely adapted varieties.

PRELIMINARY TRIALS. Preliminary trial one comprised selections from crosses between Brazilian cultivated lines with excellent seed quality and IITA materials with disease and insect pest resistance and wide adaptability. One check line, CNCx 27-2E, and 8 test lines outyielded the traditional check "Pituiba." CNCx 27-2E was free of virus and has acceptable seed color but marginal seed size (15 g/100). None of the better yielding test lines was free of virus.

Seed from IITA's preliminary, advanced and international trials of 1980 were grown in a quarantine nursery and placed in preliminary trials 2 and 3 in 1981. Because of segregation for plant characteristics and seed quality, the trials were only grown at Goiania, and selections for the 1982 advanced trials were only made on seed quality.

During dry season multiplication, the material was further purified by selection of larger white and brown seed in mixtures, and rows were purified for leaf shape, flower color and plant type. All lines were screened for resistance to *Empoasca*, cowpea curculio and cowpea severe mosaic virus (CSMV). TVx 4925-01F in preliminary trial 2 showed excellent resistance to *Empoasca* while two lines, TVx 3404-03J and TVx 3404J, in preliminary trial 3 showed excellent seed quality—light-brown color and smooth texture.

ADVANCED TRIALS. Advanced trial 1 consisted of prostrate plant type adaptable to the areas of extremely variable rainfall and sandy soils which represent a large part of the cowpea growing area. Trials in Sao Juliao Piaui received less than 200 mm of rain and yields were low. Trials in Serra Talhada, Pernambuco, were irrigated at planting because of a prolonged dry spell and yields were reasonable and representative. CNCx 24-015E, CNCx 24-016E and CNCx 27-2E were particularly impressive for virus resistance, plant type and yield.

REGIONAL TRIALS. Four new lines have been renamed and released to farmers through the National Extension Service. The cultivar "Manaus" (previously IITA line 4R-0267-01F) was released in Manaus, Amazona. It has moderate resistance to CSMV, mildew and *Empoasca* and high resistance to smut and *Cercospora* leaf spot under field conditions.

VITA-7 has been named EPACE-1 (EPACE = Ceara State Enterprise for Agriculture Research). It has been recommended for production in favorable (higher fertility and stable rainfall) agricultural areas of these states. It has an average yield of 1,624 kg/ha in some regions, which is 30 percent above the average yield for the northeast. In experimental plots in favorable areas, this cultivar produced 50 percent more than the highest yielding local check.

VITA-3 and VITA-6 are more suitable for Maranhao state. At present 14 ha are under cultivation for seed multiplication and release to state institutions.

Soybeans

The principal objective of the soybean improvement program is to develop for the tropics varieties that possess good seed longevity and the ability to nodulate with indigenous rhizobia. Considerable progress has been made in the incorporation of these characters from unimproved germplasm into improved backgrounds. Many breeding lines selected for seed quality and promiscuous nodulation were evaluated for their agronomic merit in 1981.

Newly developed varieties should be suited to the actual conditions under which they will be grown. In West Africa, the most promising region for the expansion of soybean production is the southern Guinea Savanna, where rainfall is relatively dependable and monomodal. In this region, there are 2 farming environments that must be catered to: 1) a low soil-fertility environment and 2) a medium to high soil-fertility environment.

While it would be best if 1 variety could meet the needs of both environments, results of tests carried out during recent years have indicated that the varieties best suited to the low fertility conditions grow too vegetatively under high fertility conditions, and most varieties with high yield potential under high fertility environments are very stunted and not productive under low fertility. An attempt will be made to develop a single variety that can fit both conditions by selecting large, late-maturing determinate varieties that do not lodge under high fertility conditions and test these lines for adaptation to low fertility environments. Until such lines can be developed, advanced breeding lines will be stratified by the performance on different fertility conditions.

Studies also are under way to characterize the environments and determine what fertility factors are limiting growth on the low fertility environments. Trials in 1980 and 1981 indicated that phosphorus application can enhance growth in combination with micronutrients.

Breeding lines are being screened routinely for improved seed longevity in storage. A new screening method was developed in 1981 to identify lines with resistance to field weathering of seed prior to harvest. Some lines that appeared to have resistance to field weathering in 1980 showed good levels of resistance in extensive testing during 1981.

Lines that showed tolerance to high soil aluminum associated with acid soils in 1980 were tested again in 1981. Several lines showed little reduction in growth under high aluminum soils relative to their growth on nonstressed conditions.

Genetic Improvement

Varietal trials

E.A. Kueneman

EARLY GENERATION NURSERIES. Fifty F_2 populations were sown at Mokwa (Table 44). The majority of the crosses involved parents with resistance to field weathering of seed and good agronomic characters. F_4 nurseries were sown both at IITA and at Mokwa. Because the fields were of rela-

Table 44. Early generation nurseries (1981).

		Description	Entries	Selections
Ibadan	1981	First season		
	F_4	Seed quality nursery	472	250
Ibadan	1981	Second season		
	F_4	Promiscuous nodulation	275	30
Mokwa	F_2	Promiscuous Nodulation and seed quality.	~25,000 plants	870
	F_4	Promiscuous nodulation and seed quality	~ 2,500 families	159

tively high fertility except for soil N, it was possible to select plants that were growing virgorously without rhizobial inoculants, but which did not lodge under high fertility conditions. It is hoped that some of these selections will prove to be productive in both low and high fertility environments.

ADVANCED GENERATION TESTING. The objective of these trials was to screen the numerous new breeding lines for agronomic merit and yield potential. The trials were viewed as a preliminary screening to reduce the number of entries for more thorough testing in 1982. Two replicated trials of lines selected for promiscuous nodulation and 2 trials of lines selected for seed storability were sown at 6 sites in Nigeria (Table 45). Entries were grouped according to maturation. In addition, 2 unreplicated preliminary observation trials were sown. At Ilora and Ilorin the nurseries were handled by collaborating scientists from the Nigerian Institute of Agricultural Research and Training. At Gusau, a drought of 23 days, which occurred just after planting, resulted in poor plant stands. Nodulation performance was assessed, but yield performance could not be determined. At Ilorin, several nurseries were lost due to herbicide injury.

With few exceptions, breeding lines selected for promiscuous nodulation during 1979 and 1980 nodulated very well across sites and were not visibly N deficient at 75 days after sowing. In general, plant growth was very vigorous and many of the breeding lines lodged. Such lines should not be grown under high fertility conditions. Some lines showed good agronomic characteristics and reasonable yield potential (Tables 46 and 47). The promiscuous parents, used as checks, also yielded well relative to the nonpromiscuous checks, Jupiter and TGm 294.

Several promising entries from yield trials sown to evaluate lines selected for good seed longevity are shown in Table 48. Although 50 kg N was applied at planting, N deficiency

Table 45. Multilocation soybean performance trials in Nigeria (1981).

Trial description	Entries	Reps.	Design	Lines selected
Medium maturity—promiscuous nodulation	256	2	Simple lattice	43
Late maturity—promiscuous nodulation	100	2	Simple lattice	26
Medium maturity—seed quality	196	2	Simple lattice	76
Late maturity—seed quality	6	2	R.C.B.	1
Preliminary trial—promiscuous nodulation				
Medium maturity	217	1	Unreplicated	24
Late maturity	225	1	Unreplicated	7

Locations	*Latitude*	
Gusau	*12°*	*9 min.*
NATL. Grain Prod. Co. (North of Mokwa)	*9°*	*18 min.*
Mokwa, Ahmadu Bello Univ. Farm	*9°*	*18 min.*
*Ilorin**	*8°*	*30 min.*
*Ilora**	*7°*	*50 min.*
Yandev (Eastern Nigeria)	*7°*	*23 min.*

**Collaborative trials with the Institute of Agricultural Research and Training.*

Table 46. Yield (kg/ha) and nodulation[1] score for 12 promising, medium-maturity soybean breeding lines at 4 locations in Nigeria sown without rhizobial inoculants (1981).

	Mokwa ABU/IAR		Mokwa N.G.P.C.		Yandev IAR		Ilora IAR&T		Mean	
Varieties	Yield	Nod.	Yield	Nod.	Yield	Nod.	Yield	Nod.	Yield	Nod.
Breeding lines										
DSM 1279	2167	4.00	2142	3.25	1018	3.00	1543	3.25	1718	3.38
TGx 605-09C	1845	3.50	2325	3.00	964	2.75	1723	3.00	1714	3.06
TGx 330-0102D	1707	3.75	2297	4.00	1105	3.50	1596	2.75	1676	3.50
DSM 751	1475	2.50	2473	2.75	1101	3.50	1809	2.25	1714	2.75
DSM 520	1878	3.00	2177	4.00	904	3.75	1383	2.25	1586	3.25
TGx 326-013D	1655	3.00	2063	2.75	1196	3.00	1553	2.75	1617	2.88
TGx 303-041D	2027	3.25	1688	3.50	1089	3.50	851	3.50	1414	3.44
DSM 592	1998	3.25	1558	3.25	1012	3.25	1362	1.25	1483	2.75
TGx 605-047C	1870	3.25	1517	3.75	1103	3.50	1106	3.02	1399	3.38
TGx 326-072D	2173	2.75	1096	3.25	1193	3.75	1064	2.50	1382	3.06
DSM 955	1185	2.75	2397	2.50	790	2.75	1234	3.25	1402	2.81
TGx 303-025D	2257	3.75	1295	2.75	792	3.25	1617	2.50	1490	3.06
Non-promiscuous check										
TGm 294	1063	2.25	106	2.50	312	2.75	297	1.50	444	2.25
Trial mean	1361	2.99	1175	3.00	869	3.24	M.D.[2]	2.43		
LSD (.05)	791	1.44	913	1.41	506	0.95	M.D.	1.43		
CV	29	24	39	24	30	15	M.D.	30		

[1]Nodulation scores on 1-5 scale: 1 = no nodulation, 5 = excellent nodulation.
[2]M.D. = missing data; statistical analysis not possible.

symptoms were often observed at 75 days after planting because most of the entries from this trial were not able to nodulate effectively with indigenous rhizobia.

The plot size (two 75-cm rows of 6-m length) used in 1981 was too small to accurately assess crop canopy development. Enough seed should be available in 1982 to sow larger plots.

ALL NIGERIAN COOPERATIVE TRIALS. During late 1980, IITA assisted in the organization of an All Nigerian Cooperative for Soybean Research. The first meeting was held at the Institute of Agricultural Research and Training in Ibadan, Nigeria. Scientists presented summaries of soybean research that had been conducted by their respective institutions and 2 collaborative trials were designed for 1981 sowing. Trial 1 included 10 varieties of early- to medium-maturity sown with and without fertilizer in 3 replications. Trial 2 was similar, but involved varieties of later maturity. IITA took principal responsibility for multiplication and packaging of seed, preparation of field books and data analysis. Three lines being used at IITA as promiscuously nodulating parents, TGm 344, TGm 579 and TGm 119, were submitted for evaluation in the trial. TGx 17-2G, TGx 182-1D and TGx 117 were entered as lines with good yield potential and pod shattering resistance.

The promiscuous parents nodulated well across sites as did several entries from the Institute for Agricultural Research

Table 47. Yield (kg/ha) and nodulation scores[1] for 5 promising, late-maturity soybean breeding lines at 4 locations in Nigeria sown without rhizobial inoculant (1981).

	Mokwa ABU/IAR		Mokwa N.G.P.C.		Yandev IAR		Ilora IAR&T		Mean	
Varieties	Yield	Nod.	Yield	Nod.	Yield	Nod.	Yield	Nod.	Yield	Nod.
Breeding lines										
DSM 776	3880	3.00	1093	3.50	1177	3.75	2708	4.00	2214	3.56
DSM 1449	2050	3.25	1603	3.50	1156	3.75	2604	2.00	1853	3.12
TGx 306-036D	2743	3.25	1613	3.50	1230	2.75	1771	4.00	1839	3.38
DSM 884	1903	2.50	1727	2.75	910	4.25	2500	3.50	1760	3.25
TGx 330-0102D	1916	3.25	1543	4.50	1093	3.50	2552	3.25	1776	3.62
Promiscuous parents										
TGm 344	3083	3.50	1360	3.75	790	4.25	3021	3.50	2064	3.88
TGm 119	1730	3.25	1680	3.50	777	3.75	2312	4.00	1625	3.62
TGm 579	1673	3.50	1943	3.50	1120	4.00	2500	3.50	1809	3.75
Malayan	1667	3.50	1363	3.75	673	3.75	2396	1.75	1525	3.19
Non-promiscuous check										
Jupiter	1743	1.75	1473	2.25	670	2.50	1510	1.75	1349	2.06
Trial mean	1587	2.67	1320	3.26	797	3.48	1790	2.95		
LSD (.05)	980	1.09	747	1.12	357	1.21	931	1.65		
CV(%)	31	21	28	18	22	17	26	28		

[1]*Nodulation scores: 1 = no nodules, 2 = few nodules, 3 = good nodulation, 4 = very good nodulation, 5 = excellent nodulation.*

Table 48. Yield performance of 12 promising breeding lines from the seed longevity nurseries sown at 6 locations in Nigeria (1981).

	Mokwa N.G.P.C.	Mokwa ABU	Yandev IAR Field 1	Yandev IAR Field 2	Yandev School of Agric.	Ilora IAR&T	Mean
Breeding lines	kg/ha						
TGx 340-294D	1942	1178	854	1170	981	2340	1411
TGx 536-14C	1353	1476	942	1182	1409	2159	1420
TGx 311-4C	1646	1500	1332	1039	1170	1936	1437
TGX 340-114D	1108	1372	935	1073	1481	2298	1378
TGx 297-35C	1633	1263	868	1064	1201	2053	1347
TGx 252-139C	2031	1414	822	1092	1244	1665	1378
TGx 302A-3C	1617	1633	1055	890	1187	2800	1530
TGx 573-3C	1163	1723	930	990	1051	2021	1313
TGx 299-7C	1037	1200	1016	1144	1214	2117	1288
TGx 573-106C	1417	1254	1319	828	1173	1840	1305
TGx 302A-272C	1689	1550	785	1152	1006	1617	1300
TGx 340-11D	768	1553	773	1032	1150	2148	1237
Checks							
Jupiter (yield)	379	588	793	956	773	291	630
Bossier (yield)	867	830	587	554	156	1128	687
TGm 685 (seed quality)	365	462	462	458	896	660	550
Trial mean	956	1100	800	753	909	1506	
LSD (.05)	642	554	518	346	548	780	
CV (%)	34	25	24	23	30	26	

(IAR), Samaru, Nigeria, such as M-79, M-90 and M-98. Nonpromiscuous lines often nodulated poorly and showed N-deficiency symptoms. Excessive experimental variation made varietal comparisons difficult for yield potential. Efforts will be made to better control experimental error in trials planned for 1982. Varieties Bossier, K-53, Roanoke, TGm 117 and TGm 119 will be excluded from 1982 trials. In 1982, IITA will enter several elite breeding lines from the current program on seed longevity and promiscuous nodulation.

Development of screening methods to breed soybeans with resistance to field deterioration of seed

E.A. Kueneman, S. Dassou

The rapid loss of seed vigor, and ultimate loss of seed viability constitute the greatest limitation to expansion of soybean production in humid tropical regions. While seeds lose their vigor during storage, they can also deteriorate badly even before harvest if environmental conditions during pod maturation are hot and humid. A few varieties appear to maintain their seed quality under adverse conditions, providing breeders with the opportunity to develop varieties with resistance to field weathering of seed. However, to breed resistant varieties, it is essential to have a screening method that (1) accentuates genetic differences for resistance among varieties or breeding lines and (2) minimizes uncontrolled environmental influences that can lead to inaccurate assessment of resistance.

Screening methods used elsewhere have depended on measuring seed vigor loss after a period of delayed harvest. This approach is not very satisfactory if the lines being tested are of different maturity as the varieties of different maturation will often be subjected to different environmental stresses. During 1979 and 1980, daily overhead irrigation and inoculation with *Phomopsis* were tested to see if screening precision could be improved. Both treatments increased seed deterioration, but no evidence for improvement of precision was observed.

Four weathering treatments were compared during 1981:

1) No weathering control where plants were harvested at physiological maturity and allowed to dry down in a plastic shed.
2) Delayed harvest where plants were left in the field for 3 weeks following physiological maturity.
3) Incubator weathering where pods were removed from plants at the yellow pod stage and placed in a laboratory incubator at 30°C, 95-90 percent relative humidity for 10 days. (Pods placed in cells of a plastic grid to provide a uniform environment and to minimize cross contamination.)
4) Wet bag weathering where plants were removed from the field at physiological maturity, leaves were removed and plants placed in a wet burlap bag for 10 days. (The burlap bag was sealed in a large plastic bag to maintain high relative humidity.)

In this study, 3 replications of 35 soybean varieties were sown on each of 3 dates 30 April, 28 May and 25 June at IITA. Seed from each planting date was evaluated in the laboratory for germinability, disease incidence, visual seed quality score, percentage hard seed and seed size. Seed was also evaluated for field emergence in a screenhouse.

Delayed harvest, incubator weathering and wet bag treatments all resulted in decreases in emergence and laboratory germination compared to the unweathered treatment (Table 49). The wet bag treatment appeared too severe and the coefficient of variation was very high because it was difficult to control humidity. (Some seeds germinated in the bag.) The incubator weathering treatment appears to be preferable to the delayed harvest treatment for 3 reasons. First, similar mean emergence and germination scores for the different planting dates implied that the degree of weathering was similar irrespective of the weathering conditions in the field. Second, the error variance for the incubator weathering was generally smaller than that associated with the delayed harvest treatment. Third, on any given plant, there will be a range of pod maturation.

Table 49. Mean emergence of 4 seed weathering treatments averaged across 35 varieties replicated 3 times. Experiment was sown on 3 dates.

Weathering treatments		Planting (date) 30/4/81	28/5/81	25/6/81
		(Emergence out of 50 seeds sown)		
Unweathered	Mean	47.29	39.00	41.98
	VAR[1]	4.57	44.74	27.16
Field weathered	Mean	39.12	22.8	27.22
	VAR	24.19	83.72	56.37
Incubator weathered	Mean	14.73	13.79	11.18
	VAR	14.99	27.26	27.00
Wet bag weathered	Mean	3.12	5.27	2.41
	VAR	8.93	27.81	15.55

[1]'VAR' is the error variance and is inversely proportional to the degree of precision.

In a delayed harvest test, pods that mature first will be subjected to a longer period of weathering. Consequently, vigor scores after delayed harvest tend to average over a range of pod weathering. The variability due to differences of pod maturation on a plant does not have a large effect on the incubator weathering treatments since pods of the same degree of maturation can be selected.

In general, lines performed fairly consistently across the 3 planting dates although there were a few exceptions. (For example TGm 920 which showed resistance in the April planting but performed rather poorly in subsequent plantings.) In Table 50, 12 resistant varieties are compared with 5 susceptible varieties for seedling emergence following either delayed harvest or incubator weathering for the 3 planting dates.

It is of interest to note that TGm 737^{P}, TGm 737^{W}, TGm 685,TGm 693 and TGm 618 were previously identified to have resistance to deterioration of seed in storage and have been used as parental sources for good seed longevity during the past 3 years. Data from 1980 suggested that they might be resistant to field weathering. The 1981 data confirm this.

Seed from the third planting for treatments 'not weathered' and 'delayed harvest' were subjected to accelerated aging to examine the relationship between resistance to field weathering and resistance to seed deterioration in storage. The correlation coefficient for seedling emergence for delayed-harvest not aged seed and prompt-harvest aged seed was

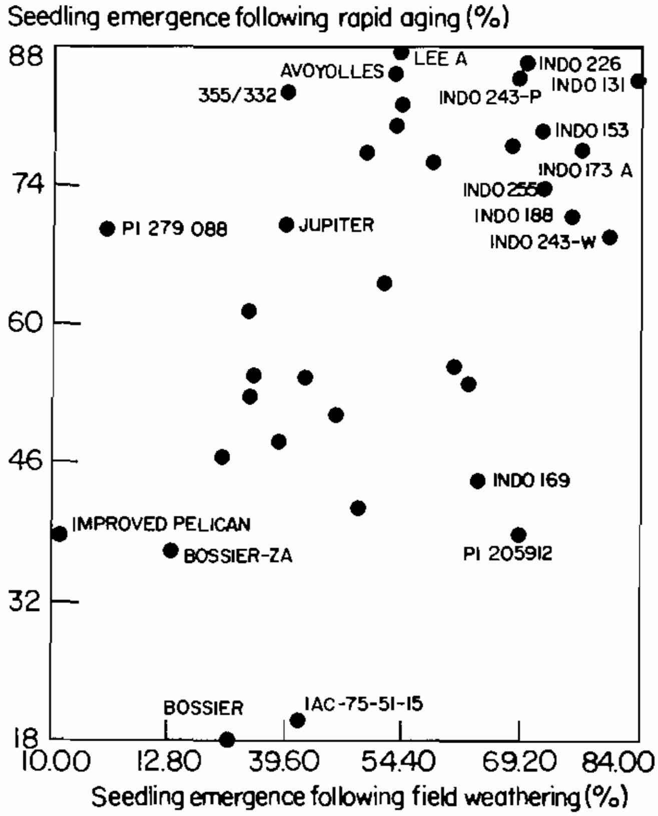


Fig. 7. Relationship between emergence following field weathering and emergence following storage (rapid aging) for 35 soybean varieties.

0.49** (Fig. 7). This correlation, though highly significant, would have been stronger except that PI-279088 and 35S/332 did not appear to have resistance to weathering in the field, but did have resistance to deterioration in storage. Also, INDO 169 and PI-205912 appeared to have resistance to field weathering, but did not store well. The correlation for seed size and emergence after delayed harvest was only 0.31.

While all large seeded varieties were susceptible to weathering, some small seeded varieties were susceptible and others were resistant (Fig. 8). The correlation for seed size and emergence after accelerated aging was 0.66**. As seen in other experiments, some small seeded lines store very well while others are only intermediate (Fig. 9). In this study, TGm 479 (Jupiter) had rather good emergence after storage. Normally Jupiter does not store well. Such occasional irregularity in performance indicates that there is merit in repeating such bioassays over several seasons so that one can get a clear picture as to which varieties are consistent in their seed keeping qualities.

Agronomy

Soybean management

D. Shannon, E.A. Kueneman

EFFECTS OF SOIL TEXTURE AND FERTILITY ON THE GROWTH OF SOYBEANS IN THE SOUTHERN GUINEA SAVANNA. Experiments were conducted at Mokwa in Niger State and at Yandev and Mkar in Benue State in the southern Guinea Savanna of Nigeria to examine factors affecting

Table 50. Seedling emergence of 12 soybean varieties resistant to field weathering of seed compared to 5 susceptible varieties for 3 planting dates (1981).

		Planting date					
		30-4-81		28-5-81		25-6-81	
		Delayed harvest 3 wks.	Incubator weathered	Delayed harvest 3 wks.	Incubator weathered	Delayed harvest 3 wks.	Incubator weathered
		% emergence					
Resistant varieties							
IITA Acct. #	Name						
TGm 1171	AVRDC 8457	80	61	46	65	38	50
TGm 46	Fort Lamy	92	65	60	62	62	42
TGm 106	LEE A	62	66	64	58	62	52
TGm 112	27A	59	58	69	62	42	36
TGm 693	INDO 153	88	58	72	54	72	50
TGm 685	INDO 131	92	46	71	34	84	28
TGm 737[P]	INDO 243	92	52	52	39	72	38
TGm 737[W]	INDO 243	84	50	60	48	72	20
TGm 618	OBO	90	62	62	39	46	52
TGm 94	Biloxi 3	90	59	42	40	66	52
TGm 730	INDO 226	84	42	70	45	68	52
TGm 122	355/332	92	50	52	32	54	48
Susceptible varieties							
TGm 80	Bossier	85	4	20	4	32	1
TGm 479	Jupiter	74	6	23	13	42	8
TGm 1262	IAC 73-51-15	70	1	4	4	40	6
TGm 7	Improved Pelican	69	1	6	4	20	2
TGm 918	Orba	32	3	21	5	50	8
Mean		78	30	46	28	54	22
LSD (.05)		16	12	30	17	24	17
Reps.		3	3	3	3	3	3

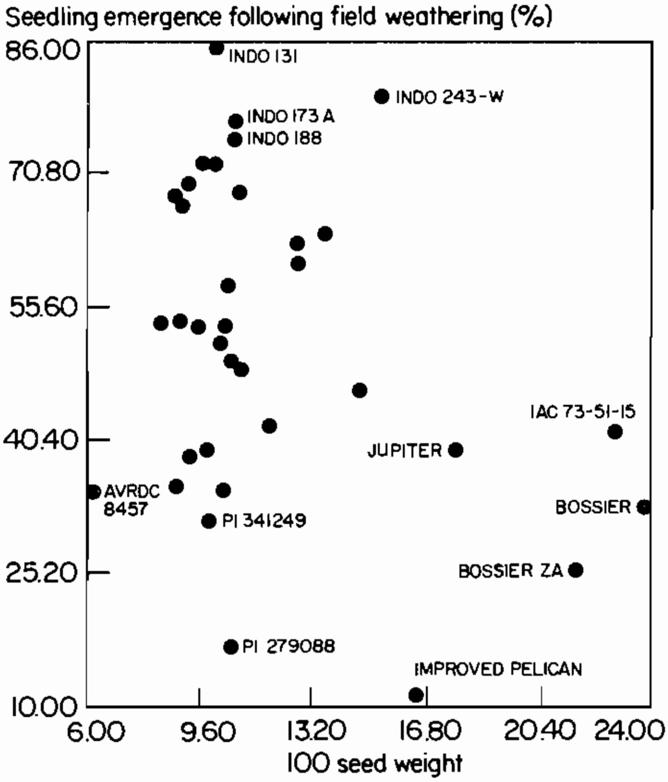


Fig. 8. Relationship between seed size and percent emergence following field weathering for 35 soybean varieties.

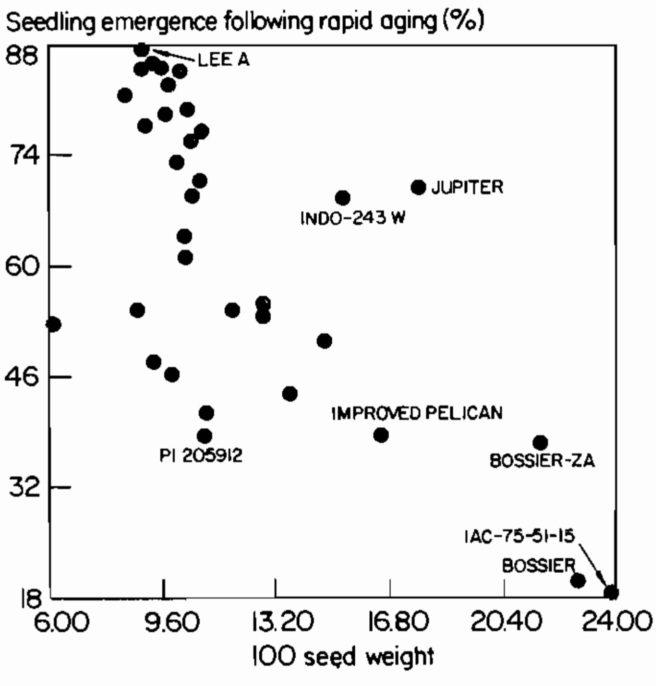


Fig. 9. Relationship between seed size and percent emergence following rapid aging for 35 soybean varieties.

soybean growth. Vegetative growth was enhanced on all soils by the application of a fertilizer combination including major elements and some micronutrients. In the presence of fertilizer, growth was nearly always more vigorous on soils with a heavy-textured B horizon within 30 cm of the surface than on soils which were sandy to depths more than 50 cm. On some sandy soils, plant growth with fertilizer application was satisfactory while on other sandy soils plants remained stunted.

These results confirm observations made in 1980 and suggest that soil texture and fertility are the major sources of variation in soybean growth in the southern Guinea Savanna. Attention to these 2 factors will be necessary in screening advanced lines for adaptation to the savanna.

Three trials were conducted to explain poor growth on some sandy soils. A liming trial was conducted on a sandy site at Yandev where plants were stunted. Only slight improvement in growth was obtained with 1.5 t finely ground dolomitic limestone/ha. Poor soybean growth at this site could not be attributed to low soil pH.

A pot trial was conducted using surface (0-15 cm) and subsurface (25-40 cm) soils obtained from a field at Mokwa which had previously been fertilized with P and K. No fertilizer was added to the pots. Growth was extremely poor on both sandy and clay subsurface soils. This suggests that the superior growth of soybeans in areas of the field containing clay near the surface cannot be attributed to better nutrient status of the clay B horizon.

At Yandev and Mokwa, small plots were irrigated during short periods when rainfall was less than optimum. No response was obtained which could explain the differences in growth between sandy- and clay-textured soils.

Though a satisfactory explanation for the effect of soil texture on soybean growth is not yet available, the magnitude of its effect makes texture an important consideration in siting soybean trials and in choosing varieties.

Fertilizer response

D. Shannon, E.A. Kueneman

Phosphorus (P) response trials were conducted at Yandev and Mkar in Benue State, eastern Nigeria. The Yandev site has a long history of cropping and fertilization as an experimental field. The soil is an Alfisol with a sand or loamy sand surface and a sandy loam horizon at 50-60 cm depth. The Mkar site had previously been cropped with groundnut and yams in the traditional fashion with only light applications of fertilizer. The soil is an Alfisol with a sandy loam texture.

At Yandev, P response was small and linear (Fig. 10). There was a greater increase (0.5t/ha) due to application of a mixture of secondary and micronutrients. Potassium at 30 kg/ha did not increase yield significantly.

At Mkar, P fertilization increased yield from about 0.5 t/ha to 2 t/ha without secondary and micronutrients and from 0.4 t/ha to 2.4 t/ha with secondary and micronutrients (Fig. 11). Contrary to the experience at Yandev where secondary and micronutrients increased yield even in the absence of added P, at Mkar yield was decreased slightly but significantly by the application of secondary and micronutrients without P. The difference may be attributed to the accumulation of P in the soil at Yandev from previous years of fertilization.

Highest yields in this trial were obtained at the high level of P fertilization, 50 kg P/ha. K had no effect on yield.

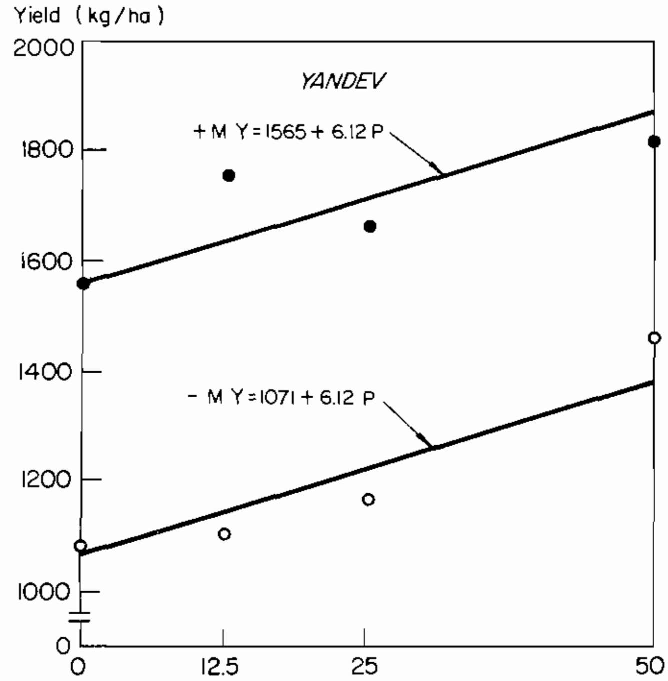


Fig. 10. Response of soybean variety TGm 579 to P and to secondary and micronutrients at Yandev, 1981. (M = secondary and micronutrients. S.E. = 45.3 and 1.33 for intercept and coefficient respectively.)

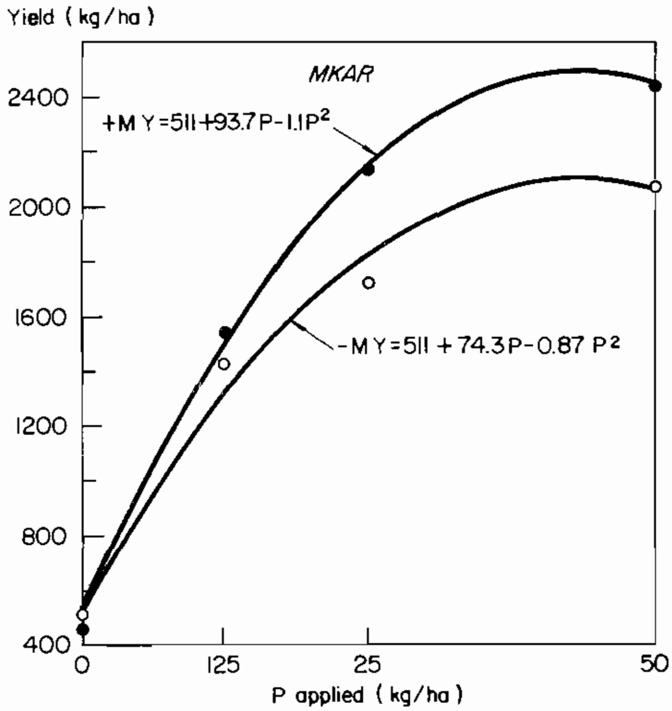


Fig. 11. Response of soybean variety TGm 579 to P and to secendary and micronutrients at Mkar, 1981. (M = secondary and micronutrients. S.E. = 59.5, 7.30 and 0.14 for intercept and first and second coefficients respectively.)

The response to secondary and micronutrients in these 2 trials is similar to results obtained in 1980 on 3 other soils in the southern Guinea Savanna (IITA Annual Report, 1980).

Screening for tolerance to aluminum toxicity in acid soils

E. Pulver

At Onne, Nigeria, 20 varieties that performed relatively well in the 1980 screening were grown with 5 check varieties on 3 fields each having a different level of Al concnetration (Table 51). The establishment of the test fields is described in IITA Annual Report, 1980. Each variety was replicated 4 times. Plant fresh weight was recorded at 60 days after planting and comparisons of growth were made between plots with low Al and plots with medium and high Al levels. Several varieties showed little reduction in growth in response to medium Al relative to the reduction in growth observed for the check varieties suggesting that they carry genes for tolerance to high Al (Table 52).

Table 51. Soil chemical properties of plots described as low, medium and high in soil acidity.

Acidity level	pH (1:1 H_2O)	Ca (meq/100 g)	Al (meq/100 g)	% Al saturation
Low	5.13	1.97	0.38	14
Medium	4.74	0.82	1.65	53
High	4.57	0.29	2.22	71
LSD (.05)	0.14	0.28	0.33	13

Table 52. Shoot fresh weight at 60 days after planting of 21 soybean varieties and 4 standards when grown under three levels of soil acidity.

Variety	Soil acidity level: Low	Medium	High	% Loss in growth at medium level
	Fresh wt. g/M			
TGm 910	345 a	343 ab	123 b	1
TGm 745	802 a	675 a	312 c	16
TGm 767	742 a	615 a	252 c	17
TGm 1168	407 a	316 a	143 c	22
TGm 372	559 a	422 b	184 c	25
TGm 975	592 a	446 b	263 c	25
TGm 316	625 a	444 b	193 c	29
TGm 1196	718 a	506 b	212 c	30
TGm 628	730 a	498 b	242 c	32
TGm 971	653 a	447 b	141 c	32
TGm 629	590 a	385 b	142 c	35
TGm 790	416 a	266 b	118 c	36
TGm 998	730 a	460 b	212 c	37
TGm 756	618 a	373 b	132 c	40
TGm 1001	802 a	472 b	225 c	41
TGm 749	600 a	346 b	183 c	42
TGm 801	555 a	323 b	159 c	42
TGm 1039	532 a	287 b	168 b	46
TGm 313	435 a	228 b	106 b	48
TGm 533	925 a	467 b	322 c	50
TGm 904	320 a	146 b	116 b	54
Standards				
Jupiter	682 a	362 b	195 c	47
Bossier	745 a	385 b	198 c	48
TGm 344	989 a	636 b	394 c	36
TGm 119	877 a	606 b	296 c	31

Selected lines will be sent to countries like Cameroon, Colombia and Brazil where Al toxicity is frequently a problem.

Percent calcium in the leaf did not reflect the relative tolerance of varieties to soil acidity (Table 53) suggesting that this parameter cannot be used to identify lines with tolerance to soil acidity.

Table 53. Calcium concentration in last fully developed trifoliate leaves of soybean varieties which exhibited degrees of tolerance based on shoot growth.

	Acidity level				Growth reduction at
Variety	Low	Medium	High	Mean	medium level
	Ca, %				
TGm 910	1.08	0.83	0.52	0.81	1
TGm 745	0.77	0.76	0.37	0.63	16
TGm 767	0.73	0.65	0.36	0.58	17
TGm 790	0.95	0.96	0.50	0.80	36
TGm 998	0.65	0.58	0.29	0.51	37
TGm 756	0.80	0.57	0.27	0.55	40
TGm 1001	0.89	0.63	0.33	0.62	41
TGm 801	0.98	0.88	0.40	0.75	42
TGm 313	0.85	0.83	0.39	0.69	48
TGm 533	0.71	0.78	0.38	0.62	50
Standards					
Jupiter	0.73	0.55	0.33	0.54	47
Bossier	1.02	0.73	0.39	0.71	48
TGm 344	0.60	0.62	0.30	0.51	36
Acidity Mean	0.83	0.72	0.37		

LSD (.05) for variety means = 0.14
LSD (.05) for acidity means = 0.13
Interaction of varieties x acidity levels not significant.

Virology

Soybean mosaic virus (SMV)

H.W. Rossel, G. Thottappilly

Soybean mosaic virus (SMV) spread in the 1981 first and second seasons throughout IITA and its off-site locations where soybean field experiments were being carried out. It has become a perennial problem at IITA particularly because of its high seed transmission rates in many breeding lines.

SMV was purified as described in IITA's 1980 Annual Report. The single virus peak in the sucrose density gradient was highly infectious on inoculation to healthy soybeans. Electron microscopic examinations of purified preparations revealed numerous filamentous particles. The virus preparations were injected into a rabbit and an antiserum produced. Further research to detect the presence of virus in seeds by ELISA is underway.

Extensive early roguing of seed-borne infected plants largely prevented a massive spread of the virus during the early 1981/82 dry season (December) when massive aphid flights were observed. Most of the materials have, thus, been safeguarded for seed transmission incidence in the next generation.

Four soybean introductions reported to be resistant to SMV in the U.S.A. were tested for resistance to 2 isolates of this virus from the soybean experimental fields at IITA. These isolates differ in their ability to systematically infect certain cultivars of soybean. Three of the 4 soybean introductions earlier mentioned also proved to be resistant to SMV isolates.

Soybean dwarf virus (SDV)

H.W. Rossel and G. Thottappilly

A severe dwarfing disease, which previously had been known to occur only at extremely low incidences in northern Nigeria, effectively reached epidemic proportions in a field under irrigation at IITA during the early 1981-82 dry season (December/January).

Possibly the extremely high susceptibility of the particular breeding line, TGm 309-021D, led to the high incidence of this disease. The disease could be readily graft-transmitted, but not transmitted by sap inoculation.

The virus causing this serious disease was identified as soybean dwarf virus (SDV) described in Japan. Ultimate identification of the causal agent of the disease was based on positive reactions obtained in serological tests using an antiserum to this virus from Japan.

Tanzania Food Crops Research

Genetic improvement

M. Price

GERMPLASM EVALUATION. Varietal evaluation of the introduced soybean cultivars, along with those developed in Tanzania, was carried out during 1980-81. Based on outstanding characteristics such as good agronomic characters, freedom from diseases and ability to nodulate with indigenous strains of rhizobia, a number of these lines were selected for further testing.

TANZANIA SOYBEAN INITIAL YIELD TRIAL. Sixty newly developed breeding lines and 2 check varieties were evaluated in augmented designs at Ilonga. Based on their disease reaction and high yield potential, 10 potential lines were selected for further testing.

The yield peformance of the 9 best lines and 2 checks is presented in Table 54.

Table 54. Grain yield (kg/ha) of the 9 best soybean varieties and 2 checks in the Tanzania soybean IET at Ilonga (1980-81).

S.N.	Variety	Yields (kg/ha)
1	79S0047 F4	2043
2	GPM L-2	2302
3	S1-4	2945
4	59S0057 F4-1	2171
5	TGM 622	2605
6	TGM 737 x 80	1962
7	S3-2	2136
8	79S0018 F4	1964
9	GPM L-4-2	1973
10	Bossier	1241
11	3H/1	2133

Microbiology

Two major findings characterized microbiology research in the legume-*Rhizobium* symbiosis. First, screening cowpea rhizobial isolates from diverse environments revealed that certain strains combine symbiotic effectiveness with tolerance to extremely high temperatures. These were used in preliminary field trials to increase cowpea grain yields at locations in West Africa. Second, an agar plate method was developed to aid microbiologists in the search for rhizobia that combine effectiveness with tolerance to extremes of acidity and aluminum.

Environmental diversity in cowpea and soybean rhyizobia

A. Ayanaba, S. Asanuma, B. Ranga Rao

SCREENING FOR DIVERSITY IN COWPEA RHIZOBIA. Preliminary data on experiments designed to study the environmental diversity of rhizobia and to select elite strains for seed inoculation were as described in IITA Annual Report 1979, 1980. Cowpeas and soybeans were grown at IITA and Onne in Nigeria as well as Maradi in Niger Republic. From these, more than 1,000 rhizobial strains were isolated and sent to collaborators at Boyce Thompson Institute (BTI) in the U.S.A. for testing. At BTI, 300 of the cowpea isolates have now been examined for diversity and 185 for effectiveness. The findings are as follows:

1) Isolates from Onne and Maradi showed great diversity among strains from the same site while those from IITA were relatively homogeneous;
2) Eighty percent of isolates from IITA and 40 percent of those from Onne were found to be highly effective, to have a broad range of hosts and to be resistant to a number of antibiotics;
3) Most of the isolates from the hot, dry environment at Maradi grew at 37°C but did not form effective symbiosis. Other experiments showed that strains from Maradi are more effective at 40°C than at temperatures between 30°C and 37°C indicating the potential of such strains for environment such as at Maradi.

DIVERSITY IN SOYBEAN *RHIZOBIUM* SYMBIOSIS. Eight promiscuous soybean cultivars and 9 cowpea cultivars selected in the 1979 and 1980 field trials were planted by collaborators in Senegal and Brazil in 1981. Nodule samples have been collected from the plants and isolations of rhizobia will again be undertaken provided that the characterization now in progress at BTI indicates a need for more diversity. Soybean growth at Sefa in Senegal was extremely poor whether 60 kg N/ha was applied or not. With N fertilizer, shoot fresh weight of 10 plants ranged from 7.6 g for TGm 519 to 15.2 g for TGm 344. Without N fertilizer, the range was from 3.4 g for TGm 294 to 7.9 g for TGm 519. Despite poor plant growth, nodulation was extremely good. The best plants had 20-44 nodules per plant.

When the same trial was conducted at Onne in 1980, fresh shoot weight of 10 plants was 147-284 g in plots without N fertilizer and 220-513 g with N fertilizer. Thus, plant growth was severely curtailed by some environmental stress at Sefa. Nodulation and probably N fixation did not appear to be limiting to plant growth.

FIELD TRIALS WITH PROMISING COWPEA RHIZOBIA. Because an objective of these investigations is to explore the possibility of using the most elite strains as inoculants to increase legume production under farm conditions, 13 rhizobia were used in preliminary inoculation trials at Gusau in northern Nigeria, Maradi in Niger Republic and Kamboinse in Upper Volta. Soil and climatic data on these locations are in Table 55. The rhizobia were selected on the basis of origin, effectiveness and tolerance to high temperatures. Five of them originated from Onne, and 4 each were from IITA and Maradi. Two strains, Irc 383C and 400A from Maradi, were the most tolerant at 37°C and one, IRc 252 from Onne, was least tolerant. There were also uninoculated and +N controls. Two high-yielding and improved IITA cowpea cultivars, 4R-0267-1F and VITA-7, and a local check were the hosts. Seed was inoculated with 10^6-10^7 rhizobia/seed as single strains. Antisera were produced against each strain to permit nodule typing for strain identity. Sampling for nodule yield, shoot dry matter production and nodule typing were conducted after 53 days at Kamboinse, 49 days at Maradi, and 47 days at Gusau.

Table 55. Site description.

	Gusau Nigeria	Maradi Niger	Kamboinse Upper Volta
Coordinate	12.18N, 6.31E	13.55N, 8.10E	12.25N, 1.30W
Ecological zone	Sudan savanna	Sahel savanna	Sudan savanna
Rainfall, mm/yr	743.0	452.4	773.9
Temperature, °C			
Mean	26.8	27.0	27.0
Maximum	38.8	43.0	42.4
Soil type	sandy loam	sand	sandy loam
Soil pH (H_2O)	5.8	5.9	5.9

Inoculation did not result in better grain yield in improved cultivars at Kamboinse. The local check was decimated by disease. In terms of nodule yield, inoculated treatments did not differ from the uninoculated. However, treatments with strains originating from Maradi yielded more nodules on the local check than strains originating from either IITA or Onne. In terms of shoot fresh weight, there were also inoculation and cultivar differences, but uninoculated plants yielded the same as inoculated ones.

There were significant differences among strains in nodule yields in all three cultivars, but the source of the strains was not important. VITA-7 and Ife Brown produced significantly more nodule mass than 4R-0267-1F. Fresh shoot weight showed no differences between the uninoculated and the inoculated treatments in all 3 cultivars. Strain source was not important in determining grain yield, although there were significant differences among strains. The most effective were IRc 252, 430A and 489B, all on VITA-7.

At Maradi, nodule yield between inoculated and uninoculated treatments of VITA-7 and TN88-63 was significantly different (Table 56). Inoculation treatments also showed differences on VITA-7 and the local check while VITA-7 produced the heaviest nodule mass.

Shoot yields for all cultivars and grain yield for improved cultivars were low. Shoot weight of the local check inoculated with IRc 256 was significantly higher than the uninoculated. All others, including the +N treatment, were not significantly different from the uninoculated.

Grain yield of TN88-63 significantly increased when it was inoculated with strains 252, 344A, 400A or 430A.

Effective strains are useless in the field unless they can compete successfully with natural field rhizobia and can form the majority of nodules on the host plant. Nodule assays by the enzyme-linked immunosorbent assay (ELISA) method were, therefore, performed to determine the competitive ability of 6 of the strains (Fig. 12). Indigenous rhizobia were generally more competitive for nodulation than the inoculum strains. The mean proportions of nodules formed by inoculum strains were low at Gusau and Maradi, but high at Kamboinse especially on cultivar 4R-0267-1F. Inoculum strains from Maradi were generally more competitive with indigenous strains at Maradi than were strains from Onne and IITA. This was probably due to their being better tolerant of high soil temperatures prevailing there.

Improved cultivars were generally more compatible with the inoculum strains than were the local checks. (At Gusau, Ife Brown—which was the check—is actually an improved, high yielding cultivar.) These results point to the potential of improving nodulation of high yielding cultivars by inoculation with selected rhizobia.

Based on these results, strains IRc 252 and IRc 430A are considered most superior. Future experiments will seek to confirm this superiority and to examine their capability to survive hot, dry environments in the absence of host plants. Other strains deserving further evaluation are IRc 344A, IRc 400A, IRc 409C and IRc 500A.

Tolerance of rhizobia to acid-Al stress

A. Ayanaba, S. Asanuma

LABORATORY SCREENING. Methods that have recently been developed for the selection of *Rhizobium* strains tolerant of soil acidity factors have one drawback—they are not

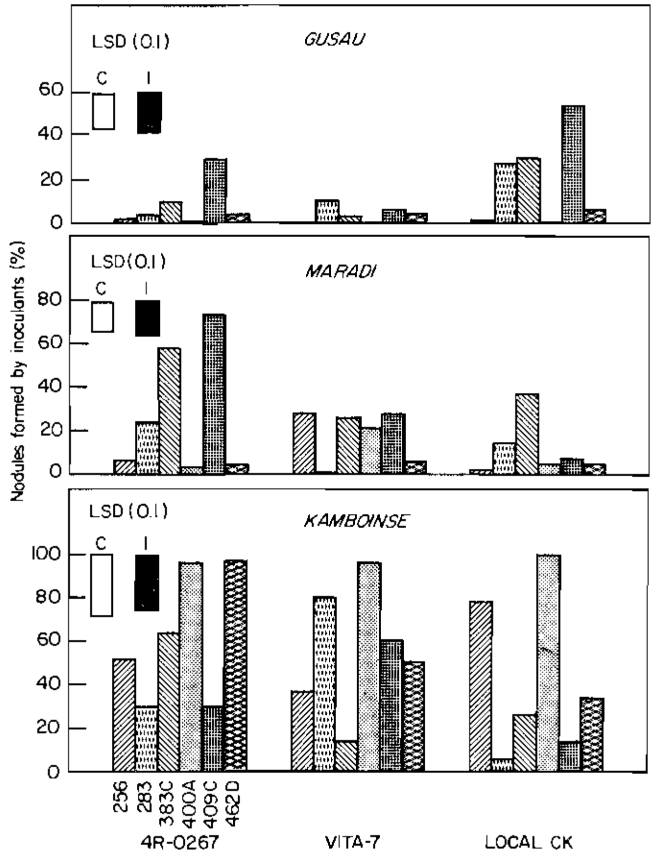


Fig. 12. Competitive ability in terms of nodulation of 6 cowpea rhizobia at 3 locations in West Africa. LSD values for comparing means of cultivars (C) or inoculant rhizobia.

Table 56. Cowpea inoculation trial at Maradi, Niger Republic.

	Shoot fresh wt. (g/plant)			Nodule dry wt. (mg/plant)			Grain yield (kg/ha)		
Treatment	4R-0267-1F	VITA-7	TN88-63	4R-0267-1F	VITA-7	TN88-63	4R-0267-1F	VITA-7	TN88-63
Uninoculated	29	23	58	24.1	62.7	13.8	290	270	1010
N-Fertilizer	34	40	74	21.5	62.4	33.5	480	430	900
Inoculated:									
IRc 252	32	43	46	38.2	123.8	37.8	380	310	1970
256	20	33	86	22.5	64.4	34.7	250	240	1370
283	27	19	31	26.5	90.5	31.7	270	210	1320
299	24	18	24	26.5	69.3	26.7	290	190	450
344A	44	37	64	24.6	50.4	24.6	400	380	1400
383C	17	22	22	39.1	62.2	63.5	180	320	510
400A	34	20	37	22.9	56.9	28.2	210	260	1680
409C	22	20	28	31.3	39.2	20.7	240	240	600
430A	22	29	49	19.1	41.9	18.6	220	430	1430
462D	29	20	29	15.7	52.1	35.5	280	300	980
489B	20	31	40	21.6	54.7	26.3	210	270	890
500A	15	17	27	40.7	61.8	28.3	250	470	920
506C	15	14	21	35.4	70.3	26.3	210	220	830
LSD(0.1) for comparing means of:									
same cultivar		22			25.9			380	
different cultivars		20			25.7			460	
Overall means for:									
Inoculation	25	25	39	28.0	64.4	31.0	260	300	1100
Onne strains	29	30	50	27.7	79.7	31.1	320	270	1300
Maradi strains	24	23	34	28.1	50.1	32.8	210	310	1060
IITA strains	20	21	29	28.4	59.7	29.1	240	320	910

Shoot fresh weight and nodule dry weight at 49 days.

readily amenable to screening large numbers of rhizobia. An agar plate method was developed to remedy this situation. Small inocula of test strains are added to 2 defined media containing salts, galactose, arabinose, sodium glutamate and either bromcresol purple indicator at pH 6.0 (control) or bromcresol green indicator and 50 *uM* Al at pH 4.6 (stress medium). Rhizobial growth and pH changes of the 2 media are observed over 10 days. There is good agreement between acid-Al tolerance on plates and in the liquid media (Table 57). The agar plate method was used to screen 226 rhizobia (Table 58). Both cowpea rhizobia and *Rhizobium japonicum* contain tolerant and sensitive members. Observations were reported in IITA's 1980 Annual Report that high tolerance to acid-Al stress by cowpea rhizobia was more frequently associated with "wet" colony-forming rhizobial strains than with rhizobial origin was further established among indigenous *R. japonicum*. "Dry" colony-forming strains were very sensitive.

POT TRIALS WITH HOST PLANTS. From these laboratory screenings, rhizobia tolerant or sensitive to acid-Al stress were selected for each of the 3 classes: cowpea rhizobia, indigenous *R. japonicum* and exogenous *R. japonicum*. Pot trials were then conducted in 2 soils to further reduce the numbers and to facilitate future field evaluation. The first pot trial with Onne soil (Typic Paleudult) was designed to select symbiotically highly effective *R. japonicum* strains that were also either tolerant or intolerant of soil acidity. For this, 11 strains (8 tolerant and 3 sensitive) were inoculated at the rate of 10^6 cells/seed onto soybean cultivars TGm 80 and TGm 119 in pots and grown for 44 days. There were uninoculated and +N controls. Some *R. japonicum* treatments were significantly better than indigenous rhizobia (uninoculated) in terms of nodulation and N fixation (Table 59). Strains IRj 2025, 2109, 2123 and 2128 were selected as those combining high acid tolerance and effectiveness. Strains IRj 2112 and 2118F were effective, but intolerant.

Parallel studies with 9 cowpea rhizobia and 9 indigenous *R. japonicum* strains were carried out with Josephine soil (Typic Haploxerult) from California, U.S.A. at pH 4.5 (49 *u M* Al) and at pH 5.8. About 10^6-10^7 cells were inoculated onto seeds of cowpea cultivar TVu 1190 and soybean cultivar TGm 344. Uninoculated and +N controls were included. After 42 (cowpea) or 47 (soybean) days, the plants were harvested to determine nodulation and shoot dry weights.

The heaviest cowpea shoots were produced in the N fertilizer treatment (Fig. 13). Rhizobia differed significantly in their

Table 57. Correspondence between acid-A1 tolerance on agar plates and in liquid media.

Rhizobium species	Strain no.	Acid-Al Tolerance On agar plates	In liquid medium*
"Cowpea"	IRc 326B	Tolerant	1.4
	353	Tolerant	0.0
	356B	Tolerant	43.2
	381	Sensitive	97.9
	405	Sensitive	79.3
R. japonicum	IRj 2005	Tolerant	0.2
	2140B	Tolerant	4.1
	2144B	Tolerant	2.6
	2163	Sensitive	95.9
	2164B	Sensitive	91.3

**Percent decrease in optical density in liquid acid-Al medium compared with nonacid-Al medium. Sensitive strains are severely inhibited by acid-Al (79-98 percent inhibition); tolerant strains are not.*

Table 58. Response of cowpea and soybean rhizobia to acid-Al stress on agar plates.

Host of isolation	Location/ source	Number of rhizobia: In test	Dry*	Response to acid-Al: No.**	%
Cowpea	Onne	46	8	27 (13)	58.7
	Maradi	36	35	0	0
	Other	16	7	6 (4)	37.5
Soybean	Onne	50	23	27 (19)	54.0
	Maradi	38	36	9 (2)	23.7
	Other	14	0	13 (12)	92.9
	Culture collection	24	13	5 (2)	46.2

**Rhizobia that form dry, pinpoint colonies on YEM agar.*
***Numbers in parentheses are of highly tolerant strains.*

Table 59. Symbiotic effectiveness of acid-Al tolerant or intolerant *R. japonicum* in Onne soil.

	TGm 80			TGm 119		
Treatment	Shoot dry wt. (g/plant)	Total N in shoot (mg/plant)	Nodule dry wt. (mg/plant)	Shoot dry wt. (g/plant)	Total N in shoot (mg/plant)	Nodule dry wt. (mg/plant)
Uninoculated	4.3	61	129	4.2	108	208
N-Fertilizer	7.8	127	72	7.1	136	202
Inoculated:						
IRj 2025	5.1	195	389	4.5	125	323
2030	3.8	79	136	3.4	96	269
2048	3.8	58	92	3.6	71	243
2052	3.4	47	137	3.4	82	354
2109	4.4	134	444	4.1	82	354
2112	3.7	84	181	3.9	129	387
2118F	4.8	105	228	3.8	97	333
2119	4.1	74	192	4.2	93	304
2120	3.6	64	193	3.9	91	313
2123	4.8	96	250	4.3	106	253
2128	4.5	85	198	4.7	124	263
LSD (.05)	0.8	20	105	0.8	36	124

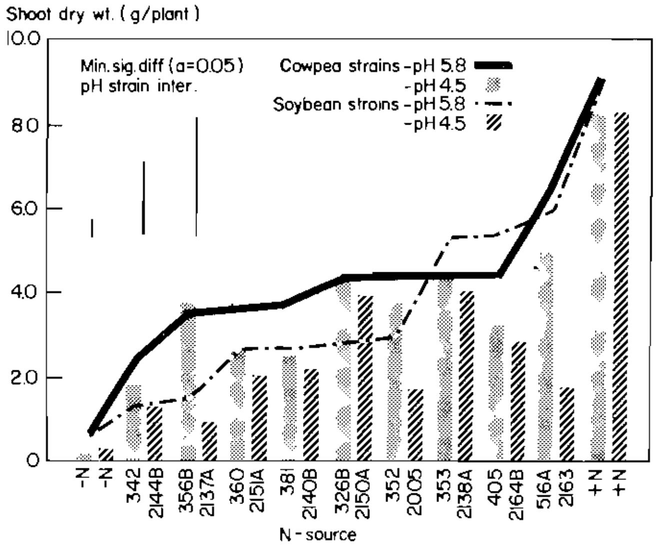


Fig. 13. Shoot yields of cowpea cultivar TVu 1190 in response to rhizobial inoculation.

effect on cowpea shoot yields. Cowpea inoculated with some strains, IRc 516A, 405, 352 and 381, were severely inhibited at pH 4.5; others, IRc 353, 326B and 356B, were not influenced by acidity. Inoculation of cowpea with *R. japonicum* strain 2150A produced significantly better shoot yields at pH 4.5 than at 5.8.

The N fertilizer treatment also produced greatest shoot yields in soybean (Fig. 14). Inoculation produced fairly good shoot yields only with 2 strains and only at pH 5.8. The strains were acid-Al tolerant strains 2140B and 2144B, but their effects on shoot yield were significantly inhibited at pH 4.5. Soybean inoculated with acid-Al tolerant cowpea strains 353 and 356B and *R. japonicum* strains 2005, 2138A and 2151A were not inhibited at pH 4.5, but shoot yields were low—about 2.5 g/plant.

Nodulation of cowpea was less inhibited by acidity than soybean. N fixation must also have been impaired in soybean

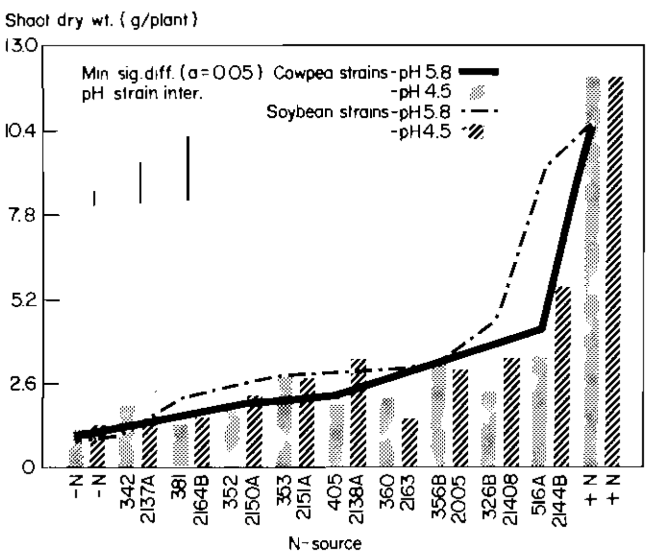


Fig. 14. Shoot yields of soybean cultivar TGm 344 in response to rhizobial inoculation.

because the +N control treatment produced significantly higher shoots than the inoculated treatment. It would, thus, appear that both nodulation and N fixation in this soil must be improved with better strains if soybeans are to depend on symbiotic N.

From the above 2 pot trials, 14 rhizobia have been selected for field testing at Onne using cowpea and a promiscuous and a nonpromiscuous soybean. Some strains combine effectiveness with acid-Al tolerance and others are effective but sensitive. The strains are as follows:

1) Cowpea rhizobia: IRc 326B, 353, 356B, and 381.
2) Indigenous *R. japonicum*: IRj 2138A, 2151A, 2144B and 2163.
3) Exogenous *R. japonicum*: IRj 2025, 2109, 2112, 2118F, 2123 and 2128.

Population sizes of "cowpea" rhizobia

A. Ayanaba

Past preliminary work indicated that soil from Fashola (50 km north of IITA in the derived savanna) did not contain rhizobia capable of supporting good nodulation of certain legumes. Experiments were, therefore, designed to determine population sizes, effectiveness and competitive ability of rhizobia in that soil. For comparison purposes, a soil from IITA was included. Isolations and effectiveness screening are in progress. Prior to those, the number of rhizobia nodulating 3 grain and 3 forage legumes were estimated by the most-probable number technique. The results (Table 60) show that there are nearly 100 times as many rhizobia in IITA as in the Fashola soil. *Leucaena* and *Centrosema* were essentially unnodulated in the Fashola soil.

Table 60. Numbers of indigenous rhizobia nodulating 3 grain and 3 forage legumes.

Legume species		No. of rhizobia/g in soil from: IITA	Fashola
Cowpea	(*Vigna unguiculata*)	1.6×10^4	3.6×10^2
Lima bean	(*Phaseolus lunatus*)	6.3×10^2	$<10^2$
Groundnut	(*Arachis hypogea*)	7.2×10^3	0.2×10^2
Centro	(*Centrosema pubescens*)	0.1×10^2	$<10^2$
Winged bean	(*Psophocarpus palustris*)	2.2×10^2	0.1×10^2
Leucaena	(*Leucaena leucocephala*)	$<10^2$	$<10^2$

Training Program

Introduction

Many past participants of the Training Program now staff regional, national and international programs and are leaders in agricultural research and education throughout Africa and other parts of the world. Considering the severe shortage of trained manpower in virtually all African countries, the Training Program has already made a significant contribution toward the development of the continent. By the end of 1981, 1,758 persons had participated in IITA training programs. About 90 percent of them came from Africa. Two-thirds were in group courses on crop production or related subjects. The remainder were in various forms of individual training, including direct participation in research activities.

Training activities

Training is organized in 2 categories: individual programs and group courses. Categories that cater to the training needs of individuals include senior research fellowships, degree-related, non degree-related, and vacation scholarship programs. In addition, the Institute awards as many as 20 junior scientistships per year to recent doctoral-level graduates in agricultural studies.

SENIOR RESEARCH FELLOWSHIPS. Senior research fellowships are for a period of 4-6 months and provide fellows with the opportunity to update their research skills or to become familiar with new agricultural technology or cropping systems.

DEGREE-RELATED TRAINING PROGRAM. Postgraduate students of universities located throughout the world conduct at IITA the field-work portions of their degrees under the supervision of the Institute's scientists. The program is designed primarily for students who come from countries of the humid and sub-humid tropics and affords them the opportu-

A field day organized by the participants of the 1981 rice production group course brought farmers and course participants in close contacts for a series of discussions on agricultural research, extension and other activities of agricultural interest.

nity to do their field work in the tropics on the crops, soils and systems to which they will return upon completion of their degree programs. The Institute generally has 40 to 50 of these students with this program, but at one time in 1981 there were 72 postgraduate degree students conducting their research under the supervision of IITA scientists.

NON-DEGREE RELATED TRAINING PROGRAM. The Institute has responded to requests for agricultural skills and technology training for employees of departments and ministries of agriculture, universities, agricultural experiment stations, international organizations and private agencies of countries of Africa and elsewhere The training is organized on an individual basis to meet the specific training needs of the participant. Because of the variability of individual needs, there is also a great variability in the length of programs falling under this category—from 2 weeks to 9 months. The Institute generally receives between 20 and 30 persons in this category each year.

UNDERGRADUATE STUDENT VACATION SCHOLARSHIP PROGRAM. This program was created to initiate and maintain collaborative relationships with faculties of agriculture in Africa, some of which have no postgraduate programs, and to identify and motivate promising young agricultural scientists. Scholarships are awarded to students in the penultimate year of their first degree courses to conduct, during their last long vacation as undergraduates, field and laboratory studies under the supervision of IITA scientists. The program has attracted nominations from faculties in French- and English-speaking Africa. The total number of awards since the program began in 1971 is 169, an average of 14 vacation scholars each year.

GROUP-COURSE TRAINING PROGRAM. Eleven courses were conducted at IITA during 1981. Group courses deal with various aspects of agricultural production in the humid and subhumid tropics and are organized as the need for training large numbers of agricultural and extension workers with common goals becomes apparent. Several courses are offered each year in crop production technology and extension. In addition, courses are organized for such areas as reduced tillage systems, post-harvest technology, various aspects of soil microbiology, tissue culture, soil and plant analysis, soil and water conservation research and genetic resources conservation. Group courses insure that participants acquire skills which improve their effectiveness in research or extension. The emphasis in each course is to prepare the participants to recognize and resolve problems in the field, to serve as a bridge between the farmer and the researcher and to acquire sufficient skills as a trainer to organize and conduct training programs for extension agents and farmers. Since the group courses program started in 1972, nominees from 64 countries of all continents but Antarctica have attended courses, representing universities, international development projects, voluntary agencies and commerical companies. About three-fourths of the courses that are held at IITA each year are conducted in both French and English with translation of training materials and simultaneous interpretation of all classroom-based activities. Of the 1,222 group participants who have received training at IITA since its beginning, approximately one-third have been citizens of French-speaking countries.

Farmers invited to IITA inspect improved rice on a field day organized by training participants.

Research Support Units

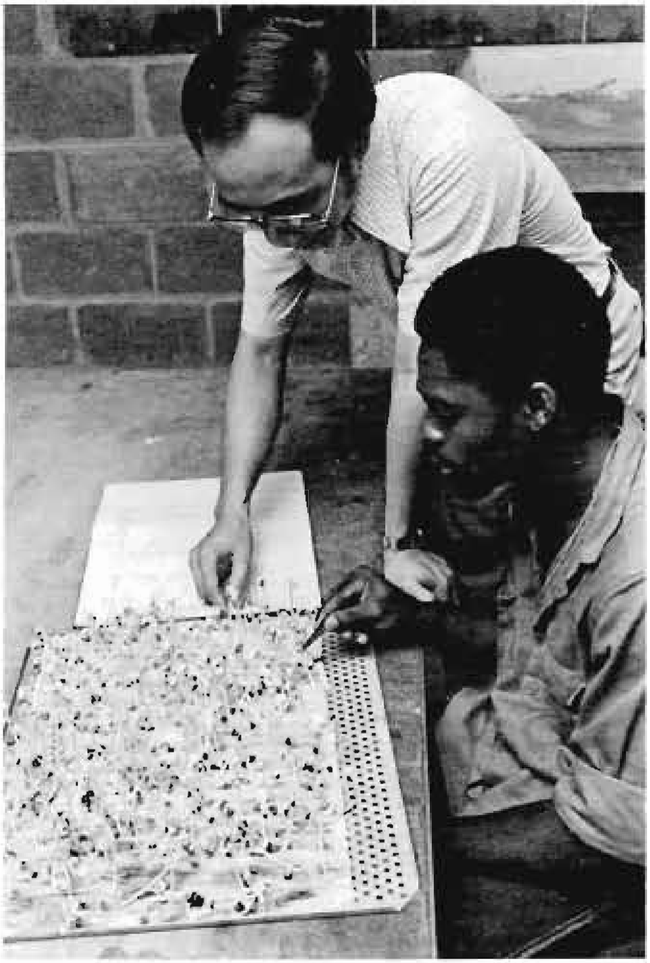
High-rainfall Substation at Onne, Nigeria

Onne continued research in farming systems and crop improvement. Granted to IITA by Rivers State in 1974, the Onne substation is an 80 ha site in the humid coastal zone of Nigeria. It assists the 4 major research programs at IITA. During 1981, the 10 ha of land cleared in 1980 making 51 ha of land available for research was destumped, cleared of debris and plowed to plant maize and upland rice. To provide on-site accommodation for principal staff and to allow for more resident scientific staff to be stationed at Onne, 5 prefabricated, 3-bedroom houses were erected. In addition, the rest house was modified. Onne placed emphasis during the year on research involving soil fertility and chemistry, agroforestry, plantain and bananas, cassava, sweet potato, maize, rice, cowpea and soybean. Reports on these activities are given under the farming systems and the crop improvement sections.

Farm Management

Farm Management continued to provide field support to all research programs at IITA and Onne substation as well as other sites in Nigeria. It also assisted IITA's cooperative projects at Kamboinse in Upper Volta and Ilonga in Tanzania in terms of developing their research facilities. Emphasis was given to mechanized planting and harvesting to reduce labor costs.

Farm development continued at IITA with building roads and drains especially on the west bank and similar work was carried out at Ikenne. Construction began on a bulk seed handling facility to help in producing high quality seed at IITA. A mobile farm mechanization unit was organized to provide efficient field operations on off-site locations up to 600 km from IITA.



Germplasm materials under storage at IITA Genetic Resources Unit are periodically tested for their viability to ensure that the valuable germplasm will not be lost.

Genetic Resources Unit

The Genetic Resources Unit (GRU) serves 4 functions:

1) to collect, multiply, preserve, evaluate and document germplasm of the food legumes, rice and root crops from subSahara Africa,
2) to distribute, on request, germplasm to scientists throughout the world,
3) to handle the multiplication and post-harvest preparation of cowpea breeding material for international trials and
4) to supply seed material for experiments at IITA. Throughout 1981, plant exploration activities were suspended.

GERMPLASM COLLECTION. The GRU continues to receive new germplasm material collected by IITA's scientists or donated by collaborating national and regional institutes. During the year, the GRU received 429 samples of cowpea, 79 of Bambarra groundnut and 1,409 of rice.

SEED DISTRIBUTION. During the year, the GRU received 145 requests from 33 countries around the world involving 5,444 samples of germplasm of 10 crop species. Also, there were 202 requests by IITA scientists for 13,345 samples, most of which were for cowpea and rice germplasm. They were evaluated by IITA scientists for resistance to insect pests and diseases or tolerance to physiological stress.

ROUTINE SEED GERMINATION TESTS. To maintain high viability in the germplasm material distributed, the GRU regenerates accession as soon as significant reduction in viability occurs in storage. A routine germination test for rice and cowpea germplasm was established in 1981. A minimum regeneration standard was set at 85 percent seed germination. Seed stored for long-term conservation is dried to 6 percent moisture content in a dehumidifier at 35°C or below and then packed in small aluminum cans or in aluminum foil envelopes.

During 1981, 1,104 accessions of *O. glaberrima*, 1,024 of *O. sativa*, 500 of cowpea, 50 of lima bean and 26 of winged bean were tested for seed viability. Results indicated that more than 26 percent of rice, 28 percent of cowpea and 30 percent of lima bean needed rejuvenation.

SEED MULTIPLICATION. A total of 7,853 accessions of germplasm were grown for seed multiplication or for rejuvenation. Thirty-one elite and advanced cowpea breeding lines were multiplied at Gusau in 1981, yielding 2.1 t.

COWPEA GERMPLASM EVALUATION. One of the objectives of the cowpea program at IITA is to breed for the large, white and rough seeded cultivars preferred in West Africa. During 1981, over 200 accessions of cowpea germplasm with such characteristics were evaluated for disease resistance. Two of these accessions were found highly resistant to cowpea yellow mosaic virus (CYMV). They will be used as sources of resistance.

Preliminary observations were made on the agronomic performance of 2,400 accessions of cowpea germplasm planted for multiplication and rejuvenation. Several accessions were high yielding and matured in about 60 days. These materials will be further tested for their performance. Observations indicate that systematic evaluation of the existing germplasm for possible use as direct introduction will be rewarding.

RICE GERMPLASM EVALUATION. In 1980, 1,132 accessions of *O. sativa* and 399 of *O. glaberrima* were screened for blast resistance both at IITA and at Onne. Accessions with little or no blast symptoms were selected and retested for blast resistance in 1981. Six hundred and sixty-one accessions of *O. sativa* and 329 accessions of *O. glaberrima* under upland condition were sprayed with blast inoculum; 125 accessions of *O. sativa* and 52 of *O. glaberrima* were severely damaged. The susceptible check and 6 of the blast index varieties as well as the disease spreader were seriously damaged (Table 1). This indicated that a fairly high incidence of blast was created in the screening field by artificial inoculation and natural infestation. The remaining 536 accessions of *O. sativa* and 277 of *O. glaberrima* showed very low damage.

Observations were carried out on the agronomic peformance of 526 accessions of African *O. sativa* sown in 2 rows of 5m plots under upland conditions at IITA for seed multiplication and botanical characterization. Some of these accessions appeared to be high yielding with good agronomic characteristics, but none of them gave as high a yield as the 2 control varieties, OS-6 and ITA 116 (Table 2). However, accession TOS 7898 yielded almost as high as the controls.

Germplasm registration, characterization and documentation continued for cowpea and rice. Ten grain characteristics of 1,600 accessions of *O. sativa* were evaluated and the data were added to IITA's rice germplasm computer data bank.

This brings to 46 documented descriptors on agrobotanical characters and 15 descriptors gathered at the time of collection and its provenance to a total of 1,750 accessions of *O. sativa* and 1,200 accessions of *O. glaberrima*. The information will be published in the form of a catalog.

Three hundred and seventy-seven new cowpea germplasm was evaluated for up to 29 agrobotanical characteristics and the data added to IITA's cowpea germplasm computer data bank which has 11,300 accessions. Information on field data gathered at the time of collection and its provenance of 829 accessions of cowpea were also added into the data bank.

Table 1. Reaction of 19 blast index varieties of rice sown among the test material for blast resistant screening at IITA, Ibadan, Nigeria.

		Blast disease score*	
Variety	Resistant genotype	Seedling	Late vegetable
Aichi Asahi	Pi-a	—	—
BL 1	Pi-b	1	1
Fugisaka 5	Pi-i	6	8
Fukunishiki	Pi-z	1	0
Ginga	—	2	0
Hokkai 189	—	1	1
Ishikari-Shiroke	Pi-i, Pi-k	2	2
K1	Pi-ta	4	4
K2	Pi-kp, Pi-a	7	8
K3	Pi-kn	7	8
K59	Pi-t	7	8
Kanto 51	Pi-k	6	8
Pi No. 1	Pi-a, Pi-ta	1	0
Pi No. 4	Pi-ta^2	0	0
Tsuyuake	Pi-Km, Pi-K	8	9
Shin 2	Pi-Ks	2	0
Toride 1	Pi-Z^t	1	1
Yashiro	Pi-ta	1	0
BG 90-2 (control)	—	9	9

Based on IRRI (1980). Standard Evaluation System for Rice (2nd edition).

Table 2. Agronomic performance of some promising *Oryza sativa* germplasm under upland conditions at IITA, Ibadan, Nigeria.

Variety	Yield (g)[1]	Days to maturity	Plant height (cm)	Tiller No./ hill	Culm strength
TOs 7898	1528	131	168	12	moderately lodged
TOs 8185	1310	118	113	16	slightly lodged
TOs 7552	1210	133	143	11	moderately lodged
TOs 8191	1199	131	142	10	moderately lodged
TOs 7505	1139	131	127	11	moderately strong
TOs 7498*	1130	128	103	33	moderately strong
Controls ITA 116	1591	117	123	10	slightly lodged
OS-6	1573	119	141	9	slightly lodged

[1]*Total grain weight of 44 plants of the 2 row plots. The spacing was 25cm between hills and 30cm between rows and 60cm between plots.*
**A lowland variety suitable to high population densities and high fertilizer levels.*

Analytical Services Laboratory

During 1981, the laboratory analyzed 9,510 soil samples, 13,486 plant samples and 4,959 water samples. A total of 123,599 assays were carried out. Compared to the previous year, the number of assays doubled.

Biometrics Unit

Datatrieval, a program for information retrieval, was purchased and an Experiment Retrieval System will soon be established. The number of scientists consulting prior to setting out their experiments has increased considerably, decreasing the amount of data salvage needed.

Virology Unit

To facilitate control of virus diseases causing economic loss in crops under investigation at IITA, the Virology Unit continued studies on the etiology of virus diseases in cassava, yam, sweet potato, cocoyam, maize, rice, cowpeas and soybeans. In addition, epidemiological studies as well as studies on resistance screening and indexing methods are aspects of work covered by this unit. The research results are listed under each program.

Conference Center

CONFERENCES. During 1981, seven conferences and workshops were held in the Herbert R. Albrecht Conference Center.

SEMINARS. Twenty-two research seminars were presented during the year.

VISITORS. There was a sharp increase in the number of visitors to IITA during 1981. They ask for information about the research programs and often request samples of IITA improved crop varieties. Among those visiting the Institute are school children, as well as people from institutions such as churches and private and government agencies.

Library and Documentation Center

During the year, 1,720 books and 1,750 periodicals were added to the collection. By the end of 1981, the library had 19,320 books, 23,100 periodicals, 3,900 pamphlets and reprints, 3,420 microfilms, 1,600 slides and 33 cassettes.

The monthly indexed list of accessions, as well as the monthly "Grain Legume Current Titles," were produced throughout the year.

The Library compiled a listing of the formal publications of the Institute since 1969 entitled, *Record of Publications*, Vol. 1 1969-1980. To facilitate use of French language agricultural publications, it also published a bibliographical guide entitled, *Le Riz: Publications en Langue Francaise Disponibles a la Bibliotheque de l'IITA.*

GRAIN LEGUME DOCUMENTATION. The International Grain Legume Information Center published 4 issues (Numbers 20, 21, 22 and 23) of the *Tropical Grain Legume Bulletin* during the year. The Bulletin went to 951 grain legume workers around the world. Of these, more than 70 percent were based in Africa, Asia, South and Central America.

Contributions to the Bulletin since its inception have come from 24 different countries. Twenty-nine requests for literature searches on grain legume subjects were received from outside IITA during 1981. During the period 1980/81, 55 requests came from Australia, Belgium, Benin Republic, Brazil, Canada, Cameroon, Ghana, India, Indonesia, Kenya, Malaysia, Nigeria, Philippines, Rwanda, Senegal, Sierra Leone, Sri Lanka, Tanzania, Trinidad, U.K. and Zambia.

Communications and Information Office

A series of technical and popular materials directed to specific audiences were produced during the year. More than 20,000 copies of IITA publications were distributed to about 5,000 requestors in 128 countries. In addition to editorial work, the Office has facilities for graphic arts, photography and printing.

PUBLICATIONS. Major publications edited during the year included IITA Research Briefs, IITA Annual Report 1980 and IITA Research Highlights 1980. Major publications edited and printed at IITA during 1981 included:

1) *IITA Research Briefs* Vol. 2, Nos. 1-4.
2) *IITA Record of Publications.*
3) *Toward Nigeria's Success in Agricultural Development.*
4) *Tasks for the Eighties—A Long Range Plan.*
5) *Land Development and Management in Tropical Africa* by E.H. Hartmans.
6) *Tropical Grain Legume Bulletin* Nos. 20-23.
7) *Enquete Sur Res systemes d'exploitation des cultures viviere dans les Zone d'action prioritaires integrees de l'Est (Zapi-Est) du Cameroon, IITA ONAREST* by E.A. Atayi and H.C. Knipscheer.
8) *Recommendations for Transporting Sweet Potato and Cassava Tissue Culture Material* and the French version: *Recommendations pour le transport et la manipulation de materiel en culture de tissue.*

Major IITA publications edited at IITA and printed abroad during 1981 included:

1) *IITA Research Highlights 1980.*
2) *Le Poin de la recherche a l'IITA 1980.*
3) *IITA Annual Report 1980.*

TRANSLATIONS. Several documents were translated from English to French and from French to English. The major translation accomplished was *Le point de la recherche a l'IITA 1980.*

FAIRS. IITA participated in several agricultural fairs in Nigeria including the first National Agricultural Show sponsored by the Ministry of Agriculture held in Kaduna and FAO's first World Food Day recognized by Nigeria's Federal Government in an exhibition in Lagos and Nigeria's second National Science and Technology Fair in Enugu. The fairs offered IITA an opportunity to show some of its major achievements to the public.

Physical Plant Services

The Institute has been completely dependent on itself for water supply and treatment for several years. For electricity, the Institute became more and more dependent on its own generators in 1981.

Construction during the year included 8 flatlet apartments, central stores, clinic and seed-handling buildings, an insect-rearing unit, 5 bungalows at Onne, a farm workshop and a mason unit and an extension to the school.

List of Personnel

Administration

E.H. Hartmans, *Ph.D., Director General*
B.N. Okigbo, *Ph.D., Deputy Director General*
M.A. Akintomide, *A.I.C.T.A., Director for Administration*
S.V.S. Shastry, *Ph.D., Director of Research*
J.E. Haakansson, *M.B.A., Assistant Director of Budget and Finance*
B. Adeola, *A.C.I.S., Accountant*
K.A. Aderogba, *D.P.A., Principal Administrative Officer*
C.A. Enahoro, *Assistant to the Director General*
O.O. Ogundipe, *M.D., Medical Officer*
M.E. Olusa, *Assistant to the Director for Administration*
E.A. Onifade, *Security Superintendent*
R.O. Shoyinka, *B.S., Personnel Manager*
D.J. Sewell, *Dormitory and Food Service Manager*
S.J. Udoh, *A.M.N.I.M., Chief Accountant*
R. Vick, *M.S., Data Processing Manager*
A. Yusuf, *B.S., Controller of Stores*

Cereal Improvement Program

Core Financed—Senior Scientists

Y. Efron, *Ph.D., Assistant Director and Program Leader*
A.O. Abifarin, *Ph.D., IITA Liaison Scientist, WARDA, Liberia*
J.M. Fajemisin, *Ph.D., Maize Pathologist/Breeder (Visiting Scientist)*
S.K. Kim, *Ph.D., Maize Breeder*
J. Yamaguchi, *Ph.D., Rice Physiologist (Visiting Scientist)**

Core Financed—Junior Scientists**

M.S. Alam, *Ph.D., Rice Entomologist*
J. Sarkarung, *Ph.D., Rice Breeder**
J. Singh, *Ph.D., Maize Pathologist*

Non-Core Financed—Supporting Mandated Research

K. Alluri, *Ph.D., Rice Agronomist/Breeder HYV Technology Project (EEC)*
V.L. Asnani, *Ph.D., Maize Breeder & Project Leader SAFGRAD Project, Upper Volta (USAID)*
F.H. Khadr, *Ph.D., Maize Breeder/Agronomist, Zaria (CEC) HYV Tech. Proj. (EEC)*
Y.S. Rathore, *Ph.D., Cowpea Entomologist, SAFGRAD, Upper Volta (USAID)*
M. Rodriguez, *Ph.D., Agronomist, SAFGRAD, Upper Volta (USAID)*

Cooperative Programs with Countries (Bilaterally Financed), Cameroon

J.H. Chung, *Ph.D., Breeder and Project Leader, NCRE (USAID)*
D.C. Goodman, *M.B.A., Administrator, NCRE (USAID)*
T.G. Hart, *Ph.D., Chief of Party, NCRE (USAID)*
D. Janakiram, *Ph.D., Rice Breeder, NCRE (USAID)*
H.J. Pfeiffer, *Ir., Agronomist, NCRE (USAID)*
A.C. Roy, *Ph.D., Rice Agronomist, NCRE (USAID)*

Cooperative Program with Centers/Institutes

J. Arrivets, *Ph.D., Rice Agronomist, IRAT Liaison Scientist*
M. Bjarnason, *Ph.D., Maize Breeder, CIMMYT Liaison Scientist*
H.N. Pham, *Ph.D., Maize Breeder, CIMMYT Liaison Scientist*
Kaung Zan, *Ph.D., Rice Pathologist, IRRI Liaison Scientist*

Grain Legume Improvement Program

Core-financed—Senior Scientists

P.R. Goldsworthy, *Ph.D., Assistant Director and Program Leader**
A.A. Ayanaba, *Ph.D., Microbiologist*
L.E. Jackai, *Ph.D., Entomologist*
E.A. Kueneman, *Ph.D., Plant Breeder*
M.J. Lukefahr, *Ph.D., Entomologist**
E.L. Pulver, *Ph.D., Physiologist/Agronomist**
V.R. Rao, *Ph.D., Microbiologist**
R.J. Redden, *Ph.D., Plant Breeder**
B.B. Singh, *Ph.D., Plant Breeder*
S.R. Singh, *Ph.D., Entomologist*
E.E. Watt, *Ph.D., Plant Breeder (Brazil)*

Non-Core Financed—Supporting Mandated Research

V.D. Aggarwal, *Ph.D., Plant Breeder, Upper Volta (IDRC)*
S. Asanuma, *Ph.D., Microbiologist (UNDP)*
F.E. Brockman, *Agronomist, Upper Volta (USAID)*

Cooperative Program with Countries (Bilaterally Financed)

M. Price, *Ph.D., Coordinator, Tanzania Project (USAID)*

FAO Associate Expert

P. Homble, *Ir.*
H. Wosten, *Ir. Physiologist*

Root and Tuber Improvement Program

Core Financed—Senior Scientists

S.K. Hahn, *Ph.D., Assistant Director, Program Leader and Breeder*
M.N. Alvarez, *Ph.D., Associate Breeder*
F.E. Caveness, *Ph.D., Nematologist*
H.R. Herren, *Ph.D., Entomologist (Biological Control)*
K. Leuschner, *Ph.D., Entomologist**
D. Perreaux, *Ph.D., Associate Pathologist*
P. Rao, *Ph.D., Biochemist**
E.R. Terry, *Ph.D., Plant Pathologist (till March 1981)*

Core Fiananced—Junior Scientists**

K.M. Lema, *Ph.D., Entomologist (Biological Control)*
S.Y.C. Ng, *M.S., Tissue Culture Scientist*

Non-Core Financed—Cooperation with Countries (Bilaterally Financed), Zaire

W.W. Fiebig, *M.S., Extension Agronomist, PRONAM (USAID)*
R.D. Hennessey, *Ph.D., Entomologist (Biological Control) PRONAM (USAID)*
S. Pandey, *Ph.D., Extension Agronomist, PRONAM (USAID)*
T.P. Singh, *Ph.D., Breeder, PRONAM (USAID)*
M. Veloso, *B.S., Physical Plant Service Officer, PRONAM (USAID)*

FAO Associate Expert

E.A. Frison, *Ir., Tissue Culture*

Research Associate Assistants

E.M. Chukwuma, *Breeding*
S.Y.C. Ng, *M.S., Tissue Culture*
Y. Yamaguchi, *B.S., Biochemistry*

Farming Systems Program

Core Financed—Senior Scientists

C.H.H. ter Kuile, *Ph.D., Assistant Director and Program Leader*
I.O. Akobundu, *Ph.D., Weed Scientist*
M. Ashraf, *Ph.D., Agricultural Economist*
P. Ay, *Ph.D., Socio-Economist*

G. Cesarini, *Ph.D., Visiting Socio-Economist*
H.C. Ezumah, *Ph.D., Agronomist*
C. Garman, *M.S., Agricultural Engineer*
A.S.R. Juo, *Ph.D., Soil Chemist*
B.T. Kang, *Ph.D., Soil Fertility Specialist*
H.C. Knipscheer, *Ph.D., Agricultural Economist**
S. Kukula, *Ph.D., Weed Scientist**
R. Lal, *Ph.D., Soil Physicist*
T.L. Lawson, *Ph.D., Agroclimatologist*
K. Mulongoy, *Ph.D., Microbiologist*
N.C. Navasero, *B.S., Associate Agricultural Engineer*
G.F. Wilson, *Ph.D., Agronomist*

Core Financed—Junior Scientists**
Y. Arora, *Ph.D., Soil Chemist*
B.S. Ghuman, *Ph.D., Soil Physicist*
M.O. Maduakor, *Ph.D., Soil Physicist*
B.S. Ngambeki, *Ph.D., Agricultural Economist*
P.S.O. Okoli, *Ph.D., Agronomist*
O.A. Opara-Nadi, *Ph.D., Soil Physicist*

Non-Core Financed—Core Supporting Scientists
R.D. Bowers, *M.S., Agricultural Engineer* (FAO)*
W.N.O. Ezeilo, *B.S., Agronomist (IBRD), Bida, Nigeria*
A. Getahun, *Ph.D., Agroforester* (IDRC)*
M.A. Gowman, *M.I. (Biol.), Weed Scientist (ICI)*
H.J.W. Mutsaers, *Ph.D., Agronomist (Ford Foundation)*
N.V. Nguu, *Ph.D., Agronomist (ZAPI-EST), Cameroon*
J. van der Heide, *Ir., Soil Scientist (IB), Onne, Nigeria*

Cooperative Program Scientists (Bilaterally Financed)
E.A. Atayi, *Ph.D., Agric. Economist, Bertua, Cameroon (USAID)*
R. Balasubramanian, *Ph.D., Soil Fertility Specialist, MIDAS, Ghana (USAID)*
J.O. Braide, *Ph.D., Agronomist, MIDAS, Ghana (USAID)*
N.S. Jodha, *Ph.D., Agricultural Economist, Tanzania (USAID)*

FAO Associate Experts
P. Rosseau, *Ir., Soil Physicist**
R. Swennen, *Ir., Plantain Agronomist, Onne, Nigeria*

Research Assistants/Associates
J.O. Adesina, *Soil Fertility*
K.L. Akapa, *Agronomy*
A.O. Dabiri, *Soil Chemistry*
C. Moradesa, *Agroclimatology*
M.A.O. Nwaogwugwu, *Agronomy*
K.O. Oduro-Afriyie, *Agroclimatology**
A.O. Oginni, *Agroclimatology*
S.O. Olubode, *Agronomy*
R.A. Raji, *Weed Science*

Farm Management

Core Financed
D.C. Couper, *B.S., Farm Manager*
P.D. Austin, *B.S., Farm Manager, Onne, Nigeria*
S.L. Claassen, *M.S., Assistant Farm Manager*
P.V. Hartley, *B.S., Farm Management Engineer*

Cooperative Program with Countries (Bilaterally Financed)
B. Chitti-Babu, *M.S., Agricultural Engineer, Tanzania (USAID)*

Training Program

Core Financed
W.H. Reeves, *Ph.D., Assistant Director and Head*
G.A. Cambier, *Lic., Translator/Interpreter*
D.W. Sirinayake, *Training Officer*
A.P. Uriyo, *Ph.D., Training Officer (Agronomist)*

International Programs

Non-Core Financed
E.R. Terry, *Ph.D., Assistant Director and Head*
E.F. Deganus, *CAR, Administrator*
F.O. Ogunyemi, *F.C.C.A., Accountant*

Analytical Services Laboratory

Core Financed
J.L. Pleysier, *Ph.D., Head*

Biometrics

Core Financed
J. McGuire, *Ph.D., Biometrician*

Genetic Resources Unit

Core Financed
N.Q. Ng, *Ph.D., Plant Geneticist*
A.T. Perez, *Ph.D., Plant Explorer**
W.M. Steele, *Ph.D., Coordinator**

FAO Associate Expert
M. Davids, *Ir., Plant Geneticist*

Virology

Core Financed
H.W. Rossel, *Ir., Virologist*
G. Thottappilly, *Ph.D., Virologist*

FAO Associate Expert
J.W.M. van Lent, *Ir., Virologist*

Library and Documentation Center

Core Financed
S.M. Lawani, *Ph.D., Head*
G.O. Ibekwe, *B.A., Principal Librarian*

Public Affairs and Development

Core Financed
J.E. Keyser, *B.S., Assistant Director for Public Affairs and Development*

Communications and Information

Core Financed
J.O. Oyekan, *B.S., Head, Communications and Information*
F.M. Gatmaitan, Jr., *B.S., Senior Graphics Designer*
J.C.G. Isoba, *M.S., Communications Officer, Publications*
R.E. Rathbone, *M.S., Editor*

Physical Plant Services

Core Financed
J.G.H. Craig, *Assistant Director for Physical Plant Services*
E.O.A. Akintokun, *Research Vehicles Service Officer*
A. Amrani, *Heavy Equipment Service Officer*
A.C. Butler, *Buildings and Site Service Officer*
O.O.A. Fawole, *Automotive Service Officer*
J.M. Ferguson, *Fabrication/Water Utility Service Officer*
G.D. Garrity, *Electrical Service Officer**
N. Georgallis, *Scientific/Electronics Service Officer*
J. Lukowski, *Electrical Service Officer*
E. Magnani, *Heavy Equipment Service Officer**
T.V. Manohar, *Refrigeration/Air Conditioning Service Officer*
M.O. Yusuf, *Construction/Site Engineering Service Officer*

**Left during the year.*
***Formerly called Post-Doctoral Fellows.*

Collaborators and Training

Collaborators

Dr. P. Antoine, *director IFA, University of Zaire, Yangambi, Zaire.*
Dr. O. Babalola, *agronomy department, University of Ibadan, Nigeria*
Prof. E. de Langhe, *Catholic University of Louvain, Belgium.*
Dr. D. Gabriels and Prof. M. de Boodt, *Soil Physics Dept., University of Ghent, Belgium.*
Prof. E.G. Hallsworth, *IFIAS, University of Sussex, U.K.*
Prof. R.K. Jana, *University of Dar Es Salaam, Morogoro, Tanzania.*
Dr. A. Kogblevi, *project d'Agro-Pedology, Cotonou, Rep. of Benin*
National Meteorological Service, Ghana.
National Meteorological Service, Nigeria.
National Meteorological Service, Togo.
Dr. L.A. Nnadi, *IAR, Anmadu Bello University, Nigeria.*
Prof. J. Oguntoyinbo, *University of Ibadan, Nigeria.*
Dr. Y.O.K. Osikanlu, *Institute of Agricultural Research and Training, University of Ife, Ile-Ife, Nigeria.*
Prof. D. Payne, *University of Reading, U.K.*
Dr. G.D. Sery, *plantain agronomist, IRFA, Abidjan, Ivory Coast.*
Dr. H. Tezenas, *Du Montcel, IRA/IRFA, Buea Cameroon.*
Prof. K. Vlassak, *Catholic University of Louvain, Belgium*
Prof. A. Wild, *University of Reading, U.K*

Research Fellows and Scholars

B.N.A. Addy *(b)**
E. Adegnika *(e)*
A.S. Ahissou *(d)*
S.O. Ajunwon *(a)*
E. Amezquita *(a)*
A.M. Andries *(d)*
M. Armon *(a)*
K. Atta Krah *(a)*
A. Bationa *(a)*
G. Chukwuma *(e)*
A.M. Clauwaert *(d)*
T.D.S. Diniz *(e)*
F.S. Djogbenou *(d)*
B. Duguma *(b)*
K.J.B. Edaye *(d)*
E.N.O. Iwuafor *(a)*
A.I. Khatibu *(b)*
J.L. Kiazolu *(a)*
E.Y. Koroma *(c)*
D. Koudoro *(d)*
Landu Kalemba *(b)*
Mafuka Mbe-Mpie *(a)*
J. Maier *(a)*
C.A. Mba *(a)*
J.S.C. Mbagwa *(a)*
M. Mbulu Ntoto *(b)*
Memadou Barthelmy *(d)*
E.L.N. Ngatunga *(b)*
A.O. Oginni *(e)*
M.E. Ogula *(a)*
L.T. Ogunremi *(a)*
W.A. Olusanya *(a)*
R.A. Raji *(e)*
M.D. Read *(a)*
W. Schmid *(b)*
R.P.A. Unamma *(a)*
S.N. Utulu *(a)*
I. Verinumbe *(a)*
G. Weckx *(d)*
C.F. Yamoah *(a)*

Root and Tuber Improvement Program

Collaborators

Dr. M. A-As-Saqui, *agronomist and head, Division of Field Crops, Central Agricultural Research Institute, Suakoko, Bong County, Republic of Liberia.*
Mr. C. Adams, *chief research and development officer, Grand' Anse Experimental and Food Production Centre, Mahe, Republic of Seychelles.*
Dr. O.B. Arene, *program leader for cassava and pathologist, National Root Crops Research Institute, Umudike, Nigeria.*
Dr. F.D. Bennett, *director, Commonwealth Institute of Biological Control, Trinidad, West Indies.*
Dr. A.I. Carpenter, *UNDP/FAO, Ministry of Agriculture, Zanzibar, Tanzania.*
Prof. H.R. Chheda, *Department of Agronomy, University of Ibadan, Nigeria.*
Dr. M.T. Dahniya, *project leader, Root and Tuber Improvement, Njala College, Sierra Leone.*
Dr. L.S.O. Ene, *acting director and breeder, National Root Crops Research Institute, Umudike, Nigeria.*
Prof. D.T.P. Hernandez, *sweet potato breeding, Louisiana State University, Baton Rouge, Louisiana, USA.*
Mr. G. Heys, *general manager, Texaco Agro-Industries Limited, Abeokuta, Nigeria.*
Mr. F. Iyamuremye, *director general, Institut des Sciences Agronomiques du Rwanda, Rubona, Rwanda.*
Mr. B. Lutaladio, *Co-director, programme national du manioc (PRONAM), M'vuazi, Zaire.*
Dr. Lyonga, *coordinator, National Root Crop Improvement Program, Njombe, Cameroon.*
Dr. J. Meyer, *laboratoire de Phytopathologie, Universite Catholique de Louvain, Belgium.*
Dr. M.A.M. Msabaha, *National Root and Tuber Improvement Program, Ukiruguru, Tanzania.*
Chief P.U. Ohunyo, *head of community development project, Shell Petroleum Development Company, Warri, Nigeria.*
Dr. O.O. Okoli, *leader of breeding, National Root Crops Research Institute, Umudike, Nigeria.*
Dr. F. Quak, *head of virology unit Research Institute for Plant Protection (IPO), Wageningen, The Netherlands.*
Dr. M.R. Villanueva, *USAID Mission to Haiti, American Embassy, Port-au-Prince, Haiti.*
Dr. D.B. Williams, *team leader, FAO Root Crop Development Project in the South Pacific.*
Prof. L.A. Wilson, *head, Department of Crop Science, University of West Indies, Trinidad.*
Dr. M. Yaseen, *entomologist, Commonwealth Institute of Biological Control, Trinidad, West Indies.*

Research Fellows and Scholars

M.O. Akoroda *(a)*
Anota Tomu *(c)*
S.K. Asiedu *(a)*
H.S. Bundu *(e)*
W. Cable *(e)*
B.M.S. Hemeng *(e)*
P.M. Herlant *(d)*
Kiala Kilusi *(c)*
N.B. Lutaladio *(a)*
A. Tamufor *(e)*
Mahungu Nzola-Meso *(a)*
M. Msabaha *(a)*
Muaka Toko *(c)*
Muimba Kankolongo *(c)*
Muyolo Gilumbu *(c)*
Nsiama She *(d)*
Nsongi Kasele Idumbo *(c)*
J.O. Otoo *(a)*
K. Sebastian *(c)*
A.T. Zannou *(d)*

Cereal Improvement Program

Collaborators

Dr. R.N. Achike, *Anambra/Imo State (World Bank) Rice Project, Enugu, Nigeria.*
Mr. C.E. Ago, *Maize Breeder, National Cereals Research Institute, Ibadan, Nigeria.*
Dr. M.K. Akposoe, *Crops Research Institute, Council for Scientific and Industrial Research, P.O. Box 3785, Kumasi, Ghana.*
Mr. K. A. Ayotade, *NCRI, Badeggi, Nigeria.*
Dr. J.A. Ayuk-Takem, *Institute of Agronomic Research, Box 80, Bamenda, Cameroon.*
Dr. G. Beye, *ISRA, B.P. 3120, Dakar, Senegal.*
Mr. S. Boli, *IHA, Dschang, B.P. Cameroon.*
Dr. J.L. Brewbaker, *University of Hawaii, Honolulu, Hawaii, USA.*
Dr. P. Camara, *Centre National de Recherches Agronomique, Bambey, Senegal.*
Dr. A.G. Carson, *Crops Research Institute, Tamale, Ghana.*
Mr. R.Q. Craufurd, *Department of Agriculture, Research Branch, Mount Makulu Research Station, P.O. Box 7, Chilanga, Republic of Zaire.*
Dr. S.N. Dazogbo, *Department de la Recherche Agronomique, Cotonou, Republic of Benin.*
Mr. C.S. De Silve, *Department de experimenta cause Producao de Arroz, DEPA, C.P. 71, Bissau, Republic of Guinea Bissau.*
Dr. N.L. Dhawan, *CIMMYT, Apdo. Postal 6-641, 06600, D.F. Mexico.*
Mr. W.R. Dingle, *UNDP, P.O. Box 553, Kitale, Kenya.*

Dr. J.P. Eckebil, *Director, IRA, IDGRST, Yaounde, R.P. Cameroon.*
Dr. S. Fagade, *NCRI, Ibadan, Nigeria.*
Dr. M.A.B. Fakorede, *Senior Lecturer, University of Ife, Ile-Ife, Nigeria.*
Mr. S.M. Gitonga, *National Irrigation Board, P.O. Box 30372, Nairobi, Kenya.*
Mr. B. Habas, *Institut de la Recherche Agronomique, SODERIM, Plaine des M'bo, R.P. Cameroon.*
Mr. M. Hainzelin, *Maize Breeder, IDESSA/IRAF, B.P. 635, Bouake, Ivory Coast.*
Dr. Q. Haque, *Food Legumes and Cereals Program, CARDI.*
Mr. E.J.R. Hazelden, *Kenya Seed Company Limited, P.O. Box 553, Kitale, Kenya.*
Mr. A. Hounkpevi, *Genetician, Station de Recherche Agronomique de Niaouli, Attagon, Benin.*
Dr. J.E. Iken, *Maize Breeder, NCRI, Ibadan, Nigeria.*
Dr. J. Johnson, *ACPO-SAFGRAD, B.P. 34, Bamako, Mali.*
Dr. J. Kafupera, *General Manager, ISABU, B.P. 795, Bajumbura, Burundi.*
Mr. A.S. Kumwenda, *Lifuwu Rice Research Station, Box 102, Salima, Malawi.*
Mr. V.G. Lambert, *Division of Agricultural Extension, ENSA, University of Yaounde, Cameroon.*
Dr. J.T. Legg, *Head, Agricultural Research, Ministry of Agriculture, Lilongwe, Malawi.*
Mr. M.A. Mansaray, *Rice Research Station, Rokupr, Sierra Leone.*
Dr. J.L. Marchand, *IDESSA/IRAF, B.P. 635, Bouake, Ivory Coast.*
Mr. J. Marquette, *IRAT Mission au Togo, B.P. 1163, Lome, Togo.*
Mr. W.R. Mills, *Department of Research and Specialist Services, P.O. Box 8108, Causeway, Salisbury, Zimbabwe.*
Ministry of Agriculture and National Resources, *Bendel State, Nigeria.*
Ministry of Agriculture and National Resources, *Rivers State, Nigeria.*
Dr. S.Z. Morris, *Plant Breeder, CAES, Suakoko, Liberia.*
Mr. D. Naik, *Mt. Makulu Research Station, P.M.B. 7, Chilanga, Zambia.*
Mr. D. Narcisse, *Department de la Recherche Agronomique Cotonou, Republic of Benin.*
Mr. F. Ndambuki, *Ministry of Agriculture National, National Agricultural Research Station, P.O. Box 450, Kitale, Kenya.*
Chief P. U. Ohunyon, *Shell-BP, Warri, Nigeria.*
Dr. S. Parasram, *Commodity Leader Maize, CARDI, University of West Indies, St. Augustine, Trinidad.*
Mr. C. Poisson, *IRAT, Bouake, Ivory Coast.*
Dr. B.L. Renfro, *CIMMYT Asian Regional Maize Program, The Rockefeller Foundation, Bangkok, Thailand.*
Mr. J.M. Rosset, *Institut de la Recherche Agronomique, Maroua, B.P. 33, Republic of Cameroon.*
Mr. Schalbroeck, *Institut de Science Agronomic de Burundi (ISABU) Burundi.*
Mr. Sompo-Ceesay, *Department of Agriculture, Cape St. Mary, Gambia.*
Dr. E.W. Sprague, *Director, Maize Program, CIMMYT, Mexico.*
Mr. F. Sumo, *CAES, Suakoko, Liberia.*
Mr. G. Van de Plas, *FAO Expert, CIAM, B.P. 2183, c/o ONU, Libreville, Gabon.*
Mr. S.R. Vodouhe, *Department de la Recherche Agronomique, Cotonou, Republic of Benin.*
Mr. E.T. Wanki, *CAES, Suakoko, Liberia.*
Mr. S.B.C. Wanki, *UNVDA, Ndop, Republic of Cameroon.*
Dr. S.Q. Zaidi, *Anambra/Imo State (World Bank) Rice Project, Enugu, Nigeria.*

Research Fellows and Scholars

C.J. Adja *(d)*
D. Akibo-Betts *(a)*
B.A. Alavo *(d)*
A.M. Alghali *(a)*
J. Ayuk-Takem *(a)*
A.M.D. Barry *(e)*
M.A. Kane *(e)*
L.K. Keita *(e)*
M. Keita *(e)*
G.B. Kouakanou *(d)*
G.N. Ngala *(c)*
K.I. Nwosu *(a)*
S. Nzuonkwelle *(b)*
V.A.P. Okoth *(e)*
M.O. Sow *(e)*
M.N. Ukungwu *(a)*
S.P.C. Wanki *(a)*

Grain Legume Improvement Program

Collaborators

Dr. A.E. Akingbohungbe, *University of Ife, Nigeria*
Prof. M. Alexander, *Cornell University, USA.*
Dr. C. Atkins, *University of Western Australia, Australia.*
Prof. B. Boutler, *University of Durham, U.K.*
Mr. O. Dina, *NCRI, Moor Plantation, Nigeria.*
Dr. A.R.J. Eaglesham, *Boyce Thompson Institute, USA.*
Dr. A.M.R. Gatehouse, *University of Durham, U.K.*
Dr. T.A. La Rue, *Boyce Thompson Institute, USA.*
Prof. O. Leleji, *IAR, Samaru, Nigeria.*
J. Meyer, *Catholic University of Louvain, Belgium.*
Prof. D.N. Munns, *University of California at Davis, USA.*
Dr. J.A. Odebiyi, *University of Ibadan, Nigeria.*
Dr. E.O. Osisanya, *University of Ibadan, Nigeria.*
Dr. G. Quinn, *APEMPU, Kaduna, Nigeria.*
Dr. R.J. Summerfield, *University of Reading, U.K.*
Dr. W.E. Taylor, *Director, ACRE Project, Njala University, Sierra Leone.*
Dr. Wilfred Schwiebert, *GTZ Project, Togo.*

Research Fellows and Scholars

O. Adjadi *(d)*
A.K. Ansari *(a)*
B. Asafo-Adjei *(b)*
H. Asumadu *(e)*
S. Dassou *(d)*
G. Gumisiriza *(e)*
W.N.O. Hammond *(b)*
Issa Drabo *(c)*
S. Kundaiker *(b)*
C. Lambot *(d)*
C.N. Nebane *(a)*
S. Njinyam *(b)*
B.R. Ntare *(a)*
O.J. Owa *(e)*
A.B. Salifu *(b)*
D. Shannon *(a)*
J.J. Sweet *(e)*
M. Ta'Ama *(a)*
K. Traore *(e)*

Genetic Resources Unit

Collaborator

International Board for Plant Genetic Resources (IBPGR)

Research Fellows and Scholars

F. Attere *(c)*
A. Laloux *(d)*

Virology Unit

Research Fellow

F. Anno-Nyako

Analytical Services Laboratory

Research Training Associate

J.P. Ouaka

(a) Research Fellow (Ph.D. candidate).
(b) Research Scholar (M.S. candidate).
(c) Research Scholar (M. Phil. candidate).
(d) Research Scholar (Ir. candidate).
(e) Research Training Associate.

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Virology Unit

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Major Seminars

Presented at the Institute by IITA scientists or by visiting scientists during 1981.

6 Feb.	*Rural development problems and agricultural sciences.* (C.H.H ter Kuile)
6 Feb.	*Insect pests of maize in Egypt.* (S. El-Sherif)
7 March	*Central American plant genetic resources conservation: why, what and how.* (J. Engels)
16 March	*Farming systems research in the savannas of Senegal and Mali - methodology adopted and experience gained.* (P Kleene)
23 March	*Production factors limiting farmer's yields of rice, maize and cotton crops in Pakistan.* (M. Ashraf)
24 April	*Basic data and the problem of research priorities.* (P. Ay)
21 May	*Education and training in African agriculture and the role of IITA in the process.* (A.P Uriyo)
5 June	*Thirty-five years with Rhizobium inoculant industry.* (J.C. Burton)
10 July	*The importance of linear programming as a tool for economic evaluation of improved technologies in Africa: The example of different zero-tillage packages.* (H C. Knipscheer)
18 Sept.	*Cropping systems research at IRRI.* (J.C Flinn)
23 Oct.	*Science and technology in AID.* (J.M Yohe)
23 Oct.	*Integrated small farming systems on marginal lands in the humid tropics.* (J. Bishop)
4 Dec.	*Rural storage in the humid tropics: problems and partial solutions.* (R.D. Bowers)

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