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Foreword

For the first time in this quinquennium, the overall financial position of the Institute has taken an upward swing. This reversal has made it possible to restore some scientific positions, maintain a full complement of junior scientists, double the participants in training courses, replace obsolete equipment, and make modest improvements in the physical plant—all of which have contributed to improved staff morale and program accomplishments.

The Institute, in preparation for the forthcoming second quinquennial review, has reappraised its long-range plan, evaluated program gains, and has more sharply defined its activity profile for the years ahead. It has escalated the decentralization of a range of activities and is increasing its collaboration with international, regional and national institutes by placing some of its key staff members in strategic locations in order to make the needed impact at national levels. Transcending its classical role in technology generation, the Institute has launched an ambitious program for on-farm research in Africa. The attention of policy makers and research leaders in developing countries is being drawn to the relevance of IITA technology for overall conservation of natural resources and for a rapid step-up in food crop production in Africa.

The Annual Report, Research Highlights and other special publications, such as Appraisal of the Tasks for the Eighties and Food Crisis in Tropical Africa, give an overview of the Institute's research objectives, thrust and output. Readers interested in scientific details not covered in these reports should consult the journal articles listed in the back of this publication or contact the scientists.

IITA has recognized from its inception that the retention of soil organic matter is most crucial for the maintenance of soil fertility in the tropics. As a result of its ongoing farming systems research, the Institute has established that the maintenance of organic matter at adequate levels can be accomplished by various options—no-till farming, alley cropping, live mulches, crop rotations, etc. The Institute has developed plans to put into effect a number of these options at the small farm level both on and off site.

The genetic improvement of crops—maize, rice, cowpeas, soybeans, cassava and yams—has progressed to the point that elite germplasm with several valuable traits is being released to farmers by national programs in Africa and Latin America. The impact of IITA's current crop improvement programs is increasingly evident in many countries in the tropics. However, the great diversity of the African "food basket" leaves no other option for IITA than to simultaneously address the genetic improvement of all the more important food crops, and concentrate at any given time on the most critical production problems in them. The Institute may have to step up its research on starchy bananas, a key food crop in the humid tropics.

Highly significant in IITA's crop protection research is the rapid development of biological control technology against the ravaging insect pest, cassava mealybug. A major regional biological control program will soon be launched by the Institute. Breeding for genetic resistance to cassava mealybug, cassava green spider mite, and bruchids, thrips and aphids in cowpeas is producing equally satisfying results.

The team of scientists and the management at IITA take this opportunity to acknowledge the generous support of its donors and the willing cooperation of innumerable national scientists and policy makers in making it possible for the Institute to be effective in carrying out its mandate.

ERMOND H. HARTMANS
Director General

MAIZE AND RICE are two of the most important cereal crops in Africa. Although the area planted to rice is still relatively small, demand for this crop has been growing steadily. This increased demand reflects the shift in diet that has resulted from urbanization. Maize, one of the leading crops cultivated in Africa south of the Sahara, is widely used for human consumption and is increasingly in demand for poultry feed. Even countries that have not traditionally been maize consumers are becoming interested in growing this crop to reduce reliance on imported supplies in their poultry industries. Both rice and maize have immense potential in Africa for yield improvement and expansion of the area cultivated.

The Cereal Improvement Program at IITA is helping Africa develop that potential by producing improved rice and maize varieties and by seeking solutions to specifically African problems. The program is placing particular emphasis on disease and insect pest resistance and drought tolerance. In these efforts it is working closely with national programs through the High Yielding Varieties Technology (HYVT) Project, which was begun toward the end of 1981 with aid from the European Economic Community (EEC). This year also saw the beginning of a new cooperative program in Cameroon, the National Cereals Research and Extension Project (NCRE), which is being carried out by IITA staff and is funded by USAID.

The program has also benefitted greatly from its involvement with two regional organizations: the Semi-Arid Food Grains Research and Development (SAFGRAD) Project and the West African Rice Development Association (WARDA). The former, which is being carried out by IITA maize scientists, has organized multilocational testing of maize varieties in 24 member countries in the semiarid zone. IITA is participating in WARDA's multilocational testing program and has posted a scientist with that organization.

In 1982 the Cereal Improvement Program continued to work closely with the International Rice Research Institute (IRRI), Institut de Recherches Agronomiques Tropical (IRAT) and Centro Internacional de Majoramiento de Maiz y Trigo (CIMMYT). All three of these institutes have scientists at IITA participating in its research.

The program also continued cooperative work with its host country, Nigeria. IITA scientists actively participated in annual meetings and workshops of the Nigerian National Cereals Research Institute (NCRI) and the National Accelerated Food Production Project (NAFPP). Improved rice and maize varieties developed at IITA are now being nominated for nationwide trials, and breeder seeds are being supplied to the National Seed Service. Close links were also established with the World Bank-supported Agricultural Development Projects (ADPs). An entirely new dimension was added to the program in 1982 when a special project for developing hybrid maize varieties was initiated at IITA, with the support of the Nigerian government.

Rice

The principal objective of IITA's rice improvement program is to increase rice production in Africa through research on dryland, hydromorphic and irrigated/shallow swamp ecologies. Our strategy for solving the problems that limit rice yields is first to develop superior adapted varieties that have resistance to stresses common in rice growing regions and second to come up with appropriate cultural practices that improve the performance of those varieties.

In 1982 screening for important African problems, such as blast, rice yellow mottle virus (RYMV), stalk-eyed fly (*Diopsis thoracica*), drought, soil acidity, iron toxicity and cold, received greater emphasis. A wide range of germplasm, introductions and breeding materials from various national and international crop improvement programs was systematically screened, and several cultivars that are tolerant to the above problems were identified.

High tolerance to RYMV was found to be associated with *O. glaberrima* and with *O. sativa* cultivars that are adapted in Africa and their derivatives, such as the ITA cultivars. Most introductions, however, proved to be either susceptible or only moderately tolerant when seedlings were innoculated. A mass screening technique for *Diopsis* was developed, and a number of promising cultivars were identified.

In addition to developing cultivars that are tolerant to iron toxicity through conventional breeding methods, IITA rice researchers irradiated with gamma rays seeds of Gissi 27, a local selection from Liberia that is highly tolerant to iron toxicity. Among the mutants, semidwarfs and photoperiod insensitive selections were identified.

Because drought was severe in 1982, we were able to evaluate a large number of breeding lines for drought resistance in several locations and identify new promising selections. This work confirmed our previous observations that ITA 116, 117, 118, 135 and 235, among others, have high drought resistance.

Systematic screening for adaption to low pH, acid soil was begun at our high rainfall station at Onne in strips varying in soil pH with and without applied P_2O_5 fertilizer. The unadapted cultivars showed very poor vigor, produced highly discolored grains or dirty panicles and suffered from blast, leaf scald and sheath diseases. This work is showing promise and will be continued.

As part of the recently begun NCRE project in Cameroon, IITA researchers evaluated for tolerance to cold, sheath rot, blast, leaf scald and drought.

Their tests indicated that the primary need is to incorporate resistance to sheath rot and blast into cold tolerant cultivars in Africa. The superior cultivars emanating from the various screening tests are being included in the hybridization program and evaluated for direct use by national programs.

Two major events in which the rice program took part in 1982 were the Upland Rice Workshop and Monitoring Tour, which was sponsored by IRRI, IDESSA/IRAT (Institut des Savanes), IITA and WARDA, and the High Yielding Varieties Technology Project Workshop.

Participants in the Upland Rice Workshop and Monitoring Tour observed differences among upland rice environments and proposed that breeding for upland rice be done on a regional basis. The HYVT Project Workshop proposed that IITA pay special attention to the major problems with rice production in all ecologies of eastern, central and southern Africa.

Rice trials were organized in cooperation with NCRI/NAFPP, the Agricultural Projects Monitoring, Evaluation and Planning Unit (APMEPU) in Kaduna, and with various river basin development authorities. Through these trials IITA researchers identified superior dryland (ITA 116, 117, 135 and 235), iron toxicity tolerant (ITA 238, 239, 247, 253 and TOx 711-18-18) and irrigated (ITA 121, 123 and 212) rice cultivars that could be used in the future for extensive cultivation.

Genetic Improvement

Early Generation Material

In continuation of their efforts to develop high yielding, high quality rice for African ecosystems, IITA rice scientists evaluated early generation upland rice breeding lines during 1982 at three locations in Nigeria—Onne, Ikenne and Ibadan. Onne is characterized by high monomodal rainfall (>2,400 mm annually), highly weathered acid soils and low solar radiation. Conditions there are similar to those in Liberia, Sierra Leone, Cameroon, Gabon, and Ivory Coast At that location 280 F_3 and 681 F_4 and later generation lines were evaluated. They were sown on 24 May in three-row plots 5 m long. ITA 212 (lowland semidwarf), ITA 117 (early maturity), ITA 116 (medium maturity), LAC 23 (tall African selection), and OS 6 (a farmers' variety) were included as check cultivars. A disease spreader composed of a mixture of blast susceptible cultivars bordered every block.

At Ikenne, which is in the bimodal rainfall zone (1,600 mm annually) and where conditions are like those in Benin, Togo, Ivory Coast and Tanzania, the same breeding materials as those used at Onne were planted on 6 June following the same design. In addition, 95 F_2 populations were planted there on 10 July. The F_2 seeds were lightly drilled, and the row spacing was 40 cm. Tall segregants were eliminated as soon as they were observed.

At Ibadan, as at Ikenne, rainfall is bimodal (1,300 mm annually), but the gravelly soils there have lower water holding capacity than the Ikenne soils. Similar conditions are found in parts of Ivory Coast, Ghana, Benin and Togo. In 1982, 610 F_4 and later generation lines were grown at Ibadan. F_1 plants from 68 crosses were also grown there under paddy conditions.

Because stresses were severe at these locations in 1982, selection pressure was high, allowing only a limited number of outstanding lines to be selected for further evaluation. Blast, leaf scald, sheath rot, and panicle discoloration diseases were prevalent at Onne. Primary emphasis was placed on observation of harvested grain for selection of lines that were free of panicle discoloration. Fifty-three F_3 and 86 F_4 and later generation lines were selected.

At Ikenne and Ibadan, severe drought occurred from mid-July to mid-August. Many lines were in or near the booting stage at that time. Blast and leaf scald were common at both locations, and neck blast, sheath rot, and leaf spot were particularly prevalent at Ikenne. But even under high drought and disease stress, we were able to select 37 F_3 lines and 27 F_4 and later generation lines at Ikenne and 52 F_4 and later generation lines at Ibadan that were superior to the check cultivars. These lines are being multiplied during the dry season and will be included in observational nurseries and/or yield trials in 1983.

The 95 F_2 populations at Ikenne were less affected by stress conditions than those at Ibadan because they escaped drought during the reproduction stage and had wider row spacing. Forty-two single plants were selected from 13 of the populations; 26 single plants and selected bulks from 11 of them; 18 populations were selectively bulked; and 53 were rejected. Selection was based primarily on plant type, large panicles and clean grain. These selections will be screened for blast and RYMV at IITA and included in multilocational trials during 1983.—*K. Alluri and J.W. Gibbons*

Upland Elite Yield Trials

The objective of the upland elite yield trials was to test the adaptability of varieties at several sites in Nigeria (Onne, Ikenne, Ibadan, Ilorin and Zaria) that represent the major upland ecosystems of West Africa. Onne, which is located in the southeastern rain forest, has a long, monomodal rainy season. Ikenne, Ibadan and Ilorin are all in the bimodal zone (at Ibadan the medium duration trial was also grown under hydromorphic conditions). Zaria, which is in the northern savanna has a short, monomodal rainy season.

Two sets of varieties were planted, one of short duration (about 70 days to heading and 100 days to maturity) and another of medium duration (about 95 days to heading and 125 days to maturity). Each set included a typical lowland variety (TOs 103, a short duration variety, and ITA 212, which has medium duration) and OS 6, a common check. Each set was sown in a randomized complete block design, with

four replications at all five locations. Each plot was 15 m^2 with row spacing of 30 cm, and the seeding rate was 50 kg/ha. Fertilizer (15-15-15) was applied at a rate of 300 kg/ha at planting, followed by 100 kg urea/ha one month later. Weeds and pests were controlled as required. The sowing dates ranged from the end of March at Onne to the end of June at Zaria.

Rainfall was high at Onne from sowing through harvest. At Zaria rainfall was adequate from sowing to heading but after mid-September was insufficient for good grain filling. At Ikenne, Ibadan and Ilorin, a very severe drought spell occurred in mid-July to late August. At Onne sheath rot (*Acrocylindrium oryzae*) and glume discoloration syndrome were very severe, resulting in poor grain quality. Leaf scald (*Rhynchosporium oryzae*) and brown spot (*Helminthosporium oryzae*) diseases were common at the other locations, but blast (*Pyriculuria oryzae*) was nowhere evident.

The erratic performance of the short duration varieties can be attributed to variation in stresses across locations. Yields were generally higher at Onne, where there was no drought. ITA 117 and IRAT 112 gave the highest yields, over 3 t/ha (Table 1). Several entries in this trial performed well at Zaria; their short growth duration made them suitable for the short rainy season of that region and enabled them to escape drought. IRAT 112, 133 and 109, TOx 1011-4-1 and ITA 150 each yielded more than 2 t/ha. ITA 117, ITA 132 and TOx 103 gave very low yields at both Ikenne and Zaria on account of their slightly longer duration, which led to drought stress at the grain filling stage. IRAT 133, 109 and 110, TOx 1011-4-1 and ITA 150 yielded 2 t or more at both Ibadan and Ilorin. At the four locations where drought was a

Table 1. Results of upland rice elite yield trials, Nigeria, 1982

	Yield, t/ha						
Variety	Onne	Ikenne	Ibadan	Ilorin	Zaria	Ibadan[a]	Mean
Early maturing							
IRAT 133	2.9	1.6	2.3	3.1	2.6		2.5
IRAT 109	2.8	1.6	2.1	3.4	2.3		2.4
IRAT 112	3.2	1.8	2.0	1.8	2.7		2.3
IRAT 110	2.3	1.7	2.3	2.7	1.9		2.2
TOx 1011-4-1	2.6	1.6	2.1	2.2	2.5		2.2
ITA 150	1.7	2.1	2.0	2.0	2.2		2.0
ITA 120	1.9	1.5	1.8	1.5	1.8		1.7
ITA 117	3.1	0.3	1.2	2.9	0.4		1.6
IAC 25	2.2	1.7	1.9	2.2	—[b]		1.6
ITA 132	2.2	0.3	2.5	1.1	0.4		1.3
TOs 103	2.3	0[c]	1.0	0.7	0.3		1.0
OS 6	1.7	0.2	0.5	1.1	0[d]		0.7
Mean	2.4	1.2	1.8	2.0	1.6		
LSD (5%)	0.3	0.4	0.5	0.4	0.6		
C.V., %	15.4	25.4	35.3	24.0	36.0		
Medium duration							
ITA 141	1.4	1.4	1.1	0.9	0.1	4.2	1.2
ITA 235	0.6	1.2	1.9	1.3	1.1	3.4	1.2
ITA 182	0.6	1.0	1.6	1.3	0.9	2.5	1.1
ITA 138	0.9	1.0	1.2	1.2	0.7	3.2	1.0
ITA 162	1.2	1.2	0.8	0.9	0.9	2.3	1.0
ITA 118	1.5	0.9	1.2	1.0	0.7	3.0	0.9
IRAT 13	1.5	0.5	0.9	1.3	0.3	3.0	0.9
ITA 142	0.8	2.2	0.1	0.7	0.1	3.3	0.8
TOx 718	0.3	0.5	1.2	0.7	0.4	2.6	0.8
ITA 116	0.9	0.7	0.3	0.8	0.7	3.4	0.7
IR 52	1.5	1.8	0[c]	0.1	0[c]	4.4	0.7
ITA 256	0.8	1.7	0.2	0.4	0.1	4.0	0.6
OS 6	0.3	0.6	0.5	0.7	0.1	3.0	0.4
ITA 178	0.9	1.1	0.7	—[b]	0.6	5.2	
ITA 212	2.0	2.1	0.3	—[b]	0[c]	6.8	
Mean	1.0	1.2	0.8	0.8	0.6	3.2	0.9
LSD (5%)	0.2	0.2	—	0.3	0.5		
C.V., %	33.22	27.0	—	42.9	54.2		

[a]At Ibadan medium duration varieties were tested under hydromorphic as well as upland conditions.
[b]Not tested.
[c]Drought sterility.
[d]Plots missing.

problem, IRAT 133, 109, 112 and 110, TOx 1011-1 and ITA 150 gave consistently better yields than the other varieties.

The performance of medium duration varieties across locations was even more erratic than that of the short duration varieties. Four varieties, ITA 118, IRAT 13, IR 52 and ITA 212, yielded 1.5 t/ha or more at Onne, where drought stress was minimal (Table 1). Low yields at Ikenne, Ibadan and Ilorin were due largely to drought, associated with panicle discoloration, which resulted in poor grain filling. At all three locations, the performance of ITA 235 was superior because of its high degree of drought tolerance. ITA 141, 182 and 138 also gave good yields in spite of severe drought at all three locations. All the test entries performed very poorly at Zaria for two reasons. First, the growth duration of the varieties was too long for that region's short, monomodal rainfall pattern. And second, drought stress was unusually severe during 1982. As at other locations, ITA 235 gave the highest yield because of its high degree of drought tolerance. IR 52 and ITA 212 were comparatively sterile at Ibadan and Zaria because of severe drought stress at grain filling.

These two trials indicate that in 1982 the early duration varieties generally performed better than the medium duration varieties because they escaped drought, especially at the grain filling stage.—*J. Arrivets, K. Alluri and J.W. Gibbons*

Screening for Acid Upland Soils

Thirty-one cultivars and 30 F_4 and later generation lines from IITA and 30 entries in IRRI's acid upland screening set were screened for acid tolerance at IITA's high rainfall station at Onne, Nigeria. Each entry was sown in two rows 4 m long in a control (pH 4.6) and an acid strip (pH 3.9). Nitrogen was applied at a rate of 60 kg/ha on both areas, and 60 kg P_2O_5/ha was applied on the control strip only. Vigor and panicle exertion scores, panicle number, plant height, days to 50% flowering and plant yields were recorded. Yields and panicle number tended to be lower in the acid strips, although the following entries were less affected than the others by the acid conditions: ITA 118, 117, 132, 134, 235, 141, 142, 150, 162, 178, 212, TOx 936-97-3-1, TOx 1011-4-1, TOx 1012-12-3, TOx 1177-17-1, three lines from TOx 1766, CICA 8, IR 11288B-6-288-1, IR 36, IR 43, IR 52, IR 5931-110-1, and IR 6032-10-1-1.

Observations made during 1981 at David, Panama, on soils with pH 4.5 and high aluminium in the international upland rice observational nursery (IITA, Annual Report for 1981) indicated that ITA 116, 117, 118, 225, 235, IRAT 13, IAC 197 and Azucena were superior among the 100 entries evaluated.

Similar observations were made in Peru this year. All of these ITA lines were selected at Onne. The results indicate that superior selections can be made at Onne for acid tolerance. This work will be intensified by the IITA rice scientist now posted at Onne.—*K. Alluri and J.W. Gibbons*

Lowland Observational Nurseries

Lowland observational nurseries were conducted at Ibadan under hydromorphic conditions in cooperation with the Animo Rice Project (funded by the World Bank) at Amaeke Abam (near Bende) and Uzo-Uwani in Nigeria. At the latter two locations the nurseries were in rice farmers' fields. At Ibadan the nursery was composed of 221 lines from 26 F_4 and later generation families and of 54 introductions from international trials. IR 50, ITA 212, ITA, 123, and ITA 121 were included as checks. Twenty-six lines from 10 F_4 and later generation families and 30 introductions from international trials were grown at Amaeke Abam and Uzo-Uwani. Plot size was 5 m^2 at Amaeke Abam and Ibadan and 2.3 m^2 at Uzo-Uwani. Plant spacing was 25 cm × 20 cm. The trial was unreplicated. Plant height, panicle number per plant, days to 50% flowering, plot yield, vigor, and leaf and neck blast scores were recorded.

The major stresses were leaf and neck blast, leaf scald, and brown spot diseases at Ibadan and imbalanced soil nutritional status (particularly low N and high Fe) resulting from fluctuations in the water table and improper drainage. Under these conditions 67 selections were made from 17 families and 10 selections from the introductions. These selections will be advanced to preliminary yield trials in 1983. In addition, seven lines from these trials were included in the crossing program to be used as sources for disease resistance, yield potential and plant type characteristics.

Lowland Advanced Yield Trials

For the advanced yield trials carried out in 1982, 35 superior cultivars were selected from the 1981 varietal trials of IITA, WARDA, IRRI and national programs. The cultivars were divided into three trials based on their maturity time. The short duration trial (100 to 115 days) consisted of 11 cultivars, and the medium (116 to 135 days) and long duration (136 days and above) trials were each composed of 12 cultivars. These trials were conducted at Ibadan (one irrigated and one hydromorphic location) and at two other Nigerian locations, Bende and Uzo-Uwani, in cooperation with the Animo Project.

In all trials 30 kg/ha each of N, P_2O_5 and K_2O were applied before transplanting and 20 kg N/ha were applied twice at three and six weeks after planting. A randomized complete block design was used with three replications; plant spacing was 25 cm × 20 cm.

Water control in the irrigated paddies at Ibadan was optimal, and no severe stresses occurred. The hydromorphic trial was damaged by birds and rats, so the results are not reported here. At Bende and Uzo-Uwani, water control was suboptimal, closely approximating farmers' conditions.

In the long duration trial, ITA 236 and ITA 239 ranked highest in yield, on the average, across the three locations, followed by IET 6279 from India and

Table 2. Results of lowland rice advanced yield trials, Nigeria, 1982

Cultivar	Yield, t/ha				At Ibadan	
	Ibadan	Bende	Uzo-Uwani	Average	Plant height, cm	Days to maturity
Medium duration						
ITA 222	6.91	5.79	[illegible].74	5.48	104	124
BG 90-2 (check)	6.69	4.68	5.03	5.47	104	122
Cisadane	5.47	5.44	5.33	5.41	118	130
ITA 212	6.36	4.48	4.69	5.18	100	123
6838	6.00	4.68	4.53	5.07	103	120
ITA 121	5.29	5.17	4.03	4.83	105	123
IR 4422-98-3	4.77	4.88	5.50	5.05	114	130
IR 42	4.45	4.99	5.02	4.82	106	130
IR 17488-2-3-2	4.90	5.17	3.94	4.67	99	130
TOs 78	4.21	4.29	5.01	4.50	96	122
ITA 231	5.84	3.09	4.19	4.37	99	121
ITA 123	5.15	3.04	3.05	3.75	104	115
LSD (5%)	1.49	1.06	1.18			
C.V., %	16.0	13.5	15.4			
Long duration						
ITA 236	5.96	5.87	4.65	5.49	122	132
ITA 239	6.19	5.58	4.65	5.47	130	132
IET 6279	4.77	6.75	4.70	5.41	128	142
IR 5 (check)	5.35	5.40	5.31	5.36	125	138
ITA 238	5.32	5.57	4.64	5.18	127	137
ITA 240	4.85	5.50	4.95	5.10	134	141
ITA 253	5.01	5.18	5.10	5.10	135	135
FARO 15 (check)	5.48	5.35	4.36	5.06	135	139
ITA 247	5.10	5.28	4.69	5.02	142	145
ITA 245	4.84	4.83	4.82	4.83	116	137
ITA 249	4.26	5.24	4.63	4.71	136	135
ITA 237	4.15	5.08	4.24	4.49	119	137
LSD (5%)	2.17	1.13	0.73			
C.V., %	25.1	12.2	9.2			

IR 5 (check) from IRRI (Table 2). At Ibadan there were no significant differences between cultivars. At Bende IET 6279 was superior in yield to all the cultivars tested, except ITA 236. At Uzo-Uwani the two highest yielders, IR 5 (check) and ITA 253, performed significantly better than the check FARO 15 and ITA 237.

In the medium duration trial, ITA 222, BG 90-2 (check), Cisadane and ITA 212 gave the best yields (Table 2). But the two top yielders, ITA 222 and BG 90-2, have two common defects: they are susceptible to blast disease, and their grains are chalky. Cisadane performed well at all three locations. ITA 212, as stated in last year's IITA Annual Report and again elsewhere in this report, is moderately resistant to blast, and its grains are not chalky. ITA 123, which was superior in last year's trials and this year in Cameroon, suffered from rat damage at Bende and Uzo-Uwani.

The short duration trial was conducted only at Ibadan. Three cultivars, FARO 27, KN 144 and IR 2042-178-1, yielded more than 6.0 t/ha (Table 3). In the past little emphasis has been placed on early maturity since most traditional African farmers grow only one rice crop per year. However, construction of irrigation dams and initiation of certain agricultural development projects has encouraged farmers to attempt to grow two or three rice crops a year. Emphasis will be given to identifying and developing short duration cultivars.—*K. Alluri and J. Arrivets*

Table 3. Results of a lowland rice advanced yield trial, short duration, IITA, 1982

Cultivar	Yield, t/ha	Plant height, cm	Days to maturity
KN 144	6.59	110	112
IR 2042-178-1	6.58	104	106
TOs 103 (FARO 27)	6.04	79	98
Taichung San Yu	5.87	95	95
Bouake 189	5.49	114	111
BPT 1235	5.30	93	97
BG 367-4	4.82	100	94
IR 36	4.33	100	93
IR 50	3.93	92	110
BKNLR 75001-83	3.42	101	94
BG 276-5	3.31	99	90
LSD (5%)	2.08		
C.V., %	24.1		

Screening for Iron Toxicity Tolerance

Screening for iron toxicity tolerance was conducted at two locations in Nigeria, Ito-Ikin and Bende. At Ito-Ikin 24 F_3 lines from seven families and 24 F_4 lines from TOx 711 were sown in two replications on 31 July, with plant spacing of 25 cm × 20 cm. The iron toxicity screening set from IRRI, which is composed of 20 lines, was also sown. Iron toxicity scoring was done with IRRI's IRTP Standard Evaluation System. In addition to the screening test at Ito-Ikin, 10 IITA cultivars and FARO 15, a local check, were grown in large plots of 120 m^2. On 6 July the seeds were drilled at a row spacing of 30 cm. The plots were flooded when plants were 15 cm tall. At Bende small plot size (4 m × 6 m) allowed testing only of selected advanced lines and cultivars. At both locations susceptible (IR 5) and resistant (IR 36) checks were included for comparison of toxicity symptoms.

Eighteen single plants from four F_3 families that had green leaves and good tillering were selected at Ito-Ikin for advancement and further testing in 1983. Among TOx 711 F_4 lines, nine had good Fe toxicity ratings as well as other desirable traits such as earliness and vigor. These lines will be screened for blast and RYMV and included in preliminary yield trials and in our breeding program. IR 48, IR 4227-109-1-3-3, IR 14632-2-3 and B 2149b-Pn26-1-1 were the superior selections from the IRRI set. These require further testing for adaptability to African conditions. In the large-plot yield trials, iron toxicity, sheath rot and brown spot were major stresses. ITA 121 and ITA 247 each yielded 3.0 t/ha, and ITA 250 yielded 2.7 t/ha in spite of stress conditions. The check, FARO 15, produced 1.9 t/ha. At Bende, where the susceptible check IR 5 did not grow, ITA 238, 239, 246, 247 and TOx 711-18-18 exhibited fewer symptoms than the resistant check IR 36.—*J. W. Gibbons*

International Trials

IITA cooperated with other international institutes—IRRI, WARDA and Centro Internacional de Agricultura Tropical (CIAT)—by exchanging germplasm; conducting the International Rice Testing Program (IRTP) trials, which are coordinated by IRRI, and the coordinated varietal trials and initial evaluation tests of WARDA; and by nominating entries for these testing networks. Table 4 shows the number of IITA lines nominated for the various trials in 1982.

All WARDA and IRTP trials were conducted at Ibadan, except the screening for tolerance to acid upland soil at Onne and to iron toxicity at Ito-Ikin. Irrigated rice yield nurseries had three replications, while upland yield nurseries had four, with a randomized plot design. Observational nurseries and initial evaluation tests were evaluated in two-row plots 5 m long. The results of those trials are presented in the paragraphs below.

WARDA coordinated varietal trial, upland, moist zone, short duration. This trial consisted of six entries from IRAT, seven from IITA, and two from other sources. All suffered severe drought stress at the tillering stage and intermittent drought stress at the reproductive stage. The dwarf variety DJ 12-539-2 from Djibelor, Senegal, produced the highest yield, while IRAT 109, ITA 132 and ITA 118 gave yields of more than 3 t/ha (Table 5). Drought tolerance ratings were highest for ITA 235, TOx 718-1-23 and IRAT 110, all of which had good panicle exertion under severe drought. IITA lines in general had better grain characteristics (grain length and translucency) than IRAT lines. Among IRAT entries, IRAT 112 had the best grain characteristics. Despite severe drought, leaf and neck blast were minimal in the test. IRAT 110 and IRAT 133 were moderately susceptible to grain discoloration and sheath rot.

WARDA coordinated varietal trial, upland, moist zone, medium duration. This trial consisted of nine entries from IRAT, three from IITA and three from other sources. Severe drought stress occurred at the tillering stage and intermittent drought stress at the reproductive stage. SEL IRAT 194/1/2 produced the highest yield, followed by IRAT 104, 156, 170 and 138, all of which yielded more than 3 t/ha and significantly more than the check variety ITA 141 (Table 5). The entry R9-1-6-1-3-1-1, because of its long growth duration and consequent high grain sterility, gave the lowest yield. ITA 162 was the only IITA line that gave higher yields than the check. SEL IRAT 194/1/2, IRAT 104 and IRAT 170 were observed to be very good in drought recovery. Leaf and neck blast were insignificant in this trial. IRAT 169 was moderately susceptible to sheath rot. ITA 162, IRAT 132 and ITA 141 were superior to the other entries in grain length and endosperm chalkiness.

WARDA coordinated varietal trial, moist zone, irrigated, short duration. In this trial, which included 15 entries, with IR 36 as the check, KN 144 produced the highest yield (7.2 t/ha), followed by BR 541-BKN-19-3-4 (6.8 t/ha) and IR 2928-7-3-1-1 (6.6 t/ha). IR 36, the earliest of the entries tested, was damaged

Table 4. Number of IITA lines nominated for international rice trials, 1982

Name of trial	Number of varieties
International rice observational nursery (IRON)	11
International upland rice observational nursery (IURON)	12
International rainfed lowland rice observational nursery (IRLRON)	8
International rice blast nursery (IRBN)	21
WARDA initial evaluation tests	
Upland	42
Irrigated	36
WARDA coordinated varietal trials	
Upland savanna	4
Upland moist zone, short duration	2
Upland moist zone, medium duration	2
Sahel	2
Moist zone, irrigated	4

by birds, so the yield figure listed in Table 6 does not reflect its true yield potential. KN 144 also produced the highest yield (7.3 kg/ha) in the 1981 WARDA coordinated varietal trial at Ibadan. BR 508-B-2-9 lodged very badly in this trial even before flowering, in spite of its intermediate stature (110 cm). Two other selections that produced higher yields than the mean, TOs 103 (from IR 790-35-5-3) and IET 4056, possessed superior grain quality.

WARDA coordinated varietal trial, moist zone, irrigated, medium duration. In this trial of 15 entries, IR 4422-98-3-6-1 gave the highest yield (8.4 t/ha), as shown in Table 6, followed by ITA 212 (7.6 t/ha) and Bouake 189 (7.2 t/ha). IR 4422-98-3-6-1 and ITA 212 also produced the highest yields (5.8 and 4.9 t/ha, respectively) in the 1981 WARDA irrigated, medium duration trial, which was conducted at 14 different locations in West Africa. ITA 212 was slightly shorter in growth duration and plant height than IR 4422-98-3-6-1, but both had excellent grain characteristics. Bouake 189, an IRAT nomination, was a selection from B 189b-52-8-3-1 from the Philippines.

WARDA initial evaluation test, upland. This trial consisted of 99 entries from IRAT, IITA, the IRTP trials and national breeding programs in West Africa. The trial suffered severe drought stress at the tillering stage and intermittent drought stress at the

Table 5. Results of WARDA coordinated varietal trials, upland, moist zone, 1982

Variety	Yield, kg/ha	Plant height, cm	Growth duration, days	Drought tolerance, 0 to 9	Glume discoloration, 0 to 9	Sheath rot, 0 to 9	Grain length, 1 to 7	Chalkiness, 0 to 9
Short duration								
DJ 12-539-2	3,240	80	120	5	3	1	5	9
IRAT 109	3,133	91	115	3	3	3	5	9
IRAT 110	1,656	78	100	1	5	5	5	5
IRAT 112	2,678	93	105	3	1	5	3	1
IRAT 133	2,440	83	105	5	5	5	5	9
IRAT 144	2,322	100	107	3	3	1	3	5
IRAT 146	1,926	91	115	5	1	3	3	5
ITA 117	2,547	87	120	5	1	1	3	1
ITA 116	2,355	115	130	3	1	1	3	1
ITA 132	3,037	110	123	5	1	3	5	5
ITA 235	3,101	102	123	1	1	0	3	1
M 55	2,742	105	102	3	1	3	5	9
TOx 1011-4-2	2,354	84	103	5	1	5	3	5
TOx 718-1-23	2,947	95	125	1	3	0	3	0
ITA 118 (check)	3,015	95	120	3	1	3	3	5
Mean	2,633							
LSD (5%)	513.5							
C.V., %	13.69							
Medium duration								
SEL IRAT 194/1/2	3,453	102	135	3	1	3	5	1
IRAT 104	3,339	120	131	5	1	0	7	9
IRAT 156	3,242	106	130	3	1	1	5	0
IRAT 170	3,141	101	130	5	1	3	7	1
IRAT 138	3,008	104	125	5	1	1	5	5
ITA 162	2,910	104	128	5	1	0	3	1
IRAT 132	2,694	102	135	3	3	1	3	1
IRAT 168	2,674	120	125	5	1	1	3	5
ITA 141 (check)	2,469	105	130	5	1	1	3	1
IRAT 169	2,455	100	123	5	3	5	5	5
IRAT 136	2,376	94	134	3	1	1	5	1
C 22	2,261	105	136	3	1	1	5	1
DJ 11-509	1,940	61	112	3	5	1	7	1
ITA 256	1,865	94	139	3	1	1	7	9
R 9-1-6-1-3-1-1	585	86	150	5	3	1	7	1
Mean	2,561							
LSD (5%)	515.5							
C.V., %	14.08							

Note: The rating scales for drought tolerance, glume discoloration, sheath rot, grain length and grain chalkiness are adapted from IRRI, Standard Evaluation System for Rice, International Rice Testing Program, Second Edition.

Table 6. Results of WARDA coordinated varietal trials, moist zone, irrigated, 1982

Variety	Yield, kg/ha	Plant height, cm	Growth duration, days	Lodging, 1 to 9	Grain length, 1 to 7	Chalkiness, 0 to 9
Short duration						
KN 144	7,238	109	118	1	5	5
BR 541-BKN-19-3-4	6,753	112	115	1	5	5
IR 2928-7-3-1-1	6,554	125	137	1	5	1
B 2360-8-5-LR 4-3	6,026	106	125	3	5	5
CR 1022	6,013	113	127	3	7	1
TOs 103	5,974	90	111	1	3	1
BR 24-2-1	5,936	90	115	1	3	5
IET 6056	5,827	117	130	3	5	0
TOx 516-19 SLR	5,824	104	125	1	7	5
IET 4506	5,707	100	111	1	3	1
CNM 31	5,680	97	115	1	5	5
BR 20-29-2	5,539	99	123	1	5	0
IET 3137	4,657	87	108	1	5	1
IR 36 (check)	4,247	99	105	1	5	1
BR 508-B-2-9	594	110	112	9	5	5
Mean	5,505					
LSD (5%)	891.4					
C.V., %	9.6					
Medium duration						
IR 4422-98-2-6-1	8,450	118	139	1	3	1
ITA 212	7,584	103	130	1	3	1
Bouake 189	7,178	115	125	1	5	1
Nigersail	6,920	115	142	3	5	1
ITA 123	6,865	106	125	1	5	1
B 2360-9-8-5	6,611	120	131	1	5	9
BW 248-1	6,584	136	124	5	5	5
Farox 188A	6,417	116	139	1	3	1
ITA 245	6,386	109	118	1	3	1
BR 168-2B-23	6,319	101	127	1	5	9
ITA 231	6,132	104	122	1	3	1
IR 2071-586-5-6-3 (IR 42)	6,082	115	128	1	3	1
BR 13-47-3	5,539	132	109	3	5	0
TOs 103 (check)	5,342	78	111	1	3	1
IR 9782-144-3-3-3	3,822	83	106	1	3	0
Mean	6,415					
LSD (5%)	868.5					
C.V., %	8.1					

reproductive stage. Leaf and neck blast were minimal. Sheath rot and glume discoloration were moderate. Panicle exertion and grain filling were observed to be poor in many entries because of drought stress. Twenty-eight entries were selected for drought tolerance and recovery, growth duration, panicle exertion, grain filling and resistance to dirty panicle syndrome. These selections will be further evaluated in the breeding program.

WARDA initial evaluation test, irrigated. This trial was originally composed of 252 entries from the IRTP, IITA and the All-India Coordinated Rice Improvement Program and a few entries from national breeding programs in Africa, Asia and Latin America. Of these entries 32 were destroyed by the Plant Quarantine Station at Ibadan for reasons of seed health. Insect and disease pressure as well as soil stresses were insignificant. Thirty-four entries were selected for vigor, plant height, growth duration, resistance to lodging, panicle characteristics and grain type. Those selections will be further evaluated and used in the breeding program.

International rice yield nursery, very early duration (IRYN VE 82). This nursery consisted of 27 entries from national breeding programs in China, India, Sri Lanka and Taiwan and from IRRI, including one international check, IR 50. The local check was TOs 78, a selection from IR 269-26-3-3-3. IR 50 gave the highest yield (6.8 t/ha), as shown in Table 7. IR 9752-71-3-2 (6.4 t/ha) and BG 276-5 (6.3 t/ha) were second and third in yield. IR 50, IR 9752-71-3-2, BG 276-5 and IR 9729-67-3 were among the best yielders in the 1981 IRYN very early trials in 17 Asian and African countries. BG 276-5 and 367-7 had short, bold,

Table 7. Performance of selected entries in international rice yield nurseries, irrigated, IITA, 1982

Variety	Yield, kg/ha	Plant height, cm	Growth duration, days	Yield per day, kg/ha	Grain length, 1 to 7	Chalkiness, 0 to 9
Very early duration						
IR 50 (international check)	6,839	93	102	67	3	1
IR 9752-71-3-1	6,448	82	100	64	3	1
BG 276-5	6,275	105	109	58	7	9
BG 367-7	6,193	107	101	61	7	9
HPU 741	5,889	94	96	61	3	1
IR 9729-67-3	5,830	91	95	61	3	5
RP 1674-4038-78-3	5,596	89	91	61	3	1
Kaohsiung Sen Yu 252	5,544	109	112	50	3	1
IR 19743-46-2-3-3-2	5,368	96	93	58	3	1
ZHU-XI	5,354	81	87	62	5	9
TOs 78 (local check)	4,916	132	125	39	3	5
Mean	4,899					
LSD (5%)	1,305.9					
C.V., %	16.31					
Early duration						
Kaohsiung Sen 7	5,957	98	118	51	1	5
UPR 82-1-7	5,467	96	115	48	3	0
IR 9828-91-2-3	5,253	85	114	46	1	1
IR 13240-82-2-3-2-3-1	5,241	81	113	46	5	1
IR 21015-80-3-3-1-2	5,181	100	114	45	3	0
IR 13429-196-1	5,176	101	111	47	3	0
Tainung Sen 12	5,115	101	118	43	3	9
TOs 103 (local check)	5,135	83	112	46	3	1
PK 95-29-2-1-1-2	4,959	81	118	42	3	1
Chianung Sen Yu 13	4,957	105	117	42	3	5
IR 36 (international check)	4,579	90	108	46	3	1
Mean	4,282					
LSD (5%)	890.7					
C.V., %	12.72					
Medium duration						
IR 54	7,235	111	121	60	3	0
IR 19670-263-3-2-2-1	6,875	114	125	55	3	5
BG 400-1	6,814	127	125	55	5	5
IR 22082-41-2	6,536	113	117	56	3	1
RP 1017-76-1-3-2	6,528	141	122	54	7	1
ITA 212 (local check)	6,404	107	121	53	5	3
B 2489B-PN-1-76-8	6,366	142	123	52	5	5
RP 1082-24-1-1-1	6,362	103	121	53	5	5
IR 13540-56-3-2-1	6,269	119	115	55	7	9
MR 24	6,228	130	121	51	7	0
IR 42 (international check)	6,158	116	126	49	3	0
Mean	5,867					
LSD (5%)	825.59					
C.V., %	8.59					

chalky grains, while IR 50, HPU 741 and IR 9752-71-3-1 had long translucent grains. Four varieties (IR 50, IR 9752-71-3-2, HPU 741 and RP 1674-4038-78-3) that had very short growth duration (91 to 102 days) and good grain quality would be worth testing in an irrigated double cropping system.

International rice yield nursery, early duration (IRYN E 82). This nursery consisted of 27 entries from national breeding programs in Bangladesh, India, Pakistan and Taiwan and from IRRI, including one international check, IR 36. The highest yielder was Kaohsiung Sen-7 from Taiwan, followed by UPR 82-1-7 from India, both of which are dwarf varieties with growth duration of about 120 days (Table 7). TOs 103, the local check, performed better than IR 36. However, all the high yielders in this trial were about one week longer in maturity than IR 36. None of the entries in this experiment produced significantly higher yields than the local check. IR 9828-91-2-3, which had excellent grain

quality, was also one of the high yielders in the 1981 IRYN early trials at several locations in Asia and West Africa.

International rice yield nursery, medium duration (IRYN M 82). The 27 entries in this nursery were nominated by national breeding programs in Bangladesh, Brazil, India, Indonesia, Malaysia, Sri Lanka and Taiwan and by IRRI. The international check was IR 42, and the local check was ITA 212 (Table 7). IR 54 gave the highest yield (7.2 t/ha), followed by IR 19670-263-3-2-2-1 (6.9 t/ha) and BG 400-1 (6.8 t/ha). ITA 212 ranked sixth in yield, with 6.4 t/ha, while IR 42 produced 6.2 t/ha. Of the top 10 entries in yield, IR 54, IR 22082-41-2 and ITA 212 had the best grain quality. IR 54 was among the top five entries for yield in 20 Asian and African locations in the 1981 IRYN medium duration trials.

International rice observational nursery (IRON 1982). This nursery had 350 entries from 20 countries and from IRRI, IITA and CIAT. Growth duration ranged from early (less than 120 days) to medium/late (more than 120 days). The varieties used as local checks were ITA 212, ITA 123 and TOs 103. Insect and disease pressure and soil stresses were minimal. Sixty-five entries were selected for vigor, plant height, growth duration, resistance to lodging, panicle characteristics and grain type. These selections will be further evaluated and used in the breeding program.

All the trials for which results are presented in the foregoing paragraphs were conducted at IITA in 1982. The experiments discussed in the following paragraphs were carried out in 1981 at other locations.

WARDA initial evaluation test, upland. A total of 49 entries from IITA's upland rice breeding program were nominated for WARDA's upland initial evaluation trials, which were conducted at 11 sites. Of the 174 entries, ITA 233 gave the highest average yield of 371 g/m^2. Of the top 25 entries, 13 came from IRAT, 5 from IITA, 4 from IRRI and 3 from other sources. Four outstanding IITA lines were ITA 178, 230, 231 and 130.

WARDA initial evaluation test, irrigated. This trial, which included 216 entries, was conducted at 11 sites. There were 14 nominations from IITA's lowland rice breeding program. IR 14632-22-3 gave the highest average yield of 511 g/m^2, followed by IR 15529-256-1 and IR 9784-142-1-3-3. The best performers among the IITA lines were ITA 252 (434 g/m^2), followed by ITA 250 (433 g/m^2) and ITA 240 (416 g/m^2).

WARDA coordinated varietal trials. IITA participated in the coordinated varietal trial network of WARDA by nominating entries from the Institute's breeding program. The entries nominated for the upland trials were ITA 116 and 117; those nominated for the Sahel, irrigated, short and medium duration trials were TOx 504-21-120-B-B, TOs 4688, ITA 230 and ITA 232. The nominations for the moist zone, irrigated, short and medium duration trials were ITA 212, ITA 123, TOx 514-16-101-1 and TOx 504-21-120-B-B. Under dryland conditions ITA 116 and 117 were found to be average performers, with yields of 2.5 to 3.5 tons at several locations. ITA 230, the best performer, yielded 6.1 t/ha and had a growth duration of 134 days in the Sahel, irrigated, medium duration trial, which was conducted at six locations. The next best varieties were IR 3273-P239-2 and IR 42. In the moist zone, irrigated, medium duration trial, which was conducted at 12 locations, ITA 212, with an average yield of 4.9 t/ha, was second to IR 4422-98-3-6-1, which produced an average yield of 5 t/ha. At the Suakoko station, ITA 212 and IR 42 were found to have some tolerance to iron toxicity.

International upland rice yield nursery. Six IITA lines, ITA 116, 117, 118, 162, 225 and 235, were nominated for this trial. According to preliminary reports from 10 locations in Asia and Africa, the mean yields of IITA lines ranged from 1.6 to 2 t, and ITA 162 was the best performer. ITA 116, 117, 118, 225, and 235 were found to be resistant to leaf blast.

International upland rice observational nursery. Fifteen IITA lines, ITA 116, 117, 118, 119, 141, 142, 158, 162, 164, 173, 175, 183, 186, 225 and 235, were among the 104 entries evaluated in this nursery. According to a preliminary report from 17 locations in Africa and Asia, several IITA lines performed well. The following were rated good for both tolerance to and recovery from drought: IR 13240-10-1, IR 3794-9-2-3, and ITA 235, 164, 173, 175, 183 and 186. Of these entries, the following were rated good for phenotypic acceptability: IR 3794-9-2-3, ITA 235, ITA 164, ITA 175 and ITA 183. Entries rated good for leaf blast resistance were ITA 117, 225, 142, 175, 118, 235 and 164.

IITA/IRAT/NCRI upland rice trial. The objective of this trial was to evaluate the agronomic characteristics, grain quality and tolerance to upland stresses in Africa of upland cultivars selected from the breeding programs of IITA, IRAT and NCRI. The trial was laid out in a randomized block design, with four replications and a plot size of 5 m × 3 m. N, P and K were applied each at the rate of 60 kg/ha in the form of 15:15:15 compound fertilizer before direct seeding with spacing of 3 cm × 15 cm. Seven weeks after seeding 30 kg/ha N was applied in the form of urea. There was severe drought stress during the tillering stage and medium stress at the reproductive stage.

IRAT 133 and 109 produced higher yields than the other test entries but had highly chalky endosperm (Table 8). Generally, endosperm chalkiness was noticeable in all IRAT varieties and in DJ 12-539-2, FAROM 4-2 and FAROX 211-8-2-3. Among the IITA varieties, TOx 1011-4-1 and ITA 150 are probable candidates for trials in the sub-Sahel and savanna ecologies because of their growth duration (about 100 days). Varieties from IITA were of medium

duration (120 to 130 days), and those from NCRI were intermediate to tall in stature, lodged to some degree and produced lower yields.—*Kaung Zan*

Entomology

Stalk-Eyed Fly

The stalk-eyed fly, which is indigenous to Africa, is a serious pest of rice on this continent. Although three different species of stalk-eyed flies are infesting rice, the species *Diopsis thoracica* West is predominant, constituting about 90% of the population.

Success in breeding for resistance to this insect depends largely on the development of reliable screening techniques. A simple method was developed at IITA for screening germplasm collections and breeding materials systematically in the screenhouse. High populations of stalk-eyed fly can be maintained inside the screenhouse, the layout of which is shown in Figure 1, and screening can be done throughout the year in the manner described in the following paragraphs.

Five border rows of 21-day-old seedlings of the variety Suakoko 8 were planted 40 days before test materials. Suakoko 8 was selected because previous studies had shown that the stalk-eyed fly is more attracted to it for egg laying. Moreover, the development rate of the maggots on this variety is lower than on others. About 2,500 *D. thoracica* were released 20 days after the border rows were planted.

Forty days after planting of the border rows, 21-day-old seedlings of the test entries were transplanted in a single row (15 hills), with two seedlings per hill, spacing of 25 cm × 25 cm and two replications. OS 6 (susceptible) and Iguape cateto (resistant) were also transplanted after every fifteenth test entry.

Between 15 and 20 days after transplanting of the test entries, another batch of approximately 2,000 insects was released inside the screenhouse to ensure that the population would be sufficient. After this second release, no more releases were made since the population in the screenhouse was then able to maintain itself.

Border rows were removed 70 days after planting (30 days after the test entries were transplanted). By that time a new generation of insects had emerged from the border rows, and the test entries were ready for infestation. New border rows were planted within 3 to 4 days. *D. thoracica* infestation was measured on test entries 45 days after transplanting.

Test entries were removed 65 days after planting, and another batch of test materials was transplanted within a couple of days. The planting schedule of border rows and test entries helped *D. thoracica* adults emerging from border rows to infest entries and to move from test entries back to border rows.

A total of 988 rice cultivars (937 of *O. sativa* and 51 of *O. glaberrima*) were screened for resistance to stalk-eyed fly in batches from March to November 1982. The cultivars, of which 73.89% were from Africa, came from 39 rice growing countries around the world. Infestation ranged from 1.25 to 66.67%, whereas under natural field conditions, the maxi-

Table 8. Performance of cultivars from IITA, IRAT and NCRI in an upland rice trial, 1982

Variety	Yield kg/ha	Plant height, cm	Growth duration, days	Endosperm chalkiness, 0 to 9	Sheath rot, 0 to 9	Grain discoloration, 0 to 9	Drought tolerance, 0 to 9
IRAT 133	4,565	102	100	9	5	3	5
IRAT 109	4,286	102	101	9	3	1	3
IRAT 110	3,725	99	95	5	5	3	1
ITA 117	3,721	110	116	1	0	3	5
TOx 1011-4-1	3,707	94	100	1	5	1	3
IRAT 144	3,631	99	100	5	1	1	3
ITA 118	3,597	119	119	5	3	3	3
DJ 12-539-2	3,385	89	112	9	1	3	3
ITA 150	3,272	120	98	1	0	1	3
ITA 235	3,159	126	115	1	0	3	1
FAROX 210-19-4-14	2,676	130	116	5	1	5	5
IR 5931-110-1	2,511	113	121	5	1	1	3
IRAT 138	2,233	117	123	5	0	3	5
FAROM 4-2	1,970	158	121	9	1	3	3
FAROX 299	1,749	144	123	5	3	5	3
FAROX 211-3-2-3	1,727	147	117	9	1	3	5
FARO 25	1,710	142	123	5	1	3	5
IR 52	1,559	95	128	1	1	3	5
ITA 141	1,430	124	126	1	0	3	3
ITA 116	1,181	132	125	1	1	3	3
Mean	2,790						
LSD (5%)	728.46						
C.V., %	18.41						

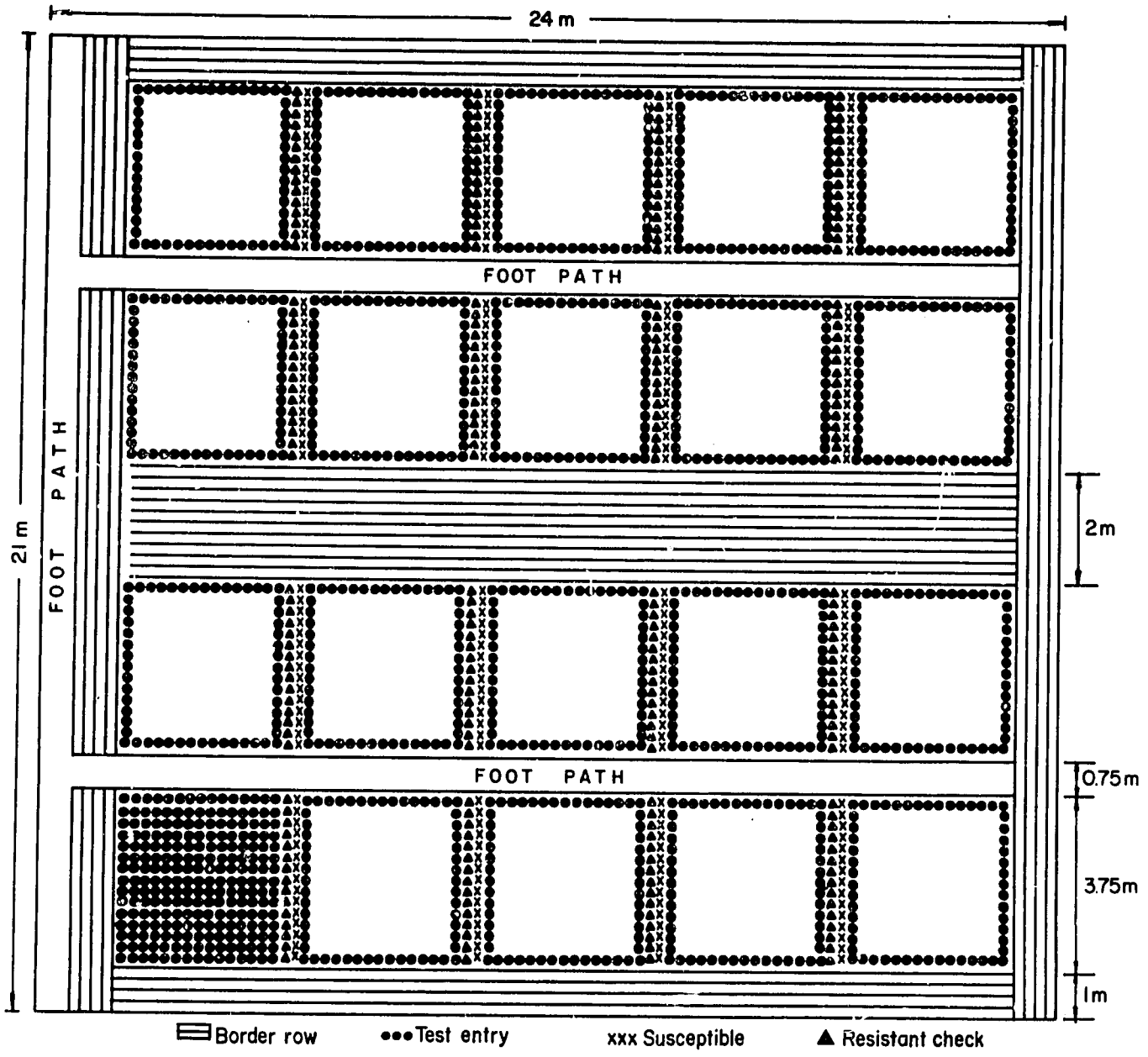


Figure 1. Layout of the procedure by which rice varieties/lines are screened in the screenhouse for resistance to stalk-eyed fly, *Diopsis thoracica*.

mum infestation by stalk-eyed fly is about 15%. Fifty-seven cultivars (37 of *O. sativa* and 20 of *O. glaberrima*) from 13 countries were found to have less than 10% infestation. Of the 57 promising cultivars selected, only 8 were improved varieties/lines; the rest were germplasm collections. The highest frequency of selected materials (39.2%) was found among the *O. glaberrima* collection, compared with only 3.9% among the *O. sativa* entries. These selected materials will be retested for final confirmation of their resistance. Cultivars with less than 4% infestation are listed in Table 9.—*M.S. Alam*

Storage Moth

Insects are reported to be the main cause of crop losses in storage. The use of rice varieties with resistance to these insects has shown promise in curtailing losses. The use of such varieties against storage moth (*Sitotroga cerealella*) infestation would undoubtedly reduce postharvest losses at no additional cost and with no risk from chemical residues. Experiments were conducted at IITA to test IITA advanced and promising lines, recommended cultivars and farmers' varieties for resistance to the storage moth under short- and long-term storage and to identify physical properties of the grains that affect the resistance of these varieties.

In short-term resistance screening, eleven rice cultivars were tested. Seven grams of grain for each of three replicates were infested with 50 eggs of *S. cerealella* in a no-choice test. The grain was placed in glass vials in an incubator maintained at 25°C and 70 to 75% relative humidity under a 12-hr-light/12-hr-

Table 9. Best 20 cultivars selected for resistance to stalk-eyed fly in a mass screening test, IITA, 1982

Designation and IITA acc. no.	Source	Infestation, %
TOs 5827	Liberia	1.2
TOs 3213	Ivory Coast	1.8
TOs 285	United States	1.8
TOs 372	Indonesia	2.0
TOs 3212	Ivory Coast	2.2
TOs 5792	Liberia	2.2
TOx 916-6-1-101-2	IITA	2.4
TOg 6390	Liberia	2.5
TOs 272	United States	2.8
TOs 5677	Nigeria	2.9
ITA 121	IITA	3.1
TOs 5267	Ivory Coast	3.3
TOs 657	United States	3.3
TOs 373	Indonesia	3.3
X.2. D.T	Vietnam	3.4
TOx 936-153-5-3-3	IITA	3.5
TOs 663	Nigeria	3.5
TOs 5734	Liberia	3.6
TOx 861-212-2-102-1-1	IITA	3.6
TOg 6481	Liberia	3.8

dark cycle. The experiment was terminated after 45 days.

Four varieties selected during the short-term screening were further tested in a long-term screening test. In this no-choice test, 260 g of grain per replicate of each test variety were infested with 50 newly emerged male and female adults of *S. cerealella* in equal ratios. The grain was stored in cloth bags under room conditions for four months.

Two indices of susceptibility were used in the short-term screening test. The first is based on the population size the variety will permit *S. cerealella* to reach under a given set of physical conditions, starting with a fixed number of eggs. This index is expressed as Log F_1/D, where F is the number of insect progeny in the first filial generation for a development period D. The second index is the percentage grain weight loss. The index of susceptibility for the long-term screening test was based on the percentage loss in weighted means. In determining the influence of the physical properties of the grain on resistance to *S. cerealella* damage, 100 grains per replicate of the samples tested in the short-term screening test were examined under the microscope for open husks, and correlation analysis was done on data obtained along with that on the number of F_1 insect emergents per variety.

Significant varietal differences were found in the number of F_1 insect progeny and loss in grain weight (Tables 10 and 11). IR 5 was the most resistant to *S. cerealella* infestation under short-term storage, and IRAT 13 was least resistant. Under long-term storage, Ceylon 49 did slightly better than IR 5, but the difference between them was not significant.

Table 10. Susceptibility of rice varieties to storage moth, IITA, 1982

Cultivar	Percent emergence	Index of susceptibility	Weight loss, g
IR 5	2.0 a	0.86 a	0.07 a
Moroberekan	8.0 ab	5.02 bc	0.07 a
Lac 23 red	8.5 ab	4.12 b	0.29 ab
Ceylon 49	13.0 bc	5.12 bc	0.10 a
Lac 23 white	15.0 bcd	6.53 bcde	0.22 a
Kolon Kalan	15.5 bcd	6.67 cde	0.37 ab
CH 128	16.5 bcd	6.76 cde	0.32 ab
TOx 86-1-3-1	19.5 bcde	7.77 defg	0.53 b
TOx 494-5-1-2	23.5 cde	8.21 efg	1.63 e
OS 6	31.0 de	9.27 fg	0.84 c
IRAT 13	35.5 e	9.85 g	1.24 d
LSD*	7.05	2.47	0.31

Note: Means followed by the same letters in the same column are not significantly different from each other.
*For emergence and susceptibility, differences are significant at the 1% level and for weight loss at the 5% level.

Table 11. Effect on rice varieties of infestation by storage moth during four months of storage, IITA, 1982

	Weight loss		Damage	
Cultivar	Mean, %	Log 10x	Mean, %	Log 10x
Ceylon 49	0.33	0.48 a	1.7	0.74 a
IR 5	0.71	0.84 ab	3.2	1.02 ab
Moroberekan	2.08	1.21 c	8.8	1.37 bc
Lac 23 red	3.01	1.43 c	13.2	1.60 c
LSD (5%)		0.56		0.52

Note: Means followed by the same letters in the same column are not significantly different from each other.

Although Moroberekan was more resistant than Ceylon 49 to *S. cerealella* damage under short-term storage, it was more susceptible under long-term storage. The most susceptible rice varieties, IRAT 13, OS 6, TOx 494-5-1-2 and TOx 86-1-3-1, were found to have a high percentage of grains with open husks and, with the exception of OS 6, had a common parent, 63-83. As indicated by the correlation coefficients in Figure 2, there were positive, highly significant correlations between the number of grains with open husks and the number of F_1 insect progeny and between the number of grains with gaps and loss in grain weight caused by *S. cerealella* damage.

The variation among rice varieties in their reaction to *S. cerealella* and in grain weight loss indicate that they have varying levels of resistance. This study suggests that the differential reactions of these rice varieties are due to a physical resistance base, namely husk tightness, which apparently is genetically controlled. Further investigations into the heritability of this resistance base and identification of other resistance mechanisms are required. If the resistance base is found to be genetically controlled, then IR 5 and Ceylon 49 could serve as resistance sources to be used by breeders in

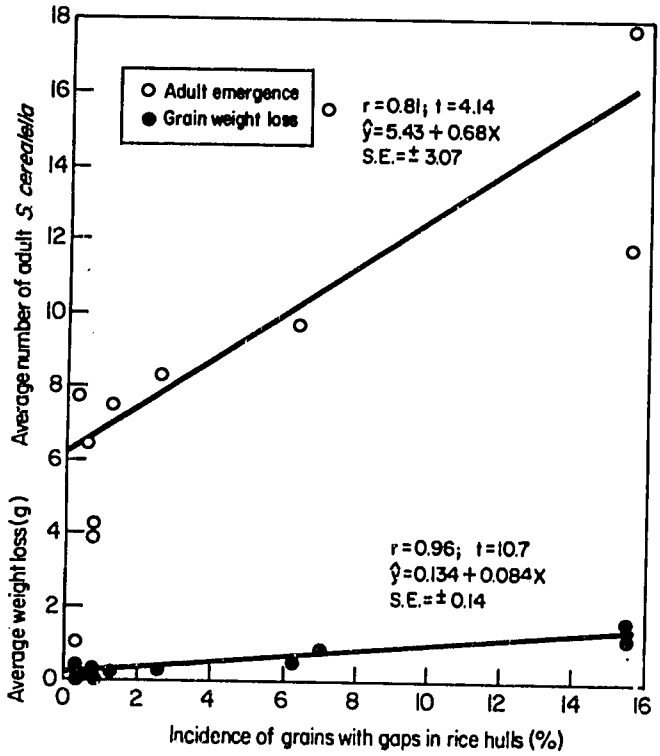


Figure 2. Relationship between the incidence of grains with open husks and the emergence of *S. cerealella* adults and grain weight loss, IITA, 1982.

crosses. In addition, identifying the source of open husks will guide rice breeders in selecting parents for crosses.—*D. Akibo-Betts*

Pathology

During 1982 emphasis was placed on developing resistance to blast and rice yellow mottle (RYMV) diseases. The former is the most widespread disease of both upland and irrigated rice in Africa, and the latter poses a potential threat in irrigated rice paddies. The major objective was to test fixed lines and early breeding materials for blast resistance and to identify donors of resistance to RYMV. Studies on yield loss caused by RYMV disease were carried out in the screenhouse. Preliminary efforts were also made to select material showing resistance to panicle discoloration and leaf scald diseases.

Blast

Blast resistance was studied in the field under upland conditions. Seeds of test entries and those of a susceptible spreader were sown at the rate of 10 g/2-m row. To initiate infection blast infected leaves were spread on the susceptible spreader lines, which consisted of a mixture of blast susceptible varieties. Nitrogen was applied at a rate of 120 kg/ha in split applications to encourage high disease pressure. The entries tested were visually scored on a scale of 0 to 9 (the standard evaluation system for rice), with 0 representing high resistance and 9 extreme susceptibility.

Table 12. Results of screening for blast resistance, IITA, 1982

	Total no. of entries tested	Percentage of entries resistant
CIAT	90	84.4
IRAT	14	35.7
IITA	160	74.4
IRRI (IRBN 81)	155	21.9
(IRBN 82)	295	34.6

Table 13. Entries in a blast screening trial with resistance and high yield potential, IITA, 1982

Entry number and pedigree	Entry number and pedigree
CIAT	**IRRI**
11295 P 2015 F4-66-5-1B	IR 1905-81-3-1
11308 P 2015 F4-82-5-1B	IR 2793-80-1
11373 P 2015 F4-148-5-1B	IR 9752-71-3-2
11377 P 2015 F4-150-4-1B	IR 13423-10-3-3
11568 P 2015 F4-46-2-1B	IR 15314-43-2-3-3
11587 P 2015 F4-140-3-1B	IR 17488-2-3-2
11643 P 2023 F4-74-2-1B	BG 367-4
11975 P 2030 F4-222-2-1B	BR 319-1-HR 12
11994 P 2030 F4-243-4-1B	
12021 P 2034 F4-25-6-1B	
IITA	**IRAT**
ITA 120 TOx 502-25-118-1-1	IRAT 13[a]
ITA 132 TOx 340-1-5-1	IRAT 118
ITA 135 TOx 378-1-6-1	IRAT 119
ITA 150 TOx 502-41-1-1	IRAT 122
ITA 152 TOx 503-7-116-1	IRAT 125
ITA 235 TOx 1785-19-18	IRAT 126
ITA 241 TOx 711-3-201	

[a]Pedigree not available.

A total of 714 entries from four sources—CIAT, IRAT, IITA and IRRI—were tested in the upland screening nursery for blast resistance. The disease was severe and almost killed the susceptible lines. The percentages of entries found to be resistant are listed in Table 12. The data clearly indicate that a higher percentage of the entries from CIAT and IITA were resistant under the upland testing conditions of IITA. Entries of the advanced lines known to have good yield potential and blast resistance are listed in Table 13.

One hundred and fifty breeding lines were tested for resistance to drought under upland conditions. Natural infection by blast in this trial killed the susceptible lines. Seventy-one entries with a score of 1 to 2 were selected for further evaluation of their yield and agronomic characters and for confirmation of blast resistance (Table 14).

Rice Yellow Mottle Virus

Three hundred and forty varieties from diverse sources were screened for rice yellow mottle virus resistance under upland conditions in a screenhouse.

Table 14. Selections with resistance to blast, IITA, 1982

	No. of lines selected	Cross
TOx 714....	8	ROK 5 × IR 937-55-3
TOx 752....	9	OS 6 × Moroberekan
TOx 891....	10	IR 8230-12-1 × LAC 23 (white)
TOx 897....	8	IR 8 × LAC 23 (white)
TOx 906....	10	4445 × OS 6
TOx 908....	16	4445 × IAC 25
TOx 936....	10	IR 1529-430-3 × Iguape cateto

Table 15. Results of screening for rice yellow mottle virus, IITA, 1982

	Total no. of entries tested	Percentage tolerant	Percentage susceptible
Asia.....	28	21.4	78.6
CIAT.....	87	0	100.0
IITA	67	61.2	38.8
TOs.....	92	83.7	16.3
TOg.....	23	100.0	0

Table 16. Entries in a rice yellow mottle virus screening trial with high resistance and yield potential, IITA, 1982

	Pedigree	Cross
ITA 116	TOx 86-1-3-1	63-83 ×IR 773 Al-36-2-1
ITA 117	TOx 356-1-1-1	13A-18-3-1-3 ×TOx 7-4-2-5-2
ITA 118	TOx 475-1-1-1	TOx 7-4-2-5-1 × 63-83
ITA 119	TOx 490-3-108-1-1	LAC 23 (red) × IET 1444, TOx 7-4-2-3-2, TOx 7-3-2-3-2
ITA 120[a]	TOx 502-25-118-1-1	63-83 × ROK 1, SE 3636, TOx 7-3-2-1-1-1-1
ITA 135[a]	TOx 378-6-1	63-83 × IR 26
ITA 141	TOx 490-125-4-1	LAC 23 (red) × IET 1444, TOx 7-4-2-3-2, TOx 7-3-2-3-2
ITA 142	TOx 494-5-1-2	63-83 × Iguape Cateto
ITA 150[a]	TOx 502-41-1-1	63-83 × ROK 1, SE 3636, TOx 7-3-2-1-1-1-1
ITA 162[a]	TOx 503-7-116-1	Moroberekan × ROK 1, Suakoko 8, TOx 7-3-2-1-1-1-1
ITA 182	TOx 516-20-102-5-1	Moroberekan × Juma 1, TOx 7-3-2-3-2, SE 363G
ITA 235[a]	TOx 1785-19-18	OS 6 DM × OS 6
	Kulu	
	IR 1846-296-3	JP 5 × YRL 1
	IR 2298-PLPB-319-1-2-1-1B	Cica 4 × Kulu

[a]Also resistant to blast.

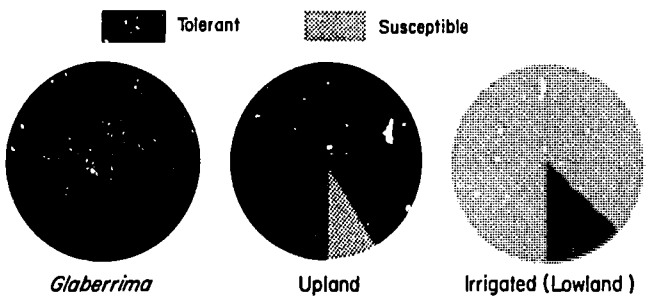


Figure 3. Reaction of entries to rice yellow mottle virus in a screenhouse test, IITA, 1982.

The test entries were inoculated mechanically 20 days after germination. Twenty-five days after inoculation, lines that seemed healthy were scored as (1) tolerant (plants look green with very little or no mottling, normal tillering and flowering but have serologically detectable virus); (2) susceptible but able to recover; and (3) highly susceptible. Table 15 lists the sources and types of material and gives their overall performance.

One hundred and fifty-two entries with tolerance to the local strain of RYMV were tested serologically for the presence of virus. All entries tested reacted positively, confirming the presence of the virus. Tolerant entries with high yield potential are listed in Table 16. Most of the entries listed in the table are suited to upland conditions. Note also that in most cases tolerance to RYMV occurs in crosses involving LAC 23, Moroberekan, OS 6 and 63-83.

Analysis of the material reacting to RYMV indicated that all the *glaberrima* varieties tested were tolerant to RYMV (Figure 3). Although most of the susceptible plants recovered from the early symptom of the disease (yellowing), they were severely stunted; their flowering was very much delayed; and their grains were chaffy and discolored. One hundred and fifty plants of each of two cultivars, one tolerant (OS 6) and another susceptible (BG 90-2) to RYMV, were grown in three replications, with 50 plants in each replicate. The trial was carried out under upland conditions 20 days after germination.

The plants were inoculated mechanically with RYMV inoculum, and proper controls, replicated as above, were maintained. The plants were allowed to flower, and the yield of 75 randomly selected plants was estimated for the two varieties. Inoculation reduced the yield of OS 6 plants from 17.64 g/plant for healthy ones to 14.36 g. Sterility was increased in these plants from 17.08 to 31.44%. Although the reduction in yield was not significant at the 1% level, the increase in sterility was. In the susceptible variety, inoculation reduced yield from 9.84 g/plant to 0.64 g and increased sterility from 45.75 to 73.97%. Both the yield reduction and increase in sterility were significant.

The low yield and high percentage of sterility in healthy, uninoculated plants of BG 90-2, a variety that is bred for cultivation on irrigated land, could be attributed to the upland conditions under which the test was carried out.

Panicle Discoloration and Leaf Scald

Observation nurseries at Onne were severely affected by panicle discoloration. Table 17 lists four entries from Onne with tolerance to panicle discoloration caused by *Acrocylindrium oryzae*, *Helminthosporium oryzae* and *Curvularia lunata*. At Ikenne, during the wet season of 1982, naturally occurring leaf scald (*Rhynchosporium oryzae*) was severe. The breeding lines shown in Table 18 may be resistant to leaf scald but need to be retested for confirmation.

It is clear from the foregoing discussion that

Table 17. Entries in observation nurseries with tolerance to panicle discoloration, Onne, 1982

	Pedigree	Cross
ITA 117	TOx 356-1-1-1	13A-18-3-1-3 × TOx 7-4-2-5-2
ITA 212	6850	BG 90-24 × Tetep
ITA 235	TOx 1785-19-18	OS 6 DM × OS 6
	TOx 1010-21-5-12-4	P 42 × TOx 494-5

Table 18. Entries in observation nurseries with resistance to leaf scald, Ikenne, 1982

Pedigree	No. of lines selected	Cross
TOx 757	1	IAC 25 × IR 8090
TOx 764	4	Taitung 16 × IB 57
TOx 908	1	444 × IAC 25
TOx 1010	6	P 42 × TOx 494-5
TOx 1766	5	(TOx 1525) F_2 dw × (TOx 1357) F_2
TOx 1780	3	(TOx 1525) F_2 dw × (Norin 6 × TOx 340) F_2

Grain discoloration in rice.

varieties with resistance to blast and tolerance to rice yellow mottle virus are available for cultivation in uplands. These varieties need to be tested now for resistance to panicle discoloration and leaf scald diseases. An even more pressing need, though, is to develop varieties for irrigated conditions with resistance to blast and rice yellow mottle virus diseases. Preliminary work is already underway to meet these objectives.—*V.T. John*

Maize

The major objective of the maize improvement program is to develop stable, high yielding varieties that are adapted to the various ecologies and consumer preferences of Africa. The program's approach in breeding is to carry out population improvement and international, multilocational progeny and variety trials in cooperation with national programs. Through this approach, the program has developed early, medium and late maturing populations with yellow or white kernels and flint or dent grain type and is now focusing mainly on achieving varietal stability through resistance breeding for the major diseases and insect pests of Africa. During 1982, as in previous years, work on maize streak virus (MSV) resistance was emphasized. As a result of improvements in the technique for mass rearing of the MSV vector, *C. triangula*, it is now possible to infest about 15,000 plants per week.

A late maturing, streak resistant variety trial (EVT-LSR) was sent for the first time to 24 locations in 18 countries. It produced very encouraging results. New varieties, including a few backcross conversions of selected CIMMYT varieties, were developed during 1982 and will be included in the 1983 EVT-LSR trials.

Also for the first time, the maize program sent for testing an international full-sib progeny trial of streak resistant, early maturing white (TZESR-W) and yellow (TZESR-Y) populations and a late maturing white population that is adapted to the midaltitude ecology. Significant progress was achieved in combining resistance to maize streak virus and downy mildew.

So they can breed for resistance to disease and insect pests more efficiently, IITA maize researchers are developing artificial infestation techniques for as many diseases and insect pests as possible. Infection with *H. maydis*, *H. turcicum*, *Curvularia* spp., *P. polysora* and *P. sorghi* is being done with pulverized infected leaves, spore suspension or both, and infection with downy mildew is being accomplished by inoculation of preplanted spreader rows. This year emphasis was given to developing techniques for artificial inoculation with the organisms that cause ear and stalk rots.

Maize borers are widespread in Africa and cause considerable yield losses. *Sesamia calamistis* is prevalent in the lowland humid tropics. Because of the heavy natural epibiotics of *Sesamia*, which causes almost complete yield loss in southeastern Nigeria, maize is not even planted in that region later in the season. Work on resistance to the insect was intensified after the arrival of a new entomologist in the program. The diet for mass rearing was modified for large scale production of eggs or larvae. A test involving artificial inoculation of previously selected families under high natural epibiotic conditions showed that significant progress was achieved in accumulating genes for resistance, as compared with TZPB, a widely grown variety in Nigeria.

The SAFGRAD/IITA team in Upper Volta continued their efforts to breed varieties adapted to the semiarid zone through regional testing and breeding. Crosses between U.S. and tropical germplasm are showing great promise under

semiarid conditions. IITA's maize agronomist with SAFGRAD carried out experiments on simple agronomic practices that can be used by small scale farmers to conserve soil moisture and improve soil management. During 1982 these practices were tested in farmers' fields.

Genetic Improvement

Population Improvement

The EEC-funded High Yielding Varieties Technology Project has widened the scope of the population improvement program and much enhanced its relations with national programs. Progeny and variety testing was proposed for 16 sites across Africa, four each in the western, eastern, southern and central regions of the continent, during the second phase of the project. The populations listed in Table 19 were selected for improvement and development of experimental varieties, with emphasis on maize streak virus resistance.

A backup unit for each type of maturity and grain color either exists or will be established in the future to provide improved germplasm for the populations. In the backup units, multiple resistance to diseases and insect pests will be emphasized. Yellow and white populations with combined resistance to downy mildew have also been developed for the areas infested with this disease, especially in Nigeria and Zaire. For each population, a two-year improvement cycle is carried out as follows:

- Year 1, season 1—Formation of full-sibs
- Year 1, season 2—International testing of full-sib families in four to six locations
- Year 2, season 1—Within-family improvement of selected families across locations
- Year 2, season 2—Half-sib recombination of the selected families
- Year 3, season 1—Formation of a new cycle of full-sibs

Following each international full-sib testing, experimental varieties are produced by recombination of the best 10 families at each testing site, along with one based on selected families across all sites. The 10 best families are first recombined in all possible combinations and later by half-sib for seed increase and testing by national programs.

TZSR-W-1 and TZSR-Y-1. Maize streak virus disease is currently the most widely distributed economically important disease of maize in Africa. The development of streak resistant varieties is therefore essential to achieving stable maize production in this region. TZSR-W-1 and TZSR-Y-1 are the two main populations from which streak resistant white and yellow grained maize varieties are being extracted.

Based on data from the 1981 international full-sib progeny trial of TZSR-W-1 and TZSR-Y-1, six experimental varieties were formed by combining the best 6 to 10 full-sibs from each of the six test locations. The test locations were Ferkessedougou (Ivory Coast), Ikenne (Nigeria) and Sekou (Benin) for TZSR-W-1 and Farako-Bâ (Upper Volta), Ferkessedougou and Ikenne for TZSR-Y-1. These six, late, streak resistant varieties, two experimental varieties each from populations TZB and TZPB, and two check entries to be supplied by the trial cooperator were combined to form one trial. The primary purpose of the trial was to compare the performance of the streak resistant varieties with that of the currently recommended improved maize varieties, such as TZB and TZPB, in various countries of Africa. A randomized complete block design with four replications was used; the plots consisted of four rows 5 m long with 75 cm × 25 cm spacing. The trial was sent to 24 locations in 17 countries.

For a number of reasons, particularly the differences in planting seasons between countries on both sides of the equator, data from only 10 locations (six countries) have so far been received. The level of streak infection was not high enough at any of the locations to allow a meaningful evaluation of streak resistance. It is encouraging, however, that in the absence of streak virus (which permitted the experimental varieties from TZB and TZPB to realize their full yield potential), the yields of the late, streak resistant varieties were not significantly different from the yields of TZB and TZPB (Table 20). The value of the streak resistant varieties is expected to become more obvious under severe streak infection.

Further improvement of TZSR-W-1 and TZSR-Y-1 was carried out in 1982. Of the 250 full-sibs tested for

Table 19. Populations selected for development of experimental maize varieties

Population	Description	Adaptation
TZSR-W-1	Late white flint	Lowland forest and savanna
TZSR-Y-1	Late yellow flint	Lowland forest and savanna
La Posta (Pop. 43)[a]	Late white dent	Lowland forest and savanna
TZMSR-WD[b]	Late white dent	Midaltitude
TZMSR-WF[b]	Late white flint	Midaltitude
TZUT-W	Intermed. white semiflint	Savanna
TZUT-Y[c]	Intermed. yellow semiflint	Savanna
TZESR-W	Early white flint	Lowland forest and savanna
TZESR-Y[c]	Early yellow dent	Lowland forest and savanna
Pool-16	Early white dent	Lowland forest and savanna

[a]From CIMMYT's maize breeding program.
[b]Presently a mixed flint and dent population.
[c]The SAFGRAD/IITA team in Upper Volta is concentrating on improvement of this population.

Table 20. Average maize yields in an international experimental trial of late, streak resistant varieties, 1982

Entries	Benin Niaouli	Cameroon Ntui	Cameroon Njombe	Ghana Nyankpala	Kenya Kikambala	Liberia Suakoko	Nigeria Ibadan	Nigeria Ikenne	Nigeria Ilorin	Nigeria Samaru	Entry mean
					kg/ha						
Ikenne LSRW 81 ...	4,380	5,203	5,002	5,348	2,291	3,172	4,2[illegible]0	6,079	5,473	4,224	4,538
Ferke LSRW 81	3,585	5,240	5,277	5,290	2,110	4,044	3,596	4,964	5,446	3,847	4,340
Sekou LSRW 81	4,165	5,673	4,507	6,379	2,583	3,093	4,514	5,327	5,897	4,888	4,703
Ikenne LSRY 81....	4,016	4,610	5,122	4,993	1,458	4,285	4,393	5,211	5,909	5,075	4,507
Ferke LSRY 81.....	3,797	5,371	5,222	4,820	2,056	3,605	4,003	4,476	5,898	5,070	4,432
Farakoba LSRY 81 .	4,502	4,158	4,559	4,982	1,586	3,706	4,450	4,895	5,403	5,901	4,414
Mokwa TZB 81.....	4,500	4,857	4,436	6,660	2,421	3,589	5,372	5,744	7,646	4,304	4,933
Gusau TZB 81.....	4,649	6,502	4,821	6,984	2,234	3,826	5,227	5,862	7,120	5,667	5,289
Onne TZPB 81	4,574	5,978	4,443	6,332	1,834	4,069	5,088	6,352	6,124	3,238	4,821
Suakoko TZPB 81 ..	5,268	5,940	5,148	7,116	2,329	3,964	5,028	6,487	6,073	4,513	5,187
Check[a].....	2,412	5,880	5,563	5,743	1,790	2,908	3,650	4,807	5,296	5,461	4,351
Check	2,890	4,967	4,520	5,295	1,816	3,640	4,451	5,310	5,279	4,304	4,247
Location Mean.....	4,062	5,365	4,885	5,829	2,042	3,658	4,491	5,460	5,964	4,708	
LSD (5%).....	753	967	ns	1,761	672	ns	1,276	1,008	1,586	1,705	
C.V., (%).....	13	12	15	21	22	32	20	13	18	25	

[a]Check varieties are selected by the national programs and differ for each location.

each population in the 1981 international progeny trials, the best 60 entries for TZSR-W-1 and the best 58 for TZSR-Y-1 were selected based on their performance at all locations. These full-sibs were selfed during the 1981–82 irrigation season, and the selected S_1 progenies were recombined by the half-sib method during the first season of 1982. Both operations were carried out under artificially induced streak pressure in order to improve the quality of streak resistance in the populations. During the second season of 1982, full-sibs were generated among the half-sib progenies of the selected full-sibs. Selection between subfamilies of full-sibs and among plants within a subfamily was based on streak resistance, good root and stalk quality, low plant and ear heights and other desirable agronomic qualities. The full-sibs will be sent to the international progeny trial in 1983.—*J.M. Fajemisin*

La Posta (population 43). CIMMYT maize breeders continued recurrent selection for yield and other agronomic characters in La Posta (population 43) through international testing in cooperation with national programs. They also concentrated on building up streak resistance in the population as such and by backcrossing with TZSR-W-1, a donor, for streak resistance.

For international testing, 250 full-sib families were generated by reciprocal plant to plant crosses. These families were sent as an international progeny testing trial to six different countries, where they were tested in a 16 × 16 simple lattice design. The cooperating countries were Costa Rica, Ivory Coast, Nicaragua, Nigeria, Thailand and Zimbabwe. The same families were planted at IITA, one replication in a streak screening nursery and another protected from MSV. The backcross program was continued by advancing the first backcross generation to F_2.

In the cooperating countries, the best families (about ten) from each progeny trial were selected for the formation of an experimental variety. An additional variety will be formed based on data from all locations. These varieties will be made from remnant seed at IITA and shipped to CIMMYT, where they will be included in the international testing program. The performance of selected families at Ikenne is presented in Table 21.

In the streak screening nursery at IITA, 12 families with a very high level of streak resistance were identified. Plants with an intermediate to moderate level of resistance were selfed in 48 additional families. The ears saved from the streak nursery will represent their original families selected on the basis of data from the international progeny testing trials in the next cycle of improvement. As of January 1983, data had been received from five locations in those trials. The population mean for yield ranged from 4.9 to 7.8 t/ha and the coefficient of variation from 11.7 to 17.3%.—*M. Bjarnason*

TZUT-W and TZUT-Y. The objective of this research is to develop a population of medium maturity (110 days from planting to maturity) that combines the efficient plant type of varieties from the Corn Belt of the United States with the disease tolerance of local materials. A base population of TZUT was established a few years ago from crosses between U.S. materials and tropical populations. This population has passed through two cycles of recurrent selection to improve general performance and uniformity, although grain color was a mixture of white and yellow.

During the third season of 1981–82, 38 families selected from 250 half-sibs were selfed to separate their S_1 progenies into white (TZUT-W) and yellow (TZUT-Y) populations. TZUT-Y will be improved by the SAFGRAD project in Upper Volta, and TZUT-W will be improved in Nigeria.

During the 1982 rainy season, 242 S_1 progenies of TZUT-W (derived from 32 half-sib families) were

grown in isolation in two replications at Samaru, Nigeria. Bulk seed of all entries were planted as males in every third row among the S_1 progenies. All S_1 progeny rows (female rows) and the undesirable male plants were detasseled before pollen shedding. The best plants within selected families were marked just before maturity, and reselection was done again before harvest. After harvest the best 182 half-sib ears were retained and shelled individually. During the third season of 1982–83, the selected half-sib entries were grown in progeny rows at Ibadan under irrigation to form full-sib families. These will be tested for the first time in international trials in 1983 to further improve the population and to form experimental varieties adapted to different countries.

At Kamboinsé, Upper Volta, yellow grains of 305 S_1 families were planted in isolation for recombination. Because of late planting and an early end to the rains this year, the plants were severely damaged by drought, so selection of recombined ears could not be done effectively. However, 589 ears were selected and planted during the dry season of 1982–83 for another cycle of recombination. A new cycle of full-sib recurrent selection will be initiated during the 1983 season.—*F.H. Khadr*

TZMSR. This population combines a high level of resistance to maize streak virus with resistance to *P. sorghi* (rust) and *H. turcicum* (blight), which are the major diseases in the midaltitude ecology. The population had previously been through one cycle of selection under rust and blight infestation at Jos, Nigeria (1,200 m above sea level), and one cycle of selection under streak infestation at Ibadan. S_1 lines were grown in progeny rows during the rainy season of 1982 at Jos. Seedlings were artificially inoculated for leaf blight two weeks after planting.

At flowering only plants that were reasonably resistant to blight were used in paired crosses among the plants of S_1 progeny rows to form full-sib families. At maturity most of the progeny rows were observed to have good levels of resistance to both blight and rust. In 1983, 256 entries, including full-sib families and local checks, will be tested in midaltitude regions of Zambia, Zimbabwe, Cameroon and Nigeria to improve the population and develop experimental varieties from the best full-sib families at each location and across locations.—*F.H. Khadr, S.K. Kim and J.M. Fajemisin*

Early maturing, streak resistant germplasm. African maize growers are badly in need of early maize varieties that are resistant to maize streak virus for planting during the second growing season or for late planting during the first season in areas where streak incidence is high. In 1977 IITA began a crossing program involving TZE 3, TZE 4, TZE 14 and TZE 15 as early parents, with TZSR-W and TZSR-Y as streak resistant parents. After several seasons of selfing and selection for agronomic characters and streak reaction, the best S_3 lines were composited in the 1980 second season to form two maize populations, TZESR-W and TZESR-Y, which are early and resistant to streak and produce acceptable yields.

In 1981 250 full-sib families of TZESR-W and 250 half-sib families of TZESR-Y were tested at two locations in Nigeria. Seventy-seven full-sib families of TZESR-W and 44 half-sib families of TZESR-Y were selected, and remnant seed of these families was planted in the third season of 1981 to generate full-sib families for testing. At harvest 165 full-sibs from each of the two populations were finally selected to form two separate progeny trials for different locations in the 1982 second season. Full-sibs of TZESR-Y were sent to Nigeria (Ikenne), Cameroon, Upper Volta and Uganda. Full-sibs of TZESR-W were tested at five locations—in Nigeria (Ikenne and Gusau), Cameroon, Tanzania and Zaire. The experimental design was a 13 × 13 simple lattice with four local checks.

The results of the trials are still coming in. Yield and agronomic data will be used in two ways. First, based on data from all sites, up to one-third of the best

Table 21. Performance of 10 families selected for the formation of an experimental variety, Ikenne 82 43, 1982

Progeny number	Yield, t/ha	Yield as a percentage of pop. mean	Days to silk	Plant height, cm	Ear height, cm	Root lodging, %
99	7.4	146	55	216	132	3.1
27	7.4	145	54	219	126	0
93	7.4	144	54	218	119	0
197	7.3	144	54	212	116	0
164	7.2	141	54	211	124	0
173	6.9	136	55	211	115	7.5
113	6.9	135	54	214	121	11.4
62	6.8	134	55	213	121	5.3
60	6.8	134	55	218	128	7.9
174	6.8	133	55	213	115	2.8
Mean of selected families	7.1	139	54	215	122	3.8
Population mean	5.1	100	55	201	112	3.4
Best check (TZPB, Onne)	5.4	106	53	220	128	7.5
C.V., %	16.6					

performing full-sib families will be selected for a new cycle of improvement. Second, experimental varieties will be created, each consisting of the 10 best families from each site and from all sites. These experimental varieties will be assembled in the first and second seasons of 1983 and will be ready for testing in late 1983.

Following the general population improvement scheme used in the second season of 1982, these two populations underwent intrafamily selection by selfing for agronomic characters and resistance to streak. During 1983 the selected families will be recombined, and then the new full-sib families will be generated for further testing.

IITA will handle the early maturing maize populations with white kernels and SAFGRAD the yellow early populations. During the second season of 1982, Pool-16, an early, white dent pool from CIMMYT, was found to be promising in the semiarid zone and underwent intrafamily improvement at IITA to introduce streak resistance into it. Population improvement on TZESR-Y was carried out by SAFGRAD/IITA scientists in Upper Volta.

An early maturing, streak resistant gene pool was constructed during 1982 that will be used to systematically broaden the genetic base of the corresponding TZESR-W and Pool-16.—*H.N. Pham*

Downy mildew and streak resistance. Since downy mildew (*Peronosclerospora sorghi*) and streak coexist in some countries of Africa, it is important to develop maize varieties that have resistance to both. During the year IITA maize breeders evaluated the current cycles of maize populations for downy mildew resistance and yield and further improved those populations for higher levels of resistance to downy mildew and streak and for better agronomic qualities.

A downy mildew resistance and yield trial was carried out that included 12 maize entries: two experimental varieties synthesized from the best 10 lines in each of the populations DMR-W and DMR-Y, bulk seed of DMRSR-W and DMRSR-Y, two DMR experimental varieties from CIMMYT (SW 8072 and SW 8075), their respective populations (populations 2 and 5), and four maize varieties/populations recommended to and grown by many farmers in Africa (TZB, TZPB, TZSR-Y-1 and Western Yellow). The experiment had a randomized complete block design with four replications, a plot size of four rows 5 m long and spacing of 75 cm × 25 cm (net plot = two center rows). The trial was planted at two locations: in a farmer's plot under natural downy mildew infection and at an experiment station under artificial infection, both sites being in the Owo Local Council Area of Ondo State, Nigeria. The percent incidence of downy mildew was recorded eight weeks after planting and the number of cobs and yield at harvest.

At both locations the downy mildew resistant varieties and populations were consistently superior to the four widely grown, recommended varieties (Table 22). Populations 2 (TLWD-DMR) and 5 (TIWF-DMR) expressed a high level of downy mildew resistance and showed promise in yield potential. Of even more significance is the fact that the DMRSR-W and DMRSR-Y populations, which have resistance to downy mildew and streak, performed far better in downy mildew resistance and yield than in last year's trials. The yield advantage of these populations, which is currently about 300% over the presently recommended varieties under downy mildew pressure is expected to be even greater under the combined effects of downy mildew and streak, a situation that is particularly common in Zaire and Nigeria.

DMR-W and DMR-Y were merged with the respective DMRSR populations during the 1981–82 irrigation season by utilizing the DMRSR population (under streak pressure) as the male parent. The reconstituted populations are still referred to as DMRSR-W and DMRSR-Y.

Table 22. Results of a downy mildew resistance and yield trial, Owo, Nigeria, 1982

Maize entries	Downy mildew infection, %	Number of cobs per hectare	Yield, kg/ha
IITA/NCRI[a]			
DMR-W	10	34,000	2,965
DMR-Y	12	34,000	3,167
DMRSR-W	11	31,000	2,803
DMRSR-Y	7	35,000	3,221
CIMMYT			
SW 8072	4	30,000	2,623
SW 8075	10	32,000	2,974
Pop. 2 (TLWD-DMR)	6	34,000	3,380
Pop. 5 (TIWD-DMR)	5	33,000	2,904
IITA			
TZPB	79	6,000	680
TZB	66	10,000	1,124
TZSR-Y-1	69	9,000	1,041
IAR&T[b]			
Western Yellow	85	5,000	579
Mean	30	24,000	2,288
LSD (5%)	8	4,000	523
C.V., %	27	16,000	23

Note: The figures listed here are means of two locations.
[a]National Cereals Research Institute, Nigeria.
[b]Institute of Agricultural Research and Training, Nigeria.

Table 23. Proportion of S_1 families of DMRSR-W and DMRSR-Y segregating for streak resistance, IITA, 1982–83

Maize population	Total no. of Entries	No. and percentage segregating for streak resistance
DMRSR-W		
Early	181	160 (88)
Late	275	238 (86)
DMRSR-Y		
Early	132	111 (84)
Late	317	261 (82)

From each population 250 ears were selected and planted ear-to-row at Owo in two sets; one set was exposed to a mild level of artificially induced downy mildew infection and the other to severe infection. Both populations had a high level of resistance even under severe downy mildew pressure (Figure 4). Resistant plants were selected for selfing within entries that had a high downy mildew resistance score and expressed good root and stalk quality. Owing to the rather wide range of maturity within each population, the S_0 ears were placed in early and late groups. These subpopulations were planted under streak pressure for half-sib recombination of streak resistant plants during the 1982–83 irrigation season. As shown in Table 23, a high percentage of the entries in each subpopulation expressed streak resistance.—*J.M. Fajemisin*

Late, white, streak resistant backup pool. The development and improvement of broad based gene pools is the best insurance against genetic erosion and provides a source of superior germplasm for current and future breeding programs. A late, white, streak resistant backup pool is being developed for TZSR-W-1 as a source of new and valuable germplasm.

Several experimental varieties from different populations in CIMMYT's international testing program and from IITA and Southeast Asia were crossed with streak resistant sources at IITA, mainly TZSR-W and TZSR-W-1. Some of these crosses were backcrossed to the nonresistant parent and then selfed once or twice for inbred line development. Other crosses were selfed directly two or three times. The best late, white, streak resistant lines were recombined by bulk sibbing. The materials that contributed to this pool are listed in Table 24.

A total of 320 families with a high level of streak resistance are now in the third cycle of half-sib recombination and selection for agronomic characters. New promising genetic material and introductions will be fed into this pool.

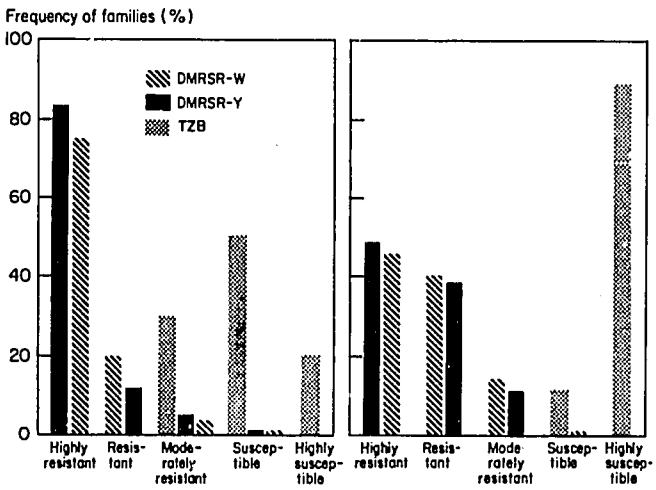


Figure 4. Frequency distribution of half-sib families of the maize population DMRSR-W, DMRSR-Y and TZB (250 families each) under mild (left) and severe (right) downy mildew pressure, Owo, Nigeria, 1982.

Table 24. Populations contributing to the late, white, streak resistant backup pool

Parent population	Relative contribution to the first cycle of recombination, %
22 Mezcla Tropical Blanca	31
43 La Posta	12
TZB	12
34 Blanco Subtropical	11
29 Tuxpeno Caribe	10
44 A.E.D. × Tuxpeno	6
32 Eto Blanco	4
28 Amarillo Dentado	3
Suwan 1	3
25 (Mix. 1 × Col. Gpo. 1) × Eto	2
26 Mezcla Amarilla	2
27 Amarillo Cristalino	1
33 Amarillo Subtropical	1
45 Amarillo del Bajio	1
36 Cogollero	1
35 Antigua × Republica Dominicana	0.5
Early DMR composite	0.5

Conversion of experimental varieties to streak resistance. At IITA a conversion program is being carried out to incorporate streak resistance into experimental varieties from nine populations that have wide adaptation and perform well in Africa. These populations are part of the international testing program organized by CIMMYT and have been described previously (IITA, Annual Report for 1981).

The streak resistant sources available at IITA were used as donors in a backcrossing program in which the best available experimental variety from each of the nine populations was used as a recurrent parent for each backcross generation. Two to three backcross generations have been developed already in each of these backgrounds. In addition to selecting for streak resistance, CIMMYT maize breeders selected for plant and grain type and maturity group of the recurrent parents in each generation.

In six of these conversions, streak resistant families with good agronomic characters were recombined in the BC_2-F_2 generation. The recombined ears were bulked, and the seed of these conversions was increased during the dry season. Five of these conversions are adapted to the lowland tropics and will enter streak resistant variety trials to be tested in Africa during 1983. The sixth conversion, of an experimental variety from population 44 (American Early Dent × Tuxpeno), is adapted to midaltitude and subtropical areas and will be made available to national programs for testing.—*M. Bjarnason*

Hybrid Project

A hybrid maize research project was begun at IITA in 1979 to develop inbred lines that are adapted to tropical zones and have resistance, high combining ability and plant vigor. At the outset of the program,

Table 25. Number of S_4 inbred lines developed in IITA's hybrid maize project by 1982

Population	No. of S_4 lines	Possible adaptation
CIMMYT[a]		
21 Tuxpeno 1	10	Lowland tropics
22 Mezcla Tropical Blanca	164	Lowland tropics
23 Blanco Cristalino-1	18	Lowland tropics
24 Antigua Veracruz 81	22	Lowland tropics
25 Blanco Cristalino-3	17	Lowland tropics/ subtropics
26 Mezcla Amarilla	39	Lowland tropics
27 Amarillo Cristalino-1	43	Lowland tropics
28 Amarillo Dentado	130	Lowland tropics
29 Tuxpeno Caribe	69	Lowland tropics
32 Eto Blanco	28	Lowland tropics/ subtropics
33 Amarillo Subtropical	54	Subtropics
34 Blanco Subtropical	110	Subtropics
35 Antigua Republica Dominicana	88	Lowland tropics
36 Cogollero	38	Lowland tropics/ subtropics
38 PD(MS)6 H.E. oz	55	Lowland tropics/ subtropics
43 La Posta	281	Lowland tropics
44 AED Tuxpeno	58	Midaltitude
45 Amarillo Bajio	12	Subtropics/temperate
Pool-16 (white dent)	172	Lowland tropics
IITA		
TZPB-EPS	218[b]	Lowland tropics
TZB	15	Lowland savanna
TZSR (late)	5	Lowland tropics
TZSR (early)	239	Lowland savanna
TZ (S5 lines)	52	Lowland tropics
TZDMRSR	280	Lowland tropics (downy mildew)
Asia[a]		
Suwan 1 + four DMR populations	82	Lowland tropics (downy mildew)
Hawaii[a]		
Hi inbred lines	229	Tropics/subtropics
U.S. Corn Belt[a]		
B73, Mo17, etc	329	Tropical savanna
TOTAL	2,857	

[a]S_4 lines were derived from CIMMYT and other populations/ lines that had been crossed with IITA streak resistant sources (TZSR-W and TZSR-Y).
[b]Susceptible to maize streak virus. All the other lines have streak resistance.

the best available high yielding maize populations and varieties from the CIMMYT and IITA maize programs as well as materials from various Asian countries, the University of Hawaii and institutions in the Corn Belt of the United States were used for the extraction of desirable elite inbred lines adapted to the tropics. By 1982 a total of 2,857 S_4 lines, most of them resistant to maize streak virus, had been developed (Table 25). In addition, other promising varieties from some African national programs and from commercial seed companies had been added

Table 26. Number of streak resistant S_2 maize inbred lines developed at IITA, 1982

Variety	No. of S_2 lines	Source
7801, Katumani, etc.	45	Kenya
Tx 379 W	28	Malawi
Ilonga, 7784, etc.	401	Tanzania
ZCA, ZUCA, etc.	340	Zambia
SR 52, R 201, etc.	61	Zimbabwe
Ekona-W and Ekona-Y	57	Cameroon
Poza Rica 7722	75	CIMMYT
Across 7729	52	
Tocumen (1) 7835	75	
TZSR-W-1	117	IITA
TZSR-Y-1	50	
TZMSR (midaltitude) streak resistant)[a]	495	
TZUT-Wb	212	
TZUT-Y[b]	180	
X 304C and X 304B	274	Pioneer
G 4747 and G 4787	238	Funk (U.S.)
TOTAL	2,700	

[a]TZMSR lines were developed from IITA midaltitude, streak resistant populations (white dent and white flint). All lines are expected to be resistant to three major diseases—highland blight (*H. turcicum*), rust (*P. sorghi*) and streak.
[b]TZUT lines are segregating for resistance to maize streak virus.

(Table 26). Attempts were also made to extract elite inbred lines directly from 12 CIMMYT populations, using correspondent experimental varieties without crossing IITA sources of streak resistance (TZSR-W and TZSR-Y).

In 1982 a special hybrid maize project was begun with financial support from the government of Nigeria through the Green Revolution Technical Subcommittee. The purpose of this project is to develop high yielding hybrid maize varieties that are adapted to the maize growing savanna areas in the northern part of Nigeria. The main trials conducted under the hybrid project this year are discussed in the following paragraphs.

Combining ability test for S_3 inbred lines. Test cross trials were conducted to identify superior lines with high combining ability for subsequent development of single-cross hybrids. One thousand and sixty-seven S_3 streak resistant lines were test crossed with selected open pollinated varieties based on maturity and grain color. Six hundred and seven test crosses were made with late maturing (110 to 125 days) varieties; 417 of these were made with white and 190 with yellow varieties. Four hundred and sixty crosses were made with early (90 to 115 days) varieties, 269 of them with white and 191 with yellow varieties. Flint lines were crossed with dent varieties and dent lines with flint varieties since these crosses were expected to have high combining ability.

All the test cross progenies were planted during the 1982 growing season at various locations in Nigeria. Progenies for 644 crosses were planted at Ikenne (forest) from 11 to 12 May, for 756 crosses at Ilorin (derived savanna) from 26 to 28 May, for 1,056

crosses at Samaru (savanna) from 15 to 24 June, and for 669 crosses at Gusau (savanna) from 25 to 27 June.

The crosses, together with open pollinated testers, were divided into sets of approximately 40 within each maturity group (late versus early) to simplify field layout and ensure the validity of the statistical comparison. More emphasis was given to testing of late maturing test crosses at Ikenne, Ilorin and Samaru, whereas at Gusau the early maturing test crosses were emphasized since early maturing varieties fit the short rainy season of the northern savanna ecology. Because of the large number of test crosses, the trials were planted in three replications of a single 5-m row (75 cm × 25 cm) at each location. The entries were evaluated for early vigor, flowering time, uniformity, ear placement, disease resistance and root lodging as well as for yield.

The numbers of high yielding test crosses selected, those that produced significantly higher yields than the top yielding open pollinated check variety in each set, are listed in Table 27. A total of 78 test crosses produced significantly higher yields than the best check variety.

In the forest area (represented by Ikenne), 17 late white and 9 late yellow test crosses gave significantly higher yields than the top yielding, open pollinated check variety. However, in the high yield potential savanna area (represented by Ilorin, Samaru and Gusau), 5 late white, 4 late yellow, 15 early white, and 28 early yellow test crosses yielded significantly more than the top yielding, open pollinated check variety.

The test crosses selected will be tested again during the 1983 growing season in larger plots for yield, agronomic traits and adaptation. The test crosses that show outstanding yield potential in the 1983 trial may be used commercially, pending the development of conventional (single, three-way and double cross) hybrids. However, since the primary objective of the test cross trials was to identify lines

IITA is developing inbred S_5 lines that are adapted to the tropics.

Table 27. Results of maize test cross trials in Nigeria, first season, 1982

Location	Number of test crosses: Tested	Selected[a]
Ikenne		
Late, white	287	17
Late, yellow	191	9
Early, white	12	—
Early, yellow	154	—
Subtotal	644	26
Ilorin		
Late, white	278	3
Late, yellow	166	1
Early, white	198	8
Early, yellow	114	11
Subtotal	756	23
Samaru		
Late, white	344	2
Late, yellow	263	—
Early, white	202	5
Early, yellow	237	4
Subtotal	1,046	11
Gusau		
Late, white	175	—
Late, yellow	136	3
Early, white	209	2
Early, yellow	162	13
Subtotal	682	18
TOTAL		78

[a]Number of test crosses that yielded significantly more than the highest yielding open pollinated check in each set.

The combining ability of inbred lines was tested by crossing them with open pollinated varieties.

Table 28. Number of inbred lines selected for single-cross hybrid production through diallel crossing, IITA, 1982

Maturity and grain color	Adaptation	No. of lines selected[a]	Expected no. of single-cross hybrids
Late, white	Savanna	17	136
Late, white	Forest	10	45
Late, yellow	Savanna	13	78
Late, yellow	Forest	10	45
Early, white	Savanna/forest	10	45
Early, yellow	Savanna/forest	13	78
	TOTAL	73	427

[a]Selection was based on yield potential in test crosses and inbred line performance per se.

that possess high combining ability, the results of those trials were taken into consideration in the selection of inbred lines for subsequent hybrid production.

Inbred lines performance trial. Successful production of commercial hybrid seed depends on high quality inbred lines. If used as male parents, the lines must have good vigor and agronomic traits to produce enough pollen. If used as female parents, they must produce good seed yields. The major purpose of this trial was to evaluate the performance of the available lines and select only those that perform well in addition to having high combining ability.

A total of 930 lines, mostly S_4, were planted at four different locations: Ikenne (748), Ilorin (547) Samaru (878) and Gusau (418). The number of lines tested at each location was based on the maturity requirement of the test location and availability of seed. The lines were evaluated for flowering date, plant vigor, uniformity, reaction to prevailing diseases, stalk and root lodging, pollen production, ear aspects and seed yield potential. All the S_4 lines tested were planted also at Ibadan under artificial streak pressure, and the selected lines were selfed. Pollination was also made at Samaru for the selection of lines adapted to the savanna.

Based on the combining ability test of the lines (in test cross trials) and their performance per se, 73 lines were finally selected for diallel cross hybrid production during the dry season of 1982 under irrigation at IITA (Table 28). Approximately 400 F_1 single crosses will be produced for 1983 testing throughout Nigeria. The diallel crosses are being produced according to maturity, grain color and adaptation to various regions.

Various male sterile sources were introduced from the United States (Illinois Foundation Seed Co. Ltd., Pioneer International and University of Hawaii) and were tested at IITA during the second season of 1982. Selected, high combining seed parental lines will be converted for male sterility to facilitate hybrid seed production in Africa.

Combining ability test for selected open pollinated varieties. The purpose of this trial was to find out which tropical maize varieties have the best combining ability. The varieties are to be used by IITA's hybrid program in a reciprocal recurrent selection scheme for inbred line development. Major emphasis has been placed on late maturing (120 days) white and yellow populations. A total of 15 selected tropical maize varieties (9 white and 6 yellow), with their 51 diallel F_1 crosses (36 white and 15 yellow), were planted at four locations in Nigeria (Ikenne, Ilorin, Samaru and Gusau). Each plot had four 5-m rows with three replicates. Only the two central rows were harvested for yield estimation. The yield of nine white varieties averaged 4.5 t/ha and ranged from 5.5 (TZB) to 3.9 t/ha (TZPB). That of the 36 F_1 crosses averaged 5.2 t/ha and ranged from 6.4 (TZB × Across 7721) to 4.5 t/ha, (Across 7823 × Poza Rica 7729), as shown in Table 29. The array mean of all possible nine crosses in each variety indicates that the white grain varieties with the best general combining

Table 29. Average grain yields of nine tropical white maize varieties and their 36 F_1 crosses at four locations in Nigeria, 1982

Parent	TZB	TZPB	TZSR-W-1	Across 7721	PR 7822	Across 7823	PR 7729	Across 7832	PR 7843	Array mean
					t/ha					
TZB (flint)	5.5	5.5	5.4	6.4**	5.3	5.0	5.0	5.9**	5.5	5.5
TZPB (dent)		3.9	4.7*	5.1**	5.0	4.7**	4.9**	5.6**	4.9**	5.1
TZSR-W-1 (flint)			4.4	5.0**	4.8	4.9**	5.5**	4.7	5.9**	5.1
Across 7721 (dent)				4.3	5.7**	5.1**	5.1**	5.6**	5.6**	5.5
PR 7822 (dent)					5.0	4.7	5.8**	5.2	5.1	5.2
Across 7823 (flint)						4.2	4.5	5.9**	5.3**	5.0
PR 7729 (flint)							4.4	4.7	5.8**	5.2
Across 7832 (flint)								4.5	4.7	5.3
PR 7843 (dent)									4.4	5.4
Parent variety mean	4.5									
F_1 mean	5.2									
C.V., %	23.7									
S.E.	0.103									

*Significantly different at the 5% level from the yield of the high yielding parent.
**Significantly different at the 1% level.

Table 30. Average yields of six tropical yellow maize varieties and their 15 F_1 hybrids at four locations in Nigeria, 1982

Parent	TZSR-Y-1	MMB	Across 7728	LM 7827	Suwan 1	Western yellow	Array mean
				t/ha			
TZSR-Y-1 (flint)	4.6	5.2**	4.5	4.6	5.2**	4.6	4.8
MMB (dent)		3.4	4.7	4.4**	4.2**	5.1**	4.7
Across 7728 (dent)			4.8	4.6	5.4**	4.6	4.8
LM 7827 (flint)				3.8	5.4**	4.6**	4.7
Suwan 1 (flint)					4.4	5.2**	5.1
Western Yellow (dent)						4.0	4.8
Parent variety mean	4.2						
F_1 mean	4.8						
C.V., %	25.4						
S.E.	0.111						

*Significantly different at the 5% level from the yield of the high yielding parent.
**Significantly different at the 1% level.

ability were TZB (5.5 t/ha) and Across 7721 (5.5 t/ha), followed by Poza Rica 7843 (La Posta) and Across 7832 (Eto).

The heterotic effects of F_1 crosses from the mid-parental value were quite variable, depending on the combination. The average heterotic effect of the 31 F_1 crosses in late white varieties was 16.4% (Table 29). Among the white varieties, five crosses showed over 30% heterotic effect: Across 7823 × Across 7832 (35.6%), TZSR-W-1 × Poza Rica 7843 (34.1%), Across 7832 × TZPB (33.3%), Poza Rica 7729 × Poza Rica 7843 (31.8%) and TZB × Across 7721 (30.6%).

On the basis of their disease resistance, general and specific combining ability, and heterotic effect, TZSR-W-1 (which is resistant to streak) and Poza Rica 7843 may be selected as base populations for reciprocal current selection in the white line development program.

As shown in Table 30, the yield of six yellow varieties averaged 4.2 t/ha and ranged from 4.8 for Across 7728 to 3.4 t/ha for Milo Maya Brazil (MMB). Yield of the 15 F_1 crosses averaged 4.8 t/ha and ranged from 5.4 (Across 7728 × Suwan 1, La Maquina 7827 × Suwan 1) to 4.2 t/ha (MMB × Suwan 1). Suwan 1, a downy mildew resistant variety from Thailand, showed the highest array mean (5.1 t/ha) estimated from all possible five crosses. The average heterotic effect of the 15 F_1 crosses in yellow varieties was 16.2%, about the same as that of the white varieties. Among the yellow varieties, three crosses showed over 30% heterotic effect: MMB × Western Yellow (37.8%), La Maquina 7827 × Suwan 1 (31.7) and Suwan 1 × La Maquina 7827 (31.7%).

Table 31. Average heterotic effects in crosses among tropical late maize varieties, IITA, 1982

Combination	Number of crosses	Heterotic effect, %
Dent × dent	9	19.1
Dent × flint	29	16.7
Flint × flint	13	13.8
Average	51	16.4

Based on their streak and downy mildew resistance and general and specific combining ability, TZSR-Y-1 (which is resistant to streak) and Suwan 1 (which is resistant to downy mildew) may be selected as base populations for yellow line development.

The general heterotic patterns of dent × dent, dent × flint and flint × flint crosses with both the white and yellow varieties used in this test are summarized in Table 31. The nine dent × dent crosses showed the highest heterotic effect (19.9%), followed by dent × flint (16.7%) and flint × flint (13.8%). Although various crosses were made between different grain types, the average heterotic effects of dent × dent and dent × flint crosses were higher than those of the flint × flint crosses. These results agree with the general heterotic pattern in maize.—*S.K. Kim, Y. Efron, F.H. Khadr and J.M. Fajemisin*

National and International Yield Trials

In cooperation with other research institutions, IITA conducted the following trials of promising experimental maize varieties at Samaru and Gusau in northern Nigeria during 1982: Nigerian national zonal trial (early and late maturing varieties) CIMMYT international trials (EVT 14A and 14B) and SAFGRAD regional trials (RUVT-1 and -2).

The results of these trials are discussed in the following paragraphs and summarized in the accompanying tables. It should be noted that a severe storm immediately after flowering caused a high degree of lodging in many of the trials at Samaru, making it extremely difficult to record plant counts and yield data at harvest. The high C.V.s were due mainly to the *Striga* infestation in some parts of the experimental plots, notably in Gusau.

National zonal maize variety trials. Pirsabak (1) 7930 at Samaru and Pool-16 at Gusau were the highest yielding varieties in the early maturing maize trials tested at these two locations (Table 32). Differences in yield among the entries tested, however, were not statistically significant at the 5% level in the Samaru trial. Nor were there significant

differences at the 5% level among varieties entered in the long duration trials at Samaru and Gusau.

CIMMYT international trials. Table 33 contains the results of trials of early maturing yellow maize (EVT 14A), in which there were 17 entries, including three local checks, and trials of early, white maize (EVT 14B), which had 17 entries. These trials were conducted at Gusau. In EVT 14A varieties extracted from population 31 (Amarillo Cristalino-2) and population 35 (Antiqua × Republica Dominicana) were the top yielders. Data from EVT 14B show that the experimental varieties from population 32 (ETO Blanco) ranked at the top. It should be noted, however, that there were no significant differences at the 5% level between these top yielding varieties and the best local checks (Pool-16 Gusau in EVT 14A and Pirsabak (1) 7930 SR BC_2 (F_1) in EVT 14B).

SAFGRAD regional trials. RUVT-1 compared the performance of promising early maturing varieties from various breeding programs. Temperate × Tropical No. 42 and Temperate × Tropical No. 3 were the highest yielding maize varieties tested at Samaru and Gusau, respectively, but there was no significant difference between the yield of these varieties and that of the local check (Table 34). Grain moisture at harvest, in contrast, varied widely among the test entries.

RUVT-2 was designed to test late maturing maize varieties. Table 35 presents yields and other information about the highest yielders in comparison with the local check. TZSR-Y-1 yielded significantly more than the check at the 5% level of probability. But in view of the much lower number of plants harvested and the shorter stature of the local check, the yield of the local check could have been underestimated.—*H.N. Pham*

Entomology

Maize breeding for resistance to stem borers has been carried out at IITA for the last several years. In screening under severe natural infestation by the pink stalk borer (*Sesamia calamistis*) at Umudike, Nigeria, the response of more than 2,000 different maize genotypes, including IITA developed lines, was compared.

Screening of field crops for resistance under natural growing conditions and optimal natural insect pressure is the cheapest method of plant selection. It has one drawback, however, that may hinder progress in breeding resistant maize cultivars. Since some plants may escape natural infestation, lines may be wrongly classified as resistant when in fact they were never infested.

This problem can be eliminated through homogenous artificial infestation. Intensive work on rearing of stem borers on artificial diets has been carried out at IITA this year, including the rearing of large populations of the pink stalk borer (*Sesamia*

Table 32. Results of Nigerian zonal trials, Samaru and Gusau, Nigeria, 1982

	Yield in t/ha and rank			Percentage of grain moisture			No. of plants
	Samaru	Gusau	Mean	Samaru	Gusau	Mean	harvested
Early varieties[a]							
Pirsabak(1) 7930	4.54 (1)	5.13 (2)	4.83 (1)	30.9	20.1	25.5	39.8
Pool-16	3.82 (6)	5.58 (1)	4.70 (2)	28.3	18.8	23.5	42.3
Kewesoke-W	4.23 (3)	4.67 (3)	4.45 (3)	30.9	18.5	24.7	39.7
Kewesoke-Y	4.09 (4)	4.67 (3)	4.38 (4)	30.1	20.5	25.3	34.0
TZESR-W	4.33 (2)	4.24 (6)	4.28 (5)	37.8	19.5	28.6	34.8
TZESR-Y	3.97 (5)	4.52 (5)	4.24 (6)	30.8	19.5	25.1	34.3
NE-Y	3.10 (7)	2.95 (7)	3.02 (7)	39.9	23.0	31.4	36.7
Mean	4.01	4.45					
LSD (5%)	1.29	1.10					
CV, %	21.6	20.5					
Long duration varieties							
NSI-Y-1	3.83 (3)	5.39 (3)	4.61 (1)	29.9	23.1	26.5	37.5
Ife Yellow Comp	3.58 (5)	5.51 (1)	4.54 (2)	28.3	22.9	25.6	32.6
TZB (check)	3.89 (2)	4.84 (6)	4.36 (3)	31.9	28.2	30.0	36.1
La Maquina 7928	3.80 (4)	4.88 (4)	4.34 (4)	31.7	25.6	28.6	36.1
Western Yellow (check)	3.90 (1)	4.77 (8)	4.33 (5)	31.7	27.6	29.6	35.6
TZSR-W-1	2.94 (10)	5.49 (2)	4.21 (6)	30.1	23.5	26.8	35.1
Los Diamantes 7823	3.09 (8)	4.83 (7)	3.96 (7)	27.6	21.1	24.4	33.3
Poza Rica 7843	3.04 (9)	4.87 (5)	3.95 (8)	27.6	24.0	25.8	34.7
RSPH-W-1	3.16 (7)	4.65 (9)	3.90 (9)	23.7	25.0	24.3	31.8
TZSR-Y-1	3.17 (6)	3.94 (10)	3.55 (10)	24.6	29.8	27.2	37.0
Mean	3.44	4.92					
LSD (5%)	1.61	1.16					
CV, %	32.3	20.3					

[a]Variety DMR-YE was excluded from the analysis because of its poor germination.

calamistis), the sugarcane stalk borer (*Eldana saccharina*) and the spotted borer (*Chilo partellus*). Initial experiments on laboratory rearing of maize borer (*Busseola fusca*) showed that the larvae easily accepted the diets used for other stem borer species, but the occurrence of diapause significantly reduced the productivity of the colony. The effect of temperature, humidity and diet composition on incidence of larval diapause is presently being investigated.

Table 33. Results of CIMMYT regional trials, Gusau, Nigeria, 1982

Variety	Yield, t/ha	Percentage of best check's yield	Moisture, %	Plant height, cm	Ear height, cm
EVT 14A					
Pichilingue 7931	5.02	131	18.3	170	71
Islamabad 8035	4.80	126	19.7	156	67
Sete Lagoas 7931	4.75	124	18.0	160	71
Across 7726 RE	4.65	122	22.5	169	82
Suwan 8035	4.45	116	20.3	162	67
Pool-16 Gusau (best check)	3.82	100	16.9	161	70
LSD (5%)	1.31				
C.V., %	23.3				
EVT 14B					
Alajuela 8032	5.37	116	23.1	192	106
Poza Rica 8032	5.22	113	22.2	182	96
Cotaxtla 8032	4.66	101	21.5	170	82
Ilonga (1) 7930	4.64	100	18.4	162	81
Kisanga 7930	4.45	100	17.9	172	90
Pirsabak (1) 7930 SR (best check)	4.62	100	19.9	171	89
LSD (5%)	1.17				
C.V., %	19.0				

Table 34. Results of SAFGRAD regional trial RUVT-1, Gusau and Samaru, Nigeria, 1982

Variety	Yield in t/ha and rank			Percentage of grain moisture		
	Samaru	Gusau	Mean	Samaru	Gusau	Mean
Temp. × Trop. No. 3	4.23 (3)	6.00 (1)	5.11 (1)	29.4	23.1	26.2
Temp. × Trop. No. 42	4.55 (1)	5.26 (5)	4.90 (2)	28.8	19.6	24.2
7/8 CDN-1/8 Comp. D	4.33 (2)	5.28 (4)	4.80 (3)	29.0	20.8	24.9
TZESR-W	3.48 (6)	5.90 (2)	4.69 (4)	30.6	18.6	24.6
Pirsabak (1) 7930	3.94 (4)	4.58 (9)	4.26 (5)	26.5	17.6	22.0
Local check	3.18 (8)	5.21 (6)	4.19 (6)	36.5	18.5	27.5
MTS	3.34 (7)	4.85 (7)	4.09 (7)	25.5	18.2	21.8
EV 7982	2.51 (10)	5.30 (3)	3.90 (8)	29.0	22.4	25.7
SAFITA-2	3.72 (5)	3.84 (11)	3.78 (9)	31.1	19.3	25.2
Pool-27	3.07 (9)	4.30 (10)	3.68 (10)	22.7	18.8	20.7
SAFITA-104	2.18 (12)	4.60 (8)	3.39 (11)	25.5	17.7	21.6
Comp. 77 BD	2.35 (11)	3.57 (12)	2.96 (12)	37.3	28.0	32.6
Mean	3.41	4.89				
LSD (5%)	1.32	1.47				
C.V., %	26.9	20.8				

Table 35. Results of SAFGRAD regional trial RUVT-2, Gusau, Nigeria, 1982

Variety	Grain yield, t/ha	Percentage of check's yield	Moisture, %	Plant height, cm	Ear height, cm	Lodging, %	No. of plants harvested
TZSR-Y-1	5.46	138	27.3	202	116	15.1	36.5
Temp. × Trop. No. 27	5.31	134	20.8	191	90	8.5	35.7
Golden Crystal	5.20	132	24.8	202	97	19.2	35.5
TZPB	4.56	115	22.6	202	107	31.0	37.7
Comp. 4	4.50	114	20.7	237	132	11.7	41.2
Local check	3.95	100	19.9	180	81	22.3	26.0
LSD (5%)	1.48						
C.V., %	22.6						

Table 36. Composition of the diet used for rearing *Sesamia* and *Eldana* larvae at IITA

	Amount
Water	3,600 ml
Agar	559 g
Soy flour	256 g
Wheat germ	114 g
Salt mixture W	38 g
Sugar (sucrose)	46 g
Ascorbic acid	40 g
Ground corn stems or maize leaf powder	25 g
Aureomycin	10 g
Benlate	2 g
Vitamin mixture[a]	26 ml
KOH	20 ml
Chlorine chloride	26 ml
Acetic acid	42 ml
Sorbic acid[b]	10.5 ml
Methyl p-hydroxy benzolate[c]	20 ml
Phosphoric acid in propionic acid[d]	23 ml
Formaldehyde[e]	2.5 ml

[a]Mixture of 100 ml of distilled water with 1.2 g of calcium penthatenate, 0.6 g of niacin, 0.3 g of riboflavin, 0.3 g of folic acid, 0.15 of thiamine NC1, pyridoxine, 0.15 g of HC1, 0.12 g of biotin and 0.0006 g of B12.
[b]Solution of 100 g of sorbic acid in 50 ml of 95% ethyl alcohol.
[c]Solution of 280 g of methyl p-hydroxybenxoate in 1,000 ml of 95% ethyl alcohol.
[d]Mixture of 836 ml of propionic acid with 84 ml of phosphoric acid and 1,080 ml of distilled water.
[e]37% solution of formaldehyde.

New diets and rearing techniques are being developed at IITA for *Sesamia* and *Eldana*.

Rearing Stem Borers on Artificial Diets

The completion of a new insect rearing laboratory in 1982 and modifications made in the diet composition and techniques used in the past at IITA made it possible to obtain approximately 2,000 pupae of *Sesamia* per week. Techniques developed for rearing of *Eldana* (IITA Research Briefs, Vol. 3, No. 1, 1982) were found to be effective in meeting all the requirements of field work. Preliminary work on rearing of the maize borer (*Busseola fusca*) on an artificial diet was also begun.

Larvae of *Sesamia* are presently reared in plastic containers that are 18 cm in diameter and contain 500 ml of diet. The plastic cover has an opening 6 cm in diameter that is covered with 80 gauge brass mesh to prevent escape of the larvae and buildup of humidity inside the containers, which accompanies the development of larvae in the diet. One or two paper tissues are placed under the cover to allow developed larvae to find a dry place for pupation. About 60 to 70 eggs, sterilized in 1% of bleach or 1% of formalin solution for 15 minutes, are pinned and placed in the middle of the diet.

The diet composition is shown in Table 36, and the preparation procedure is as follows: (1) add 55 g of agar to 1,800 ml of distilled water, bring to a boil and then cool to 60°C before adding vitamins; (2) mix 1,800 ml of water with soy flour and the ground corn stems or maize leaves, boil to prevent contamination with microorganisms, and cool to 60°C; (3) to this mixture add a salt mixture, wheat germ, sugar, ascorbic acid, aureomycin and Benlate, blend for one minute, add the agar portion, and blend for another minute; (4) add the mixture of vitamins, KOH, chlorine chloride, acetic acid, methyl p-hydroxybenzoate, phosphoric acid and propionic acid and formaldehyde and blend for three minutes; and (5) pour 500-ml portions into containers, allow them to cool to room temperature for 12 hours and store at 5°C before elimination of excess water. The containers are kept in the larval rearing rooms under 50 to 60% relative humidity and 26 ± 1°C. Most of the larvae pupate after 24 to 26 days (the range is 21 to 29 days).

Pupae are collected from the paper towels or drying diet and kept at 20° to 21°C and 75 to 85% relative humidity. Approximately 200 pupae are placed in a round wire cage 15 cm in diameter and 22 cm high. Male adults emerge after 10 to 12 days and females after 11 to 13 days. The sex of adult insects is determined from the dimorphism shown by their antennae and by their abdominal shape. Twenty-five pairs are released in the oviposition wire mesh cage (30 cm × 40 cm × 70 cm), which has two long pieces of wooden brush handles wrapped with wax paper to provide a smooth surface with closely overlapping edges for oviposition. A 5% sucrose solution is provided in four plastic cups with a piece of paper towel for adult feeding. Egg masses are removed by cutting small pieces of paper, each with one to two

masses. These are sterilized and stored in petri dishes or plastic containers, the bottoms of which are lined with a moist paper towel for incubation, and kept at 20° to 21°C under high humidity. Most of the larvae hatch after six days.—*Z.T. Dabrowski and L. Jackai*

Screening Maize for *Sesamia* Resistance

Infestation of three- to four-week-old maize plants with *Sesamia* has been done both with eggs in the "blackhead" stage and with newly hatched larvae. Twelve maize families selected previously under natural field infestation and a maize cultivar (TZPB) were infested under screenhouse conditions to avoid natural infestation by other species of stem borers. Two infestations with 25 larvae per plant at weekly intervals caused 95% mortality among the TZPB plants but only 30 to 40% among the new IITA families (Figure 5).

In screening maize germplasm for resistance to *Sesamia*, there should be only one infestation of four-week-old plants with a maximum of 25 larvae to allow plants showing good agronomic characters but a low level of resistance to produce some seeds. The accumulation of genes responsible for low levels of resistance should lead to development of resistant cultivars.

Another 142 half-sib families selected as moderately resistant to stem borers under natural field infestation are being evaluated in a randomized complete block with four replications under field conditions. The plants are infested with 25 to 30 eggs in the blackhead stage. Leaf damage, formation of "dead hearts" and overall plant damage are being observed.—*Z.T. Dabrowski*

Mass Production of Leafhoppers

Mass rearing of leafhoppers (*Cicadulina triangula*), a vector of maize streak virus (MSV), was begun at IITA in 1975. To develop resistant varieties, it was necessary to infest a large number of plants

New IITA maize lines with resistance to stem borers compared to a susceptible check (center).

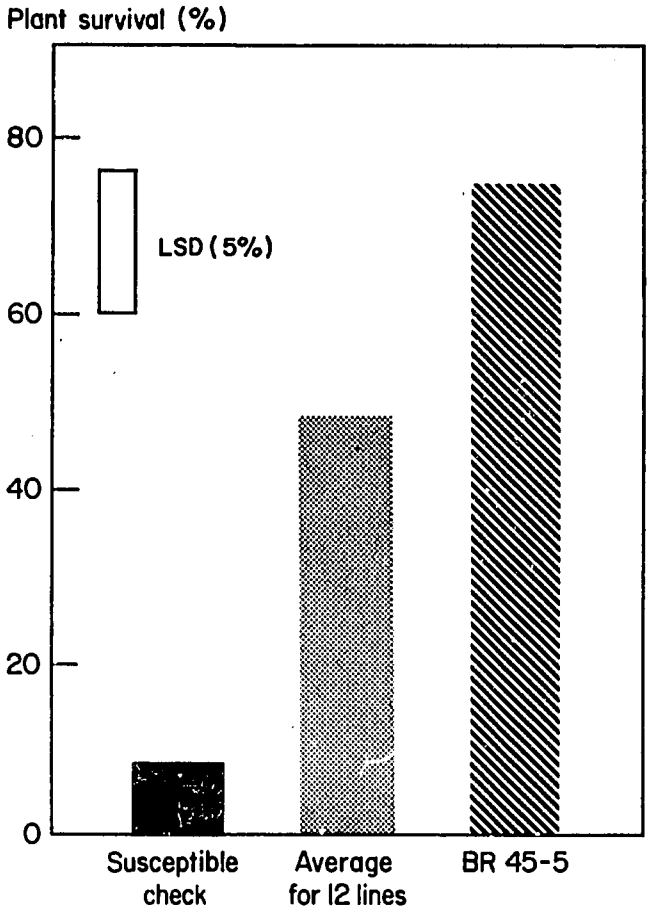


Figure 5. Plant survival of some new IITA maize lines artificially infested with *Sesamia* under screenhouse conditions, 1982.

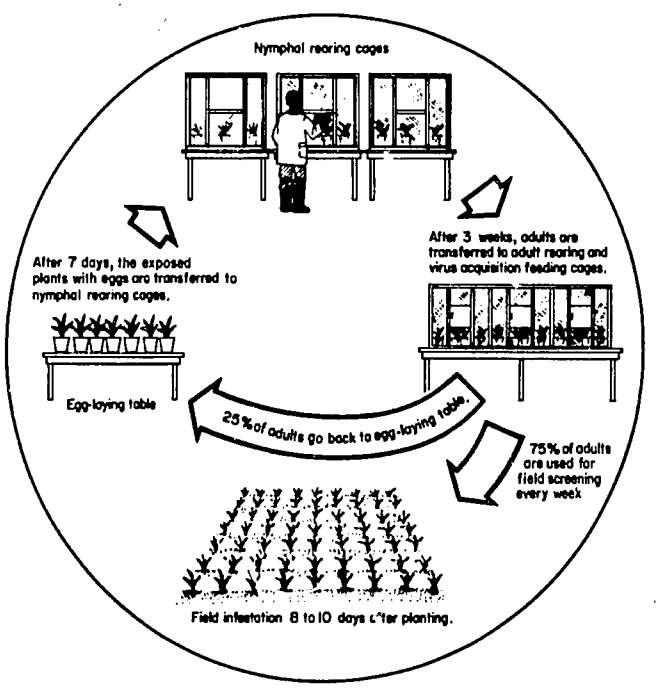
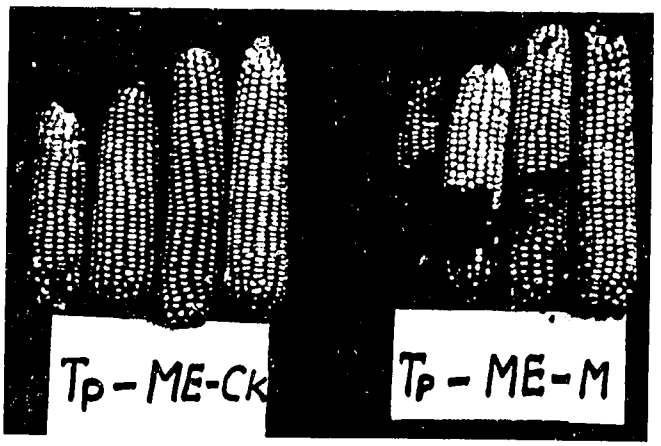


Figure 6. Procedure used at IITA for mass rearing of *C. triangula*.

Table 37. Incidence of maize streak virus disease on artificially infested plants, IITA, 1982

	No. of plants infested	Incidence of MSV, %
April	28,770	83.30
May	27,489	78.35
June	40,005	88.43
July	59,620	87.79
August	25,200	84.23
September	29,001	87.94
October	37,470	85.75
November	41,154	88.84
Mean	36,088.63	85.58

Note: In measuring incidence of infestation, five random samples were taken (100 plants per sample) 15 days after each infestation date.



Check versus treatment in an experiment that evaluated various methods of ear rot inoculation.

The plant at left has sclerotia of *Rhizoctonia solani*, which commonly causes ear and stalk rot in high rainfall areas of Africa.

artificially every season. This task required efficient procedures for mass production of leafhoppers in the insectary, uniform field infestation and evaluation of the plant reaction.

A few years ago, a uniform field infestation technique and an efficient method of evaluation were developed at IITA. Mass production of leafhoppers in the insectary remained a problem, however, with the result that only 4,000 plants could be infested each week. To overcome this problem, a modification was made during 1982 in the procedure for mass production of leafhoppers. The modified procedure is illustrated in Figure 6.

Using this procedure, about four times more leafhoppers can be collected each week in the same amount of space as before, enough to infest at least 10,000 maize plants per week with two to four leafhoppers per plant. With the improved technique for field infestation and with earlier infestation (8 to 10 days after planting), incidence of infection by MSV in screening plots ranged from 78.35 to 88.84%, as shown in Table 37, with an average of 85.58%.—*M.S. Alam*

Pathology

Stalk and ear rots, which are prevalent in all the maize growing areas of Africa, lead to significant yield losses by causing premature plant senescence, stalk lodging and deterioration in grain quality. Efforts to develop reliable techniques for germplasm evaluation against stalk and ear rots continued at IITA in 1982.

Table 38. Effect of plant age at inoculation on the severity of stalk rot, IITA, 1982

Pathogen and variety	Age at inoculation, weeks after planting 4	6	8	10	Variety mean	Pathogen mean
Macrophomina						
TZESR-W	0.2	0.3	1.2	0.8	0.61	
TZSR-W-1	0.3	1.6	1.1	1.4	1.09	0.85
Diplodia						
TZESR-W	0.3	1.1	1.0	1.1	0.87	
TZSR-W-1	0.2	2.3	1.7	1.4	1.41	1.14
Fusarium (seed isolate)						
TZESR-W	0.5	2.1	2.2	0.7	1.36	
TZSR-W-1	0.8	1.9	2.3	1.0	1.50	1.43
Fusarium (stalk isolate)						
TZESR-W	0.4	2.2	1.8	0.7	1.29	
TZSR-W-1	0.6	1.6	2.1	1.8	1.54	1.42
Soil suspension						
TZESR-W	0.7	1.2	0.4	1.0	0.81	
TZSR-W-1	0.5	0.9	1.0	0.9	0.82	0.82
Check						
TZESR-W	0.3	0.7	0.9	0.6	0.60	
TZSR-W-1	0.3	0.7	1.0	0.9	0.71	0.66
Age mean	0.41	1.37	1.39	1.03		
LSD (5%)		0.10				0.15
C.V., %		29.6				24.2

Note: Stalk rot is rated on a scale of 0 to 4, where 0 = no rot, 1 = 25%, 2 = 50%, 3 = 75% and 4 = 100% of the inoculated internodes rotten.

Stalk Rots

An experiment was carried out to determine the best age at which to inoculate maize with stalk rot pathogens. Two maize varieties were used: TZESR-W, an early maturing (90 days) variety, and TZSR-W-1, a late maturing (120 days) variety. The plants were inoculated 4, 6, 8 and 10 weeks after planting. The pathogen treatments were *Macrophomina phaseoli* (agent for charcoal rot), *Diplodia maydis*, *Fusarium moniliforme* (seed isolate), *F. moniliforme* (stalk isolate), a maize soil suspension and a check. Each of the pathogens was raised on sterilized toothpicks. Uninfested, sterilized toothpicks were used as the check. A factorial combination of the treatments was tested in a randomized complete block design with four replications, a plot size of four rows 3 m long and spacing of 75 cm × 25 cm. For each of the treatments, the first fully elongated internode of each plant in the two center rows was inoculated. At maturity the stalks were split longitudinally for rot evaluation, using a scale of 0 to 4, where 0 = no rot and 4 = 100% rot of the inoculated internode.

As observed in a similar experiment last year, inoculation four weeks after planting was not effective (Table 38). Inoculation eight weeks after planting gave the highest average rot scores, but these were not significantly different from ratings for inoculation six weeks after planting.

From the 1981 and 1982 data, it was concluded that at four weeks after planting, maize cannot be reliably evaluated for stalk rot infection using the toothpick method. Inoculation at eight weeks has given the most consistent results, and inoculation at six weeks is also reliable, particularly for early maturing varieties (Figure 7). The time for reliable stalk rot inoculation corresponds approximately to the midtasseling stage for both late maturing (eight weeks after planting) and early maturing (six weeks) varieties.

F. moniliforme induced the greatest degree of rot, although there were no significant differences between the seed and stalk isolates. *Diplodia* was more important than *Macrophomina* under the conditions of the experiment. The soil suspension was not appreciably better than the check treatment in inducing rot. The data indicate that the technique could be used to evaluate plants for *Fusarium* sp., which is the most prevalent organism causing stalk rot in the various ecological zones of the tropics. Figure 8 shows the wide variation among plants in reaction to *Fusarium* stalk rot. Using this technique and the appropriate breeding method, the sensitive plants can be progressively eliminated in the population/variety.

Ear Rots

An experiment to evaluate different methods of ear rot inoculation was repeated this year using three maize varieties: one opaque-2 high-lysine variety (NCBRbo2) and two normal-grained varieties,

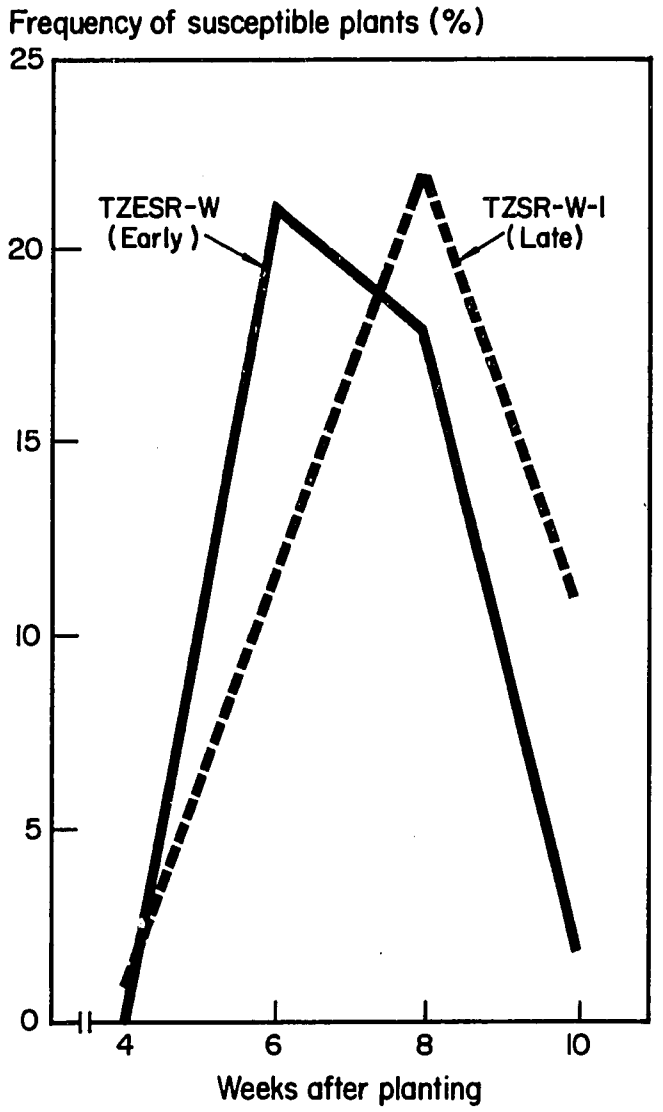


Figure 7. Effect of age at inoculation on the susceptibility of two maize varieties to Fusarium stalk rot, IITA, 1982.

TZESR-W, an early maturing (90 days) variety, and TZSR-W-1, a late maturing (120 days) variety. Four methods of inoculation were tested: a pathogen infested toothpick was inserted through the shank, middle of the ear and tip of the ear, and fungal suspension was injected through the tip of the ear. The pathogens used were *Macrophomina phaseoli*, *Diplodia maydis*, *Fusarium moniliforme* (seed isolate), *F. moniliforme* (stalk isolate), a mixture of these pathogens and a check (uninfested toothpick or sterile distilled water with the suspension method). Inoculation was carried out 7 to 10 days after midsilk. At maturity the ears were harvested and evaluated on a scale of 1 to 4, where 1 = no rot and 4 = severe rot.

As in the 1981 experiment, inoculation with an infested toothpick through the middle of the ear gave the highest rot score for every pathogen treatment in all three varieties (Table 39). *F. moniliforme* was the most effective in causing rot under the conditions of the experiment, and there was no significant

difference between the seed and stalk isolates. The mixed inoculum treatment induced mostly *Fusarium* symptoms. There was a significant interaction between the method and pathogen. This was evident from the fact that, although inoculation with the spore suspension through the ear tip was not effective for *Macrophomina* and *Diplodia*, it was reliable for *Fusarium*. There were no significant differences among varieties.

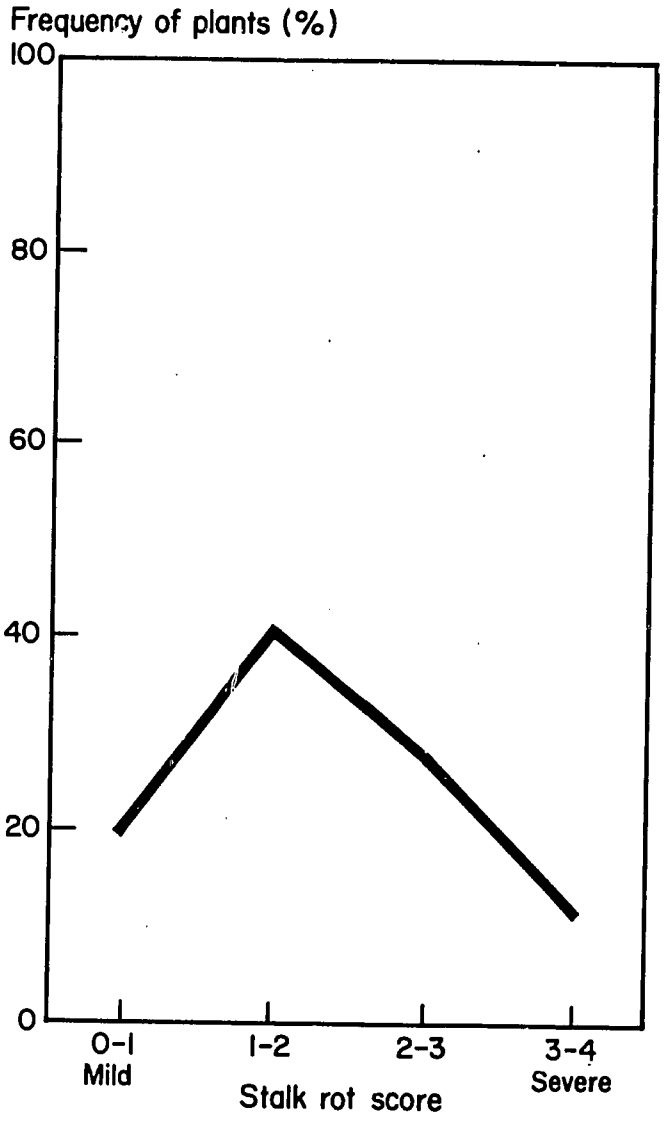


Figure 8. Distribution of maize plants (combined data for TZESR-W and TZSR-W-1) according to their reaction to Fusarium stalk rot, IITA, 1982.

Rhizoctonia solani is a common pathogen of maize in the humid rain forest region of Africa. The entire shoot is susceptible to this pathogen, which is known for its wide host range (including cereals, legumes and root crops). Owing to the high incidence of this pathogen in 1982 on maize at Suakoko (Liberia), N'toum (Gabon) and Ikenne (Nigeria), an experiment was set up to determine a reliable inoculation technique to be used in a study of this pathogen. Four inoculation methods were used: the sclerotia of the fungus (raised on potato dextrose agar medium) were deposited through the shank, the middle of the ear and ear tip with a galvanized nail dipped in 90% ethanol and placed between the ear and the stalk. Two maize varieties (TZPB and TZSR-W-1) were used but in two separate experiments. Ten replicates (five ears per replicate) were arranged in a completely randomized design. Inoculations were carried out 7 to 10 days after midsilk. At harvest rot damage was rated on a scale of 1 to 4.

Inoculating the middle of the ear gave the highest rot score for both varieties, followed by placing the sclerotia between the ear and stalk (Table 40). Results for shank and ear tip inoculations were not consistent for both varieties.—*J.M. Fajemisin*

Table 40. Ear rot scores on maize inoculated with *Rhizoctonia solani*, IITA, 1982.

Inoculation method	Maize varieties	
	TZPB	TZSR-W-1
Shank	1.7	1.1
Midear	3.0	2.8
Ear tip	1.0	1.3
Between ear and stalk	1.8	1.5
LSD	0.5	0.4
C.V., %	27.5	27.8

Note: Ear rot was rated on a scale of 1 to 4, where 1 = 0, 2 = 1 to 10, 3 = 11 to 100 and 4 = over 100 rotten kernels per ear.

Table 39. Effect of inoculation method and pathogen on the severity of maize ear rot, IITA, 1982

	Pathogen						
	Macrophomina	*Diplodia*	*Fusarium* (seed isolate)	*Fusarium* (stalk isolate)	Mixture of all pathogens	Check	Method mean
Toothpick, ear tip	1.0	1.0	1.4	1.5	1.4	1.3	1.27
Toothpick, midear	1.0	1.4	2.1	2.1	2.4	1.7	1.78
Toothpick, shank	1.0	1.0	1.3	1.4	1.4	1.2	1.22
Spray, silk	1.0	1.0	1.6	1.6	1.4	1.3	1.32
Pathogen mean	1.00	1.10	1.60	1.65	1.65	1.38	
LSD (5%)			0.06				0.06
C.V., %			11.2				13.3

Note: Ear rot was rated on a scale of 1 to 4, where 1 = 0, 2 = 1 to 10, 3 = 11 to 100 and 4 = over 100 rotten kernels per ear. Each figure is a mean of three maize varieties, with each variety replicated three times and 25 plants per replicate.

Virology

Virus From *Rottboellia exaltata*

The virus found in the wild grass species, *Rottboellia exaltata* (IITA, Annual Report for 1981), was found to occur more widely in *R. exaltata* plants at IITA's main site this year. Transmission experiments, in which healthy seedlings of *R. exaltata* and some maize lines were inoculated with an extract of infected *R. exaltata* plants, had shown that in spite of its high concentration the virus can be transmitted mechanically only with difficulty.

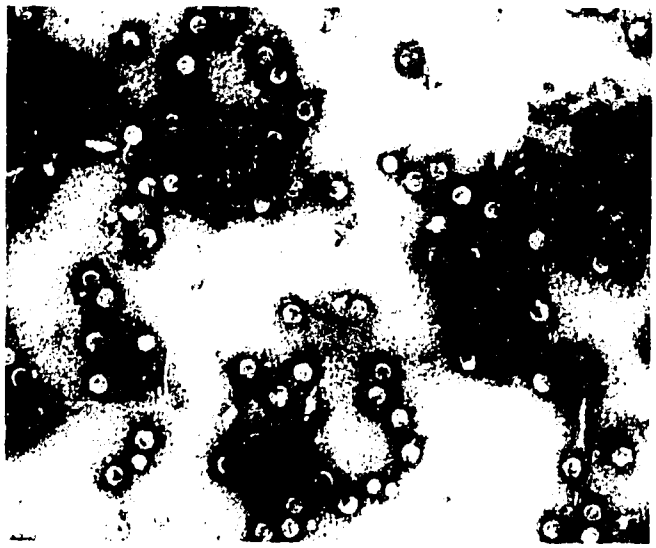
In addition to being a host of maize stripe virus (MStrV), *R. exaltata* apparently acts as a natural host of yet another virus that is potentially capable of infecting maize, although surveys at IITA have not revealed any natural infections in the crop.

Further studies have shown that mechanical transmission is very difficult. In one typical experiment, it was found that only 1 out of 30 inoculated *R. exaltata* plants had become infected. Fifteen out of 65 inoculated maize plants of a susceptible variety became systemically infected, showing symptoms varying from yellow mottle, mosaic and chlorotic striping to complete yellowing of the leaves. All systemically infected plants were stunted. Several plants that had not become systemically infected showed chlorotic rings on the inoculated leaves. Presence of virus in the inoculated leaves could be shown by using a specific antiserum (IITA, Annual Report for 1981). Apparently, the virus becomes systemically established in maize plants only with difficulty.

In host range studies, many other plant species tested did not become infected, including, among others, several *Nicotiana* and *Chenopodium* species, *Datura stramonium*, *Lycopersicon esculentum*, *Petunia hybrida*, *Vigna unguiculata*, *Phaseolus vulgaris*, *Cucumis sativis* and *Pisum sativum*. Furthermore, the virus failed to infect rice, millet, wheat and some other grasses tested, perhaps in part because of the low rate of transmission achieved by sap inoculation. The virus could be readily purified from infected *R. exaltata* plants, yielding more than 2 mg of virus per gram of infected tissues.

The virus appeared to be unstable in the presence of EDTA, but $MgCl_2$ had a stabilizing effect on the particles. In CsCl gradients the virus sedimented in a single band with a density of 1.38 g/cm^3, while in Cs_2SO_4 gradients multiple banding occurred. The sedimentation coefficient of the virus particles was 113 S. The coat protein of the virus particles had a molecular weight of 26.800 D.

In agar gel diffusion tests, the virus did not react with antisera against 35 isometric viruses, among which were southern bean mosaic virus, rice yellow mottle virus, sowbane mosaic virus, cocksfoot mottle virus, Phleum mottle virus, cocksfoot mild mosaic virus, St. Augustine decline virus, Panicum mosaic virus, Molinia streak virus, Cynosurus mottle virus, maize white line mosaic virus and maize chlorotic mottle virus.



Electron micrograph of a purified preparation of maize mottle/chlorotic stunt virus (67,200×).

Although until now this virus has not been found in maize, it is potentially capable of infecting the crop especially since incidence of the virus in *R. exaltata* at IITA appears to be increasing. For the first time, the virus was found this year in *R. exaltata* along bush edges at a distance of some 3 km from IITA in Ibadan. *R. exaltata*, being a strict annual grass species, is probably not the only grass species naturally infected with this virus since the virus has reoccurred for the second consecutive year of observation. Seed transmission, which we have not studied so far, may also account for the annual reoccurrence.—*J.W.M. van Lent*

Maize Mottle/Chlorotic Stunt

The recently discovered maize mottle/chlorotic stunt disease (MMCS) causes an inconspicuous chlorosis and/or vague chlorotic mottle in the newly developing whorl leaves, which in susceptible varieties is followed by severe chlorotic stunt (IITA, Annual Reports for 1979 and 1980). In 1981 we reported that a small quantity of virus was purified and that electron microscopic examination revealed spherical particles. Since the virus concentration in infected plants appears to be extremely low and is probably phloem restricted, purification of maize mottle virus has been extremely difficult.

After testing several solvents for initial clarification, it was found that a 1:1 mixture of chloroform and carbon tetrachloride is slightly better than chloroform or carbon tetrachloride alone. The following purification procedure was used. Three to four weeks after artificial inoculation using viruliferous leafhoppers, young infected maize leaves were homogenized in a blender with 0.1 *M* phosphate buffer, pH 7.4, containing 0.1% 2-mercaptoethanol (2 ml/g of tissue). A 1:1 mixture of cold chloroform and carbon tetrachloride (1 ml/g of tissue) was added, and the mixture was homogenized for another minute.

After low speed centrifugation, the virus in the supernatant was precipitated by adding 0.2 *M* NaCl and 10% polyethylene glycol. The virus was further purified by two cycles of differential centrifugation. The partially purified preparation was layered on top of a sucrose density gradient. A single peak was observed, which was collected and concentrated. This virus preparation was layered on a second sucrose density gradient, and the virus was recovered as before.

Numerous virus particles could be associated with the band in the gradient. The particles were spherical and about 40 nm in diameter. The virus fraction was assayed for infectivity by a membrane feeding method, using virus free leafhoppers. The leafhoppers transmitted the virus, and the maize seedlings showed typical symptoms both of mottle and chlorotic stunt.

Rabbits were immunized by six weekly intramuscular injections with 1 ml of a purified preparation emulsified with 1 ml of Freund's incomplete adjuvant, followed by two intravenous injections. Rabbits were bled 10 days after the last injection and weekly thereafter. The antiserum reacted with purified virus preparations in an agar gel diffusion test. However, no positive reaction could be obtained using crude juice.

Maize mottle virus can be differentiated from many other viruses from graminaceous hosts by its symptomatology, by its not being gap transmissible and by its transmission by the leafhopper, *Cicadulina triangula*. Further, in an agar diffusion test, purified maize mottle virus preparations did not react with the antisera against several graminaceous viruses with spherical particles, such as cocksfoot mild mottle, phleum mottle, panicum mosaic, cocksfoot mottle, molinia streak, cynosurus mottle and rice yellow mottle viruses. Also, an antiserum produced against a spherical virus in *Rottboellia exaltata* (IITA, Annual Report for 1981) did not react with maize mottle/chlorotic stunt virus.

Maize Stripe Disease

Maize stripe is a disease of maize in many African countries and a major problem with maize production in São Tomé (Rossel, unpublished data). Maize stripe disease has also been reported from the United States, Venezuela and Peru. Although some workers have reported that an isometric particle is associated with maize stripe disease, this has not been confirmed by studies done in the United States and IITA. Work done at the College of Wooster, United States, indicates that the disease is caused by an unusual filamentous nucleoprotein approximately 3 nm in diameter that is considered to be a member of a new virus group.

In order to see whether maize stripe in Nigeria is related to the disease reported from the United States, infected samples were tested using antisera against this virus. In an agar gel diffusion test, the antiserum obtained from Wooster against the maize stripe virus (Gingery et al, 1981) as well as an antiserum against noncapsid protein, which is associated with this disease (Balk and Tsai, 1982), reacted with sap from maize stripe infected plants from Nigeria. There was also a positive reaction with *Rottboellia exaltata* plants that showed maize stripe symptoms.

Based on the persistent transmission of the Nigerian isolate of maize stripe by *Peregrinus maidis*, the symptoms it causes in maize and especially its serological relationship with maize stripe virus from the United States, it appears likely that the two isolates are related or identical.—*G. Thottappilly and H. W. Rossel*

SAFGRAD Project in Upper Volta

Genetic Improvement

The maize breeding program of the Semi-Arid Food Grains Research and Development (SAFGRAD) Project was initiated in 1978. Most of the work so far has been concentrated in the 700- to 900-mm rainfall zone. The major objectives of this work are to develop and identify early maturing varieties (85 to 90 days) with reasonably good yields (4 t/ha) and to distribute the promising materials through various national programs, 27 of which are participating in the SAFGRAD Project. In all maize breeding trials and breeding nurseries during 1982, NPK was applied at 74:46:30 kg/ha, and plant populations were 53,000 per hectare.

Earliness and yield. Three approaches are being followed in breeding for earliness and good yield: (1) selection for yield in early maturing populations, (2) selection for yield and earliness in temperate × tropical germplasm, and (3) crossing early with medium maturing populations and selecting for both yield and earliness in segregating generations.

Full-sib recurrent selection in eight early maturing populations was begun in 1980. Based on 1981 trials, a total of 24 experimental varieties were developed by combining 8 to 10 selected families of the various populations involved. These experimental varieties were tested in a trial with a randomized block design at Kamboinsé and Loumbila during 1982. Table 41 gives the performance of selected varieties compared to the check variety. There was no significant difference in yield among the varieties at Loumbila. However, at Kamboinsé, E.V. Across TZE 12 Y and E.V. Kamboinsé TZE 12 Y yielded significantly higher than the check variety. E.V. Across TZE 12 Y performed well at Loumbila also. This variety will be further tested in large plots at various locations in 1983.

To identify early maturing, high yielding varieties, several promising varieties developed by various international and national institutes were tested in regional uniform variety trial 1 (RUVT-1) with a randomized block design at Kamboinsé and Loumbila.

Table 41. Performance of selected experimental varieties and results of regional uniform variety trial 1, Upper Volta, 1982

Variety	Yield at Loumbila, kg/ha	Yield at Kamboinsé, kg/ha	Average Yield, kg/ha	Average Days to flower	Average Plant height, cm	Average Ear height, cm
Test of experimental varieties						
E.V. Across TZE 15 Y	3,467	2,720	3,093	41	170	85
E.V. Across TZE 12 Y	3,232	2,933	3,082	43	172	93
E.V. Kamboinsé TZE 8 Y	3,093	2,720	2,906	41	168	87
E.V. Across TZE 16 Y	3,360	2,293	2,826	41	162	87
E.V. Kamboinsé TZE 12 Y	2,379	2,880	2,629	43	170	86
E.V. Saria TZE 16 Y	2,467	2,133	2,300	42	158	77
Pool-27 (check)	3,339	2,283	2,811	41	164	82
LSD (5%)	ns	555				
C.V., %	35.6	16.0				
Regional uniform variety trial 1						
Temperate × Tropical Filler No. 3	6,080	2,811	4,445	49	187	96
TZESR-Y	5,547	2,731	4,139	46	171	86
E.V. 7982	4,853	2,357	3,605	45	173	87
E.V. Pool-16	5,013	2,171	3,592	47	159	78
Pool-27	4,960	1,920	3,440	43	149	70
Temperate × Tropical Filler No. 42	5,173	1,707	3,440	50	162	76
MTS	4,960	1,547	3,253	49	183	94
Comp. 77 BD	4,533	1,451	2,992	54	181	101
TZESR-W	6,187	—	—	47	178	93
Pirsaback (1) 7930	5,173	—	—	43	140	66
DMR-Ye	4,427	—	—	39	139	60
E.V. Across Pool-16	—	2,827	—	45	176	89
Pool-18	—	2,624	—	42	165	80
Early Yellow	—	2,567	—	50	179	94
Jaune Flint de Saria (local check)	4,533	2,747	3,640	40	160	73
Average	5,120	2,288				
LSD (5%)	ns	869				
C.V., %	21.6	26.4				

This trial, coordinated by the IITA/SAFGRAD program, was sent to 20 countries in 1982. The results obtained in Upper Volta are presented in Table 41. Twelve varieties were tested in this trial. Although the differences in yield among the varieties were not statistically significant at Kamboinsé, TZESR-W, Temperate × Tropical No. 3 and TZESR-Y yielded 22 to 36% more than the local variety. At Loumbila none of the varieties tested performed significantly better than the check.

In an effort to increase the yield of early maturing composites, population improvement was carried out following the full-sib method in one yellow grained composite, TZESR-Y, and one white grained composite, Pool-16. The full-sibs in Pool-16 were developed during the dry season of 1981–82 at Kamboinsé and in TZESR-Y at IITA. Two hundred and fifty full-sibs of Pool-16, along with six checks, were tested at Kamboinsé in regional full-sib testing trial 1. One hundred and sixty-five full-sibs of TZESR-Y, along with four checks, were tested in another trial at Kamboinsé. Based upon the yield, days to flower and other agronomic characters, 12 full-sibs of Pool-16 and 13 of TZESR-Y were selected. The performance of selected full-sib progenies of Pool-16 and TZESR-Y is given in Table 42. Experimental varieties are being developed, utilizing the remnant seed of selected families of both populations. These varieties will be tested in regional trials during 1983.

Table 42. Performance of selected full-sib families of Pool-16 and TZESR-Y, Kamboinsé, Upper Volta, 1982

	Yield, kg/ha	Days to flower	Plant height, cm	Ear height, cm
Mean of selected Pool-16 families	7,307	43	166	79
Mean of all Pool-16 families tested	5,696	46	150	70
Checks:				
Pool-16	6,119	42	156	75
Jaune Flint de Saria	4,693	41	143	75
Mean of selected TZESR-Y families	8,205	44	182	92
Mean of all TZESR-Y families tested	6,549	46	183	99
Checks:				
TZESR-Y	6,613	45	178	80
Jaune Flint de Saria	4,480	40	165	80

Over the last three years, several populations representing temperate × tropical germplasm have been recombined and mildly selected through selective bulk sibbing at Kamboinsé. In 1982, 21 promising populations, along with four checks, were tested in a trial with a randomized block design at Kamboinsé and Loumbila. Table 43 records the performance of selected populations, compared to check varieties. There were significant differences in yield among

Table 43. Performance of selected temperate × tropical populations, Upper Volta, 1982

Population	Yield at Loumbila, kg/ha	Yield at Kamboinsé, kg/ha	Average Yield, kg/ha	Days to flower	Plant height, cm	Ear height, cm
Temperate × Tropical:						
No. 66	7,360	5,120	6,240	43	197	93
No. 18	8,000	4,053	6,027	46	172	92
No. 6	7,894	3,734	5,814	43	169	83
No. 73	7,040	4,214	5,627	44	189	87
No. 42	7,680	2,934	5,307	45	187	93
No. 14	7,254	3,334	5,294	47	193	90
No. 27	7,574	2,987	5,281	50	179	88
No. 4	7,680	2,560	5,120	46	187	96
Check:						
Pool-27	5,440	3,013	4,227	41	167	92
SAVITA-104	5,654	3,334	4,494	39	177	73
E.V. Kamboinsé Pool-16	6,400	3,587	4,994	41	185	92
SAVITA-102	8,854	4,480	6,667	51	190	97
LSD (5%)	1,408	1,546				
C.V., %	9.9	22.0				

the varieties at both locations. Among the early maturing check varieties, E.V. Kamboinsé Pool-16 was the highest yielding entry at both locations. (SAFITA-102 yielded more, but it is a later maturing variety). A few populations, including Temperate × Tropical No. 66, No. 18 and No. 6, yielded 16 to 25% higher than E.V. Kamboinsé Pool-16.

The remaining temperate × tropical materials, along with the promising populations indicated above, were tested in another trial at Kamboinsé. A total of 81 materials, along with check varieties, were included in this trial. Based on the yield and other agronomic characters, 13 have been selected (Table 44). These populations will be tested again in 1983, and the most promising ones will be utilized in developing one or two composites.

Table 44. Performance of selected temperate × tropical populations, Kamboinsé, Upper Volta, 1983

Population	Average Yield, kg/ha	Days to flower	Plant height, cm	Ear height, cm
Temperate × tropical:				
No. 2	4,069	49	179	89
No. 38	3,669	50	178	81
No. 66	3,589	48	160	67
K. 81 No. 58	3,546	48	164	80
No. 33	3,536	48	154	73
No. 25	3,493	52	181	94
No. 9	3,402	51	168	81
K. 81 No. 46	3,386	50	169	81
No. 31	3,322	47	156	73
No. 12	3,296	49	164	84
No. 17	3,216	50	166	81
No. 40	3,173	48	149	73
No. 70	3,162	50	157	85
No. 21	3,136	50	159	75
No. 47	3,029	50	157	68
Checks:				
SAFITA-104	3,174	44	150	69
Pool-27	2,694	46	138	71
TZUT	2,416	51	168	81
TZPB	1,814	58	175	90

Medium maturing populations. In addition to breeding for early maturing varieties, the IITA/SAFGRAD project is also developing and identifying medium maturity varieties, particularly for the zone of the semiarid tropics that receives 900 to 1,100 mm of rainfall annually. RUVT-2, a regional uniform variety trial consisting of 12 medium maturity varieties was organized in 1982 and sent to 18 countries participating in the SAFGRAD project. This trial was conducted at Kamboinsé, Loumbila and Farako-Bâ in Upper Volta (Table 45). There were significant differences in yield among the varieties at Kamboinsé and Farako-Bâ. IRAT-178 produced the highest yields at all locations. Elite × EM Comp., Fereke 7622 and Comp. 4 also showed promise at Kamboinsé, Farako-Bâ and Loumbila, respectively.

Two trials, early variety trial (EVT) 16A and EVT 16B, were conducted at Kamboinsé to test medium maturing varieties developed by CIMMYT. Twenty-four varieties were tested in EVT 16A and 16 in EVT 16B. Differences in yield among the varieties tested in both the trials were statistically nonsignificant. Moreover, none of the varieties gave a higher yield than the check variety SAFITA-102 in EVT 16B, and only Across 7748 RE yielded more than the check in EVT 16A, although it should be noted that SAFITA-102 was the latest maturing variety in both trials.

In addition to these two trials, high quality protein materials developed by CIMMYT were tested in the trial QPMT 11B at Kamboinsé. Eight high quality protein varieties, along with three checks (normal), were tested. There were no significant differences in yield among the varieties tested. Pool-34 QPM (RSF) was found to be most promising not only in yield, but in stability of modifiers for hard endosperm. Seed of

Table 45. Results of regional uniform variety trial 2, Upper Volta, 1982

Variety	Yield (kg/ha) at: Kamboinsé	Farako-Bâ	Loumbila	Average: Yield, kg/ha	Days to flower	Plant height, cm	Ear height, cm
IRAT-178	8,533	6,096	2,693	5,774	53	173	105
Elite × EM Comp	8,213	5,045	2,123	5,127	54	218	121
Comp. 4	7,733	5,003	2,156	4,964	56	233	142
Pozarica 7843	7,200	5,776	1,813	4,930	56	219	124
TZPB (filler)	7,627	4,997	1,856	4,827	55	213	118
Fereke 7622	7,040	6,059	1,200	4,766	56	166	111
SAFITA-102	6,987	5,525	1,760	4,757	55	197	103
Golden Crystal	5,973	5,381	1,856	4,403	54	209	117
TZSR-Y-1	6,613	4,677	1,867	4,386	55	214	117
Temperate × Tropical No. 27 (filler)	7,253	3,867	1,947	4,356	52	172	103
Comp. Y	5,387	3.371	1,493	3,417	55	224	130
Jaune Flint de Saria (check)	4,213	5,387	2,251	3,950	44	173	105
Average	6,896	5,099	1,920				
LSD (5%)	1,659	1,380	ns				
C.V., %	16.8	19.0	31.6				

this composite is being multiplied for further improvement and wider testing during 1983.

Evaluation of local germplasm. In the last three years, efforts have been made to collect and evaluate the local varieties normally grown by small farmers in Upper Volta. After multiplying the seed of these varieties, 28 local varieties and 21 others were tested in a trial at Kamboinsé. Because of soil variability and drought, the C.V. was very high, so it is difficult to draw definite conclusions. However, some local varieties, such as Local Kamboinsé May 30, Local Nedogo and Local Koudougou, did seem to give comparable or higher yields than improved varieties under these conditions. Additional testing and utilization of these varieties in the breeding program is planned for 1983.

Tolerance to drought. During the dry season of 1981–82, preliminary work on tolerance to drought was initiated at Loumbila. The primary objective was to gain experience in the methodology to be used for evaluating tolerance to drought. Another objective was to identify populations with high tolerance to water stress so that selection for drought tolerance in these populations can be intensified. Twenty-six populations representing a wide genetic background were tested in a replicated trial in four blocks. Thirty-six days after germination, block 1 was subjected to eight days of water stress by cutting off irrigation. Block 2 was subjected to 15 days of water stress and block 3 to 21 days. Block 4 received continuous irrigation (every third day). The degree of leaf rolling in the morning and afternoon, delay in male and female flowering, plant and ear height, percentage of barren plants, yield, and yield components were recorded for all the blocks. The performance of various varieties under no stress was compared to their performance when subjected to different periods of water stress.

It was difficult to interpret the data and draw

A monitoring tour organized by the SAFGRAD/IITA team in Upper Volta.

conclusions because of soil variability, the effect of topography on infiltration and movement of water, and unexpected rain. In spite of these difficulties, however, two varieties, Pool-16 and Jaune Flint de Saria, seemed to be more tolerant to water stress than the others. Some plants that exhibited more tolerance to water stress than others in blocks 2 and 3 were selected and selfed. Seventy-six S_1 ears were obtained and planted during the 1982 rainy season for seed increase (sibbing). This experiment is being repeated with some modifications in the 1982–83 dry season. Seventy-six S_1 families selected for tolerance to water stress are also being planted.

Semiarid regional adaptation testing. Since 1979 the IITA/SAFGRAD project has organized and coordinated regional uniform variety trial 1 (RUVT-1) and RUVT-2 to breed and identify promising varieties for various national programs participating in the project. RUVT-1, which consists of 12 early maturing varieties, was sent to 20 countries for testing in 1982. RUVT-2, consisting of 12 medium maturing varieties, was sent to 18 countries. In addition to these two trials, one regional full-sib testing trial (RFTT-1) for population improvement in Pool-16 was also sent to three national programs. So

far, data from 12 countries have been received for RUVT-1 and from 6 countries for RUVT-2.

The results for RUVT-1 are as follows. In Cameroon TZESR-W, Temperate × Tropical No. 42, Pirsabak (1) 7930 and SAFITA-104 were promising varieties. SAFITA-104 was seven to eight days earlier in days to flower. In Guinea TZESR-W, Pirsabak (1) 7930 and SAFITA-2 performed well. In Ghana the local check variety gave the highest yield. Pool-27 and SAFITA-104 flowered seven to eight days earlier than the local check variety. In Nigeria Temperate × Tropical No. 42 and TZESR-W were promising. In Senegal Temperate × Tropical No. 42, SAFITA-2 and TZESR-W yielded well. In Upper Volta the promising varieties were TZESR-W, Temperate × Tropical No. 3, Temperate × Tropical No. 42 and Pirsabak (1) 7930. In Niger, Gambia and Mauritania, the yield levels were very low, and the coefficient of variation was too high for any conclusions to be drawn.

These are the results of RUVT-2. In Cameroon Temperate × Tropical No. 27, TZSR-Y-1, Comp. 4 and IRAT-178 were the promising varieties. In Benin Comp 4, TZPB, TZSR-Y-1 and SAFITA-2 performed well. In Nigeria the promising varieties were TZSR-Y-1, Temperate × Tropical No. 27 and Golden Crystal. In Senegal IRAT-178 and Pozarica 7843 yielded well. In Ghana IRAT-178, TZPB and Comp. 4 were the promising varieties. In Upper Volta IRAT-178, Fereke 7622 and Pozarica 7843 were the promising varieties.

As for RFTT-1 the full-sib families selected in Upper Volta and Nigeria are being recombined to develop experimental varieties. The new cycle of recurrent selection will be initiated in the dry season of 1982–83.—*V.L. Asnani*

Entomology

The results of entomology trials conducted in Upper Volta and other SAFGRAD member countries revealed that millipedes, termites, armyworms and *Amsacta* spp. have been doing slight to moderate damage to maize. To determine the level of infestation, a survey of insect pests of maize was sent in 1982 to Gambia, Senegal, Somalia and Upper Volta. At the time of this writing, results were available only from Upper Volta. There the trial was planted on 19 July (D1) and 4 August (D2); it included two varieties, SAFITA-2, and an improved local variety, Jaune Flint de Saria.

Millipedes feed on the coleoptile region of maize plants during the seedling stage, causing them to fall down and dry out. In 1982 the infestation of millipedes was very low, ranging from 0 to 0.6% of the plants. Infestation by aphids was also quite low (0.9 to 6.1%). Nymphs and adults of this insect suck the sap from the leaves, tassels and cobs. With severe infestation the tassel dries out, and pollen is not produced. This insect has never been a serious pest in Upper Volta, however.

Armyworm caterpillars feed voraciously on the leaf margins at night and in the day hide in and feed on the whorls. On adult plants the caterpillars feed on the silk and after cutting it penetrate the cob. Infestation is usually more serious at the whorl stage. This year it was very low on both varieties in D1 throughout the growing period. But in D2 it was 2.5% in Jaune Flint de Saria and 5.2% in SAFITA-2 35 days after planting. The infestation increased as the crop matured. By 70 days after planting, the infestation had reached 40.2% on SAFITA-2 and 25.7% on Jaune Flint de Saria.

Sesamia calamistis was the only borer species found to damage maize in Upper Volta. *Eldana* was observed only rarely. *Sesamia* larvae feed on the stems, tassels, cobs and grain. By 90 days after planting, *Sesamia* had infested 0.9% of SAFITA-2 and 9.8% of Jaune Flint de Saria in D1 and 1.6 and 7.9% of those varieties, respectively, in D2.

Termites feed on the roots, stem, leaves, cobs and grain. It appears that the termite species feeding on the roots are not the same as those feeding on the aboveground portions. Under heavy infestation, the whole plant is covered with termite galleries, and the cob looks like a lump of soil. This year's severe drought was quite favorable for termite infestation. Termites became active 35 to 45 days after planting in both varieties in D1 and D2. At 90 days after planting, 12% of the plants of both varieties were infested in D1. In D2 60.6% of the SAFITA-2 plants were infested and 32.5% of the Jaune Flint de Saria.

At harvest in D1 85.2% of the SAFITA-2 plants lodged because of termites and 77.1% of the Jaune Flint de Saria. Of those, 75% in both varieties lodged as a result of root feeding. In D2 30.6% of the plants lodged because of termites in SAFITA-2 and 31.7% in Jaune Flint de Saria. In SAFITA-2 25.7% and in Jaune Flint de Saria 23.9% of those plants lodged because of root feeding. Plant lodging caused by stem damage ranged from 4.8 to 12.9% in both varieties in D1 and D2.—*Y.S. Rathore*

Agronomy

The SAFGRAD maize agronomy program was initiated in 1979 to identify and help solve agronomic problems with maize production in the semiarid tropics of Africa. The main agronomic problems identified in the 700 to 900-mm rainfall belt, where most of the work has taken place and to which most of the research results are applicable, are drought stress, poor soil fertility, soil compaction and termite damage.

Results from the past four years show that the risk of drought stress can be decreased by the following practices: soil tillage; tied ridges (established at planting or at the time of earthing up); planting maize on lower slopes and hydromorphic soils; making scarifications to break the soil crust or sealed soil surface; using small holes, catchments or terrain irregularities to retain rainfall water and slow runoff; use of crop residues as mulch; use of early

maturing varieties; and planting at the appropriate date. The soil fertility problems, which relate mostly to deficiencies of phosphorus and nitrogen, can generally be corrected with moderate applications of fertilizer. The problem of soil compaction can be reduced by tillage.

The 1982 growing season in Ouagadougou and other parts of Upper Volta was characterized by very poor rainfall distribution. Total precipitation was 710 mm, about 100 mm below the long-term average. The rains started very early (March) and ended in October. Early plantings (early June) were hindered by a three-week dry period in July at the preflowering stage and late plantings (last ten days of July) by a very early end to effective rainfall in the first days of September. As a result, maize yields were generally very low, except in plantings on the hydromorphic soils. Nevertheless, this year's research tended to confirm results obtained in previous years. The bad rainfall distribution resulted also in low or no response to fertilizer applications and a very high coefficient of variation in many trials.

Intensive research has been conducted during the past four years on methods of soil preparation, date of planting, plant density, seedbeds, plant spatial arrangement, mulching, scarification, evaluation of local varieties, maize cowpea rotations, ridge tying and earthing-up systems, and toposequence studies. Only a portion of the work is reported here. For additional information refer to the SAFGRAD/IITA annual reports.

Soil preparation. Research has shown that tillage can improve maize growth by reducing soil compaction and increasing water infiltration and storage in the soil. The latter is also increased by tying the ridges. An experiment begun in 1981 was continued in 1982 to determine whether crop response to tied ridges is affected by the soil preparation method.

The experiment was conducted at Kamboinsé and involved four soil preparation methods, two management levels and two earthing up systems. The two levels of management were: low (14-23-15 kg NPK/ha and 44,400 plants/ha) and high (74-46-30 kg NPK/ha and 59,300 plants/ha). The two earthing-up systems were: planting on the flat with no earthing up, and planting on the flat with earthing up 26 days after planting and ridge tying (except in the zero-tillage plots, where planting was done directly on rows that had been earthed up and tied in the previous year). The variety used was Jaune Flint de Saria.

Yield was significantly improved in all cases by earthing up with ridge tying, particularly under zero tillage (Table 46). As in 1981, yields obtained with zero tillage were consistently lower than those of any other soil preparation method. Little or no yield advantage was gained this year by tractor plowing, compared to traditional hand hoeing. With plowing yields were somewhat lower than with hand hoeing in 1982 perhaps because the depth of plowing was quite variable and shallow (3 to 10 cm rather than the usual 6 to 8 cm). In addition, some of the plots plowed with oxen were on very bad patches of land. The accumulated results from 1979 show, however, that plowing with oxen or a tractor often gives higher yields than hand hoeing.

Table 46. Effect of soil preparation method and earthing up with tied ridging on maize yield, Kamboinsé, Upper Volta, 1982

Soil preparation and management	No earthing up, kg/ha	Earthing up and ridge tying, kg/ha	Yield increase kg/ha	Yield increase %
Zero tillage				
Low	310	780	470	152
High	430	1,250	820	191
Hand hoeing				
Low	810	1,170	360	44
High	1,310	1,770	460	35
Oxen plowing				
Low	520	990	470	90
High	990	1,490	500	51
Tractor				
Low	1,220	1,700	480	39
High	1,280	1,920	640	50
LSD (5%)			356	

Table 47. Effect of crop position along the toposequence and ridge tying on maize yield, Kamboinsé, Upper Volta, 1982

Position	Simple ridges	Ridge tying every second furrow	All ridges tied
	kg/ha at 0% moisture		
Plateau	480	1,150	1,240
Upper slope	1,240	1,710	2,260
Midslope	1,030	1,770	1,870
Lower slope	830	1,470	2,330
Bottomland	3,190	2,580	3,060
Mean	1,350	1,740	2,150
LSD (5%) for comparing			
Ridging systems		202	
Ridging systems at each position		452	

Note: The values listed here are means of two planting dates.

Toposequence studies. The risk of drought stress depends not only on rainfall distribution, but on soil characteristics that influence soil water infiltration, percolation and storage. These characteristics change markedly along the toposequence. Plateau soils tend to be sandier or more gravelly, less deep and lower in organic matter content than the hydromorphic soils of the lower part of the toposequence. Drought stress is less likely in maize planted in hydromorphic soils. In 1980 our research results showed that although ridge tying increases water storage in the soil, this practice could hinder maize growth in hydromorphic soils during very wet years. So, in 1981 we started an experiment to determine the positions along the toposequence for which ridge tying should be recommended in maize.

The experiment was conducted again in 1982 at Kamboinsé, using the variety Jaune Flint de Saria.

There were five strips of land more or less perpendicular to the slope, each of which represented one of the following positions on the toposequence: plateau, upper slope, midslope, lower slope and hydromorphic bottomland. Each strip was subdivided into three blocks to make three replications running parallel to the slope. The experiment was a factorial combination of two planting dates and three ridging systems: simple ridges, ridges tied every other furrow and all ridges tied. The land was tractor plowed and ridged before planting.

The mean yields for both planting dates are presented in Table 47. Yield was significantly higher at the 1% level for the first date than for the second (2,280 kg/ha for 22 June, compared to 1,220 kg/ha for 13 July). This result is opposite that of 1981, when late planting (14 July) gave significantly higher yields than early planting (26 June). The difference can be accounted for by the different rainfall distribution patterns in these years.

As was the case in 1981, the effect of the crop's position on the toposequence and of the ridging systems was also highly significant at the 1% level. The highest yields were always obtained in the hydromorphic bottomland and the lowest in the plateau soil with simple ridges. Tying the ridges in every second furrow increased yields by about 80% on the average, except in the bottomland. Additional but variable increases in yield were obtained when all the ridges were tied except, as before, in the bottomland strip. No detrimental effect of ridge tying was evident in the bottomland position under the relatively dry conditions of 1982.

Earthing up. Since earthing up and ridge tying have shown such promise, we have continued to refine these practices and try to learn more about their effects. In 1980 a long-term experiment was begun in which the traditional soil preparation method (shallow tillage with a hand hoe) was used and the local Kamboinsé variety was planted on the flat. The objectives of the experiment were to measure the effects of earthing up and ridge tying separately, to determine whether the ridges should be tied in all furrows or only in every second one, and to learn whether the ridges and ties last for more than one season, permitting farmers who use the hand hoe method of soil preparation to greatly reduce the labor costs of earthing up and ridge tying after the first year. The experiment involves four earthing-up systems: no earthing up, earthing up one month after planting, earthing up and tying of every second furrow, and earthing up and tying of all furrows.

After the first crop in 1980, the first and second treatments were cultivated with a hand hoe in 1981, and the ridges in the second treatment were levelled. Maize was planted on the flat in the first two treatments and on the tied ridges built in 1980 in treatments three and four. The earthing-up treatments described above were again applied one month after planting. Little labor was required in the third and fourth treatments because the ridges made and tied in 1980 lasted until 1981. This process was repeated for the 1982 crop.

The experiment was conducted under two management levels: low and high as described under the soil preparation experiment, except that the nitrogen applied at both levels was increased by 23 kg/ha.

As shown in Table 48, there were significant differences in yield between the earthing-up systems in both 1981 and 1982. Although at both management levels there was no difference in yield between no earthing up and simple earthing up, planting on the tied ridges built or maintained during the previous season increased yields by about 1 t/ha. Tying all the ridges rather than every second one gave no additional yield increase under low management (since fertility became a limiting factor) but significantly increased yield under high management in 1981.

That did not happen in 1982 for the most part it seems because of termite damage to the roots. The early onset of the rains in 1982 encouraged weed growth, especially in plots with high fertility and tied ridges, which also had larger amounts of crop residues from the previous season. The partial incorporation of these residues and weeds encouraged termite activity below the soil surface and root pruning by the termites. As a result, the high management plots with tied ridges often exhibited more symptoms of leaf wilting from planting to flowering than the plots without tied ridges, even though the former evidently had better soil moisture conditions.

The economics of ridge tying. Ridge tying can be used before or after planting at the time of earthing up. The ridges and ties can be made with a hand hoe, oxen or tractor. Of the three methods, the first is presumably the most expensive. Yield increases of 1 t/ha or more are obtained with ridge tying. The magnitude of the increase depends upon several factors. For example, the more uniform the rainfall distribution pattern, the less the response to tied ridges. The yield response is generally highest in the plateau and upper slope soils and smallest in the lower slope and hydromorphic bottomlands. Soils

Table 48. Effect of earthing up and ridge tying on maize yield, Kamboinsé, Upper Volta, 1981 and 1982

Earthing-up system[a]	Low mgmt.		High mgmt.	
	1981	1982	1981	1982
	kg/ha			
No earthing up	1,040	1,270	1,480	2,270
Earthing up	990	1,080	1,470	2,690
Earthing up and tying of every second furrow	1,840	2,560	2,540	3,100
Earthing up and tying of all furrows	2,040	2,230	3,280	3,240
LSD (5%)	58[a]	677	588	677

[a]The soil is prepared according to the traditional hand hoe method, but tied ridges are maintained from year to year.

Table 49. Effect of ridge tying and fertilizer on maize yield in farmers' fields, Upper Volta, 1981 and 1982

	Pabre				Kamboinsé			
	Farmer E		Farmer Z		Farmer D		Farmer J	
Ridging system	Without fert.	With fert.	Without fert.	With fert.	Without fert.	With fert.	Without fert.	With fert.
1981				*kg/ha*				
Planting on the flat	360	910	1,260	1,320	1,340	1,250	18	1,020
Planting on tied ridges	910	950	920	1,800	—	—	64	1,416
Planting on the flat, earthing up and ridge tying	930	1,730	1,140	1,780	1,480	1,870	79	1,482
LSD (5%, at same fert. level)	1,394		801		723		585	
1982								
Planting on the flat	130	370	760	690	310	360	47	201
Planting on tied ridges made in 1981	230	440	680	810	—	—	115	780
Planting on tied ridges made in 1981 and cultivated and built up in 1982	120	410	450	470	480	900	122	830
LSD (5%, for ridging systems)	348		344		469		251	

with low effective water infiltration rates respond more to ridge tying, even the hydromorphic bottomlands. But if yield is limited by poor soil fertility or other factors, ridge tying will bring about little or no yield increase.

The amount of labor involved in earthing up and ridge tying with a hand hoe was estimated to be 216 h/ha or 27 man days/ha. Assuming a wage of $0.35/h and a price of $0.17/kg for maize, the labor cost of earthing up and ridge tying with a hand hoe is equivalent to 445 kg of maize. This does not take into account the fact that the opportunity cost of labor is likely to be far below $0.35/h, that earthing up can be combined with weeding or fertilizer incorporation, or that in many soils the ridges are useful for more than one season. An additional consideration is that ridge tying reduces the risk of yield loss created by the variable rainfall distribution of the semiarid tropics.

On-farm testing of tied ridging. Four on-farm trials of tied ridging were conducted during 1981 and six in 1982 at Kamboinsé and Pabre, Upper Volta. The trials were established not in the compound plots where farmers normally grow maize as a garden crop, but on fields with poorer soils where farmers normally grow sorghum or millet. Traditional hand hoeing was used in all cases except one, in which donkey cultivation was used.

The 1981 experiments consisted of three ridging systems: planting on the flat with no earthing up, planting on tied ridges, and planting on the flat, with earthing up and ridge tying four weeks after planting. The experiments involved two fertility levels: low (no fertilizer) and high (74-46-30 kg NPK/ha).

The results are shown in Table 49. The statistical analysis for each site indicated no significant response to planting on tied ridges or to earthing up and ridge tying partly because the trials involved only two replications and because there were very large coefficients of variation (up to 50%). A joint analysis of all sites showed that planting on the flat gave significantly (at the 5% level) lower yields than planting on tied ridges or earthing up and ridge tying. The mean yield increase over the check (planting on the flat) was 131 kg/ha with no fertilizer and 487 kg/ha with fertilizer. Obviously, the farmers' situations varied markedly. Some benefited from ridge tying at planting or at the time of earthing up even without fertilizer, while others benefited from it only if they improved the soil fertility.

The response to fertilizer in the four farm plots was low (from no response to 1,400 kg/ha) partly because of the bad rainfall distribution in 1981, shallow soil preparation with the hand hoe and problems with stand establishment. Tied ridges markedly improved the efficiency of fertilizer recovery.

To determine if the fertilizer applied in 1981 would have any residual effect, the trials were conducted again in 1982. One half of each plot received no fertilizer, and the other half received the same amount applied in 1981. Since one of the objectives of the trials was to evaluate the usefulness of tied ridges from one season to the next, the ridging systems were modified in 1982 as follows: hand hoe cultivation and planting on the flat; planting on tied ridges made in 1981, without hand hoe cultivation before planting (except for scraping of weeds and slight fertilizer incorporation); and planting on tied ridges made in 1981 after hand hoe cultivation to build up the ridges. The last two treatments were earthed up and tied one month after planting.

As shown in Table 49, yields in 1982 were very low (under 1 t/ha at all four sites) because of low rainfall and bad rainfall distribution at both locations, especially in Pabre (598 mm). The trials were planted on 19 July, but the rains stopped at the end of August before pollination was complete.

The residual effect of fertilizer applied in 1981 was very small (below 200 kg of maize per hectare) and nonsignificant. The 1982 results in Table 49 are the means of plots with and without residual fertilizer. The response to fertilizer applied in 1982 was also

Table 50. Rice yield trials of the NCRE Project in Cameroon, 1982

Location	Ecosystem	Trial	No. of entries	Altitude, m	Min. and max. temperature (C)	Avg. annual rainfall, mm[a]	Stresses
Dschang	Irrigated	Comparative yield trial	10	1,400	14° to 26°	1,700	Cold, blast, sheath rot and grain discoloration
Mbo Plain	Upland	Med. duration yield trial	16	700	16° to 28°	1,800	Blast, leaf scald and sheath rot
	Irrigated	Comparative yield trial	12				
Ndop Plain	Upland	Comparative yield trial	22	1,100	20° to 30°	1,600	Blast, partial drought, leaf scald and sheath rot
	Irrigated	Comparative yield trial	16				
Karewa	Irrigated	International rice yield nursery (med. duration)	28		16° to 35°	700	No major stresses

[a]The peak period of rain is August to September.

small in all cases, although it was statistically significant for farmers E and J.

There was no significant difference in yield between the three ridging systems at the two sites in Pabre, but in Kamboinsé planting on tied ridges gave significantly higher yields than planting on the flat if fertilizer was applied. Based on this year's results, it seems unnecessary to hand hoe the ridges made in the previous season. Maize can be planted directly on them, with only as much cultivation as is necessary for weed control and fertilizer incorporation.

These results illustrate some of the problems farmers face in trying to grow maize in the 700- to 900-mm rainfall belt. The growing conditions of 1982, which were bad not only for maize but for other cereals as well, underscore the farmers' need for a wider range of improved varieties, particularly ones that mature earlier than 90 days. The three-week drought in July delayed planting or made replanting necessary after 19 July. Under "normal" conditions rainfall ends by mid- to late September, about two months after planting. In those situations the farmer could certainly benefit by planting a variety that matures earlier than 90 days.—*M. Rodriguez*

Table 51. Performance of selected entries in upland and irrigated yield trials, Cameroon, 1982

Variety	Yield, kg/ha
Upland	
Mbo Plain:	
ITA 212	4,516
IR 52	4,048
ROK 16	2,514
ITA 118	2,384
Check	2,357
Average yield	1,789
LSD (5%)	640
C.V., %	28
Ndop Plain:	
IRAT 109	4,406
ITA 118	3,969
387-113D	3,688
IRAT 112	3,594
IR 52	3,500
ITA 116	3,500
IRAT 10	3,313
Check	2,656
Average yield	2,742
LSD (5%)	940
C.V., %	24
Irrigated	
Mbo Plain:	
ITA 212	6,044
ITA 233	5,763
ITA 222	5,288
IR 3273-339-2-5	5,245
Check	4,030
Average yield	4,772
LSD (5%)	1,147
C.V., %	14
Irrigated, continued	
Ndop Plain:	
ITA 123	7,002
ITA 222	6,643
ITA 212	5,857
ITA 233	5,785
Essimbi	5,355
Check	5,214
Average yield	4,682
LSD (5%)	1,045
C.V., %	16.7
Dschang:	
5235-28L2	4,570
5256-8L1	4,490
5236-29L1	3,650
Check	3,390
Average yield	3,109
LSD (5%)	891
C.V., %	22
Karewa:	
RP 1017-76-1-3-2	7,657
IR 19670-263-3-2-2-1	7,209
IR 54	7,155
IR 13525-43-2-3-1-3-2	7,050
B 24896-PN-1-76-8	7,040
Check	6,853
Average yield	6,438
LSD (5%)	1,217
C.V., %	15

NCRE Project in Cameroon

Rice

The major objectives of IITA's rice improvement program in the National Cereals Research and Extension (NCRE) Project are to identify superior rice cultivars with high yield potential and resistance to stresses and to study appropriate management practices for increasing production with a minimum of cash inputs. In Cameroon rice is grown under at least four distinct types of ecological conditions: in hilly areas where the air and water temperatures are around 20°C, in upland areas on the Mbo and Ndop plains, in irrigated areas on the Mbo and Ndop plains, and in irrigated areas of the drier northern part of Cameroon. The main rice cropping season in the country is between June and November. Table 50 gives details on the locations where tests are being conducted.

Genetic Improvement

At its outset the rice improvement program in Cameroon tested various rice selections from IITA, IRAT, WARDA and IRRI in observational nurseries in each ecosystem and from them picked superior selections with high yield potential and resistance to the prevalent stresses. These selections were then

put in upland and irrigated yield trials during 1982 (Table 50). The performance of the superior lines in these trials is given in Table 51.

The yield of several varieties on the Mbo and Ndop upland plains was quite high in spite of stresses. The reason is probably the partially clayey soils and high rainfall of these areas. In addition to these yield trials, testing of observational nurseries, with selections from various sources, was continued during 1982. The nurseries included mainly early generation (F_4 to F_5) lines and were tested for resistance to stresses such as drought, cold, blast and leaf scald. Table 52 shows the number of selections made from these nurseries this year. The 296 lines selected are a potentially rich base for further evaluation in yield trials.—*D. Janakiram*

Agronomy

Agronomy experiments were conducted in Cameroon on crop responses to the major elements (N, P and K), the effect of seedling age on yield, and the residual effect of phosphorus. The experiments also included tests of various phosphorus sources and herbicide trials. Because of the good rice yields under upland and lowland conditions in Cameroon, emphasis was placed on effective management practices. All the experiments were conducted in the large upland and irrigated area of the Mbo and Ndop plains.

Effects of seedling age on rice yields. Cultivation of irrigated rice on the Mbo Plain is a relatively recent venture, so knowledge of appropriate agronomic practices is still lacking. In general, seedlings three to four weeks old are suggested for best yields. In practice, however, because of various management problems at the farm level, such a strict age schedule cannot be followed. No attempt has been made to solve this problem.

An experiment was conducted with the long duration variety IR 5995-PP889-1 and IRAT 10, a short duration variety. The age of the seedlings varied from three to eight weeks. Yield declined gradually with increased seedling age in both varieties (Figure 9). In IR 9559-PP889-1, the yield of three-to-four-week-old seedlings (4.85 t/ha) was highest and declined to about 4.3 t/ha for eight-week-old seedlings. Increasing seedling age thus had only a slight effect on the yield of the long duration variety.

In contrast, for IRAT 10 the age of the seedlings was a critical factor in yield. Three-week-old seedlings produced about 2.9 t/ha, but with each subsequent week, the yield decreased considerably, reaching a low of about 1.7 t/ha for seedlings seven to eight weeks old. These results suggest that on the Mbo Plain, seedlings of long duration varieties can be transplanted when three to seven weeks old without an appreciable loss in yield. Seedlings of short duration varieties, however, should be three to five weeks old at planting.

Testing of phosphatic fertilizer on irrigated rice. In Cameroon most phosphatic fertilizers are imported and costly. Earlier fertility trials on the Mbo Plain indicated that irrigated rice needs high P. A trial was begun in 1981 to evaluate different commercial phosphate fertilizer products as sources of P. Seven different P sources were applied at 200 kg P_2O_5/ha in combination with 78 kg N and 60 kg K_2O on the first crop in 1981.

The results show that the plots which received Scorie Thomas, a ground phosphate rock, yielded 3.5 t/ha, while the check plots produced 1.8 t/ha. Triple and superphosphates ranked second and third. Diammonium phosphate promoted abundant vegetative growth probably because of the nitrogen in it and, as a result, heavy leaf and neck blast.

Table 52. Selection from observational nurseries, Cameroon, 1982

Material	No. of entries tested	No. of entries selected
IITA		
Upland	201	25
Early generation	323	42
Lowland	203	40
IRRI		
Upland	185	39
Blast resistant	342	32
Leaf scald resistant	63	8
Lowland	350	72
Cold tolerant	165	32
Iron toxicity tolerant	22	6
Total	1,854	296

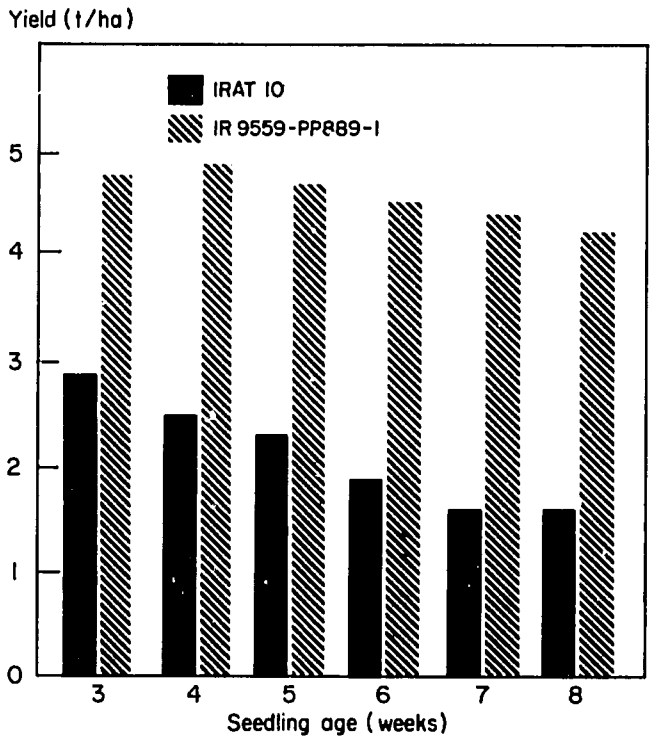


Figure 9. Effect of seedling age on yield of IRAT 10 (short duration) and IR 9559-PP889-1 (long duration) under irrigation, Mbo Plain, Cameroon, first season, 1982.

Response of upland rice to nitrogen. The yields of upland rice are generally low. In a repeatedly cropped area where rice has been grown for four years, an experiment was carried out using IRAT 10, an upland variety that is highly responsive to nitrogen. The N level ranged from 0 to 100 kg N/ha applied as urea in three equal splits. The yields increased from 1.6 to 2.2 t/ha as the N level was increased from 0 to 100 kg/ha. However, significant yield increases were obtained with only 60 kg N/ha.

Response of upland rice to residual phosphate. Earlier fertility experiments on the Mbo Plain indicated that P deficiency is one of the major nutritional limitations in upland rice. In an earlier experiment, begun on the second crop in 1979, each plot was divided in two; one half received no P, while the other received 70 kg P_2O_5. Four successive crops were grown, the last being IRAT 79 in 1982. The no P check produced 1.0 t/ha, whereas the plot receiving 70 kg P_2O_5 yielded 1.6 t/ha.

A long-term NPK fertility trial. Since little information is available on the effect of NPK fertilizer in irrigated rice on the Ndop Plain, an experiment was begun with the varieties Kulu and China 1039, both of which were severely affected by blast. Fertilizer was applied at 60 kg N, 60 kg P_2O_5 and 40 kg K_2O/ha. The complete NPK treatment gave the highest yield of 3.5 t/ha, compared to 2.3 t/ha for the checks. Nitrogen in combination with P or K increased yields, but the combination of P and K without N did not increase the yield over that of the check.

Weed management in irrigated rice. Weeds are a major hindrance to successful rice production, particularly in upland areas. They can also pose a serious problem in irrigated rice if initial land preparation and water management are poor, particularly when farmers normally prepare their paddies with spades. This trial was designed primarily to determine the predominant weed species of transplanted rice on the Ndop Plain and to evaluate the effect of different levels of weed management on yield. Unweeded check plots produced 1.6 t/ha, compared to 2.7 t/ha in weed free plots. Application of Basagran at 8 l/ha or Tamarin at 4 l/ha was as good as one hand weeding. *Cyperus deformis* and *Scirpus* spp. were the dominant weeds in the irrigated fields. The experiment shows that one hand weeding is essential at the early growth stage to produce satisfactory yields.—*A.C. Roy*

Maize

Genetic Improvement

During its first year the maize improvement program of the NCRE Project concentrated on evaluating numerous internationally available improved maize varieties, either as sets of experimental variety trials (EVTs) from IITA and CIMMYT or as individual entries from other sources such as Zaire. Varieties developed by Institut de la Recherche Agronomique (IRA), local varieties provided by farmers and materials grown commonly by parastatal organizations and farmers were also included. All seven provinces of Cameroon in the three major agroclimatic zones (lowland rain forest, lowland savanna and midaltitude) were covered. For a complete listing

Table 53. Yield of best entries in CIMMYT early variety trials and in an IITA, late, streak resistant variety trial, Cameroon, 1982

Variety	Yield, kg/ha[a]	Variety	Yield, kg/ha
EVT 12 (tropical, white, late)			
Ekona (460 m)		**Sanguere (210 m)**	
Chiquisaca (1) 7822	6,639	Sta. Rosa 8022	6,637
La Maquina 8022	6,324	San Audres 8043	6,437
Los Diamantes (1) 8043	6,280	Poza Rica 8022	6,319
Across 8043	6,112	La Maquina 8022	6,176
Cotaxtla 8043	6,016	Across 7622 RF	6,161
Sta. Rosa 8022	5,954	Los Diamantes (1) 7921	6,150
Across 7622 FR	5,867	Chiquisaca (1) 7822	5,972
Ekona white (best check)	5,077	TZPB (selected) (best check)	5,890
LSD (5%)	946	LSD (5%)	1,385
EVT 14B (tropical, white, intermediate)			
Ekona		**Sanguere**	
Ferke (1) 8023	6,928	Marucay 8023	5,855
Marucay 8023	6,602	Across 8023	5,672
Los Diamantes 7823 RE	6,511	Los Diamantes 7823 RE	5,615
Across 8023	6,338	Poza Rica 8032	5,356
Pirsabak 8023	6,038	Alajuela 8032	5,291
Alajuela 8032	5,973	Poz a Rica 8023	5,236
Ekona Synth (best check)	5,507	TZPB (selected) (best check)	3,879
LSD (5%)	1,027	LSD (5%)	1,144
EVT 16A (subtropical-temp., yellow, early-interm.)			
Foumban (1,140 m)		**Bambui Plain, Bamenda (1,225 m)**	
Obregon 8045	7,709	Across 7844	3,903
Antlya 8045	6,805	COCA	3,893
Chiquisaca (1) 7833	6,266	Across 7845 RE	3,476
BACOA (check)	6,138	BACOA	3,249
Poly hybrid 290 (check)	5,901	Chiquisaca (1) 7845	3,210
Across 8045	5,666	Chiquisaca (1) 7833	3,192
LSD (5%)	2,287	LSD (5%)	999
Late, streak resistant variety trial			
Njombe (40 m)		**Ntui (500 m)**	
Poza Rica 7843	5,563	Gusau TZB 81	6,502
Ferke LSRW 81	5,277	Onne TZPB 81	5,978
Ferke LSRY 81	5,222	Suakoko TZPB 81	5,940
Suakoko TZPB 81	5,148	Poza Rica 7843	5,880
Ikenne LSRY 81	5,122	Sekou LSRW 81	5,673
Ikenne LSRW 81	5,002	Ferke LSRY 81	5,371
Ekona M. Color (local check)	4,502	Ekona Syn (local) check	4,967
LSD (5%)	1,031	LSD (5%)	961

[a]At 15% moisture.

of the trials and results refer to the NCRE Annual Report.

CIMMYT EVT 12 (tropical, white, late) was grown at Ekona (which is cool and wet and has an elevation of 460 m) and Sanguere (hot and dry with an elevation of 210 m). Most varieties from population 22 (Mezcla Tropical Blanco) performed well in both locations. Those from population 43 (La Posta) did well at Ekona but not as well at Sanguere. Widely grown local checks, such as Ekona white (Ekona) and Samaru 123 (Sanguere), were among the lowest yielding varieties in the trials (Table 53).

CIMMYT EVT 148 (tropical, white, intermediate) was also planted at Ekona and Sanguere. At both locations the top yielders were from population 23 (Blanco Cristalino 1) and outyielded the widely grown local checks, Ekona white and Samaru 123 (Table 53).

CIMMYT EVT 16A (subtropical, yellow, early-intermediate) was grown at Foumban and Bambui Plain. At Foumban check varieties BACOA and Poly hybrid 290 performed well. The highest yielder was Obregon 8045. At Bambui Plain the average yield was lower probably because of blight infection and soil problems. Across 7844 and COCA gave the highest yields (Table 53).

CIMMYT EVT 16B (subtropical-temperate, white, late) was planted at Foumban, Wassande and Moungel. The LSDs were large, and at Wassande the highest yields were quite low probably as a result of nutrient deficiencies. Among the varieties from populations 34, 44 and 47 and the checks H614 and Poly hybrid 290, the only consistent performer by rank was Across 7734 RE. Poly hybrid 290 was last at Wassande producing a low average yield, and first at Moungel, where it gave an intermediate average yield. H614 performed well at both of these locations, but poorly at Foumban, and was very tall.

An IITA, late, streak resistant variety trial was grown at Njombe and Ntui (Table 53). At Njombe the top yielders were Poza Rica 7843 (check), Ferke LSRW 81 (white) and Ferke LSRY 81 (yellow), the latter two of which are streak resistant varieties. At Ntui the top four yielders were experimental varieties without streak resistance, followed by four streak resistant entries and a local check. Streak was not severe enough to affect yield.

Quality protein maize (CIMMYT QPMT 11B, subtropical-temperate) was tested at Babungo, including both normal and QPM materials. The top four yielders were two local checks and two normal endosperm reference experimental varieties, followed by all QPM materials, a few of which (from population 41) yielded nearly as well as the lowest check. The QPM materials suffered more from ear rots than normal, and the LSDs in this trial were high.

A collection of midaltitude varieties was tested at Babungo, which has an altitude of 1,140 m. The best yielders were COCA (Cameroon), Shaba I (Zaire), SAP I Syn. II (South Africa via Illinois), Across 7844 (CIMMYT) and Kasai I (Zaire). In a small observation trial of highland materials, the local varieties COCA and BACAO outyielded Across 7844 from CIMMYT population 44.—*J. Chung*

Table 54. Maize Yields averaged across fertilizer levels at three midaltitude locations in Cameroon, 1982

	Babungo		Foumban		Wassande	
Variety	Yield, kg/ha	Rank	Yield, kg/ha	Rank	Yield, kg/ha	Rank
Shaba 1	9,014	1	7,756	1	6,609	3
Across 7844	8,993	2	7,571	5	7,437	1
Kasai 1	8,770	3	7,676	3	6,310	7
COCA	8,655	4	7,739	2	7,437	2
Kasai-K	8,425	5	7,139	7	6,269	8
Salongo 2 SR	8,131	6	6,099	10	6,371	6
Salongo 2	7,930	7	7,272	6	6,520	4
BACOA	7,841	8	7,619	4	5,850	9
Shaba 1 SR	7,741	9	6,260	9	5,639	10
PNM 1 SR	7,615	10	6,717	8	6,451	5
Kasai-1 SR	6,558	11	5,254	12	4,608	11
Salongo-K	6,116	12	5,309	11	3,903	12
LSD (5%)	1,275		651		960	

Table 55. Maize yields averaged across fertilizer levels, Sanguere, Cameroon, 1982

Variety	Yield, kg/ha
Poza Rica 7843	5,624
Poza Rica 7822	4,944
TZPB (Gwathmay)	4,607
La Maquina 7928	4,513
Ekona Synthetic	4,493
Ekona Yellow	4,487
TZPB (SODECOTON)	4,293
Across 7845	3,648
Samaru 123	3,201
Garoua Flinty white	1,876
LSD (5%)	496

Agronomy

Preliminary agronomic trials were conducted in 1982 to compare varieties at different locations and fertilizer levels. Three sets of one experiment were carried out at three sites in the midaltitude zone, and another experiment was conducted in the lowland savanna zone. Varieties that have performed well over several years in other countries with climates similar to those in Cameroon were compared with local check varieties, twelve in the midaltitude and ten in the savanna zones. Three fertilizer rates were used in the midaltitude zone and four in the lowland savanna.

Although there were no fertilizer × variety interactions at any of the locations, there were significant (1% level) main effect yield differences resulting from different fertilizers levels (except at Wassande) and varieties. At Babungo and Foumban (midaltitude), the fertilizer differences were due to

Table 56. Yield and agronomic characteristics of top yielding sorghum lines, Maroua, Cameroon, 1982

Entry	Yield, kg/ha	Days to 50% flowering	Plant height, cm	Panicle length, cm	Plant count at harvest	Harvestable heads	Days to maturity
Locally improved elite lines							
Samuel	8,250	77	330	25	214	240	120
Damougari Ord	7,967	71	210	14	226	230	106
137-62GR	7,283	71	205	22	229	232	110
Composite GJIG. ARI	7,150	79	335	15	200	192	120
137-62	6,933	72	210	23	218	224	106
CE 99 (check)	5,417	70	180	27	187	216	106
IRAT 55 (check)	5,017	68	235	21	213	198	106
Grand mean	5,739	73			174	180	
LSD (5%)	1,246	3			45	41	
C.V., %	13	3			16	14	
From ICRISAT/IAR, Ouagadougou							
Damougari	6,556	60	200	11	139	135	
M-36056	5,806	67	225	23	118	107	
M-36121	5,694	60	230	27	81	82	
IS-115	5,389	60	240	22	116	111	
IS-10023	5,333	60	222	23	150	142	
CE 99 (check)	4,722	58	170	26	136	136	
IRAT 55 (check)	4,583	57	183	19	97	101	
Grand mean	4,438	61	214	24	116	112	
LSD (5%)	1,290	ns	16	1	29	30	
C.V., %	18	13	4	3	15	16	
Int. prel. yield trial from ICRISAT/IAR, Zaria							
S 35	8,028	61	245	29	95	93	
S 32	7,194	69	217	33	92	90	
S 38	7,028	64	220	29	123	128	
Djigari (local)	6,806	68	300	14	121	133	
Damougari (local)	6,750	75	215	14	180	167	
IRAT 55 (check)	6,361	61	203	26	122	150	
CE 99 (check)	2,361	52	202	19	100	96	
Grand mean	5,209	66	214	26	120	122	
LSD (5%)	1,220	2	14	0.5	29	33	
C.V., %	14	2	4	1	15	17	

differences in nitrogen level but not in phosphorus, whereas at Sanguere (lowland savanna) the fertilizer effect was only significant at the highest level.

Yields at the midaltitude locations under three fertility levels (69-46, 128-46 and 128-92 kg N-P_2O_5/ha) were 7,288 kg/ha, 8,318 kg and 8,341 kg, respectively, at Babungo, 5,902 kg, 7,011 kg and 7,198 at Foumban, and 6,042, 6,151 kg and 6,165 kg at Wassande. At Sanguere in the lowland savanna, the yields at four fertilizer levels (55-60-40, 75-60-40, 85-120-80 and 110-120-80 kg N-P_2O_5-K_2O/ha) were 4,111 kg/ha, 4,155 kg, 3,928 kg and 4,481 kg, respectively.

Across the three midaltitude locations, Shaba I, Across 7844, and COCA gave the highest yields. Shaba I yielded highest at Babungo and Foumban. Among the varieties tested in the lowland savanna zone, Poca Rica 7843 gave the highest yield, while Samaru 123 and Garoua Flinty white and the local checks, which are recommended and extensively grown, gave the lowest yields (Tables 54 and 55).—*T.G. Hart, J. Kikafunda-Twine and H. Talleyrand*

Sorghum and Millet

The primary objective of the NCRE Project in sorghum and millet improvement is to develop suitable cultivars with high yield potential and proven stability over a range of environments. The first phase of the program for attaining this objective was begun in 1982 with evaluation of germplasm available in Cameroon and from national and international institutions for release as varieties or use as parents for future hybridization programs.

Evaluation of Local Sorghum Lines

In one of the three experiments for evaluating locally improved IRA lines, most of the 16 test entries outyielded the exotic checks (E35-1 and SPV35), but were very tall and late in maturity. The entries were also susceptible to gray leaf spot (*Cercospora sorghi*), oval leaf spot (*Ramulispora sorghicola*), sooty stripe (*Ramulispora sorghi*), zonate leaf spot (*Gleocercospora sorghi*) and anthracnose (*Colletotrichum*

Table 57. Yield and agronomic characters of entries in the pearl millet African regional yield trial from ICRISAT/IAR (Zaria), Maroua, Cameroon, 1982

Entry	Yield, kg/ha	Days to 50% flowering	Plant height, cm	Panicle length, cm	Disease reaction[a]		
					Downy mildew	Ergot	Smut
INMB 1253	4,625	51	255	35	0	1	1
INMB 40 NC × IVSPT	4,542	48	250	45	1	1	1
INMB 2053	4,542	50	243	32	1	1	1
INMB 3253 F_1	4,333	49	244	33	1	1	1
INMB 70 MSS	4,292	50	240	45	1	1	1
INMB 72VE2F_2	4,125	48	240	32	1	1	1
INMB 37 S_3F_1	4,125	52	275	41	1	1	1
INMB 4 MSS	4,000	50	250	40	1	1	1
INMB 46 S_3 EVAL	3,979	51	275	45	1	1	1
INMB 33 S_3F_1	3,937	50	299	50	1	1	1
KDMC	3,792	48	160	35	0	1	1
INMB BC_2F_2	3,652	51	275	50	1	1	1
INMB 74 MSS	3,313	48	200	35	1	1	1
INDIARI (local)	2,667	68	350	36	0	1	1
MOURI (local)	2,271	64	315	25	0	1	1
Grand mean	3,874	52	258	39			
LSD (5%)	868	5	ns	ns			
C.V., %	16	7	2	1			

[a]Disease reaction was rated on 0 to 5 scale, where 0 = resistant, 1 = 1 to 10% incidence, 2 = 11 to 20%, 3 = 21 to 35%, 4 = 36 to 50% and 5 = over 50%.

graminicola). The top five yielders are listed in Table 56. Of the 134 lines assessed in the other two experiments, 14 were found to be superior to the improved local checks (CE 99 and IRAT 55) in yield and resistance to diseases and pests.

Evaluation of Introduced Germplasm

A total of 223 sorghum lines, crosses and breeding materials comprising introductions from Centre National de la Recherche Agronomique (CNRA), Bambay (Senegal); the All-India Coordinated Sorghum Improvement Project (AICSIP); the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Ouagadougou (Upper Volta); ICRISAT, Hyderabad (India); and ICRISAT/Institute of Agricultural Research (IAR), Zaria (Nigeria), were evaluated in 19 different experiments during the 1982 rainy season at IRA's Guiring Research Station, Maroua. The purpose was to identify adapted materials with high yield and resistance to the major diseases and insect pests. IRAT 55 and CE 99 were used as the local checks in most of the experiments.

In one trial 26 entries, including two checks, were evaluated. Yolobri, a local entry, did not flower until the experiment was harvested. Damougari, another local entry, gave the highest yield, followed by M-36056, M-36121, IS-115 and IS-10023 (Table 56). Damougari was observed to be early in maturity and medium in height but had short and compact panicles with red, medium sized grains. Two of the entries, M-36056 and M-36121, were found to be promising; they were medium in height, had long, semiloose panicles and white, bold grain type, and were resistant to leaf spots, grain mold and stem borers.

Of the 109 grain mold resistant crosses from ICRISAT, Hyderabad, 26 were selected on the basis of high yield, early maturity, medium height, semiloose, long panicles, and resistance to grain mold, leaf spots and stem borer. In another experiment none of the 15 lines introduced from Sudan were found to be adaptable to the conditions of northern Cameroon. Similarly, all the 16 accessions from CNRA, Bambey, were found to be inferior to the check variety (IRAT 55) in yield and other desirable agronomic characters, and none of the eight introductions from AICSIP outyielded the local checks.

Among the 55 introductions from ICRISAT/IAR, Zaria, which were evaluated in two experiments, nine entries outyielded the better local check (IRAT 55) and were also better in characters such as early maturity, medium height, long, semiloose panicles, good grain quality, and resistance to stem borer, gray leaf spot and zonate leaf spot. They were, however, susceptible to anthracnose.

In the international preliminary varietal yield trial from ICRISAT/IAR, Zaria, 28 entries, including two hybrids and six local varieties, were evaluated. Entries S-35 (8,028 kg/ha), S-32 (7,194 kg/ha) and S-38 (7,028 kg/ha) were very promising in yield, early maturity, panicle length, grain quality and resistance to stem borer and leaf spots but were susceptible to anthracnose (Table 56). The two hybrids, CSH-6 (5,583 kg/ha) and CSH-5 (4,999 kg/ha), performed poorly compared with the open-pollinated varieties, ranking fifteenth and twentieth, respectively.

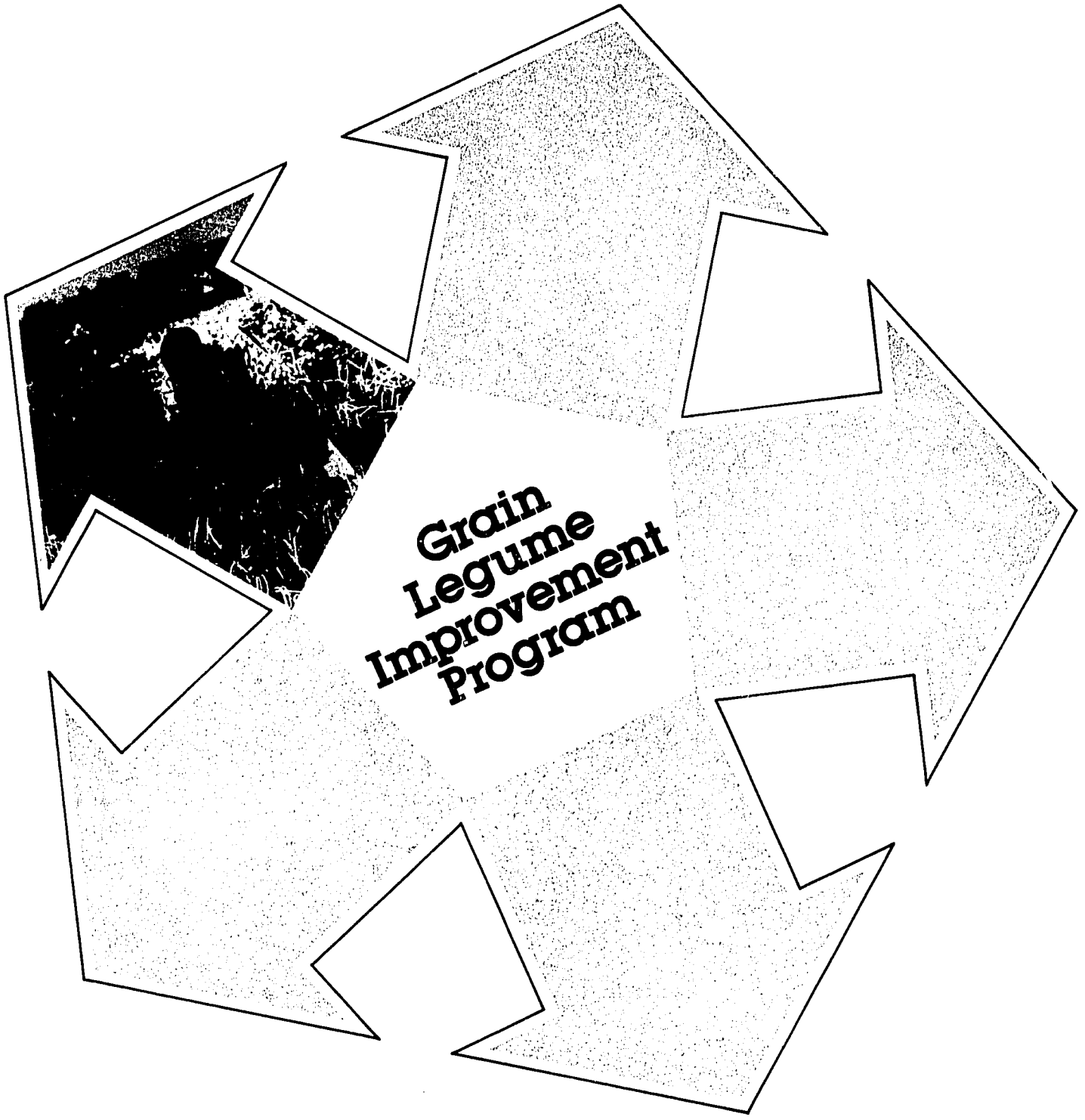
Evaluation of Dry Season Cultivars

Work was begun on dry season sorghum by establishing 57 Muskwari (dry season sorghum) entries collected by IRA and 52 entries from ICRISAT/IAR, Zaria, in observation nurseries. They were transplanted during the first week of October 1982 at the IRA Sarlak Research Station near Maroua. Data will be collected on adaptation characteristics, yield potential and other desirable agronomic characters.

Pearl Millet Yield Trials

Three experiments, the pearl millet exchange nursery from ICRISAT/CNRA, Maradi (Niger), and two pearl millet African regional yield trials from ICRISAT/CNRA, Maradi, and ICRISAT/IAR, Zaria (Nigeria), were planted to assess their performance under the conditions in Cameroon.

All 10 test entries in the exchange nursery trial were lower yielding than the local check (IDIARI) but were earlier in maturity; two of them (ITV 8001 and CTV) were also tolerant to downy mildew, ergot and smut. In the African regional yield trial from ICRISAT/IAR, Zaria, all 13 entries were higher yielding than the two local checks, IDIARI and MOURI (Table 57). None of the 12 entries evaluated in the African regional yield trial from ICRISAT/CNRA, Bambey, was higher yielding than the two local checks (IDIARI and MOURI), although many of them were tolerant to downy mildew and ergot.—*O.P. Dangi*


Grain
Legume
Improvement
Program

THE GRAIN LEGUME IMPROVEMENT PROGRAM deals with two crops, cowpeas, for which IITA has international responsibility, and soybeans, for which it has regional responsibility in Africa. Cowpeas originated in West Africa but are now common in many other parts of the continent. They are also cultivated under marginal moisture and poor soil conditions in Asia and South and Central America. Cowpeas are an extremely important source of plant protein for the poorest of the world's poor. Soybeans, although they are not cultivated as extensively in Africa as are cowpeas, have enormous potential for expanded production and could do much to help meet the growing demand for vegetable oil and for both human food and animal feed.

To help farmers boost cowpea production, the Grain Legume Program is developing varieties with good seed quality, resistance to insect pests and diseases, and different maturity periods to fit the various ecological zones of the tropics. In soybean research primary emphasis is placed on seed storability, compatibility with indigenous rhizobia and yield capability. Genetic improvement of both crops is reenforced by soil microbiology research, which so far has focused primarily on increasing yields through biological nitrogen fixation.

Cowpeas

During IITA's first decade of cowpea research, a major effort was made to develop improved plant types and to identify sources of resistance to insect pests and diseases. In recent years we have concentrated on combining insect and disease resistance with improved plant type and on developing extra-early maturing cowpeas.

These efforts are beginning to pay off. For the first time, resistance to the cowpea storage weevil (bruchid) has been incorporated into cowpea cultivars with superior agronomic characters. Bruchids are causing enormous losses throughout the world. In Nigeria alone the losses are estimated to be over $30 million a year. Improved bruchid resistant lines are now being sent to cooperators in about 40 countries for evaluation of yield and bruchid resistance.

IITA has also developed extra-early cowpeas that mature in only 60 days and have acceptable seed quality. An international trial of nine extra-early cultivars with variable seed quality is being distributed to over 40 countries. These varieties should fit well into the cropping systems of various ecological zones. They should be particularly suitable in areas such as the Sahel and Sudan savanna that have a very short rainy season and in the lowland humid tropics after the main rice crop, when the land is normally left fallow and no other crop can be grown.

A major effort was made this year, through a staff position created for a project in northern Nigeria (Zaria) that is being funded by the European Economic Community, to identify and develop resistance to three major cowpea diseases—Septoria, scab and brown pod blotch—which are predominant in the traditional cowpea growing areas of the Sahel and Sudan savanna. Our advanced material has not previously had resistance to these diseases. Through screening for resistance in northern Nigeria, a few lines have been identified that combine resistance to these diseases with good agronomic characters.

IITA scientists working in the Semi-Arid Food Grains Research and Development (SAFGRAD) Project in Upper Volta have identified two cowpea cultivars that are resistant to *Striga* (commonly known as witchweed), which is causing considerable yield losses in the Sudan savanna of West Africa. A hybridization program was begun at Kamboinsé, Upper Volta, to incorporate *Striga* resistance into advanced lines.

Several cowpea varieties developed at IITA or its regional stations were multiplied and released to farmers this year through national programs in several countries. The variety TVx 3236, for example, which was released to farmers last year, is now being multiplied on a large scale. In Kano State alone, in northern Nigeria, farmers plan to multiply this variety in 500 villages on about 5,000 hectares under the supervision of the Kano State Agricultural and Research Development Authority. If well managed the seed should be sufficient for planting 0.5 million hectares next year.

After extensive tests the Ministry of Agriculture in the South American country of Guyana has recommended four IITA cowpea varieties to farmers. These varieties, ER-7, TVx 66-2h, TVx 2907-02D, and VITA-6, have been named Minica I, II, III and IV, respectively. In Brazil IITA cowpea varieties VITA-3 and VITA-6 were released as EMAPA 822 and 821 by the Maranhao State Enterprize for Agricultural Research, Empressa Brasiliera de Pesquisa Agropecuária (EMBRAPA) and National Center for Research on Rice and Beans (CNPAF). IITA varieties have had a significant impact on cowpea production in Brazil. In recognition of this contribution, IITA was recently awarded with a trophy from EMBRAPA and CNPAF.

Genetic Improvement

The cowpeas grown in West Africa are specifically adapted to the environments and cropping systems in which they evolved. Characteristically, they are of indeterminate type, with a spreading growth habit and maturity period of up to 150 days. In most parts of West Africa, large, white, rough seeded cowpeas are preferred, although several other varieties with

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different seed characteristics are also cultivated. In many other parts of the tropics, specifically Asia and Latin America, brown, red and black seeded varieties are cultivated in addition to the white ones.

The major objective of the cowpea breeding program at IITA is to develop improved cowpea varieties that are suited to the environments in which cowpeas are grown. These varieties must have wide adaptation, acceptable seed types, resistance to diseases and pests, improved plant type and high yield potential. Toward that end, several early and advanced generation lines were evaluated in a series of trials at several locations in Nigeria that represent the forest, Guinea savanna and Sudan savanna zones. International trials were sent to 40 different countries for evaluation of yield and pest resistance.

Hybridization and Early Generation Materials

A total of 350 different types of crosses were made during the year involving parents of different maturity groups, with disease and insect resistance and with desirable seed quality. F_1 plants were grown in the greenhouse. In addition, 110 F_2 populations, 279 F_3, 40 F_4 and 56 F_5/F_6 populations, comprising several thousand progenies from the previous year, were evaluated, and desirable individual plants/progenies were selected. These are again being grown in the dry season for generation advance.

Several advanced breeding lines are available that possess resistance to one or more diseases, along with individual resistance to thrips, aphids and bruchids. Efforts are now being made to develop varieties that combine multiple disease and insect resistance. A generalized breeding strategy for developing multiple disease and insect resistant lines has been developed. By using the greenhouse and dry season nurseries, four cowpea crops can be grown every year, and within two years one cycle of recombination and pedigree selection for disease and insect resistance and yield can be completed. The promising lines can be recrossed for another cycle of recombination and selection until the desired level of resistance to diseases and insects is achieved.

Several crosses involving donor parents with thrips resistance (TVx 3236), aphid resistance (TK-1R), bruchid resistance (IT 81D-1137 and IT 81D-1064), early maturity (IT 82E-60) and multiple disease resistance (TVx 1850-01E, TVx 4659-03E, etc.) were made. A systematic backcrossing program was also initiated to incorporate multiple disease resistance and aphid and bruchid resistance into TVx 3236 and other advanced lines.—*B.R. Ntare and B.B. Singh*

Variety trials

In the cowpea variety trials, lines from the F_5 generation and beyond are tested in three stages. The first is preliminary yield testing, which is carried out at locations in Nigeria that represent different ecological zones. Lines selected from the preliminary trials form advanced trials. The international trials consist of materials selected from the advanced trials and are sent to cooperators in more than 40 countries around the world.

Preliminary yield trials. These trials were conducted at IITA and two other locations in Nigeria, Mokwa and Samaru. The trials consisted of lines selected from F_5/F_6 entries that were evaluated in 1981. Some of these materials possess high levels of resistance to several diseases and have good seed quality. A total of 126 lines were evaluated at each location. Each trial had a random block design, with four replications and a plot size of four rows 4 m long. Ife Brown, VITA-7 and TVx 3236 were included as check varieties.

Twenty-five lines performed as well or better than the check varieties. The most promising of these were TVx 3236-5-2, IT81D-1186, IT81D-1202, IT81D-1148, IT81D-1205 and IT81D-1032. The mean yield of these lines was over 1,700 kg/ha, compared to 1,350 kg/ha for the checks.

Advanced yield trials. The three advanced yield trials were also planted at IITA, Mokwa and Samaru in Nigeria. Advanced trial 1 consisted of 17 entries and three check varieties, Ife Brown, VITA-7 and TVx 3236. These entries were of the medium maturity group (75 to 85 days), varied in seed color and for the most part had smooth testa. There was no significant difference between their yield and that of the checks at IITA and Mokwa. However, at Samaru four lines appeared to be superior to the check varieties. In advanced trial 2, which consisted of early maturing lines (60 to 65 days) with desirable seed characteristics, one line significantly outperformed the checks at Samaru. There was no significant difference in advanced trial 3 between the yield of the top lines, which combined bruchid resistance with desirable agronomic characteristics and seed type, and that of the check varieties (Table 1).

International Trials. Varieties selected from advanced trials in 1981 because of their yield potential and resistance to diseases were included in two cowpea international trials this year. International trial 1 consisted of 9 white seeded varieties and international trial 2 of 19 varieties with red, brown or cream colored seed. Each trial had a complete randomized block design with four replications and a plot size of four rows 4 m long. In each trial the national improved variety was included as a local check. Over 90 sets of trial 1 and 82 sets of trial 2 were sent to 40 countries around the world.

The yields of the varieties in international trial 1 at 10 locations are listed in Table 2. The yields in trials located outside Nigeria, which were supervised by national scientists, were generally low at all locations. TVx 3236 gave the highest overall yield. Other lines that performed well were TVx 4659-03E, VITA-5 and TVx 4662-09D, which combine good seed

quality with disease resistance. TVx 4659-03E has strap leaves and medium maturity and is resistant to cowpea yellow mosaic, cowpea aphid borne mosaic, anthracnose, bacterial pustule, bacterial blight, brown blotch, Septoria and Cerospora leaf spot.

For international trial 2, data are available only from seven locations; the mean yields of the varieties are listed in Table 3. TVx 4678-088E and TVx 4678-03E gave the highest yields and were consistently superior to other varieties at most locations. Both of these lines are resistant to several foliar diseases.—*B.B. Singh, B.R. Ntare and Remi Adeleke*

Extra-Early Varieties

A systematic program was begun to develop extra-early cowpea varieties that fit in multiple cropping systems and perform well in low rainfall areas of the tropics. A number of varieties selected from different segregating populations as well as germplasm were evaluated for yield and other characters at different locations in Nigeria. Fifty-five planned crosses were made between extra-early varieties and sources of disease and insect resistance. A backcrossing program was also begun to systematically incorporate resistance to different diseases and insects into selected extra-early varieties.

The most promising early maturing varieties, selected on the basis of earliness, yield potential and disease resistance, were evaluated in two different trials. Early maturity trial 1 consisted of 20 varieties that matured within 60 to 65 days and early maturity trial 2 of 20 varieties that required 70 to 75 days to mature. Ife Brown was included as a check. Both of these trials were conducted at IITA, Mokwa and Samaru, which represent different ecological zones in Nigeria.

The mean yields of the best six varieties from the extra early group and those of the early maturity group are listed in Table 4. During the second season at IITA, the varieties generally performed poorly because of extreme drought and poor germination.

Table 1. Performance of IITA cowpea lines in advanced yield trials at various locations in Nigeria, 1982

Line	Yield, kg/ha IITA	Mokwa	Samaru	Mean
Advanced trial 1				
TVx 4654-044E	1,192	1,899	2,307	1,799
TVx 4659-05E	1,406	1,565	2,296	1,755
TVx 4678-03E	1,192	1,941	2,012	1,715
TVx 4662-07E	1,273	1,189	2,115	1,526
Check varieties:				
Ife Brown	1,035	1,044	770	950
VITA-7	1,454	1,670	1,737	1,620
TVx 3236	1,124	1,837	919	1,293
LSD (5%)	427	425	454	
C.V., %	26.8	18.3	18.4	
Advanced trial 2				
IT81D-1157	1,228	2,750	2,129	2,036
TVx 5592-0C	1,424	2,594	1,795	1,938
IT81D-1137	1,130	1,828	1,701	1,553
TVx 5054-010C	1,279	1,766	1,609	1,551
IT81D-1064	1,153	1,766	1,701	1,540
Check varieties:				
Ife Brown	1,205	2,375	1,534	1,705
VITA-7	1,176	2.016	1,766	1,653
TVx 3236	1,014	2,516	977	1,502
LSD (5%)	358	588	408	
C.V., %	20.7	20.8	18.6	
Advanced trial 3				
IT81D-1052	1,450	1,587	1,865	1,634
IT81D-1031	1,299	1,785	1,642	1,575
IT81D-1007	1,358	1,795	1,169	1,441
IT81D-1020	1,423	1,430	1,528	1,467
IT81D-1036	1,348	1,722	1,099	1,390
Check varieties:				
Ife Brown	894	1,451	1,[illegible]	1,292
VITA-7	1,310	1,503	1,433	1,415
TVx 3236	1,139	1,701	1,155	1,332
LSD (5%)	316	354	576	
C.V., %	19.4	17.1	18.6	

Table 2. Mean yields of cowpea varieties in international trial 1, 1982

Variety	Yurimaguas, Peru	Kila, Nigeria	IITA, Nigeria First season	IITA, Nigeria Second season	Mokwa, Nigeria	Samaru, Nigeria	Kano, Nigeria	Malamaduri, Nigeria	Nyankpala, Ghana	Mogadishu, Somalia	Chungbuk, Korea	Mean
						kg/ha						
TVx 3236	1,423	1,280	900	672	1,868	772	1,827	459	1,090	334	1,602	1,107
TVx 3627-012F	1,025	753	972	609	1,190	1,086	1,200	919	885	132	1,183	905
TVx 3671-7C-02D	1,218	1,350	629	683	1,096	877	1,415	522	468	409	272	813
TVx 3671-14C-01D	—	1,409	323	690	981	518	1,566	522	363	361	487	722
TVx 4262-09D	1,270	968	1,040	753	825	1,488	1,639	585	380	330	—	928
TVx 4262-014D	—	1,280	572	327	1,326	789	1,378	480	864	322	1,028	837
TVx 4659-03F	1,383	1,992	1,253	650	83[illegible]	714	1,983	334	601	274	—	1,002
Local check	1,088	—	—	467	1,321	—	549	877	231	301	519	744
Standard checks:												
VITA-5	1,303	1,482	554	781	1,211	1,065	1,962	605	378	289	872	955
Ife Brown	1,073	1,322	553	691	1,246	643	2,104	522	714	302	967	922
LSD (5%)	287	368	437	206	495	386	837	371	440	208	383	
C.V., %	16	19	40	22	27	30	37	44	50	47	30	

Table 3. Mean yields of cowpea varieties in international trial 2, 1982

Variety	IITA, Nigeria First season	IITA, Nigeria Second season	Mokwa, Nigeria	Mogadishu, Somalia	Chungbuk, Korea	Nyankpala, Ghana	Yurimaguas, Peru	Samaru, Nigeria	Mean
					kg/ha				
VITA-7	1,578	795	1,503	325	1,128	1,505	1,663	1,336	1,229
TVu 3629	817	721	1,326	165	876	1,008	1,430	710	882
TVx 1836-013J	976	921	1,378	298	419	1,142	1,477	731	918
TVx 1948-01F	1,434	910	1,795	397	515	1,407	1,580	1,253	1,161
TVx 133-16D-2	1,229	615	1,336	217	334	1,111	967	731	817
TVx 2394-02F	1,606	962	1,388	284	1,134	994	1,673	752	1,100
TVx 2724-01F	1,171	838	1,242	410	696	1,244	1,610	835	1,006
TVx 3381-02F	1,175	936	1,472	914	539	1,033	1,543	1,023	1,079
TVx 3410-02J	929	863	1,837	520	387	1,136	1,597	1,148	1,052
TVx 3627-03G	1,131	870	1,639	251	1,238	1,413	1,503	1,378	1,178
TVx 3871-02F	967	828	1,232	285	506	624	1,410	877	841
TVx 4577-02D	1,241	792	1,346	91	929	1,816	1,830	1,420	1,183
TVx 4661-07D	935	841	1,461	376	1,047	994	1,703	1,253	1,076
TVx 4677-088E	1,975	1,019	1,931	461	730	1,440	1,826	1,691	1,384
TVx 4678-03E	1,275	730	2,025	579	1,052	1,893	1,450	1,357	1,295
Local check	—	645	2,035	827	980	1,432	1,450	—	1,228
LSD (5%)	569	215	506	235	824	509	258	855	
C.V., %	33	18	23	41	74	28	10	36	

But overall, the early maturing varieties yielded as well or better than Ife Brown, even though the difference in maturity was more than two weeks. Most of the extra-early varieties matured in 60 and 65 days, whereas Ife Brown matured in 77 to 85 days. All the early maturing lines had a moderate to high level of resistance to several diseases, except for IT 82E-56, IT 82E-60 and IT 82E-77, which were just as susceptible to brown blotch and cowpea yellow mosaic as Ife Brown.

Table 4. Mean yield of extra-early and early maturing varieties at various locations in Nigeria, 1982

Variety	IITA First season	IITA Second season	Mokwa	Samaru	Mean
			kg/ha		
Early maturing trial 1					
IT 82E-32	1,961	1,143	2,109	1,809	1,755
IT 82E-9	2,003	978	2,078	1,614	1,668
IT 82E-56	1,810	1,713	1,875	1,049	1,612
IT 82E-5	1,420	1,074	1,845	2,018	1,590
IT 82E-77	1,285	—	1,594	1,559	1,479
IT 82E-60	1,374	—	1,563	1,127	1,369
Ife Brown (standard check)	2,151	1,205	1,484	1,264	1,526
LSD (5%)	428	240	307	444	
C.V., %	21	24	14	22	
Early maturing trial 2					
IT 82E-16	3,023	986	2,188	1,620	1,954
IT 82E-18	2,444	737	2,391	1,893	1,866
IT 82E-25	2,016	818	2,719	1,781	1,834
IT 82E-3	2,207	1,349	2,141	1,447	1,786
IT 82E-12	1,972	934	2,281	1,706	1,723
IT 82E-17	2,042	1,141	2,047	1,656	1,721
Ife Brown (standard check)	2,441	826	2,031	1,177	1,618
LSD (5%)	531	401	493	364	
C.V., %	18	30	17	16	

The early maturing varieties vary in seed coat color. IT 82E-32 has a red seed coat, IT 82E-9 has a black one, that of IT 82E-5 is brown, and IT 82E-56, IT 82E-60 and IT 82E-77 have large, white seeds with a rough seed coat. Most of the varieties in early maturity trial 2 had brown seed coats, except IT 82E-17, which has dark red seeds.

Preliminary trials of these early maturing varieties, conducted at Onne in southern Nigeria, gave very encouraging results. The trials were planted in rice fallows on 28 October 1982 after the rice crop was harvested. The residual moisture supplemented with occasional showers was enough for a successful cowpea crop. All the varieties matured within 60 days, and the trials were ready for harvest by the last week of December 1982. The yields ranged from 600 to 1,300 kg/ha; the best varieties were IT 82E-12, 82E-4, 82E-18, 82E-32 and 82E-56. These varieties will be further evaluated in the coming season at various locations.

At present, no crop is grown in this region after rice harvest. The results reported here indicate that early cowpea varieties could be successfully grown on residual moisture after rice. This double cropping system could be of immense economic importance to farmers. Not only would it give them extra income and enable them to make better use of their land and labor, but it would also provide them with more nutritious diets.

Bush Type Vegetable Cowpeas

In several countries of Asia cowpeas are grown for their long, fleshy, tender pods, which are used as a

IITA extra-early cowpea varieties for multiple cropping systems and low rainfall areas of the tropics.

Newly developed vegetable cowpeas with strong stems that make staking unnecessary.

fresh vegetable. Most of the vegetable cowpea varieties need staking to keep pods from touching the ground and to avoid pod rotting. Staking involves extra expense and limits the size of the area cultivated. A systematic breeding program was begun at IITA to develop bush type vegetable cowpea varieties that yield as much as the climbing type now available and have similar pod characteristics but do not require staking. Several advanced breeding lines were evaluated for yield and other agronomic characteristics. Twenty-five populations were generated that included climbing and bush type vegetable cowpeas, and the F_2/F_3 populations were screened for various diseases and for plant type.

Twenty vegetable cowpea varieties, including newly developed bush type varieties, were evaluated for seed yield and green pod yield. Because only a limited quantity of seed was available, this trial was conducted only at IITA; two replications were harvested for seed and two for green pod yield. Green pods were picked 53 days after planting and weekly afterwards until most of the varieties had stopped producing pods. Pods were picked a total of seven times.

The cumulative totals of the most promising lines are listed in Table 5 along with data on pod length, moisture content and percent protein. The IT-1228 varieties are of the bush type, and TVx 3442-27E and FARV-13 are climbers. The bush type varieties yielded from 14 to 19 t of green pods per hectare, compared to 12 to 15 t for the climbing type varieties. It was also observed that TVx 3442-27E provided most of the pods in the first two flushes but that all the bush types continued flowering and podding up to five weeks after the first pick. Moreover, all the bush type varieties were resistant to cowpea aphid borne mosaic, cowpea yellow mosaic and most of the other foliar diseases.

The data on pod characteristics and percent protein indicate that bush type varieties are as good as climbers in succulence, pod size and protein content. In a general acceptability test conducted at IITA, the two groups of varieties received equal ratings. FARV-13 has been released in Nigeria under the name of Dinner, but because of its climbing habit and need for staking, it is not popular. Nevertheless, the bush type vegetable varieties are expected to gain popularity in Africa and elsewhere.—*B.B. Singh and B.R. Ntare*

Insect Resistance

Bruchids. The cowpea seed beetle, *Callosobruchus maculatus*, causes substantial losses of cowpeas in storage. Even the most conservative estimates indicate that annual losses exceed $50 million in West Africa alone. Concerted efforts have been made during the past several years at IITA to develop cowpea varieties that are resistant to bruchids. A single source of bruchid resistance, TVu 2027, was identified in 1977. Using this line as a parent, several

advanced breeding lines have been developed that combine bruchid resistance with high yields, disease resistance and good seed quality.

A number of these lines were evaluated in multilocational trials during 1982. The mean yield and level of bruchid resistance of the most promising lines, which vary in seed color, are listed in Table 6. The lines that showed higher yield potential than Ife Brown at all locations, IT 81D-1157, 81D-1148, 81D-1032, 81D-994 and 81D-1007, also proved to be just as bruchid resistant as TVu 2027 and even better in disease resistance. These lines also have desirable seed quality that is acceptable in different regions. IT 81D-985 and IT 81D-992 have large white seed with a rough seed coat; IT 81D-1157 and IT 81D-1148 have tan seed; that of IT 81D-1032 and IT 81D-1064 is red, and IT 81D-1137 has white seed with a smooth seed coat. Seed of these lines has been multiplied for distribution to various national programs in 1983.

Two new sources of resistance to bruchids were identified this year. They were selected from the local variety Kanan Nado, which was obtained from the Gombe area of Bauchi State, Nigeria, courtesy of J.G. Quinn. The bulk sample had white and speckled seed, which was sorted and bioassayed separately for bruchid resistance. Both samples, now maintained as Kanan Nado White (KNW, TVu 11952) and Kanan Nado Speckled (KNS, TVu 11953), were found to be just as resistant as TVu 2027. Data on the level of bruchid resistance in these lines are presented in Table 7 along with data on TVu 2027 and some susceptible varieties, including Ife Brown and TVx 3236. Emergence of bruchids in the resistant lines was delayed and staggered, and fewer adults emerged than in the susceptible lines, in which a large number of adults emerged early and quickly.

TVu 2027 was originally collected from the Rima Valley of Sokoto State, which is about 1,000 miles east of the Gombe area. For that reason and because the pod characteristics of TVu 2027, KNW (TVu 11952) and KNS (TVu 11953) are quite different, these resistance sources may be of independent origin. Genetic studies have been initiated to ascertain whether the genes for resistance in these lines are the same or not. As is apparent from Table 7, the level of resistance in these lines is only moderate and cannot provide complete protection under severe infestation.

The inheritance of bruchid resistance was studied in nine populations, in which TVu 2027, KNW and KNS as resistant parents were crossed to several susceptible parents. Data from F_1, F_2 and backcross populations indicate that two recessive gene pairs are required in the homozygous condition for bruchid resistance, and a typical ratio of 15 susceptible to 1 resistant plant was observed in F_2. Data from one of the crosses, TVu 2027 × TKx 133-16D-2, are presented in Table 8, and the frequency distribution in different populations of the same cross is shown in Figure 1. The F_1 seeds behaved just like the maternal parents. F_2 seeds were susceptible, irrespective of the

Table 5. Performance of vegetable cowpea varieties, IITA, 1982

Variety	Dry seed yield, kg/ha	Green pod yield, kg/ha	Pod length, cm	Moisture content in green pods, %	Percent protein in: Green pods Fresh	Green pods Dry	Seeds
IT 81D-1228-13	1,312	18,913	25	89.5	2.94	28	24
IT 81D-1228-14	776	16,778	29	89.3	2.78	26	25
IT 81D-1228-15	888	15,468	28	89.6	2.91	28	26
TVx 3442-27E	982	14,767	32	89.3	2.78	26	25
FARV-13 (check)	555	12,504	31	89.1	2.73	25	26
LSD (5%)	604	3,356					
C.V., %	34	13					

Table 6. Performance of bruchid resistant breeding lines at various locations in Nigeria, 1981

Variety	Seed color	Yield, kg/ha: IITA, first season	IITA, second season	Mokwa	Samaru	Mean	Bruchid emergence, %: 33 DAI[a]	40 DAI	50 DAI
IT 81D-1157	tan	1,336	1,228	2,750	2,129	1,861	0	16	50
IT 81D-1148	tan	1,453	1,399	2,609	1,472	1,733	0	15	63
IT 81D-1032	red	1,489	1,630	2,031	1,321	1,618	0	9	38
IT 81D-994	white	—	1,532	2,000	1,388	1,640	2	35	43
IT 81D-1007	red	1,291	1,358	1,795	1,169	1,626	0	25	30
IT 81D-1064	red	1,604	1,153	1,766	1,701	1,556	0	5	65
IT 81D-1137	white	1,433	1,130	1,828	1,701	1,523	2	37	70
IT 81D-985	white	—	1,212	1,378	1,261	1,284	5	32	48
Ife Brown	brown	918	1,077	1,713	1,443	1,288	77	86	95
TVu 2027	white	—	—	—	—	—	6	22	48
LSD (5%)		516	358	463	501				
C.V., %		38	21	22	20				

[a]Days after infestation.

Table 7. Bruchid emergence in resistant and susceptible parents, 1982

Accession	No. of eggs	Total no. of adults emerged	Pattern of adult emergence 27-32 DAI[a]	33-38 DAI	39-44 DAI	45-50 DAI
TVu 2027	30	7	0	3	2	2
TVu 11952 (KNW)	36	14	0	3	8	3
TVu 11953 (KNS)	30	16	3	8	4	1
Ife Brown	35	33	32	1	0	0
TKx 133-16D-2	34	30	30	0	0	0
Cross 1-16E ..	32	32	23	9	0	0
TVx 3236	33	33	29	3	0	1

[a]Days after infestation.

maternal parent, and represented the true hybrid phenotype, indicating maternal control of bruchid resistance as well as complete dominance of susceptibility. The pooled F_2 population (F_3 seeds from F_2 plants) segregated into 102 susceptible and 7 resistant plants, fitting the 15:1 ratio closely.

Similar results were obtained in reciprocal crosses. The backcross population towards the resistant parent segregated into 15 suspectible and 6 resistant plants, which is a ratio of approximately 3 susceptible to 1 resistant plant. The other backcross population, involving a susceptible parent, was completely susceptible as expected. The frequency distribution (shown in Figure 1) showed a similar trend and supported the genetic data. The results from all other crosses were similar and confirmed the digenic inheritance of bruchid resistance.—*B.B. Singh, S.R. Singh, O. Adjadi and B.R. Ntare.*

Aphids. Aphids are a major problem in cowpea cultivation; not only do they reduce yield directly, but also indirectly by transmitting virus diseases. Breeding for resistance to this pest is one of the major objectives of IITA's cowpea improvement program. Several sources of resistance have been identified, and a number of crosses have been made to combine high yield potential and disease resistance with aphid resistance.

Screening of several hundred germplasm lines of cowpea revealed a number of lines with a high level of resistance and verified sources of resistance reported previously, including:

TVu 18	109	801	3000	9929
36	310	1037	3273	9930
42	408	2755	9836	9944
62	410	2896	9914	

When aphids are infested on resistant cultivars, they die within 24 hours, indicating that antibiosis is the mechanism of resistance.

The genetics of aphid resistance was studied in five crosses involving resistant and susceptible parents. The resistant parent, TK-1R, was derived from the cross TK-1 × TVu 62. The F_1 plants in all the crosses were resistant, indicating complete dominance of resistance over susceptibility. The F_2 populations of

Table 8. Segregation pattern for bruchid resistance in TVu 2027 × TKx 133-16D-2, IITA, 1982

Population	Number of plants: Bio-assayed	Resistant	Susceptible	X^2
TVu 2027 (P_1)	39	39	—	—
TKx 133-16D-2 (P_2)...	40	—	40	—
F_2 seed (from F_1)...				
TVu 2027 × TKx 133-16D-2 (F_1)	19	—	19	—
TKx 133-16D-2 × TVu 2027 (RF_1)....	36	—	36	—
F_3 seed (from F_2)				
TVu 2027 × TKx 133-16D-2 (F_2)	33	1	32	0.584 (IR:15S)
TKx 133-16D-2 × TVu 2027 (RF_2)....	76	6	70	0.351 (IR:15S)
Backcross (F_2 seed)				
$F_1 \times P_1$:B_1	21	6	15	0.143 (IR:3S)
$F_1 \times P_2$:B_2	66	—	66	—

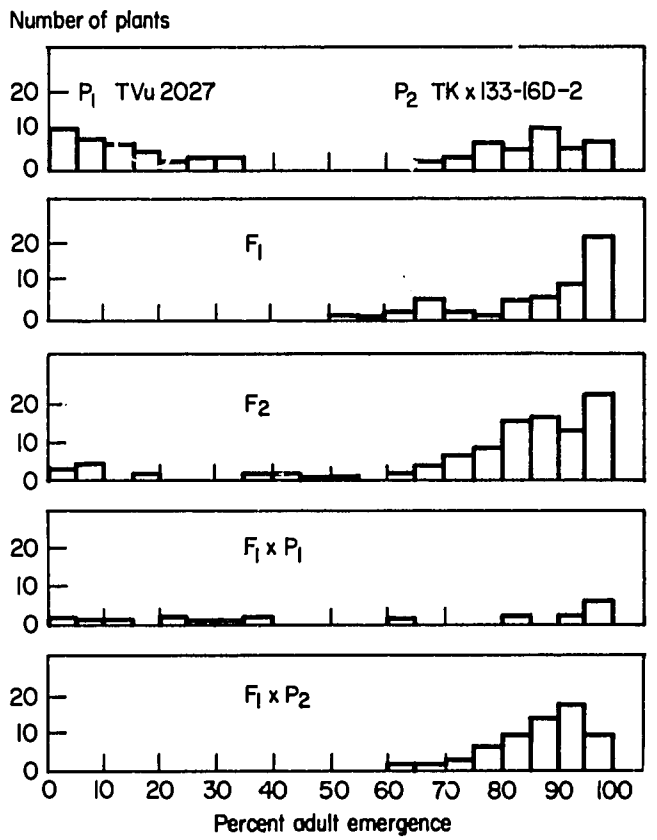


Figure 1. Frequency distribution of percent bruchid emergence in different populations of the cross TVu 2027 × TKx 133-16D-2 at 33 days after infestation, IITA, 1982.

all the crosses segregated in a ratio of three resistant to one susceptible plant (Table 9), suggesting that inheritance of aphid resistance is monogenic.

Twenty-five crosses were made between selected high yielding varieties and the aphid resistant lines TVu 3000, TVu 801 and TK-1R. The F_1 and F_2 populations were screened in the greenhouse under

Table 9. Segregation pattern for aphid resistance in F_2 populations, IITA, 1982

Population	No. of plants: Resistant	Susceptible	X^2 (3:1)	Probability
TVx 3236 × TK-1R[a] ...	54	23	0.17	.30-.50
Ife Brown × TK-1R ...	36	14	0.24	.50-.60
TVx 4031 × TK-1R....	82	33	0.84	.30-.50
TVu 4551 × TK-1R....	130	51	0.97	.30-.50
TVu 4545 × TK-1R....	109	28	1.52	.20-.30
Pooled	411	149	0.77	.30-.50
Heterogeneity X^2			3.77	.30-.50

[a]TK-1R is a breeding line derived from the cross TK-1 × TVu 62.

artificial infestation. The resistant F_2 plants were raised till maturity, and the resulting F_3 progenies will be evaluated for agronomic characters and aphid resistance in the coming season. A systematic backcross program was also initiated to incorporate aphid resistance into TVx 3236 and IT 82E-60.—*S.R. Singh, B.B. Singh and B.R. Ntare*

Disease Resistance

Several diseases can cause substantial yield losses if a high incidence of the disease occurs in the early stage of plant growth. The major diseases in the humid tropics are cowpea aphid borne mosaic, cowpea yellow mosaic, anthracnose, web blight, bacterial pustule and bacterial blight. Septoria, brown blotch and scab are more important in the savanna regions.

A continuous effort has been made at IITA to develop cowpea varieties with multiple disease resistance. In the initial stage of the cowpea improvement program, a large number of germplasm lines were screened, and sources of resistance to various diseases identified. These were then used as parents in the hybridization program, and most of the advanced breeding lines possess resistance to one or more diseases.

Concerted efforts are now being made to combine multiple disease resistance and high yield potential. Through a combination of field screening under natural infestation and artificial screening in the greenhouse, all the segregating populations are evaluated for resistance to several diseases from F_2 to F_6 generations. Lines showing high susceptibility to any major disease are eliminated; only those with a moderate to high level of resistance are selected for advance generations.

Considerable progress had been made, and a number of advanced breeding lines have been developed that combine multiple disease resistance with high yield potential. All the advanced breeding lines included in the 1982 variety trials were screened for various diseases. Some of these lines have multiple disease resistance and high yield potential.

The lines that showed resistance to seven diseases (bacterial blight, bacterial pustule, anthracnose, cowpea aphid borne mosaic virus, cowpea yellow mosaic virus, brown blotch, Septoria and web blight) were TVx 1850-01E, 4033-1, 4659-02E, 4659-03E, 4662-013E, 4662-024E, 5802-1, 5804-1 and 5822-1. In addition, several high yielding breeding lines were also identified that had resistance to four or five diseases. Some of the important ones are IT 81D-1007, 81D-1137, 81D-1148, 81D-1032, 82E-10, 82E-18, 82E-32, 82E-77 and TVx 3236-5-2.—*B.B. Singh, H.W. Rossel, S.A. Shoyinka and F. Oni*

Entomology

Insect Surveys

Pod borers (*Maruca*). Studies on trends in the population of this insect were conducted at IITA during the first planting season (April) and the second season (September) and at Mokwa (August planting), which is located about 300 km north of Ibadan at the southern limit of the region of intensive cowpea production. Mokwa was identified in the past as a "hot spot" for infestation by cowpea insect pests.

The results of these studies are shown in Figure 2. Although the pod borer infestation was higher in the second season at IITA than in the first season and at Mokwa, the populations throughout the experimental period at both locations were high enough to cause economic yield losses. Second season populations are generally higher at IITA possibly because of the double cropping; the population in the first crop helps build up the second season population. Similar studies will be carried out at other locations in Nigeria on a north-south axis to observe zonal trends. This information should help us determine the population levels to which cowpeas are exposed and the level of resistance required to provide adequate pod borer control.—*L.E.N. Jackai*

Pod bugs. Studies were conducted at two locations, IITA and Mokwa, during the cowpea growing seasons to monitor pod bug populations and collect basic information for the formulation of integrated pest management strategies. Changes in

An IITA cowpea line with multiple disease resistance (right) compared with a susceptible check.

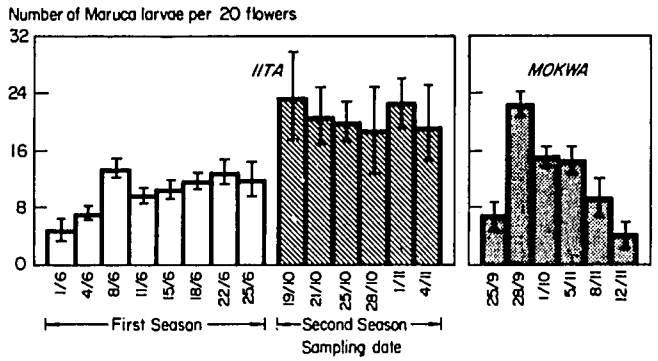


Figure 2. Fluctuation in the population of *Maruca* on monocropped VITA-7 at two locations in Nigeria, 1982. The vertical lines on the bars represent standard errors.

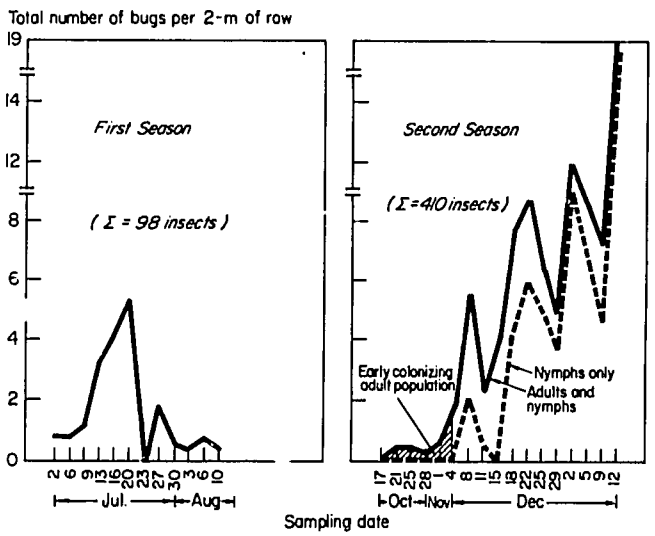


Figure 3. Fluctuation in the population of pod sucking bugs in VITA-7, IITA, 1982. The number in parentheses is the total population sampled.

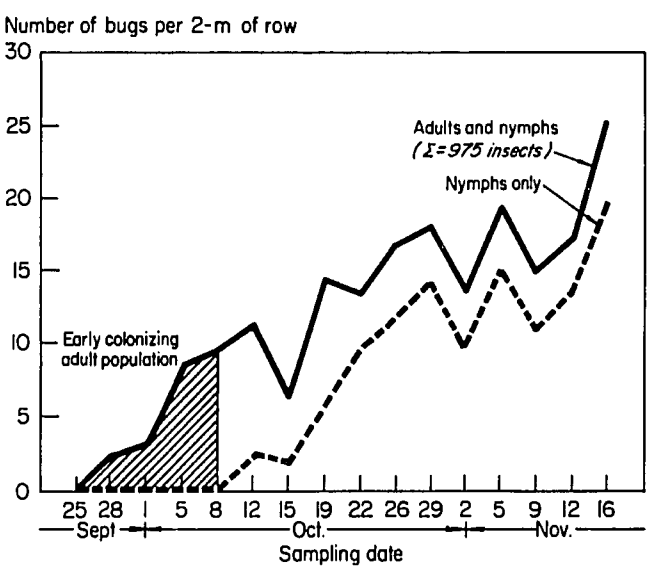


Figure 4. Fluctuation in the population of pod sucking bugs at Mokwa, Nigeria, 1982. The number in parentheses is the total population sampled.

the population levels are shown in Figures 3 and 4.

At IITA the first season population consisted mainly of *Clavigralla shadebi*. During the second season, *C. tomentosicollis* accounted for 80% of the population, which was four times that of the first season. At Mokwa the major species was *C. tomentosicollis*, which accounted for almost 95% of the population. The early population consisted entirely of adults, suggesting migration from an external source. But because the insect breeds in the crop, the population increased rapidly until it was two times the IITA population during the second season. Extremely high populations were observed about 55 days after the crop was planted.

These results indicate that Mokwa would be a good location for pod bug resistance screening. Furthermore, it seems possible to avoid great damage to the crop either by planting earlier (assuming normal rainfall) or using extra-early maturing cowpea varieties and thus avoiding the extremely high populations. The fact that pod bugs migrate into cowpea fields in large numbers suggests the existence of reservoir/alternate hosts. This finding led to work on the host range of these pod bugs.

In a survey for wild host plants of *C. tomentosicollis* and *C. shadebi* between November 1981 and December 1982, *Eriosema psoraleoides* Hook (*Papilionaceae*) was found to be the most common alternate host plant for *C. tomentosicollis* and *C. shadebi* as well as for other pod sucking bugs, namely *Mirperus jaculus*, *Riptortus dentipes*, *Nezara viridula*, *Piezodorus guldinii*, *Anoplocnemis curvipes* and *Aspavia* sp. Although we did not determine whether this species is the immediate source of initial infestations of cowpeas, it did seem to play an important role in the ecology of *C. tomentosicollis* by hosting the pest during part of the dry season in the southern Guinea savanna (Mokwa) and in the derived savanna or transition zone (Ogbomosho).

Cassia mimosoides L. (*Caesalpinaceae*) was observed to be quite important as a source of infestation by *C. shadebi* and other bugs. Other host plants that were found to host many pod sucking bugs, but not *Clavigralla* species, were *Cassia occidentalis* and *Eriosema glomeratum*.

The life cycle of *C. tomentosicollis* was affected by its source of food when the insect was reared in the laboratory, where the temperature varied between 21° and 27°C. As shown in Table 10, there was no significant difference in the duration of the first two instars *Vigna unguiculata*, *Cajanus cajan* and *Eriosema psoraleoides*. All the nymphs died during the second instar when reared on *Crotalaria juncea*, *Cassia mimosoides* and *Cassia occidentalis*.

To investigate the onset of pod sucking bug infestations in relation to time of planting and crop phenology, a planting date trial was conducted at Mokwa between May and November 1982. The dates of planting were 27 May, 24 June, 22 July and 19 August. The species composition is presented in Table 11. *C. tomentosicollis* and *C. shadebi* had the

Table 10. Effect of host plant on the development stages of *C. tomentosicollis*, IITA, 1982

Host plant	Duration of instars, (±S.E.) 1	2	3	4	5	
V. unguiculata	2.21 (±0.024)	2.67 (±0.211)	3.44 (±0.236)	4.28 (±0.266)	5.90 (±0.489)	18.50
C. cajan	2.22 (±0.187)	2.57 (±0.306)	3.40 (±0.228)	4.00 (±0.160)	5.63 (±0.290)	17.82
E. psoraleoides	2.17 (±0.117)	2.90 (±0.373)	3.73 (±0.160)	4.78 (±0.556)	6.57 (±0.605)	20.15
LSD (5%)	0.14	0.32	0.19	0.35	0.48	0.64
C.V., %	6.6	12.7	5.7	8.6	8.4	3.7

Table 11. Percent composition of pod sucking bugs at various planting dates, IITA, 1982

Pod bug species	Planting date 8 July–19 Aug.	5 Aug.–16 Sept.	2 Sept.–14 Oct.	30 Sept.–11 Nov.
Piezodorus guldinii	1.6	4.3	8.0	2.0
Clavigralla tomentosicollis	0.6	0.9	45.0[a]	83.0
Clavigralla shadabi	77.1	44.7	9.2	0.0
Riptortus dentipes	0.8	14.0	2.8	0.0
Mirperus jaculus	13.1	9.8	14.3	4.0
Nezera viriduala	5.0	15.3	13.0	6.0
Anoplocnemis curvipes	1.2	5.9	3.0	2.0
Aspavia armigera	0.6	5.1	4.7	3.0
No. of bugs per meter[b]	5.2	2.1	6.3	23.8

[a]Highest number during each sampling period.
[b]Mean for seven weeks.

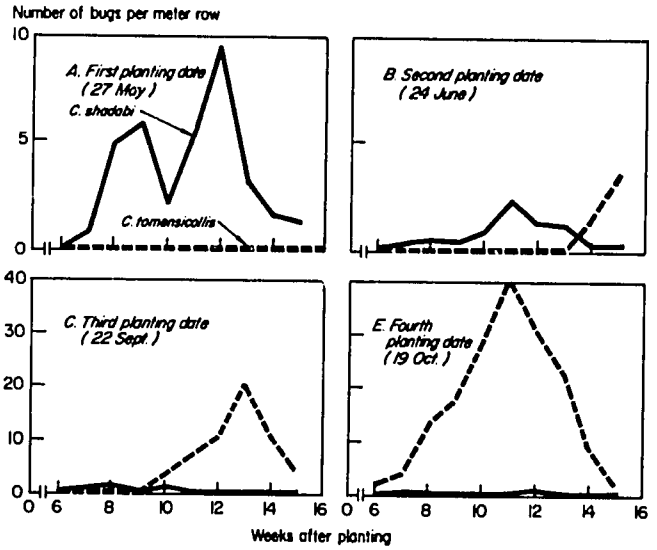


Figure 5. Changes in population levels of *C. tomentosicollis* and *C. shadebi* at different planting dates, Mokwa, Nigeria, 1982.

highest population levels. The onset of *C. shadebi* was the earliest, occurring in July at 56 days after planting (Figure 5). Although *C. tomentosicollis* was more devastating in its attack, not until the end of September did a sudden outbreak of the species occur. The crop planted on 22 July was 70 days old and almost ready for harvesting. It thus escaped serious damage. But the crop planted on 19 August suffered serious damage by *C. tomentosicollis*.

These preliminary results appear to suggest that planting cowpeas by 20 July (or earlier if rainfall permits) in the Mokwa area would most likely cause the crop to escape high *C. tomentosicollis* infestation. This conclusion needs further investigation, however.—*L.E.N. Jackai and W.N.O. Hammond*

Insect Resistance

Pod borers (*Maruca*). Using the field screening method developed at IITA (Annual Reports for 1980 and 1981), 1,000 cowpea cultivars from the world germplasm were screened for resistance to the cowpea pod borer at two locations, IITA and Mokwa. A total of 24 cultivars with 20% or less damage to pods were selected for further testing. In addition, over 600 plant progenies, 433 at the F_3 stage and 254 at the F_5 stage, were screened. At Mokwa 39 single plants were selected for *Maruca* resistance from F_5 progeny rows for further screening in replicated trials at different locations. Another 277 single plants were selected from F_3 progeny rows for further testing. Also, work on the development of a pod borer culture on artificial diet was continued.

In earlier reports we referred to the difficulty of getting pod borer adults to mate, which was hindering progress in screening cowpea germplasm under artificial infestation. This year we achieved a major success in obtaining a high percentage of consistent adult mating in a setup at the exposed basement of the entomology laboratory. These studies, done in cooperation with scientists from other institutions, have shown that high relative humidity (80 to 100%) and moderately low temperatures (22° to 25°C) are essential for mating to take place (Figure 6). The level of mating also depends on the length of time for which males and females are held together (Figure 7). An average of 305 eggs per female was obtained after five nights of pairing, and moths lived for as long as 10 days. Females mated only once, mostly between 0200 and 0300 hours. With this development appropriate bioassays for screening will now be the main focus of our work.

Pod bugs. The identification of sources for resistance to pod sucking bugs has been slow because of the species diversity, but our work during the past two years has shown clearly that *C. tomentosicollis* is the most important and damaging in the complex. Field populations are high enough to facilitate the screening of our germplasm.

Forty cultivars, which were selected on the basis of an earlier classification based on less damage by pod bugs, were screened at two locations, Mokwa and IITA, under natural infestation. The evaluations were based on damage to seed. In the first season at IITA, TVu 6863 was the only cultivar for which mean seed damage was significantly less than that of the susceptible check and that had a seed damage ratio of 0.3, compared to a ratio of 1 for the check, Ife Brown (Table 12).

At Mokwa TVu 6863 and TVu 1890 performed best in both plantings, although damage ratings were higher at the second planting (Table 13). This confirms our suggestion in another part of this report that early planting or the use of extra-early maturing varieties would reduce damage by pod bugs.

The data on insect numbers appears to suggest that, whereas TVu 1890 possibly possesses a tolerance mechanism, TVu 6863 may be exhibiting an antibiosis type of resistance mechanism. These points are being studied under controlled conditions in the laboratory.—*L.E.N. Jackai*

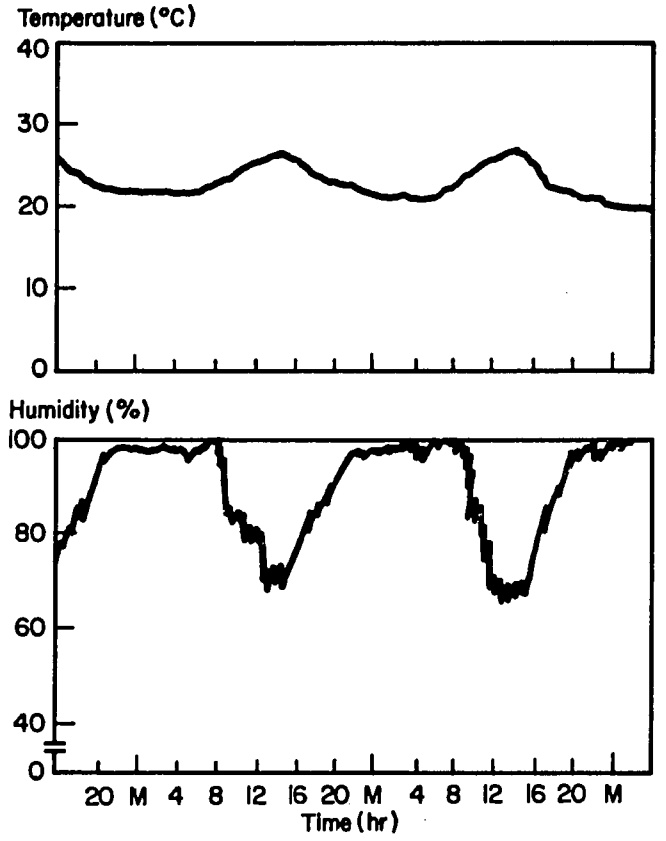


Figure 6. Optimum temperature and relative humidity for *Maruca* mating, IITA, 1982.

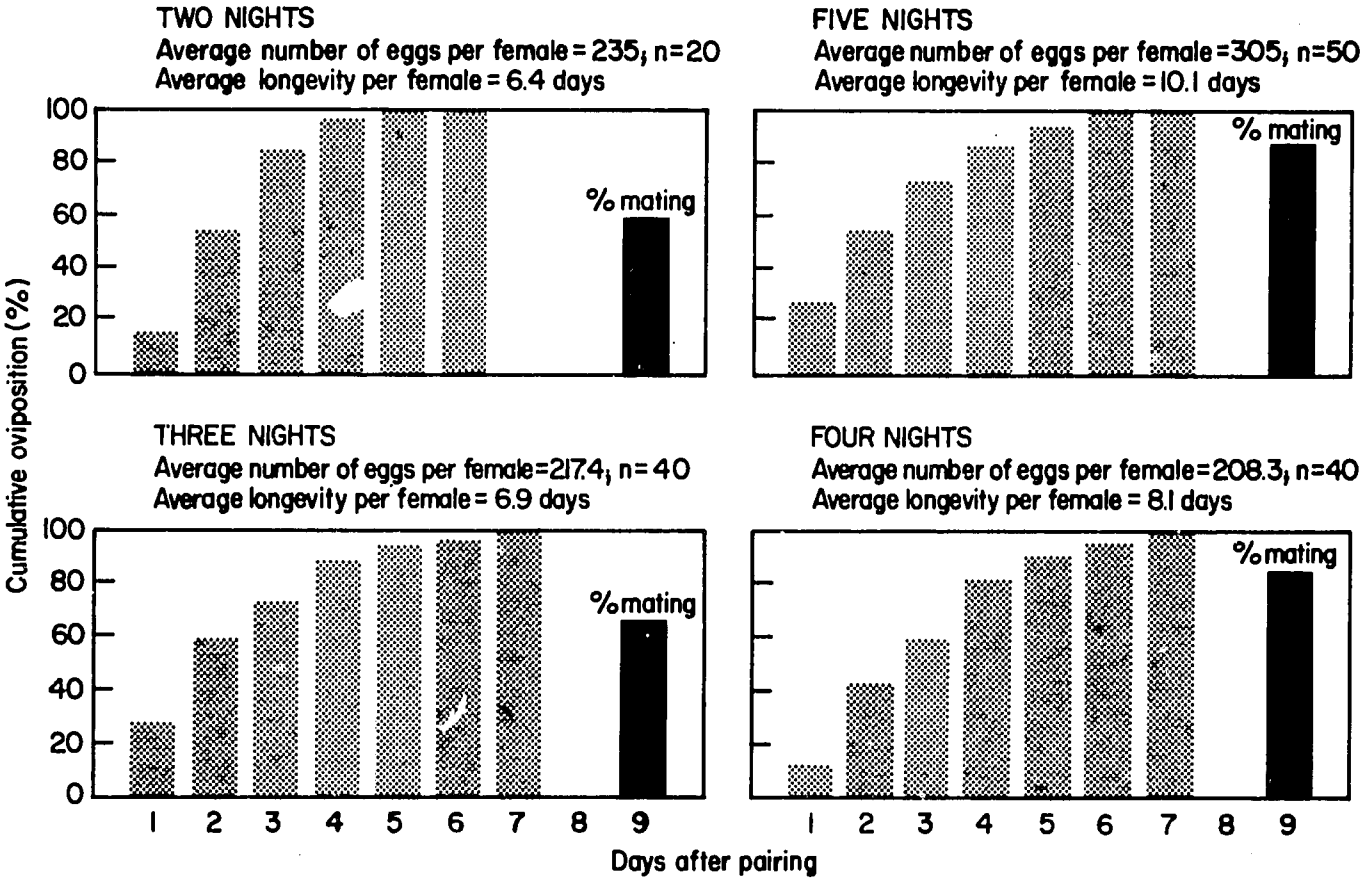


Figure 7. Effect of pairing *Maruca* adults for two, three, four and five nights on mating and oviposition, IITA, 1982.

Table 12. Field screening of selected cowpea cultivars for resistance to pod sucking bugs, IITA, first season, 1982

Cultivar	Percent seed damage	Seed damage ratio (test variety to Ife Brown)
TVu 6863	25.5	0.30
TVx 309-1G	74.2	0.85
VITA-4	75.3	0.88
TVu 1890	86.0	0.98
TVu 1846	89.5	1.02
TVu 1	99.1	1.15
Ife Brown (check)	87.1	1.00
Mean	76.8	0.88
S.D.	29.2	0.28
C.V., %	31.5	31.8

Table 13. Pod bug counts and damage on selected cowpea cultivars, Mokwa, Nigeria, 1982

Cultivar	Seed damage, %		Seed damage ratio[c]		No. of of bugs per 3 m of row[d]
	First plant.[a]	Second plant.[b]	First plant.	Second plant.	
TVu 1890	7.5	46.1	0.22	0.66	256.0
VITA-4	22.2	75.9	0.66	1.09	141.0
TVu 6863	8.2	44.1	0.24	0.63	30.0
TVu 1846	33.2	68.3	0.99	0.98	81.0
VITA-6	42.3	74.2	1.26	1.06	201.5
Ife Brown	33.6	69.8	1.00	1.00	83.0
Mean	25.1	60.5	0.75	0.87	116.4
LSD (5%)	6.6	12.7	0.17	0.20	26.9
S.E.	4.0	4.0	0.12	0.13	21.3

[a]First planting was on 28 August 1982.
[b]Second planting was on 13 September 1982.
[c]Ratio of test variety to Ife Brown.
[d]Visual counts (for second planting only).

Table 14. Cowpea cultivars with resistance to flower thrips, IITA, 1982

Cultivar	Pedigree	Days to first flowering	Resistance rating[a]
TVu 7376	Ex-Tamale market	43	1.5
TVu 8154	Ex-Legon collection	42	1.6
TVu 4548	Ife hybrid 27-1-2	43	2.1
TVu 4544	Ife hybrid 113-1	43	2.2
TVu 6863	Kano	38	2.4
TVu 4571	Ife hybrid 178-1	42	2.5
TVx 3236, resistant check	TVu 1509 × Ife hybrid 62-1 (Ife Brown)	42	2.6
VITA-7 (TVx 289-4G), susceptible check	TVx 33-IB × TVx 23-2B	43	4.6
LSD (5%)			0.53
C.V., %			14.60

[a]Resistance ratings: 0 to 1 = highly resistant, 1 to 2 = resistant, 2 to 3 = moderately resistant, 3 to 4 = susceptible and 4 to 5 = highly susceptible.

Table 15. Damage caused by flower thrips on cowpea cultivars, IITA, 1982

Cultivar	Flower abscission, %	Reduction in pod set, %
TVu 1509	4.4	4.3
TVx 3236	5.9	5.6
Ife Brown	24.3	50.0
VITA-7	27.3	45.7

Thrips. In the past at IITA cowpea germplasm from TVu 1 to TVu 4000 has been screened for resistance to flower thrips *Megalurothrips sjostedti*. Only two lines, TVu 1509 and TVu 2870, were found to be moderately resistant to thrips; the rest were found to be highly susceptible. In field tests, both lines were often resistant under normal field populations, but the resistance broke down under heavy thrips pressure. Several crosses were made utilizing these two cultivars. From one cross utilizing TVu 1509 and Ife Brown, a local improved variety, a variety was developed (TVx 3236) that combines resistance to thrips with the superior agronomic characters of Ife Brown. TVx 3236 is only moderately resistant to thrips. Even so, the thrips resistance of this variety is superior to that of all the others tested so far and has been found extremely useful.

During 1982 efforts were made to identify thrips resistant lines superior to those identified earlier. The germplasm collection from TVu 4001 to TVu 10,300 was screened. In a negative screening conducted during planting in the first season, about 10 cultivars appeared to be superior to the others. During the second season, when the thrips population is high, these cultivars were tested in a replicated trial and compared with TVx 3236 for thrips resistance. Two cultivars appeared to have greater resistance than TVx 3236 (Table 14). They will be further tested next year in replicated trials at several locations to confirm the level of resistance. During the test period, the thrips populations were sampled in VITA-7, a susceptible check, at 38, 43 and 48 days after germination. The thrips populations per peduncle were 4.1 (S.D. ±1.7), 11.3 (S.D. ±4.1) and 9.5 (S.D. ±3.8), respectively. These populations are considered fairly high; thrips samples taken on farms in Nigeria during the growing season varied from 2.1 (S.D. ±0.3) to 6.2 (S.D. ±1.9), indicating that the level of resistance in the newly identified cultivars (assuming that it is confirmed in next year's tests) should be adequate.

Flower abscission and reduction in pod set were studied in the two thrips resistant cultivars, TVu 1509 and TVx 3236, and in two susceptible cultivars, Ife Brown and VITA-7. In measuring flower abscission and pod set, cultivars protected by in-

secticide were compared with unprotected cultivars. The thrips populations per peduncle on unprotected VITA-7 varied from 3.6 (S.D. ±1.1) to 6.1 (S.D. ±1.7). As shown in Table 15, there was less flower abscission and less of a reduction in pod set in the two resistant cultivars than in the check.

A study of mechanisms of resistance to thrips was carried out in the greenhouse. The resistant variety TVx 3236 and the susceptible variety VITA-7 were artificially infested with 50 adult thrips per plant in cages. The thrips populations were measured 14 and 21 days after infestation. At 14 days the mean population of thrips larvae per plant in TVx 3236 was 3.9 (S.D. ±1.8) and at 21 days 12.0 (S.D. ±2.3). The population in VITA-7 was 20.7 (S.D. ±6.3) at 14 days and 45.1 (S.D. ±8.6) at 21 days. The differences between the populations on the two varieties were highly significant ($P < 5\%$) at both sampling dates. The low thrips populations on TVx 3236 indicate that antibiosis is the mechanism of resistance.

In another experiment the natural population of thrips was observed from 37 to 60 days after planting on TVu 3236, VITA-7 and Ife Brown grown in the field in adjacent unprotected plots. The thrips populations were lower on TVx 3236 than on the other two cultivars as shown in Figure 8.—*S.R. Singh and A.B. Salifu*

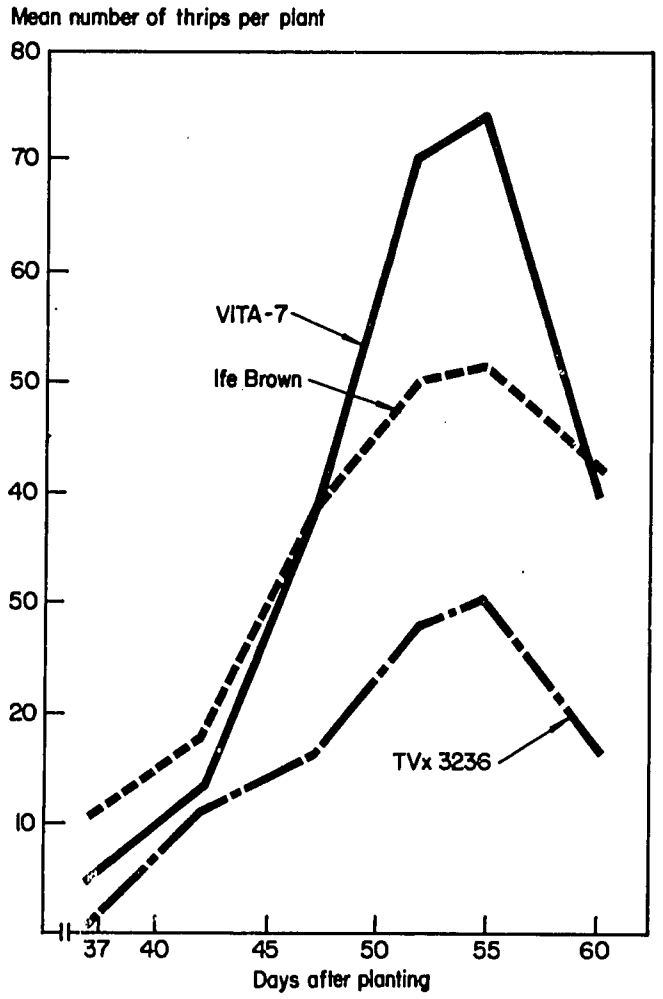


Figure 8. Comparison of thrips populations on resistant and susceptible cowpea cultivars, IITA, 1982.

Insecticides

Efficacy of foliar insecticides. Nine different insecticide formulations were evaluated for flower thrips control in the field. Thrips populations and cowpea yields are listed in Table 16. All the insecticides tested were effective against thrips except Dipel®, which had no effect on thrips populations.

Application with the Electrodyn sprayer. Four insecticide formulations applied on two crop rows with an Electrodyn sprayer were compared for their effectiveness against flower thrips. As shown in Table 17, the Cymbush® and Cymbush + Dimethoate® formulations were significantly more effective than Actellic® and Dimethoate®.—*S.R. Singh*

Control of bruchids in storage. This experiment was conducted primarily to develop technology for small farmers who are storing only a few kilograms

Table 16. Effectiveness of insecticides applied as high volume foliar sprays against thrips, IITA, 1982

		Mean number of thrips				
		Per peduncle		Per flower		
Insecticide	Dosage, g/ha	32 days after planting	42 days after planting	46 days after planting	52 days after planting	Yield, kg/ha
Decis + Dimethoate®	12.5 + 400	11.0	4.0	10.7	4.0	904.7
Sherpa® (Cypermethrin)	30	7.7	2.2	3.0	4.2	878.5
Thiodan + Decis®	620 + 12.5	6.5	2.7	5.5	10.2	833.3
Cvbolt® (Flucythrinate)	30	17.5	7.0	17.0	13.0	819.6
Oftanol®	500	9.0	1.0	2.0	2.0	785.6
Zolone® (Phosalone)	210	9.0	4.5	37.0	11.2	748.1
Tamaron®	600	17.2	7.2	18.2	14.0	710.6
Dipel® (*Bacillus thuringiensis*)	1,000	17.5	15.2	34.7	29.0	467.4
Control		17.5	14.5	40.0	24.2	461.1
LSD (5%)		7.5	6.7	19.6	15.4	156.9
C.V., %		49.0	99.3	79.3	96.5	14.5

Note: Insecticides were applied 30 and 40 days after planting.

of harvested cowpeas and have limited inputs for controlling cowpea bruchids, *Callosobruchus maculatus*. The treatments were as follows: mixing groundnut oil with cowpeas at a rate of about 5 ml/kg, adding ash (about 40% by volume) to cowpeas, mixing white sand (about 40% by volume) with them, and an untreated control. Each treatment consisted of 3 kg of cowpeas in a cloth bag and was replicated four times. Each bag was infested with 35 pairs of one-day-old bruchids, and the percentage of seeds damaged was recorded four months after infestation. Three samples, each containing 200 g of seed, were taken from each bag at random, and the total numbers of live and dead weevils per sample were compared. As shown in Table 18, the groundnut oil treatment was the only one found to be effective in controlling bruchids.—*S.R. Singh and F.O. Bewaji*

Cultural Methods of Control

Cowpea variet TVx 3236 was interplanted with two cassava varieties, the high yielding TMS 30001 with normal leaves and the low yielding TMS X with strap leaves, to study the cowpea pest populations in different crop combinations. Table 19 gives a summary of the results. The number of thrips in the intercropped cowpeas was significantly lower than in the monocropped cowpeas during both cropping seasons. There was no real difference between the populations of the two intercropping combinations. The *Maruca* populations were essentially the same in all treatments except during the second season, when the population on TVx 3236/TMS 30001 was lower as a result of poor growth caused by excessive shading. Pod bug populations were much higher in the monocropped than in the mixed crop plots.

These differences could have occurred for any of several reasons. For example, the barrier provided by cassava may have hindered the movement of thrips. Or the cassava may have served as another food source for the bugs, thus diverting part of the population from the cowpeas. Nor should the possible effects of differences in micrometeorological factors, primarily the result of shading, be ignored. An important observation made was that the major species of pod bugs in the second season was *Mirperus jaculus*, which would not have been the case had the cowpeas been planted alone. It is clear from these results that interplanting cowpeas with cassava could be an important component in the integrated control of cowpea pests.

In another experiment TVx 3236 was planted between border rows of *Crotalaria*, reported to be a host of the pod borer, to test the use of this species as a trap crop for the pest. As shown in Table 20, the percent yield in plots with *Crotalaria* borders and no insecticide was higher than in plots without *Crotalaria*. *Maruca* populations were also lower on cowpea/*Crotalaria* plots with no chemical protection than on the unprotected monocropped cowpeas during the second cropping season. The reverse was true in the first season probably because of inadequate flowering by the monocropped cowpeas (Figure 9). *Crotalaria* may therefore provide some protection against the borers, but its effects on other pests have yet to be assessed.—*L.E.N. Jackai*

Table 17. Effectiveness of insecticides applied with an Electrodyne sprayer, IITA, 1982

Insecticide	Mean number of thrips: Per peduncle 35 days after planting	Mean number of thrips: Per flower 46 days after planting	Yield, kg/ha
Cymbush®	9.0	11.0	958.9
Cymbush + Dimethoate®	4.5	14.0	932.1
Dimethoate®	12.2	25.7	637.4
Actellic®	9.2	55.0	453.5
Control	15.0	57.7	414.7
LSD (5%)	7.5	31.3	209.9
C.V., %	48.6	78.6	19.5

Note: Insecticides were applied 30 and 40 days after planting.

Table 18. Effectiveness of different treatments against cowpea bruchids, IITA, 1982

Treatment	Damage, %	No. of weevils per 200 g of seed
Groundnut oil	0.0	0.2
Ash	67.4	199.0
White sand	98.0	167.6
Control	97.0	193.0
LSD (5%)	32.2	55.9
C.V., %	46.0	38.2

Virology

Screening for Resistance

Evaluation of cowpea breeding lines and potential breeding parents for resistance to virus diseases continued in 1982. Most materials were screened for resistance to cowpea yellow mosaic virus (CYMV) and cowpea aphid borne mosaic virus (CAbMV), the

Table 19. Insect counts on cowpeas interplanted with two varieties of cassava, IITA, 1982

Cropping pattern	No. of thrips per 20 flowers: First season	No. of thrips per 20 flowers: Second season	No. of *Maruca* per 20 flowers: First season	No. of *Maruca* per 20 flowers: Second season	No. of pod bugs per 30 m: First season	No. of pod bugs per 30 m: Second season
TVx 3236/TMS 30001 (interrow)	23.0 (±8.9)	2.4 (±0.7)	5.9 (±1.8)	4.2 (±1.0)	5.2 (±1.8)	22.8 (±7.3)
TVx 3236/TMS X (interrow)	37.7 (±4.4)	5.7 (±1.4)	5.6 (±1.5)	8.7 (±2.0)	4.9 (±1.4)	40.5 (±14.9)
TVx 3236 (monocropped)	73.1 (±8.9)	276.1 (±85.9)	5.8 (±1.5)	8.1 (±1.8)	13.2 (±3.4)	66.8 (±20.6)

Table 20. Effect on yield of planting *Crotalaria* with cowpeas, IITA, 1982

Treatment	Percent yield of check	
	First season	Second season
Crotalaria/cowpeas, insecticide (check) ..	—	—
Crotalaria/cowpeas, no insecticide.....	67.2	95.5
Cowpeas, insecticide.....	9.4	70.1
Cowpeas, no insecticide.....	1.0	68.0

two most important virus diseases of cowpeas in Africa. The only two, large, white, rough seeded cowpea germplasm introductions found to remain symptomless after inoculation with CYMV (TVu 7483 and TVu 5971) were shown to be immune to this virus in back-tests that involved grafting to a highly susceptible cowpea variety. One cowpea germplasm accession, a selection from TVu 128, was identified that remained symptomless after inoculation with six different cowpea viruses that are prevalent in Nigeria. Although this accession is highly susceptible to anthracnose, it appears to be a good virus resistance donor for the breeding program.

In addition to screening for resistance to CYMV and CAbMV, potential breeding parents were screened for resistance to cowpea mottle virus (CMeV) and cucumber mosaic virus (CuMV), two other viruses that are found in Nigeria. Also, some advanced breeding lines from IITA's cooperative cowpea improvement program with EMBRAPA were tested for resistance to the three most important viruses in Africa (CYMV, CAbMV and CuMV). All eight lines tested were found to be highly resistant to CYMV, a typical African virus of cowpeas.

CAbMV was studied in great detail and compared with types of this virus reported from the United States and East Africa as well as with a somewhat similar soybean virus. A good antiserum was obtained that allows rapid serological identification of the virus in *N. benthamiana* by the SDS agar gel diffusion method. This technique did not, however, give positive results when attempts were made to detect the virus in cowpeas. Nor were positive results obtained with the enzyme linked immunosorbent assay (ELISA).

Seed lots of 31 elite cowpea breeding lines, multiplied for international testing, were evaluated for seed transmission incidence of CuMV. Only in four introductions was some seed transmission observed, though at low rates (0.4 to 3%). As usual, 500 seeds of each introduction were germinated, and plants were inspected through the first-trifoliate stage. Perhaps because introductions known for their high seed transmission rates had previously been omitted, neither any noticeable virus spread in this year's multiplication plots nor subsequent seed transmission of CuMV was observed. This virus thus apparently does not occur in the wild flora and is perpetuated through seed borne infections only, as is

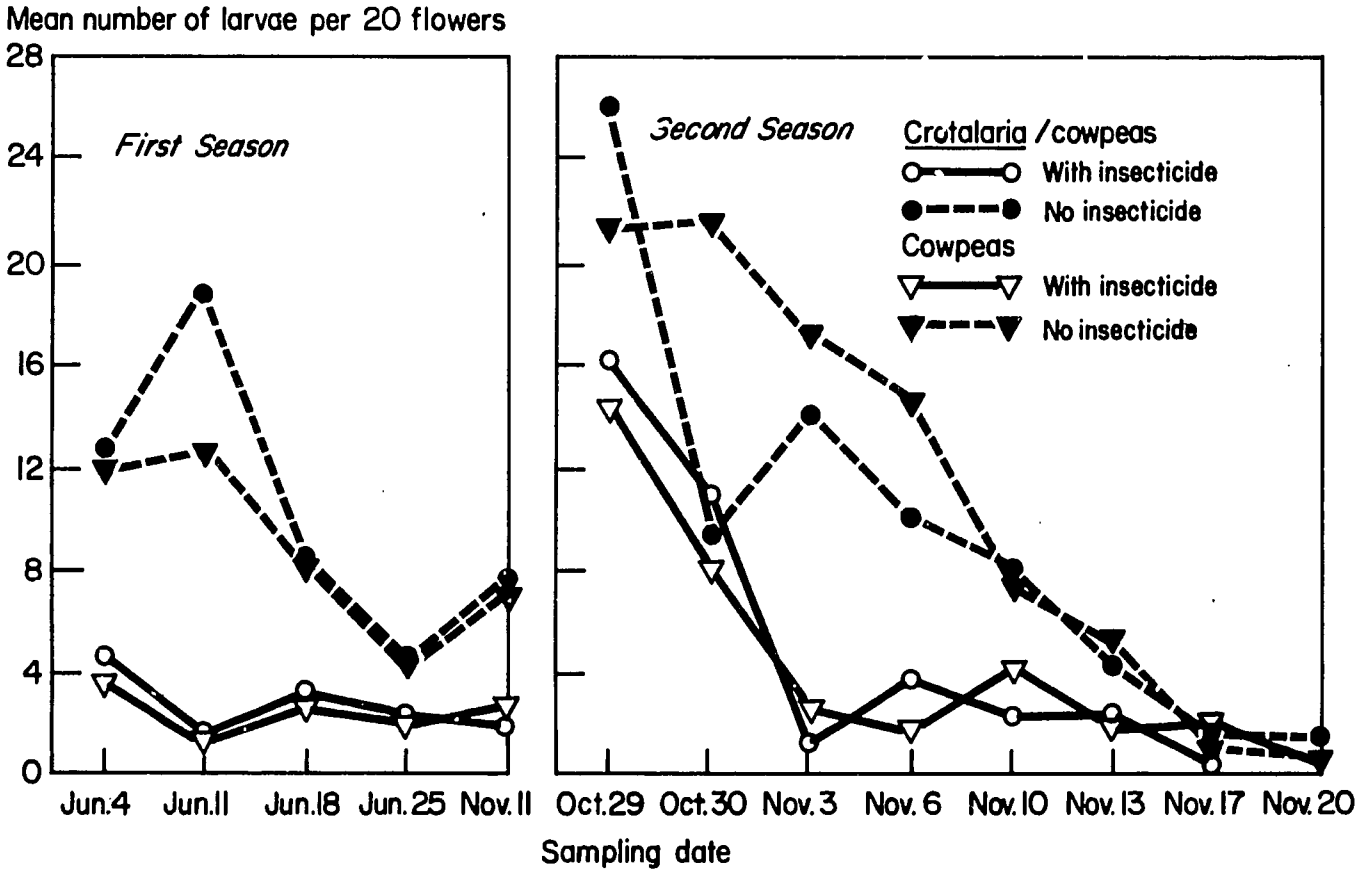


Figure 9. Population levels of *M. testulalis* larvae under four treatments during two growing seasons, IITA, 1982.

the case with soybean mosaic virus (SMV) in soybeans.

These 31 introductions were also evaluated for resistance to CuMV. All introductions developed readily detectable symptoms, which in most cases were comparatively mild (2 to 3 on a 1 to 5 scale). Assessment of seed transmission, routinely performed according to the method described above, seems reliable enough to be continued.

Cowpea golden mosaic virus (CGMV), which is common at IITA's substation at Onne near Port Harcourt in the tropical rain forest zone of Nigeria, was also observed in certain, apparently susceptible introductions during large scale germplasm rejuvenation at IITA during the 1981–82 dry season. The reactions of germplasm introductions known to be susceptible (TVu 22 and TVu 4557) with an isolate from IITA's fields were identical to the symptoms induced in these introductions with isolates from the Onne substation.—*H.W. Rossel and H. Huttinga*

Cowpea Cucumovirus

For the first time, a good antiserum was obtained this year for the cucumber mosaic-like virus, which commonly occurs in cowpeas and lima beans in Nigeria (IITA, Annual Reports for 1978 and 1979). The virus was also tested with antisera to some isolates of CuMV (obtained from the Office de la Recherche Scientifique et Technique Outre-Mer), which is reported to occur on various crops in Ivory Coast. The isolates of CuMV for which the antisera had been prepared were from cowpeas, wing beans and peppers. With all three sera, a positive reaction was obtained. The cucumovirus, originally obtained from cowpeas at IITA and maintained for further characterization as well as for resistance screening, was propagated on *N. glutinosa*. The virus was purified from *N. glutinosa* according to a procedure described by Loebenstein et al (1977). An antiserum was prepared by injecting a rabbit with the purified preparations. The antiserum has a titer of 256 in microprecipitin tests and 128 in agar gel diffusion tests, using purified virus as an antigen. The antiserum proved to be suitable for detecting the cucumovirus in crude juice of infected *N. glutinosa* as well as cowpeas, when using agar gel diffusion tests.—*J.W.M. van Lent*

SAFGRAD Project in Upper Volta

Genetic Improvement

A major objective of the cowpea breeding program of the Semi-Arid Food Grains Research and Development (SAFGRAD) Project is to develop improved cowpea varieties that combine resistance to major diseases and pests with high yield potential for the dry savanna region. In 1982 emphasis was placed on development of improved grain types and on incorporation of insect resistance into promising cowpea lines.

Improved grain types. Crosses were made between the white, large seeded, bruchid resistant cultivar TVu 2027 and Local Kamboinsé, SUVITA-2, B-27 and Worthmore. Selections made for seed character and other agronomic traits are at the F_3 stage. Plants whose seed color and size differed from that of TVx 3236 were also selected from crosses involving TVx 323C.

Plant type and maturity. Three trials were conducted at different locations in Upper Volta to evaluate a range of photosensitive and nonphotosensitive materials that vary in plant type and maturity. The first trial consisted of 256 F_6 lines, most of which were photosensitive. The trial was planted at two locations, Kamboinsé (annual rainfall, 717 mm) and Farako-Bâ (annual rainfall, 1,222 mm). The lines were sown in single-row plots 5 m long in a 16 × 16 simple lattice design with two replications. Maturity, yield, disease reaction, seed size and color were recorded. KVu 22-2, KVu 10-1 and TVx 6484-6B2-K were the most promising lines.

The second trial, which consisted of 225 nonphotosensitive lines, was planted at Kamboinsé and Saouga (annual rainfall, 317 mm) in single-row plots in a 15 × 15 simple lattice design with two replications. Disease reaction, maturity, yield, seed size and color were recorded. TVx 30-438-69, TVx 30-523-24 and TVx 30-470-30 were the most promising lines.

The third trial, carried out at Kamboinsé, consisted of 24 early maturing lines introduced from IITA and collected locally from Upper Volta. The yield, maturity and seed characters of the promising lines are presented in Table 21. All the cultivars matured in less than 60 days. There were distinct differences in seed characters, and those of the IITA lines IT 82E-71 and IT 82E-60 were the most desirable. The former is a rough, white seeded line, and the latter has white, smooth seed.

Insect resistance. The aphid resistant cultivar TVu 36 was crossed with KN-1 and SUVITA-2, and second backcross material of these two varieties was planted in the field for selection under natural aphid infestation. Five to ten percent of the plants were found to be susceptible and were uprooted. A total of

Table 21. Best cowpea lines in an early maturity trial, Kamboinsé, Upper Volta, 1982

Line	Days to 50% flowering	Days to 50% maturity	Yield, kg/ha	Seed color and texture
KVu 55	39	57	1,496	BMS[a]
KVu 68	38	55	1,466	BMS
KVu 69	35	52	1,020	BS
IT 82E-60	37	58	1,316	WS
IT 82E-71	36	55	1,046	WR
LSD (5%)	2.1	2.4	196	
C.V., %	2.7	2.1	22.1	

[a]B = brown, M = mottled, S = smooth, W = white and R = rough.

24 plants from the backcross of KN-1 and 56 from that of SUVITA-2 were harvested. In addition, triple crosses involving (KN-1 × TVu 36) × TVx 3236 and (SUVITA-2 × TVu 36) × TVx 3236 were screened for resistance to aphid infestation. Disease reaction and plant and seed characters were also recorded. About 160 plants involving KN-1 and 57 plants involving SUVITA-2 were harvested. These have been planted in family rows to be screened for aphid resistance.

Crosses were made between the bruchid resistant cultivar TVu 2027 and SUVITA-2 and KN-1 to incorporate bruchid resistance, desirable seed quality and agronomic characters into those varieties. From the cross TVu 2027 × SUVITA-2, individual plant selections were made and have been advanced to F_4. Some of the lines have a high level of bruchid resistance. From the cross TVu 2027 × KN-1, 42 F_2 plants with resistance to bruchids were selected and advanced to F_3.

***Striga* resistance.** The objectives of this work were to confirm resistance in SUVITA-2 and 58-57 and initiate parallel studies on inheritance of *Striga* resistance. To confirm the *Striga* resistance of 58-57 and SUVITA-2, a field trial was conducted in a checkerboard design in which the test varieties were surrounded by the susceptible variety KN-1. The same material was also evaluated in pots in the screenhouse. Each variety was sown in 16 pots, 8 of which were infected with *Striga* and the other eight left uninfested. The varieties 58-57 and SUVITA-2 were found to be resistant both under field and screenhouse conditions. Their level of resistance appears to be quite high.

The inheritance of resistance to *Striga* was studied, using F_1, F_2, BC_1 and BC_2 populations from a cross between SUVITA-2 and KN-1, along with parent material. The experiment was planted in a *Striga* infested plot. The plants infested with *Striga* were counted at weekly intervals until plant maturity. The results obtained are presented in Table 22. The segregation ratio of susceptible to resistant plants in the F_2 generation fitted the expected ratio of 9:7 very closely, indicating a complementary gene action. However, the presence of complementary gene action was not supported by the segregating ratio obtained in backcross populations, which indicated monogenic inheritance. Further studies are needed to elucidate the exact nature of the inheritance.

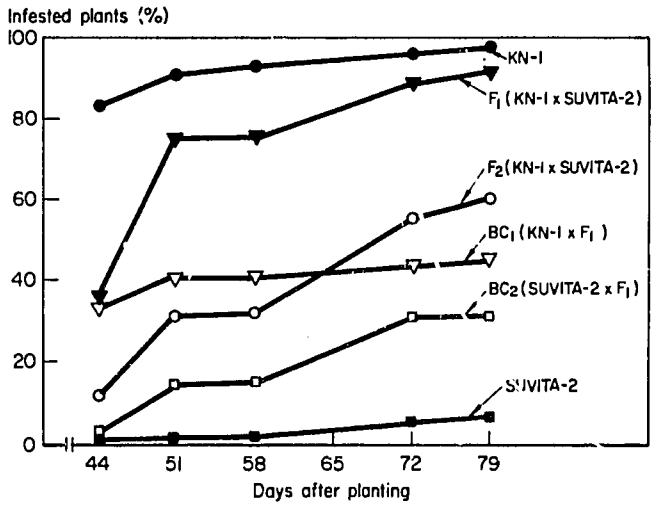


Figure 10. Rate of increase of *Striga* in a cross between a resistant and susceptible cowpea variety, Upper Volta, 1982.

The relationship between percent infestation and time of *Striga* emergence in the material discussed above was also studied. The results showed that *Striga* emergence was generally earlier in the most susceptible parents and in their subsequent susceptible segregents (Figure 10).

Twenty-one F_5 bulk populations involving SUVITA-2, along with two susceptible and two resistant check lines, were evaluated for *Striga* resistance and other agronomic characters, including yield and resistance to diseases. The fact that varieties 58-57 and SUVITA-2 had low infestation confirms their resistance. The susceptible check varieties, VITA-5 and TVx 3236, had infestation

Table 23. Yield and *Striga* infestation in promising cowpea lines, Kamboinsé, Upper Volta, 1932

Line	Yield, kg/ha	Plants infested with *Striga*, %
TVx 30-141-1G	1,394	0.0
TVx 30-166-3G	1,515	0.0
TVx 30-312-3G	1,321	0.0
58-57	1,244	0.0
SUVITA-2	1,041	2.3
VITA-5	1,041	31.7
TVx 3236	1,326	76.9
LSD (5%)	266	—
C.V., %	30.3	—

Table 22. Segregation for *Striga* resistance in different populations of a cross between KN-1 and SUVITA-2, Kamboinsé, Upper Volta, 1982

Population	Total no. of plants	No. infested with *Striga*	Segregation ratio: Susceptible	Segregation ratio: Resistant	X_2 value	P value
KN-1	82	80	1	0	0.49	.90–.75
SUVITA-2	80	5	0	1	0.31	.75–.50
F_1 (KN-1 × SUVITA-2)	57	52	1	0	0.44	.75–.50
F_2 (KN-1 × F_1)	211	128	9	7	1.67	.25–.10
BC_1 (KN-1 × F_1)	140	136	1	0	0.11	.75–.50
BC_2 (SUVITA-2 × F_1)	206	93	1	1	1.94	.25–.10

levels of 31.7 and 76.9%, respectively (Table 23). There were no significant yield differences between the resistant varieties and the check variety TVx 3236.—*V.D. Aggarwal*

Entomology

Screening for thrips resistance. A trial consisting of TVu 1509, TVu 2870, TVx 3236 and two susceptible check varieties, KN-1 and Ife Brown, was planted during 1982 in a farmer's field and at the research station at Kamboinsé, Upper Volta. The trial had a split-plot design. Its objective was to compare the severity of the thrips attack under farmer's conditions with that at the research station.

For each variety treated and untreated plots were compared. The treated plots were totally protected by application of monocrotophos at a rate of 400 g a.i./ha during the raceme initiation stage to control thrips and endosulfan at 200 g a.i./ha 45 and 58 days after planting to control *Maruca* and pod sucking bugs. The untreated plots received only endosulfan to control *Maruca* and pod sucking bugs.

The results obtained in the farmer's field are given in Table 24. Significantly fewer thrips were found in the treated than in the untreated plots. In the treated plots, there was no significant difference among varieties in thrips population, neither in the racemes nor in the flowers. In the untreated plots, however, the thrips population was significantly smaller in the racemes of TVu 1509, followed by TVx 2870. There were also fewer thrips in the flowers of TVu 1509, but the difference between this population and those of TVx 2870 and TVx 3236 was not significant. Ife Brown and KN-1 had maximum thrips populations both in the racemes and flowers.

The performance of these varieties at the research station is also given in Table 24. There the trial was planted in large plots and was not replicated. The trend in thrips population was much the same as in the farmer's field, although the thrips population was somewhat lower at the research station. In the untreated plots, TVu 1509 had the fewest thrips in the raceme, followed by TVx 3236 and TVx 2870. In the flowers TVx 2870 had the fewest, followed by KN-1. Both trials indicated that TVu 1509 has higher resistance than the other varieties.

Table 24. Thrips populations in promising cowpea cultivars, Kamboinsé, Upper Volta, 1982

Cultivar	No. of thrips per raceme[a]	No. of thrips per flower[b]
Untreated, farmer's field		
Ife Brown	34.8	86.9
KN-1	27.4	78.2
TVx 2870	17.2	52.2
TVx 3236	21.5	54.3
TVu 1509	11.1	41.2
Treated, farmer's field		
Ife Brown	4.4	7.5
KN-1	3.9	5.7
TVx 2870	3.5	2.6
TVx 3236	2.3	2.7
TVu 1509	2.5	2.3
LSD (main plot)	7.9	16.0
LSD (subplot)	3.9	9.4
LSD (submain)	10.0	—
C.V. (main plot), %	56.5	43.9
C.V. (subplot), %	44.4	41.7
Untreated, research station		
Ife Brown	26.2	32.8
KN-1	18.9	19.4
TVx 2870	15.0	17.2
TVx 3236	13.9	29.4
TVu 1509	10.0	24.9
Mean	16.8	24.7

[a]A total of eight samples were taken at three-day intervals.
[b]A total of six samples were taken at three-day intervals.

Table 25. Effect of various dosages of monocrotophos on thrips and *Maruca* population and on yield, Kamboinsé, Upper Volta, 1982

Monocrotophos, g a.i./ha	No. of thrips per raceme[a]	No. of thrips per flower[b]	No. of *Maruca* per flower	Yield per plot, g
0	13.6	24.3	0.8	633.98
15	8.5	15.3	1.1	556.72
30	7.1	12.9	1.3	627.48
60	7.8	12.8	0.9	582.78
120	6.6	12.6	1.1	689.85
240	7.8	12.2	1.1	715.63
480	5.8	11.3	1.2	802.08
LSD (5%)	2.7	4.3	—	—
C.V., %	27.8	25.2	44.3	29.88

[a]A total of eight samples were taken at three-day intervals.
[b]A total of seven samples were taken at three-day intervals.

Economic threshold of thrips. The objective of this study was to determine the relationship between thrips population and cowpea grain yield. In the past two years, experiment results have shown a positive correlation between yield and monocrotophos dosage. But these results have not revealed any clear-cut relationship between thrips population and yield. An experiment was conducted in 1982 with the variety KN-1 to establish this relationship. Different concentrations of monocrotophos were sprayed once at the raceme initiation stage to create varying populations of thrips. Endosulfan was applied twice, once 45 days after planting at a rate of 250 g a.i./ha and again at 57 days at a rate of 400 g a.i./ha to control *Maruca* and pod sucking bugs. The results obtained are reported in Table 25. There was no significant difference between the monocrotophos dosages in their effect on the thrips populations, neither in the raceme nor in the flowers. Significant differences did exist, however, between the plots that received insecticide and those that did not. But these differences were not reflected in the yield, which did not differ significantly among treatments. This was probably due to the low population of thrips.

Table 26. ***Maruca*** **infestation in selected cowpea cultivars, Kamboinsé, Upper Volta, 1982**

Cultivar	No. of larvae per 10 flowers[a]	Percentage of pods infested[b]	Percentage of grains damaged[b]	No. of larvae per 100 pods	Grain yield kg/ha	Percent yield reduction in untreated plots
TVu 1	21.7	7.2	0.7	2.2	990.97	−18.17
TVu 946	17.9	24.3	4.0	4.7	629.92	− 7.57
TVu 946-1E	29.5	52.7	4.7	8.7	1,418.53	−10.98
TVx 3236	19.9	41.3	2.4	4.5	1,267.00	−23.31
VITA-5	18.4	54.5	3.9	6.2	836.60	−41.71
SUVITA-2	22.5	37.0	2.8	1.5	1,775.05	− 7.79
Local Kamboinsé	10.5	0.7	0.1	0.0	1,033.43	−13.27
Mean	20.1	31.1	2.7	3.9	1,135.93	−17.54

[a]A total of six samples were taken at three-day intervals.
[b]Based on a sample of 600 pods.

Screening for resistance to pod borers ***Maruca.*** Pod borers are another serious pest of cowpeas in the semiarid environment. Trial results in 1981 indicated that TVu 946, TVu 946-1E and Local Kamboinsé had lower infestations than other varieties tested. In 1982 a trial consisting of those and other promising varieties was conducted to confirm the resistance of those lines and evaluate others for *Maruca* resistance. The trial was unreplicated but was carried out in large plots (14 m × 10 m).

All the lines were evaluated with and without treatment. In the treated plots, monocrotophos was applied during the raceme initiation stage at the rate of 200 g a.i./ha to control flower thrips and during the pod formation stage at the rate of 400 g a.i./ha to prevent damage caused by pod sucking bugs. In addition to monocrotophos, the treated plots also received decamethrin at the rate of 20 g a.i./ha to control *Maruca*. In the untreated plots, only monocrotophos was applied to control flower thrips and pod sucking bugs.

The number of larvae in flowers and pods, the percentage of pods infested, the percentage of grains damaged and the yield are reported in Table 26. TVu 946-1E had the largest number of larvae in the flowers. Local Kamboinsé had the smallest number, followed by TVu 946 and VITA-5. The varieties TVu 1, TVx 3236, SUVITA-2 and VITA-5 were in the intermediate range. As shown in Figure 11, the distribution of the *Maruca* population, based on the number of larvae in the flowers over a two-week period, was lowest in Local Kamboinsé at all sampling dates. The number of larvae in flowers was relatively high in the other varieties, as indicated by the peak in the figure. Flowering was, however, not synchronized for the test varieties. The number of larvae trapped in pods was lowest in Local Kamboinsé, followed by SUVITA-2 and TVu 1.

Yield was evaluated as a percent reduction from the yield of the treated plots. The yields of TVu 946, SUVITA-2 and TVu 946-IE were reduced less than those of the other varieties. Local Kamboinsé suffered a yield reduction of 13.27%, caused by *Spodoptera littoralis*, which infested 51% of the pods and damaged 16.81% of the seeds. All measures indicate that Local Kamboinsé, TVu 1 and TVu 946 showed greater resistance than the other varieties.—*Y.S. Rathore*

Agronomy

The objectives of the cowpea agronomy research program of IITA/SAFGRAD are to identify problems in cowpea production and to develop new production technology for achieving maximum economic yields in the African semiarid zone. Since this zone is so large, comprising 25 countries and stretching from West Africa through the Sahel and East Africa to southern Africa, it has been impossible to conduct research simultaneously in all parts of the zone. So, the program has concentrated its main efforts in West Africa.

Maize/cowpea relay cropping. An experiment was conducted to determine the best time for planting photoperiod sensitive cowpea cultivars with maize in a relay cropping system. With this system the farmer should be able to make better use of the available moisture and inputs by obtaining a

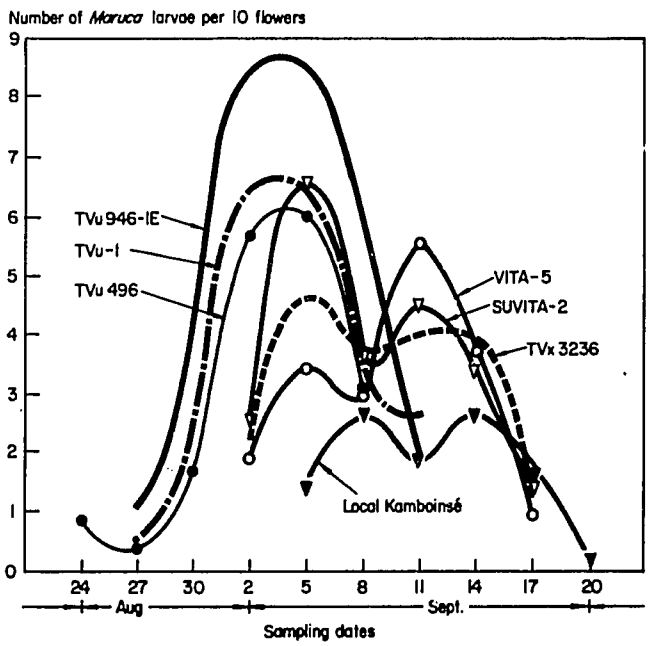


Figure 11. Distribution of *Maruca* population in seven cowpea cultivars at different sampling dates, IITA, 1982..

Table 27. Effect of cowpea planting date on maize yield in a relay cropping system, Farako-Bâ, Upper Volta, 1982

Cowpea cultivar	Cowpea planting date 7 July	23 July	5 August	15 August	Mean
	kg/ha at 15% moisture				
VITA-5	4,789	5,623	5,081	5,544	5,259
IAR 1696	4,370	5,273	5,521	5,668	5,208
Kaya Local	5,126	5,815	5,668	5,138	5,437
Mean	4,762	5,570	5,424	5,450	5,301

Comparison of means	LSD (5%)	C.V., %
Cowpea planting dates	ns	18 ± 3.6
Cowpea cultivars	ns	
Date × cultivars	ns	

Table 28. Yield of cowpeas relay cropped with maize, Farako-Bâ, Upper Volta, 1982

Cowpea cultivar	Cowpea planting date 7 July	23 July	5 August	15 August	Mean
	kg/ha				
VITA-5	767	555	645	668	658
IAR 1696	638	698	185	349	468
Kaya Local	822	838	849	785	824
Mean	742	697	560	600	650

Comparison of means	LSD (5%)	C.V., %
Cowpea planting dates	ns	43.5 ± 5
Cowpea cultivars	199	
Date × cultivars	ns	

full yield of maize and a yield of cowpeas on the same piece of land during the same growing season.

Two photoperiod sensitive local cowpea cultivars (Kaya Local and IAR 1696) and one improved photoperiod insensitive cowpea cultivar (VITA-5) were planted at four dates in solid rows alternated with maize rows. The spacing in cowpeas was 0.75 m between rows and 0.20 m between plants within rows. The crop was sprayed four times at ten-day intervals, beginning at floral bud initiation, to control flower thrips and pod sucking bugs. The maize cultivar Pool-16 was planted on 19 June at the optimum density (53,333 plants/ha) and at spacing of 0.75 m × 0.25 m. The crop was fertilized at planting with 35:25:13 and four weeks after planting with 45 kg N/ha as urea.

The results are presented in Tables 27 and 28. Maize yield was slightly depressed when cowpeas were planted 28 days after maize, but later planting had no effect on maize yield. The yield of cowpeas relay cropped with maize was significantly affected only by the cultivar. The early photoperiod sensitive cultivar Kaya Local yielded significantly more than the late cultivar IAR 1696. The nonphotoperiod sensitive cultivar VITA-5 was intermediate in yield between the two. Early plantings of this variety performed better this year than in 1981 because of poorer growth in the associated maize. The photoperiod sensitive IAR 1696 flowered very late, suffered more from pod sucking bug damage and yielded less than the nonphotoperiod sensitive VITA-5. These results indicate that cowpeas can be relay cropped with maize as early as three to four weeks after maize planting without depressing maize yield.

In another experiment two maize cultivars of different maturities—Pool-16 (90 days) and IRAT 102 (100 to 105 days)—were relay cropped with two photoperiod sensitive cowpea cultivars (Kaya Local, which is relatively early, and IAR 1696, which is relatively late) and one nonphotoperiod sensitive cultivar (VITA-5) at Farako-Bâ, Upper Volta. The maize cultivars were planted on 20 June and the cowpea cultivars on two dates, 26 July and 14 August. The experimental design was a factorial combination of two maize cultivars, three cowpea cultivars and two dates of planting in randomized complete blocks repeated four times.

Neither the main nor the two- or three-way interactions affected maize yield significantly. Despite significant differences in plant height (153 cm for Pool-16 and 215 cm for IRAT 102) and in time of flowering (227 days for Pool-16 and 234 for IRAT 102), the two cultivars yielded about the same (4,306 kg/ha at 15% moisture for Pool-16 and 4,202 kg/ha for IRAT 102).

Cowpea yield was significantly affected by cowpea cultivar and by date × cowpea cultivar and maize cultivar × cowpea cultivar interaction effects. The photoperiod sensitive cultivar Kaya Local outyielded the two other cultivars at both dates of planting and with both maize cultivars (Table 29). However, the difference in yield between that cultivar and IAR 1696 at the 14 August planting and between VITA-5 and IAR 1696 when relay cropped with the maize cultivar IRAT 102 was not statistically significant. The nonphotoperiod sensitive VITA-5 significantly outyielded the photoperiod sensitive IAR 1696 only when planted on 26 July and when relay cropped with Pool-16.

The reaction of cowpeas to late planting and to relay cropping with the tall and medium maturing maize cultivar IRAT 102 varied with the cultivar. Late planting did not significantly depress the yield of VITA-5 and Kaya Local but increased the yield of IAR 1696. IRAT 102 significantly depressed the yield of Kaya Local, increased the yield of IAR 1696, and had no effect on VITA-5.

Table 29. Yield of cowpeas intercropped with maize cultivars of different maturities, Farako-Bâ, Upper Volta, 1982

Cowpea cultivar	Cowpea planting date 26 July	14 August	Maize cultivar Pool-16	IRAT 102
	kg/ha			
VITA-5	487	382	452	417
Kaya Local	767	634	808	593
IAR 1696	200	515	240	474

Comparison of means	LSD (5%)	C.V., %
Date × cowpea cultivars	195.1	38.5 ± 4
Maize × cowpea cultivars	195.1	

An experiment was conducted to determine if the total productivity of a maize/cowpea relay cropping system can be increased by maintaining maize yield at a satisfactory level while increasing the yield of cowpeas through adjustments in maize row spacing and plant population.

The maize cultivar Pool-16 was planted on 21 June at three row spacings (0.75, 1.125 and 1.50 m) and two plant populations (44,444 and 66,666 plants/ha). Two rows of VITA-5 were planted between maize rows, except in the maize with 0.75-m row spacing, where only one cowpea row was planted. The cowpea plant population for each treatment was 66,666 plants/ha.

Only the maize row spacings significantly affected the yield of Pool-16. Wide row spacings depressed maize yield by more than 50%, from 5,987 kg/ha at 0.75-m row spacing to 2,555 kg/ha at 1.125-m spacing and to 2,470 kg/ha at 1.50-m spacing (C.V. = 33.8% ± 3.8). Neither the main effects nor their interactions significantly affected the yield of relay cropped cowpeas, which produced an average of 727 kg/ha (C.V. = 19.3 ±4.2). It should be noted that maize vegetative growth was very poor (the mean plant height was 110 cm and the C.V. was 19% ± 2) because of the temporary N deficiency that occurs when maize is planted at the top of a rotational sequence after a long fallow period in the Guinea savanna. Strong competition between plants within rows at wide row spacings may also have contributed to the reduced maize yield in these treatments.

An experiment was carried out to determine whether reduced cowpea growth in relay cropping with maize can be compensated for by increasing plant population per unit land area. Pool-16 was planted on 21 June at a population of 66,666 plants per hectare and spacing of 0.90 m × 0.167 m). Two cowpea cultivars, VITA-5 and IAR 1696, were planted in maize on 6 August each at four plant populations, (22,222, 66,666, 111,111 and 155,555 plants/ha). A pure-stand treatment consisting of 66,666 plants/ha for VITA-5 and 22,222 for IAR 1696 was also included. The experimental design was a split plot repeated four times. The cowpea cultivars were the main plots, and the plant densities were the subplots.

Neither the cowpea cultivars nor the cowpea plant densities significantly affected maize yield, which averaged 2,612 kg/ha at 15% moisture (C.V. = 31.7% ±3.9). However, cowpea yield was significantly affected by the cowpea cultivars and treatments. The pure-stand cowpea treatment significantly outyielded relay cropped cowpeas at all plant populations (Table 30). Yields in the various relay cropping treatments did not differ significantly from one another, though yield did tend to respond positively to increasing density and reached an optimum level at 66,666 plants/ha. The nonphotoperiod sensitive cultivar VITA-5 significantly outyielded the photoperiod sensitive IAR 1696.

Cowpea management. An experiment was conducted to determine the optimum planting date and to identify environmental factors (drought, disease or parasites other than insect pests) that may limit cowpea yields at various planting dates. Seven photoperiod sensitive local cowpea cultivars and an improved nonphotoperiod sensitive cultivar, KN-1 (formerly VITA-7), were tested at four planting dates in the northern Guinea savanna at Farako-Bâ, Upper Volta, on a sandy-clay-loam ferrallitic soil (an Oxisol with a clay fraction that is rich in kaolinite and sequioxides of Fe, Al and Mn).

A similar experiment with six cultivars (only one of them, KN-1, was nonphotoperiod sensitive) was established at three planting dates at two sites (one with medium slope and the other with lower slope) in the Sudan savanna on "Sol ferrigineux" (an Oxisol that is rich in kaolinite and free iron, some of which is present in the form of concretions) at Kamboinsé, Upper Volta. The experimental design was a split

Table 30. Effect of increasing cowpea plant population on yield of cowpeas intercropped with maize, Farako-Bâ, Upper Volta, 1982

No. of plants per hectare	Cowpea cultivar VITA-5	IAR 1696	Mean
Relay cropping		*kg/ha*	
22,222	402	218	310
66,666	615	331	472
111,111	614	301	458
155,555	574	248	411
Pure stand			
66,666	990	696	843
Mean	639	359	499
Comparison of means	LSD (5%)		C.V., %
Cowpea cultivars	73.2		14.6 ± 0.5
Plant populations	236.9		43.9 ± 13.6
Plant pop. × cowpea cult.	ns		

Table 31. Effect of planting date on cowpea yield, Farako-Bâ, Upper Volta, 1982

Cultivar	Planting date 8 July	26 July	5 August	15 August	Mean
Ouahigouya			*kg/ha*		
Local	2,306	1,340	951	668	1,316
Kaya Local	1,454	1,628	1,347	935	1,341
337	1,307	1,616	1,166	1,049	1,284
Kamboinsé Local Noir	1,537	1,670	1,809	1,272	1,572
Kamboinsé Local Rouge	1,791	1,852	1,059	999	1,425
Logrousso Local	1,374	1,529	1,123	1,136	1,290
IAR 1696	1,124	1,325	685	512	912
KN-1 (improved)	2,721	1,939	1,297	1,218	1,794
Mean	1,702	1,612	1,180	974	1,367
Comparison of means			LSD (5%)		C.V., %
Planting dates			103		49 ± 9
Cultivars			72		30 ± 7
Cultivars, same date			125		
Cultivars, diff. dates			153		

plot, with planting dates as main plots and cultivars as subplots. Each plot received 50 kg P_2O_5/ha as superphosphate.

In the northern Guinea savanna, KN-1 yielded better than any other cultivar at the 8 July planting date (Table 31). When planted late it yielded about the same as most local cultivars, but significantly less than Kamboinsé Local Noir at the 5 August planting date.

During the growing season, the foliar disease rust infected all the cultivars except KN-1 and was most damaging to cowpeas planted after 26 July. Some cultivars (Ouahigouya Local, Kaya Local and Kamboinsé Local Rouge) were highly sensitive to the disease; their leaf area and yield were drastically reduced (Table 31). Other cultivars (Kamboinsé Local and Logfrousso Local) proved to be more tolerant. Since insecticide was applied only four times at 10-day intervals (beginning at floral bud initiation by KN-1), IAR 1696, which flowered very late, was not well protected and suffered severe damage from pod sucking bugs.

In the Sudan savanna crop yields were markedly reduced by *Striga gesnerioides* and severe drought in September and October. The performance of each cultivar depended on its resistance, tolerance or susceptibility to *Striga* and drought. Gorom Local, which was grown only at the medium-slope site, yielded better than the other cultivars (Table 32). Since it was free of *Striga*, its yield reduction reflects only drought damage. Even though this cultivar was more drought resistant than the others, its yield was significantly reduced by as much as 50% at the latest planting date. Ouahigouya Local yielded about as much as KN-1 at both sites when planted on 19 July (Table 32). It outyielded KN-1 at both locations when planted at the later dates except for 31 July at the medium-slope site, where the difference in their yields was insignificant.

Table 32. Effect of planting date on cowpea yield, Kamboinsé, Upper Volta, 1982

Cultivar	Planting date 19 July	31 July	10 August	Mean
Medium-slope soils		*kg/ha*		
Ouahigouya Local	612	341	297	416
Kaya Local	15	66	149	77
Kamboinsé Local Noir	55	181	275	170
Gorom Local (SUVITA-2)	1,003	681	582	755
IAR 1696	5	2	0	2
KN-1 (improved)	595	247	176	339
Mean	381	253	246	293
Comparison of means		LSD (5%)		C.V., %
Planting date		103		49 ± 9
Cultivars		72		30 ± 7
Cultivars, same date		125		
Cultivars, diff. dates		153		
Lower-slope soils				
Ouahigouya Local	742	922	330	665
Kaya Local	57	145	126	109
Kamboinsé Local Noir	69	176	180	142
Kamboinsé Local Rouge	262	257	204	241
IAR 1696	182	9	0	64
KN-1 (improved)	961	397	266	541
Mean	379	318	184	294
Comparison of means		LSD (5%)		C.V., %
Planting date		287		138 ± 62
Cultivars		224		93 ± 22
Cultivars, same date		388		
Cultivars, diff. date		454		

Table 33. Effect of planting date, seedbed preparation and position in the toposequence on cowpea yield, Kamboinsé, Upper Volta, 1982

	Planting date 19 July	5 August
Seedbed preparation	*kg/ha*	
Flat	668 b	120 d
Tied ridges	910 a	575 c
LSD (5%)	80.3	
C.V., %	23 ± 2	
Position in the toposequence		
Upper slope	555 c	257 f
Medium to upper slope	923 a	324 ef
Medium slope	989 a	360 de
Lower to medium slope	703 b	328 ef
Lower slope	774 b	467 cd
LSD (5%)	127	
C.V., %	23 ±	

Note: Means followed by the same letter are not statistically different at the 5% probability level.

Quahigouya Local flowered 46 days after planting and KN-1 at 42 days. *Striga* emerged in the former 46 to 49 days after planting and in the latter at 53 to 59 days at both sites. In the poor yielding cultivars (Kaya Local, Kamboinsé Local Noir and IAR 1696) planted at the two early dates, *Striga* emerged long before flowering and therefore may have been responsible for their poor performance. IAR 1696 suffered both from *Striga* and drought.

The low soil water infiltration rate of the ferriginous soils that are prevalent in the Sudan savanna is responsible for the severe drought stress experienced by crops in that zone. A study was carried out to find ways of reducing runoff of rainwater and drought stress in cowpeas. The cowpea cultivar KN-1 was planted on tied ridges and on flat beds at two dates, 20 July and 14 August, and at five positions in the toposequence. The experiment had a 2^2 factorial design (two soil preparation methods and two planting dates); treatments were randomly allocated in complete blocks with four replications at each position. The plots were not fertilized.

The main effects, seedbed preparation method and planting date, and two two-way interactions (planting date × seedbed preparation and planting date × position in the toposequence) significantly affected cowpea yield. Cowpeas planted on tied ridges and at early dates significantly outperformed those planted

Table 34. Number of days from planting to first emergence of *Striga* in cowpeas, Kamboinsé, Upper Volta, 1982

Cultivar	Planting date 19 July	31 July	10 August	Mean
	days after planting			
Ouahigouya Local	45	44	50	46
Kaya Local	45	46	48	46
Kamboinsé Local Noir	46	50	51	49
Gorom Local (SUVITA-2)[a]	165	153	141	153
IAR 1696	48	57	60	55
KN-1	47	49	81	59
Mean	66	67	72	68

Comparison of means	LSD (5%)	C.V., %
Planting dates	ns	27 ± 4
Cultivars	8	14.5 ± 3
Cultivars, same dates	14	
Cultivars, diff. dates	18	

[a]This cultivar was free of *Striga*, which means that it delayed *Striga* emergence indefinitely. To simplify statistical analysis, 31 December was used as the probable date of emergence.

Table 35. Density of *Striga* in cowpeas under natural infestation, Kamboinsé, Upper Volta, 1982

Cultivar	Position in the toposequence: Medium slope	Lower slope
Ouahigouya Local	3.0 ab*	2.5 b
Kaya Local	3.5 a	3.7 a
Kamboinsé Local Noir	2.7 b	2.7 b
Kamboinsé Local Rouge	—	2.4 b
Gorom Local (SUVITA-2)	1.0 c	—
IAR 1696	2.6 b	3.1 ab
KN-1	2.7 b	2.5 b
LSD (5%)	0.6	0.8
C.V., %	29 ± 6	33.6 ± 8

Note: *Striga* density was rated on a 1 to 5 scale, with 1 = no *Striga* and 5 = *Striga* plants almost 30 cm apart and scattered throughout the plot.

*Means followed by the same letter are not significantly different at the 5% probability level.

in flat seedbeds and at late dates (Table 33). Early planting seemed particularly important. Even in flat seedbeds, early planting gave higher yields than planting late on tied ridges. Planting on medium to lower slopes on the toposequence gave higher yields than planting on upper slopes. But this ceased to be an advantage, except on lower slopes, with late planting.

***Striga* resistance.** *Striga gesnerioides* is becoming a major problem in cowpeas in the semiarid zone of Africa. This study was begun to gather information on the date of *Striga* emergence and on *Striga* density and to examine their relationship to cowpea yield. Data on *Striga* emergence and density were gathered in planting date experiments conducted on medium and lower slope soils at Kamboinsé (described in the preceding section on cowpea management). Information on flowering date was also collected so that it

Table 36. Time of flowering of cowpeas under *Striga* infestation, Kamboinsé, Upper Volta, 1982

Cultivar	Planting date 19 July	31 July	10 August	Mean
	days after planting			
Ouahigouya Local	50	46	43	46
Kaya Local	115	52	45	71
Kamboinsé Local Noir	66	52	45	54
Gorom Local (SUVITA-2)	43	42	39	41
IAR 1696	84	73	82	80
KN-1	42	41	43	42
Mean	67	51	50	56

Comparison of means	LSD (5%)	C.V., %
Planting date	14	36 ± 6
Cultivars	13	30 ± 7
Cultivars, same dates	23	
Cultivars, diff. dates	26	

and the findings on date of *Striga* emergence could be related to yield losses caused by *Striga*.

Cultivars and cultivar × planting date interaction significantly affected the date of *Striga* emergence on medium slopes. At all planting dates, the cultivar Gorom Local (SUVITA-2) was found to be free of *Striga* after maturation (Table 34). In only 2 out of 12 plots, a few dead seedlings were found that had failed to grow after germination. When planted on 10 August, KN-1 delayed *Striga* emergence significantly longer than the other four cultivars. This suggests that it has some level of resistance, a finding that appears to be supported also by the tendency of KN-1, though not significant, to delay *Striga* emergence at the two early planting dates. (Table 34).

On lower slopes only planting date significantly affected *Striga* emergence. In cowpeas planted on 19 July, *Striga* emergence was delayed until 52 days after planting, and in those planted on 10 August, it was delayed until 51 days. In both cases the delay was significantly greater than that caused by planting on 31 July (45 days). In cowpeas planted on that date, the soil was moist and soft around 45 days after planting, whereas in cowpeas planted at the other dates, the soil was dry and hard. It thus appears that hard soil may delay *Striga* emergence. The fact that the cultivar had no significant effect on *Striga* emergence on lower slope soil was to be expected since the only *Striga* resistant cultivar, Gorom Local, was not grown at that site.

Striga density was affected significantly only by the cultivar on both medium and lower slope soils (Table 35) and by date of planting on the latter. On the lower-slope soils, *Striga* density was 3.4 on a 1 to 5 scale in cowpeas planted on 19 July, significantly greater than in those planted on 31 July (2.3) and 10 August (2.0). Cultivars in which *Striga* emerged early tended to be heavily infested.

The date of flowering was significantly affected by all main effects and their interaction on soils with medium slopes (Table 36). Similar results were

observed on lower slope soils, except that the effect of planting date was not significant. It was also observed that cultivars flowering before or close to *Striga* emergence yielded better than those that flowered after *Striga* emerged. Thus, in the absence of resistance, early flowering may be a critical factor in limiting *Striga* damage.—*N. Muleba*

Soybeans

National programs are becoming increasingly interested in expanding soybean production in Africa, and the future for the crop on this continent looks bright. To facilitate this expansion, IITA is seeking solutions to the problems that have frustrated soybean growers in the more humid tropics. For example, to overcome the problem of rapid seed degradation, IITA is developing soybean varieties with superior seed storability. The Institute has also developed new varieties that are able to nodulate with the indigenous rhizobia (this character has been called "promiscuous nodulation"), thereby allowing the crop to be grown without application of fertilizer nitrogen or rhizobial inoculants, which are not available to small farmers in developing countries. These new varieties are now being tested for adaptation both within and outside Nigeria. In addition, insect pest problems are being monitored to develop strategies for control.

Genetic Improvement

The principal objective of the soybean improvement program is to develop soybean varieties that are adapted to the tropics, maintain good seed viability during storage, and nodulate with indigenous rhizobia. Germplasm lines identified as having these traits were crossed with high yielding lines. Advanced generation progeny with good agronomic characteristics, promiscuous nodulation and acceptable seed longevity are now being tested. Among the other desirable traits being incorporated into soybeans adapted to the tropics are resistance to bacterial pustule (*Xanthomonas phaseoli*) and soybean mosaic virus, pod sucking bugs, lodging, shattering and field weathering of seed.

Most soybean varieties are relatively sensitive to soil fertility. We have recently developed several late (120 to 160 days), determinate varieties that we believe will show greater yield stability in the southern savanna regions, where the rainy season is of adequate length. These varieties will be tested at several sites in 1983.

In 1982 the soybean improvement program distributed international trials to 25 cooperators in Africa, Asia and South America. Researchers from IITA and from Ivory Coast, Zaire, Zambia, Zimbabwe and Cameroon exchanged germplasm and visited one another's research sites. IITA medium and late maturity varieties were grown by cooperators in the all-Nigerian cooperative trials at twelve sites in Nigeria. Breeding lines were grown in multilocational trials at five locations in Nigeria (Table 37) and early generation breeding nurseries were grown at Zaria and at Mokwa, which represent, respectively, the northern and southern Guinea savanna. Other projects begun or continued in 1982 were screening of germplasm and breeding lines for shattering resistance, identification of lines that are immune or highly resistant to bacterial pustule, and reselection and purification of superior advanced lines.

International Trials

To determine the range of environments in which IITA breeding lines will nodulate with indigenous rhizobia and to characterize the general adaptation and seed longevity of those lines, a medium and late maturity observation trial was sent to several countries in 1981. The breeding lines had been selected primarily for the promiscuous nodulation character. Most of the breeding lines nodulated well as shown in Figure 12.

The breeding lines had also been screened for seed longevity, and only lines thought to have intermediate or good longevity were included. Cooperators receiving the trials were asked to keep seeds under ambient conditions for 8 to 12 months before testing seedling emergence and reporting the results. As a result, we have not yet received data from many of the cooperators. Results are available, however, from Ivory Coast, where seed storability is a problem because of the high relative humidity between growing seasons (Figure 13). Numerous breeding lines maintained better seed vigor between seasons than the check varieties from the United States and Brazil.

Seed Longevity

Multilocational trials. Thirty-four advanced generation lines that showed superior seedling emergence following an accelerated ageing test (40°C and 75% relative humidity for six weeks) were included in a replicated trial grown at five sites in Nigeria. Bossier, which has poor seed longevity, and TGm 737p, which has good longevity, were included

Table 37. Sites for multilocational soybean trials in Nigeria, 1982

Location	Latitude	Cooperator
Zaria	11°	Institute of Agricultural Research (IAR), Ahmadu Bello University
Mokwa....	9° 30 min	IAR and the National Grain Production Company (NGPC)
Ilorin	8° 30 min	Kwara State Agricultural Development Project
Ilora.....	7° 50 min	Institute of Agricultural Research and Training, Ife University
Ibadan	7° 23 min	

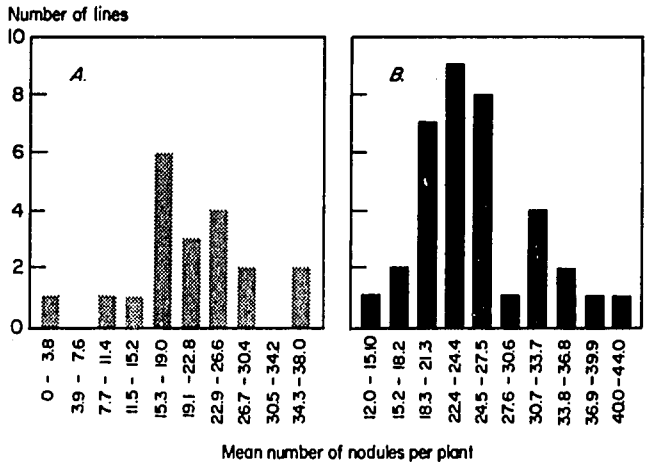


Figure 12. Frequency distribution for number of nodules per plant, averaged in (A) over two locations in Ivory Coast for 20 medium maturing soybean breeding lines and in (B) over one location in Zimbabwe and two in Ivory Coast for 36 late maturing lines, 1982. For A, the number of nodules per plant of the local checks ranged from 1 to 8. For B, the number was 1 for the Zimbabwe checks and 1 to 16 for the Ivory Coast checks.

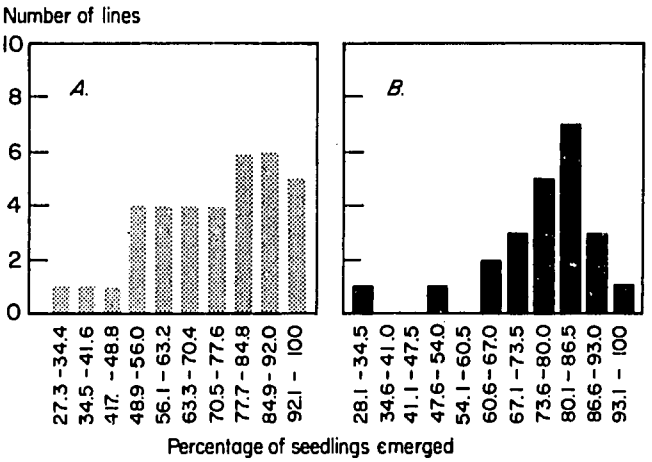


Figure 13. Frequency distribution for percentage of seedlings emerged after eight months of ambient storage for (A) 36 late maturing soybean breeding lines and (B) 23 medium maturing lines, Ivory Coast, 1982. Seedling emergence for the local checks ranged from 28 to 36%.

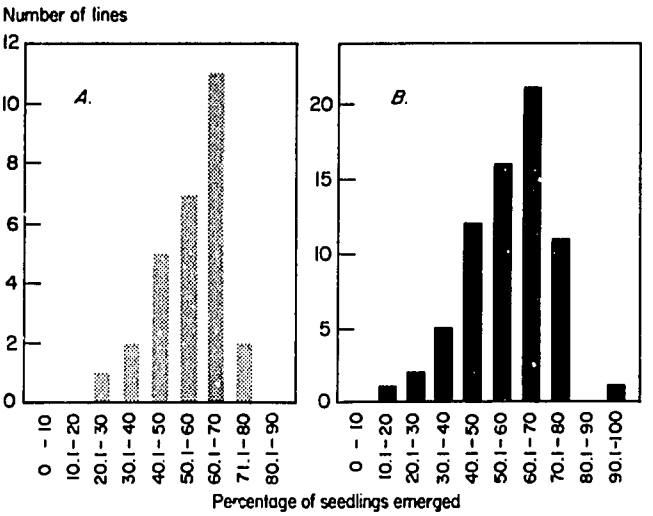


Figure 14. Frequency distribution for percentage of seedlings emerged at various locations in Nigeria after accelerated ageing (by storing seeds six weeks at 40°C and 75% relative humidity) for (A) 33 soybean breeding lines selected for seed longevity and (B) 69 F_6 lines, 1982. Seedling emergence for the poor check (Bossier) was 15% and for the good check (TG9m 737p) 77%.

Table 38. Mean yield of soybean lines with superior seed quality at various sites in Nigeria, 1982

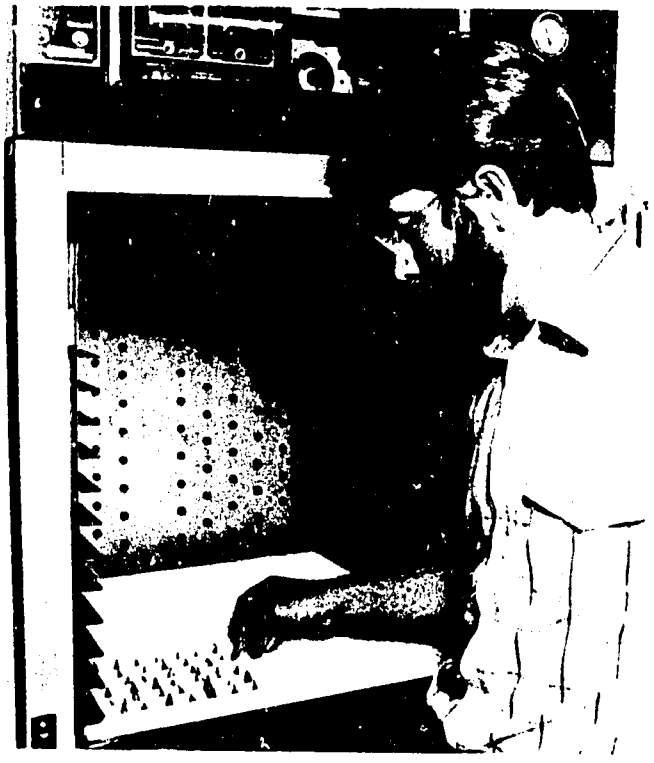
Selection	Zaria	Mokwa NGPC[a]	Mokwa ABU[b]	Ilorin	Ibadan	Avg.
			kg/ha			
TGx 297-192C	2,925	1,915	1,820	1,881	2,165	2,141
TGx 297-35C	2,237	2,235	1,177	2,192	1,441	1,856
TGx 542-2C	2,352	2,208	1,444	1,824	1,167	1,799
TGx 536-100C	2,661	1,846	975	1,367	1,653	1,700
TGx 533-37C	2,638	1,811	1,553	1,551	1,515	1,814
TGx 252-3C	2,287	1,361	944	1,793	1,865	1,650
TGx 533-65C	2,470	1,111	1,426	1,797	1,399	1,640
Check						
Bossier	—	635	505	1,111	293	—
TGm 737p	2,120	856	983	1,521	1,045	1,305
Trial mean	2,249	1,482	1,229	1,540	1,346	
LSD (5%)	425	640	259	498	629	

[a]National Grains Production Company.
[b]Ahmadu Bello University research station.

as checks. Yields of some outstanding lines are shown in Table 38. The maturity of the lines in this trial ranged from 100 to 115 days. The plants were relatively tall and showed fairly good resistance to lodging. Seed storability tests, based on accelerated ageing, indicated that many of the lines had good seed longevity (Figure 14).

Other trials. A preliminary trial of lines with superior seed quality was grown at Mokwa and Ibadan. The trial included 123 lines that have shown superior seed longevity but that have not yet been evaluated for yield or agronomic quality. Sixty-six lines from this trial and the multilocational seed quality trials are being multiplied for further multilocational testing in 1983. In addition, 305 single plant selections were made from lines that were not acceptably uniform in the two seed quality trials. These lines are being grown in progeny rows, and the superior ones will constitute a preliminary trial in 1983. Single plant selections from multiplication plots grown during the 1981–82 dry season at Ibadan were sown in progeny rows in two nurseries at Mokwa during the rainy season. One hundred and eighty lines were agronomically promising and sufficiently uniform to be multiplied for multilocational testing 1983.

Field weathering. In the IITA Annual Report for 1981, we reported on a technique for laboratory screening of soybeans for resistance to field weathering. Since then we have found, using a newly



A new system for identifying soybean varieties with resistance to field weathering of seed. Pods taken at physiological maturity are kept in an incubator at 30°C and 95% relative humidity for one week. The seeds are then germinated.

developed laboratory incubator method, that there is a close relationship between resistance to field weathering and resistance to seed deterioration in storage. During the 1981–82 dry season, 154 F_5 breeding lines were evaluated. Only the lines that were superior to the check variety Jupiter in field weathering resistance were included in preliminary trials during 1982. The seed quality of several elite lines is shown in Table 39.

Table 39. Seed quality of elite F_5 soybean lines, based on seedling emergence after incubator weathering, IITA, 1982

Breeding lines	No. of seeds that emerged, out of 50
Top three for emergence	
TGx 729-01D	46
TGx 718-05D	44
TGx 775-03D	43
Promising for agronomic characters	
TGx 726-01D	42
TGx 709-06D	36
TGx 789-02D	36
TGx 724-01D	35
TGx 709-03D	31
TGx 713-06D	30
TGx 725-01D	24
Jupiter (check)	11
Trial mean	24
LSD (5%)	7
C.V., %	15

Promiscuous Nodulation

Advanced generation trial. The objective of this experiment was to evaluate the agronomic characteristics, yield and nodulation of 28 lines bred to nodulate with indigenous rhizobia. One nonpromiscuous variety, Bossier, was included as a check. To evaluate the lines for efficiency of nodulation, a trial was carried out in which some plots received fertilizer nitrogen treatment and others were untreated. The treated plots received a total of 120 kg N/ha as a side-dressing in three 40-unit applications at 25, 50 and 75 days after planting. The trial was sown at Zaria, at two locations in Mokwa (the Ahmadu Bello University research station and the National Grains Production Company) at Ilorin and at Ibadan on soils with no previous history of inoculant application.

The soybeans nodulated and yielded well at Ilorin in spite of drought, but because N was not applied at that location the data are not presented here. Nodulation was also good at Mokwa (NGPC) and Ibadan. It was fair at Mokwa (ABU) but very poor at Zaria (Table 40). Nitrogen application resulted in a significant and biologically meaningful increase in yield at Zaria and Mokwa (ABU). The poor nodulation at Zaria was unexpected. The field had been cleared from native bush vegetation four years earlier and had been cropped in maize for three years prior to our experiment. The indigenous rhizobia were obviously present in low numbers, as indicated by the lack of nodulation on both promiscuous soybeans and on cowpeas that were sown in the field as a check for nodulation. The yields and nodulation of several of the most promising lines are shown in Table 41.

Table 40. Mean yield and nodulation of 28 promiscuously nodulating soybean varieties at various locations in Nigeria, 1982

	Yield, kg/ha	Percent increase in yield	Nodulation[a]
Zaria			
With fertilizer N	1,518	27	1.6
Without fertilizer N	1,194		2.1
Mokwa (NGPC)			
With fertilizer N	2,107	6	2.3
Without fertilizer N	1,997		3.0
Mokwa (ABU)			
With fertilizer N	1,477	23	2.1
Without fertilizer N	1,204		2.6
Ibadan[b]			
With fertilizer N	873	0	2.6
Without fertilizer N	887		3.1

[a]Nodulation scores: 1 = poor nodulation, 2 = fair nodulation, 3 = good nodulation and 4 = excellent nodulation.
[b]Yields at Ibadan were relatively low because of drought.

Preliminary trial of medium maturity lines. The objective of this experiment was to assess the

Table 41. Yield and nodulation of elite, promiscuously nodulating soybean varieties, Zaria and Mokwa, Nigeria, 1982

Variety	Zaria With N	Zaria Without N	Mokwa (NGPC) With N	Mokwa (NGPC) Without N
TGx 326-034D				
Yield, kg/ha	2,264	1,469	2,553	2,553
Nodulation[a]	2.2	2.2	1.8	2.7
TGx 330-054D				
Yield, kg/ha	2,426	1,320	2,367	1,978
Nodulation	1.5	2.2	2.8	3.9
TGx 457-060C				
Yield, kg/ha	2,012	1,499	2,467	2,298
Nodulation	2.1	2.0	2.1	2.5
TGx 604-028C				
Yield, kg/ha	1,658	1,018	1,967	1,890
Nodulation	1.5	2.3	2.8	3.0
DSM 490				
Yield, kg/ha	1,092	1,292	2,378	2,270
Nodulation	2.7	2.5	2.5	3.7
M-79 (IAR[b])				
Yield, kg/ha	1,843	1,544	2,225	2,167
Nodulation	1.8	2.4	3.0	4.0
Bossier (nonpromiscuous check)				
Yield, kg/ha	—	—	1,595	897
Nodulation	1.0	1.0	1.2	1.6
Trial means				
Yield, kg/ha	1,518	1,194	2,107	1,997
Nodulation	1.6	2.1	2.3	3.0
LSD (5%)				
Yield, kg/ha	130		89	
Nodulation	0.2		0.6	

[a]Nodulation scores: 1 = poor nodulation, 2 = fair nodulation, 3 = good nodulation and 4 = excellent nodulation.
[b]Institute of Agricultural Research, Ahmadu Bello University, Nigeria.

agronomic characteristics and ability to nodulate with indigenous rhizobia of F_6 generation breeding lines derived from complex crosses involving parents that have the promiscuous nodulation character, superior seed storability and good agronomic characteristics. As mentioned above, nodulation with indigenous rhizobia at Zaria was very poor, at Mokwa (ABU) fair, and relatively good at Ilorin and Ibadan. Yields were low at Ibadan because of drought stress. The performance of several promising lines is given in Table 42. The storability of most breeding lines was superior to that of the check variety, Bossier (Figure 14).

Preliminary trial of late maturing lines. As with the medium maturity preliminary trial, the objective of this trial was to assess the agronomic characteristics and ability to nodulate with indigenous rhizobia of F_6 generation breeding lines. The trial was sown at Ilorin and Ibadan, but because of severe drought stress at Ibadan, that trial was discarded. Several lines that performed well at Ilorin are listed in Table 43.

Table 42. Yield and nodulation of promising, medium maturity breeding lines in a preliminary yield trial at various sites in Nigeria, 1982

Line	Zaria	Mokwa (ABU)	Ilorin	Ibadan
M-90 (IAR)				
Yield, kg/ha	1,927	1,624	1,522	338
Nodulation[a]	2.3	2.8	3.9	3.1
TGx 725-01D				
Yield, kg/ha	1,064	1,485	1,681	1,138
Nodulation	1.7	2.7	3.1	3.1
TGx 724-01D				
Yield, kg/ha	1,048	1,649	1,531	1,036
Nodulation	1.2	2.2	2.7	2.3
TGx 789-02D				
Yield, kg/ha	1,210	1,644	1,937	1,563
Nodulation	1.3	1.8	2.7	2.6
TGx 713-06D				
Yield, kg/ha	1,538	1,301	1,511	1,567
Nodulation	1.0	1.5	2.3	2.0
TGx 709-06D				
Yield, kg/ha	1,650	1,314	1,598	1,269
Nodulation	2.6	3.0	3.8	4.0
TGx 709-03D				
Yield, kg/ha	1,582	1,602	1,253	988
Nodulation	2.3	2.8	3.1	3.1
TGx 726-01D				
Yield, kg/ha	1,032	1,782	1,698	611
Nodulation	1.7	2.7	3.4	3.5
Jupiter (nonpromiscuous check)				
Yield, kg/ha	1,456	1,009	1,307	1,374
Nodulation	1.0	1.3	1.7	1.5
Trial mean				
Yield, kg/ha	1,204	1,274	1,375	961
Nodulation	1.6	2.1	2.8	2.7
LSD (5%)				
Yield, kg/ha	611	515	472	403
Nodulation	0.8	0.8	0.8	0.9

[a]Nodulation scores: 1 = poor nodulation, 2 = fair nodulation, 3 = good nodulation and 4 = excellent nodulation.

Table 43. Yield and nodulation of promising, late maturing breeding lines in a preliminary yield trial, Ilorin, Nigeria, 1982

Line	Yield, kg/ha	Nodulation[a]
TGx 742-3D	1,723	2.3
TGx 742-5D	1,609	3.3
TGx 293-03D	1,420	3.4
Malayan (local check)	1,325	3.1
Jupiter (nonpromiscuous check)	1,029	2.5
Trial mean	1,106	2.6
Trial LSD (5%)	591	0.9

[a]Nodulation scores: 1 = no nodulation, 2 = fair nodulation, 3 = good nodulation and 4 = excellent nodulation.

Early generation nurseries. Selections from early generation nurseries and F_2 populations were advanced one generation at Ibadan during the 1981–82 dry season and grown at Zaria and at Mokwa during the 1982 main season (Table 44). All lines and populations represented a second cycle of crossing

Table 44. Early generation nurseries

Nursery	Entry	Selection
1981–82 dry season, Ibadan		
F_2 promiscuous nodulation, seed longevity and pod bug resistance	7 populations	Advanced in bulk
F_3 promiscuous nodulation, seed quality and early maturity	402 lines	987
1982 rainy season, Mokwa and Zaria		
F_2 promiscuous nodulation, seed longevity and pod bug resistance	98 populations	368
F_3 promiscuous nodulation, seed longevity and pod bug resistance	7 lines	296
F_4 promiscuous nodulation, seed longevity and early maturity	987 lines	1,369
1982–83 dry season, Ibadan		
F_2 promiscuous nodulation, seed longevity, stem strength and shattering resistance	164 populations	
F_3 promiscuous nodulation, seed longevity and pod bug resistance	368 lines	
F_4 promiscuous nodulation, seed longevity and pod bug resistance	296 lines	
F_5 promiscuous nodulation, seed quality and early maturity	1,369 lines	

between superior breeding lines involving promiscuous nodulation and seed longevity. The new parent material also included parents with pod bug resistance, stem strength, shattering resistance and early maturity.—*E.A. Kueneman and W.R. Root*

Entomology

Two soybean varieties (TGm 344 and TGm 579) were planted at Mokwa and one (TGm 17-2GE) at IITA for a survey of the major insect pests associated with the crop. Only pod sucking bugs were observed in considerable numbers at both locations.

The predominant species was *Nezara viridula*, which represented up to 75% of the population at

Table 45. Species composition of pod bugs at two locations in Nigeria, 1982

	Mokwa		IITA
	TGM 344	TGM 579	TGM 17-2GE
Nezara	74.8	70.1	55.7
Piezodorus	11.1	11.1	1.1
Acrosternum	6.2	1.8	6.3
Aspavia	3.8	13.4	29.4
Others[a]	4.0	3.6	7.5

[a]Others include *Anoplocnemis, Clavigralla tomentosicollis, C. shadebi* and *Riptortus*.

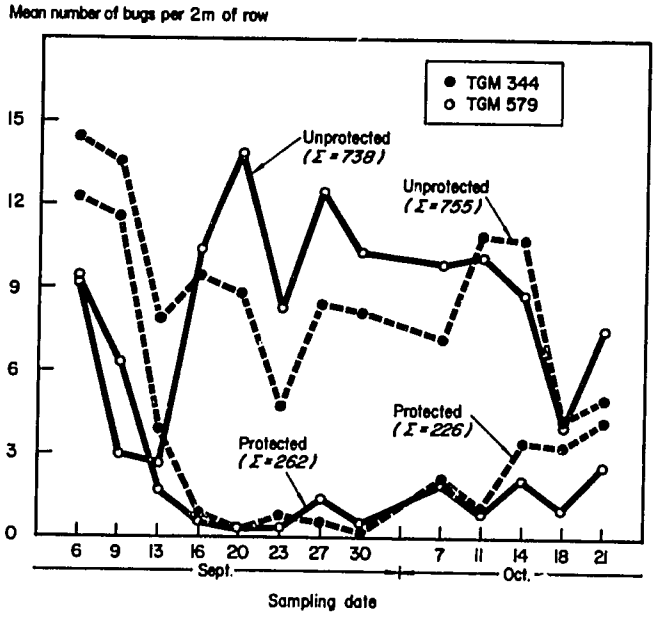


Figure 15. Population of pod sucking bugs on two cowpea varieties, Mokwa, Nigeria, 1982.

Table 46. Soybean yield in protected and unprotected plots at two locations in Nigeria, 1982

Variety	Protected	Unprotected	Percent loss
Mokwa			
TGm 344 (±S.E.)	2,620.5 (±123.8)	1,585.1 (±123.4)	39.5
TGm 579[a]	1,527.2	651.8	57.3
IITA			
TGm 17–26E[a]	1,657.6	1,222.4	26.3

[a]Unreplicated plots.

Mokwa and 56% at Ibadan (Table 45). The bug populations on the two varieties planted at Mokwa were identical (Figure 15); their means for the entire sampling period were around eight bugs per 2-m row, which is the economic threshold (4 to 8 bugs per 2 m) reported from other countries. This population was large enough to cause substantial yield loss (Table 46). TGm 579 may have suffered a greater loss because of its earlier maturity, which could have caused it to attract a greater number of pod bugs much earlier than did TGm 344. At IITA, where bug populations were lower, yield loss was still close to 30%.

The results clearly indicate the importance of pod sucking pests at certain locations in Nigeria. There is an immediate need for concerted research efforts to obtain the data needed to formulate control measures.—*L.E.N. Jackai*

Virology

Soybean viruses can cause yield losses and, when seed borne, prevent movement of germplasm among countries. Several viruses identified in Nigeria are being studied to ensure that virus diseases do not reach epidemic levels.

Soybean Mosaic Virus

Soybean mosaic virus (SMV), the most common soybean virus disease, was of little or no importance in this year's crop at IITA and in off-site experiments at various places in Nigeria. Extensive rogueing in the preceding breeding and multiplication cycle has apparently paid off. High seed transmission rates of this virus in many genotypes is beyond doubt the most important factor in reoccurrence and subsequent epidemic spread of this virus in any new crop. In locally grown soybeans (Malayan), no SMV was found during surveys this year. Absence of seed transmission in these types must be considered responsible for the absence of SMV since Malayan is not resistant to the disease.

A set of 20, well-performing, SMV resistant lines obtained from the International Soybean Program (INTSOY) at the University of Illinois at Urbana-Champaign, United States, was tested with the two SMV isolates that we are maintaining for further studies and for resistance screening. Fifteen of these proved to be highly resistant to our SMV isolates, and the rest developed only mild symptoms. Marginal differences were observed between the reactions to the two isolates.

Soybean Dwarf Disease

The severe and potentially important dwarfing disease, which earlier was tentatively identified as soybean dwarf virus (SDV) and was reported from Japan, appears to be caused by an entirely different and probably hitherto undescribed virus. It was found to be efficiently transmitted by white-flies (*Bemisia tabaci*). Still, as found earlier, clearly positive reactions were obtained in agar gel diffusion tests, using an SDV antiserum, with most field infected plants, but not with those inoculated in the greenhouse. No explanation can be given for this result since precipitation lines are typical of virus-specific reactions and no such lines have ever been obtained with healthy plants.

Interestingly enough, the Malayan germplasm introduction TGm 107 was found to be highly susceptible to this disease. But although the virus was found to occur in experimental fields of Malayan, it was not seen in locally grown Malayan in the major growing area around Yandev, Nigeria. On testing Malayan collected from farmer's fields in that region, we found that it possessed a considerably higher level of resistance to this disease than TGm 107, which explains the absence of this disease from farmers' Malayan in the major soybean growing area of Nigeria.

Blister Mosaic

In addition to SMV and a potyvirus similar to one isolated earlier from African yam-bean (soybean isolate 2), a new potyvirus that causes a characteristic mosaic was seen at low incidence in soybeans at IITA both during the rain-fed growing season and in the dry season. This new potyvirus appears to be different from SMV and the African yam-bean-like virus in that it causes a characteristic blister mosaic. All infections found in the dry season multiplications appeared to be secondary (natural) infections from outside the crop and not seedborne infections. The virus therefore seems to be indigenous to this region and does not appear to have come in through seedborne infection.

A New Virus Disease

In the main growing area around Yandev in south central Nigeria, both in experimental plots as well as in farmers' fields, yet another severe viruslike disease was observed, though at low incidence. Symptoms are a blotchy, whitish yellow vein pattern, mosaic and distortion. No disease of this kind has been observed previously. Although a virus was isolated from field samples by means of inoculation to *N. benthamiana* (but not to soybeans), transmission from *N. benthamiana* back to soybeans proved successful, and symptoms similar to those seen in the field were observed.

In spite of the sap transmissibility and severe symptom expression in soybeans with one of the three isolates maintained, no virus particles of a definite type could be associated with the disease. Even in *N. benthamiana*, in which the virus apparently reaches a high concentration, no virus-like particles could be identified with certainty.—*H. W. Rossel*

Soybean (2) Virus Isolate

A new disease in soybeans (code named soybean (2) virus) was recognized that causes curling of leaves and mild mosaic. This disease can be differentiated from the most common virus disease of soybeans, soybean mosaic, by the fact that soybean (2) virus causes severe symptoms in *Nicotiana benthamiana* (Rossel, unpublished data). Electron microscopic examination of leaf dip preparations revealed filamentous particles typical of those in the potyvirus group.

The virus was purified according to the method described by Lima et al (1979), with a slight modification, followed by two cesium chloride centrifugations as described by Taiwo et al (1982).

An antiserum was prepared by injecting rabbits with the purified virus preparations. The antiserum obtained has a titer of 1/256 in microprecipitin tests. In immunodiffusion tests (SDS) the virus proved to be remotely serologically related to CAbMV as it occurs in cowpeas in Nigeria. Further experiments are underway to study the relationship of this virus with other potyviruses observed in soybeans.—*G. Thottappilly and H. Huttinga*

Table 47. Results of host range tests with soybean Abuja virus, 1982

Plant species	Reaction[a]
Beta vulgaris	—
Brassica sinensis	—
Canavalia ensiformis	S
Chenopodium amaranticolor	L
Chenopodium quinoa	L
Cucumis melo	—
Cucumis sativus	—
Cucurbita maxima	—
Glycine max (Malayan)	S
Glycine max (Bossier)	S
Gomphrena globosa	S
Lathyrus odoratus	S
Lycopersicon esculentum (Moneymaker)	—
Lycopersicon esculentum (Bonny's Beste)	—
Lycopersicon esculentum (Rutgers)	—
Nicotiana benthamiana	L, S
Nicotiana clevelandii	L
Nicotiana megalosiphon	L
Nicotiana glutinosa	—
Nicotiana tabacum (Samsun NN)	L
Nicotiana tabacum (White Burley)	L, S
Nicotiana tabacum (Xanthii n.c.)	L
Phaseolus aureus	S
Phaseolus vulgaris (Bataaf)	L, S
Phaseolus vulgaris (Dubbele witte zonder draad)	L, S
Physalis floridana	—
Pisum sativum (Kelvedon Wonder)	S
Pisum sativum (Mansholt)	S
Pisum sativum (Koroza)	S
Pisum sativum (Rondo)	S
Solanum melongena	—
Vicia faba	—
Vigna cylindrica	S
Vigna unguiculata (Ife Brown)	L
Vigna unguiculata (TVu 4526)	—

[a]L = local symptoms, S = systemic symptoms and — = no infection, as determined by back inoculation.

Soybean Abuja Virus

A virus disease of soybeans (named soybean Abuja virus) that was originally found in the Abuja region of Nigeria is characterized by chlorotic mottle, leaf deformation and mosaic in soybeans and chlorotic ring spots on inoculated leaves of *Nicotiana benthamiana*, which later develop into systemic symptoms (IITA, Annual Report for 1979).

In order to study the host range of the soybean Abuja virus, several test plant species were inoculated with crude juice from infected *N. benthamiana*. The results of host range studies were determined by visual observation and back inoculation onto *N. benthamiana* (Table 47).

Serological tests, using an antiserum against the Abuja virus and CYMV as the test antigen, and tests with CYMV antiserum and the Abuja virus, revealed a close relationship between CYMV and the Abuja virus. However, it was observed in host range studies that differences exist between the two. For example, *Vigna unguiculata* (Ife Brown) is highly susceptible to CYMV, whereas only a few necrotic lesions and no systemic symptoms occur with the Abuja virus. Also, TVu-4526, which is highly susceptible to CYMV, did not show visible symptoms with the Abuja virus.

To determine whether the Abuja virus is transmitted through seed, *Glycine max* (Malayan) was inoculated with the virus, and seeds were collected from infected plants. The 600 seeds were sown in an insect proof screenhouse and observed for symptoms for six weeks. Suspected plants were individually inoculated to *N. benthamiana*, but no seed transmission could be detected, although it is possible that seed transmission occurs in other varieties.—*G. Thottappilly and H.W. Rossel*

Microbiology

In 1982 soil microbiology research in the Grain Legume Improvement Program focused almost exclusively on cowpeas. Field evaluation of cowpea rhizobial inoculants was begun in eight countries (five African, one Asian and two Latin American). Although not all trials have been completed, it appears at this point that rhizobial inoculants are not likely to increase cowpea grain yield. Two inoculation methods were tested under two soil fertility levels; granular inoculants seemed to be more suitable than peat inoculants for field use. The effects of *Rhizobium* inoculation and starter nitrogen on early maturing cowpeas were investigated, and a rhizobial strain that is effective in early nodulation and initial growth of plants was found. Seasonal variation in the population sizes of indigenous rhizobia in a semiarid tropical soil was examined, and a nondestructive, inexpensive test for detecting ureide compounds in plants was tested on cowpeas under field conditions in the tropics.

Testing of Cowpea Rhizobial Inoculants

Inoculation trials were conducted at three locations in West Africa: Samaru in northern Nigeria, Maradi in Niger and Kamboinsé in Upper Volta. VITA-7 was grown at each location along with a local check: cultivar IAR 48 at Samaru, TN 88-63 at Maradi and SUVITA-2 at Kamboinsé. Five *Rhizobium* strains were tested at each location. Strains IRc 252, IRc 430A and IRc 500A were selected because of their superior performance in preliminary trials (IITA, Annual Report for 1981). Strains NUM 716 and T 242 from the Microbiological Resources Centre in Nairobi were included to increase the diversity of strains tested under West African conditions. The five strains came from Onne (Nigeria), Maradi, IITA, India and Kenya. Each strain was used as a single strain inoculant, except IRc 500A, which was included only in the mixed inoculant containing all strains.

Symbiotic effectiveness was evaluated by measuring plant growth and nodulation 5 to 6 weeks after planting, and yield was measured at maturity in relation to yields of uninoculated and nitrogen fertilized control treatments. Soil nitrogen content was very low at all locations (0.021 to 0.075% total N). The competitiveness of inoculated strains was evaluated by typing nodules, using an enzyme linked immunosorbent assay (ELISA) technique for strain identification.

At Samaru, although there were differences in nodulation between inoculation treatments, the uninoculated plants had the highest nodule mass (Figure 16). Results of nodule typing showed that inoculated strains were less competitive than indigenous strains. Inoculation had no significant effect on yield (Table 48).

At Maradi plant growth was poor because of inadequate soil moisture. Total rainfall in 1982 was 285.8 mm, almost 40% less than the mean annual rainfall for the past eight years. Nodulation and yield were greater in TN 88-63 than VITA-7, indicating that the former is more adaptable to the environmental conditions at Maradi (Figure 16 and Table 48). Inoculating plants did not significantly affect nodule mass (Figure 16). Inoculated strains were not competitive with indigenous strains for nodulation of either cowpea host cultivar (Table 49). Inoculation reduced the number of nodules per plant, and inoculated plants produced the same yield as uninoculated ones, suggesting that the inoculated strains may be symbiotically more effective than indigenous rhizobia.

At Kamboinsé soil moisture was not limiting. The yield of VITA-7 was higher there than at the other locations, and the check, SUVITA-2, outperformed the checks used at other locations (Table 48). *Rhizobium* strain IRc 252 was highly competitive with indigenous rhizobia for nodulation of both cultivars (Table 49). IRc 430A was moderately competitive. As at Maradi inoculated plants produced less nodule mass than uninoculated ones (Figure 16), yet differences in plant growth and yield between inoculated and uninoculated treatments were not significant (Table 48).

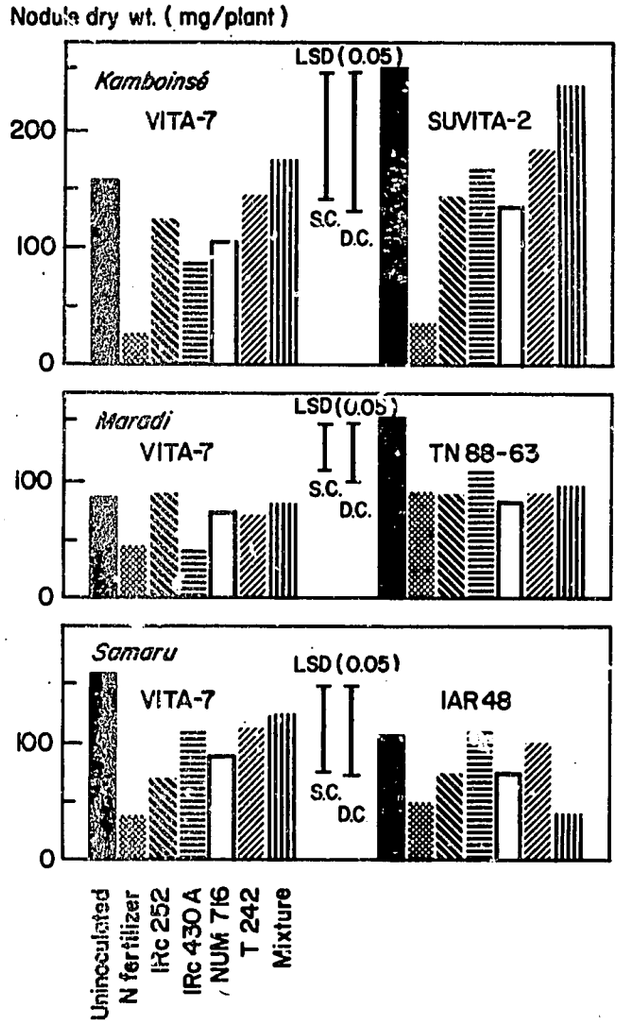


Figure 16. Effect of inoculation on nodulation of cowpea cultivars at locations in West Africa. The mixture contained equal proportions of the four strains. S.C. and D.C. are the values for comparing means of the same and different cultivars, respectively.

Since 1979 we have isolated, screened and selected effective and competitive rhizobia from diverse environments, and these have now been used in

Table 48. Yield of cowpeas at three locations in West Africa, 1982

Treatment	Samaru, Nigeria		Maradi, Niger		Kamboinsé, Upper Volta	
	VITA-7	IAR 48	VITA-7	TN 88-63	VITA-7	SUVITA-2
				kg/ha		
Uninoculated	1,090	610	330	1,040	2,000	1,980
N fertilizer	980	640	540	1,050	1,980	1,900
Inoculated:						
IRc 252	1,050	500	360	930	2,000	1,720
IRc 430A	830	570	360	1,180	2,050	1,720
NUM 716	1,140	630	330	1,000	2,090	1,990
T 242	820	460	230	1,200	2,210	1,660
Mixture	1,060	550	360	1,150	2,060	2,030
LSD (5%):						
Same cultivar	300		370		420	
Different cultivars	220		390		320	

Table 49. Proportion of nodules formed by inoculants in cowpea cultivars at three locations in West Africa, 1982

Inoculant	Samaru, Nigeria		Maradi, Niger		Kamboinsé, Upper Volta	
	VITA-7	IAR 48	VITA-7	TN 88-63	VITA-7	SUVITA-2
			percent			
IRc 252	41.2	7.1	43.3	9.5	88.2	90.0
IRc 430A	25.2	14.9	25.1	40.4	59.4	68.9
LSD (5%):						
Same cultivar	40.7		63.5		50.7	
Different cultivars	24.6		29.3		37.4	

Note: Nodules were collected five or six weeks after planting.

extensive field trials in West Africa (IITA, Annual Reports for 1979, 1980 and 1981). Based on that past work and this year's results, we draw the following conclusions concerning the use of *Rhizobium* inoculants with cowpeas in West Africa. First, rhizobia in West African soils nodulate cowpeas effectively and fix enough atmospheric nitrogen to support plant growth and produce good grain yields. Second, to increase symbiotic nitrogen fixation under the high temperature and drought stresses that frequently occur in West Africa, it is necessary to find highly effective *Rhizobium* strains that combine tolerance to desiccation and high temperature with superior competitiveness for nodulation. Third, alternative methods of inoculation that are more suitable to dry soil conditions are required if rhizobial inoculants are to be used.

Inoculation Methods

Highly effective rhyzobia are useless unless, when inoculated under farm conditions, they survive in the soil and infect the roots of the host plant. In addition to intrinsic characteristics of the inoculum, such as competitiveness against native rhizobia and tolerance to adverse environmental factors, the form of inoculum has a major effect on the survival and overall effectiveness of inoculated strains.

Results of past experiments showed that seed inoculation with peat powder based *Rhizobium* may not provide sufficient rhizobia for maximum infection. Therefore, a preliminary experiment was conducted at Maradi, Niger, to test the effectiveness of two inoculation methods at two soil fertility levels. Rhizobia were inoculated either by coating seeds with peat based inoculum (peat inoculant) or by adding a peat granule based inoculant to the soil underneath the seed (granular inoculant). Peat inoculants require that seeds be inoculated prior to sowing and also require special handling during sowing. Granular inoculants combine greater effectiveness with convenience of handling under field conditions; above all, they provide greater numbers of rhizobia per seed than powdered peat.

Two fertility levels were established by either adding 75 kg of single superphosphate per hectare, a common practice among farmers in the area, or adding 400 kg of single superphosphate, muriate of potash and other fertilizers, including micronutrients and farmyard manure (high fertility). Two *Rhizobium* strains, IRc 252 and 430A, were used as single strain inoculants. Both were found to be superior, based on their performance under field conditions (IITA, Annual Report for 1981). VITA-7 and a local cultivar, TN 88-63, were the host cultivars; shoot growth and nodulation at six weeks after planting and yield at maturity were compared to that of uninoculated treatments, with and without N fertilizer. Nodules were analyzed by ELISA to evaluate competitiveness of inoculated *Rhizobium*.

Hot, dry soil conditions at sowing reduced germination considerably, causing plant stands to be generally poor. These stresses were favorable, however, for studying the survival of inoculated strains. Shoot growth and yield of TN 88-63 responded significantly to chemical nitrogen under low fertility (Figure 17 and Table 50). Nodulation did not respond to inoculation (Figure 18). Under high fertility growth and nodulation of TN 88-63 were improved. Inoculation did not improve nodule mass, compared to that of uninoculated plants, but *Rhizobium* strain IRc 252 improved the yield of TN

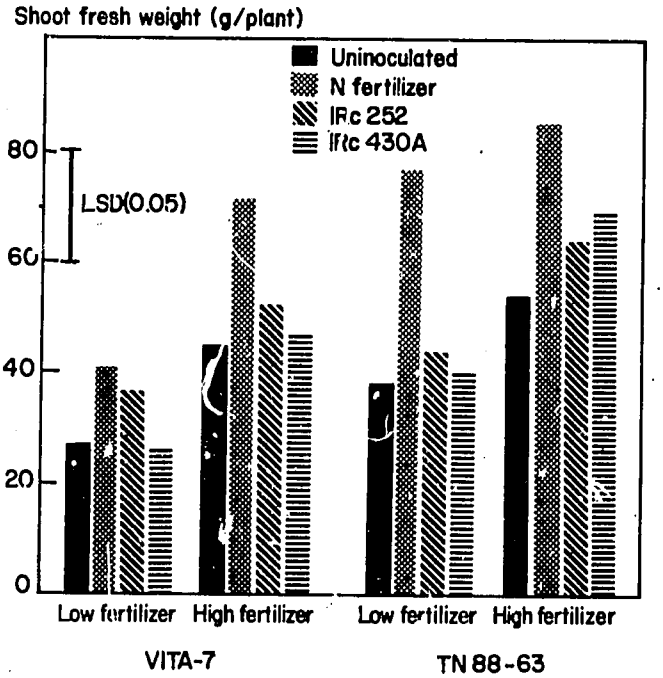


Figure 17. Plant growth of cowpeas at different soil fertility levels, Maradi, Niger, 1982.

88-63 at high fertility, indicating its greater symbiotic effectiveness.

Growth of VITA-7 was adversely affected by environmental stresses, but yields were improved under high fertility (Table 50). Inoculation, however, had no significant effect. Granular inoculants increased the proportion of nodules formed by IRc 252 on VITA-7 (Table 51). Nodulation by IRc 430A on TN 88-63 was also improved by granular inoculant under low fertility. High fertility decreased the competitiveness of the granular form of IRc 430A inoculant. The unexpected drought this year severely reduced plant establishment and growth, thereby preventing full evaluation of the effects of fertility level and inoculation methods. This trial will be repeated.—*S. Asanuma and A. Ayanaba*

Populations Sizes of Cowpea and Soybean Rhizobia

Variation in the population sizes of rhizobia that are capable of nodulating cowpeas and two soybean cultivars with different symbiotic promiscuities was assessed in 1980 at three locations (IITA, Onne and Maradi) that represent diverse soil types and climates. IITA in southwestern Nigeria represents the rainforest-savanna transition zone, where the soils are predominantly Alfisols. At Onne, located in southeastern Nigeria in the rainforest zone, the soils are Ultisols with low Ca, high acidity, high exchangeable aluminium and high rainfall. The soil at Maradi, Niger, in the Sahel savanna is sandy, low in N and available P and Ca, and subject to extremes of temperature and prolonged drought.

Soil samples were collected at depths of 0 to 5 cm, 5 to 15 cm and 15 to 30 cm at planting time, six weeks after planting and at the end of the dry season in fields cropped to cowpeas during the rainy season and in uncultivated fields adjacent to the cropped area. Rhizobia were enumerated by the most probable number (MPN) method for microbial populations with 10-fold dilution series and five replicates per dilution. The plant infection test was used in growth pouches containing Jensen's solution. Cowpea cultivar ER 1 was used to enumerate cowpea rhizobia, the American soybean cultivar TGm 80 (Bossier) for *Rhizobium japonicum*, and soybean cultivar TGm 344 to enumerate rhizobia that nodulate soybeans with symbiotic promiscuity.

IITA soils contained significantly more rhizobia than those at Onne and Maradi (Table 52). Low rhizobia numbers at Maradi and Onne account partly for poor nodulation and corroborate our earlier observation (IITA, Annual Report for 1979) that the cowpea-*Rhizobium* symbiosis is less effective at those locations. Because there were less than a thousand rhizobia per gram of dry soil at Maradi, this location should be suitable for cowpea and soybean inoculation experiments, and there should be minimum competition between inoculum rhizobia and the native populations.

Table 50. Yield of cowpea cultivars grown at different fertility levels, Maradi, Niger, 1982

N source	VITA-7 Low fert.	VITA-7 High fert.	TN 88-63 Low fert.	TN 88-63 High fert.
		kg/ha		
Uninoculated	370	650	760	1,040
N fertilizer.....	610	650	1,000	1,200
Inoculated with:				
IRc 252	450	550	820	1,410
IRc 430A.....	400	630	960	1,180
LSD (5%).....		220		

Table 51. Proportion of nodules formed on cowpeas by different *Rhizobium* strains at two fertility levels, Maradi, Niger, 1982

Inoculant form	VITA-7 Low fert.	VITA-7 High fert.	TN 88-63 Low fert.	TN 88-63 High fert.
IRc 252		*percent*		
Powder.....	0.8	0.0	0.5	2.3
Granule	27.3	26.0	7.5	16.1
IRc 430A				
Powder.....	14.1	8.8	10.5	13.0
Granule	11.3	7.7	36.2	18.6
LSD (5%).....		16.8		

Note: *Rhizobium* strains were inoculated as peat and granular inoculants. Nodules were collected five to six weeks after planting.

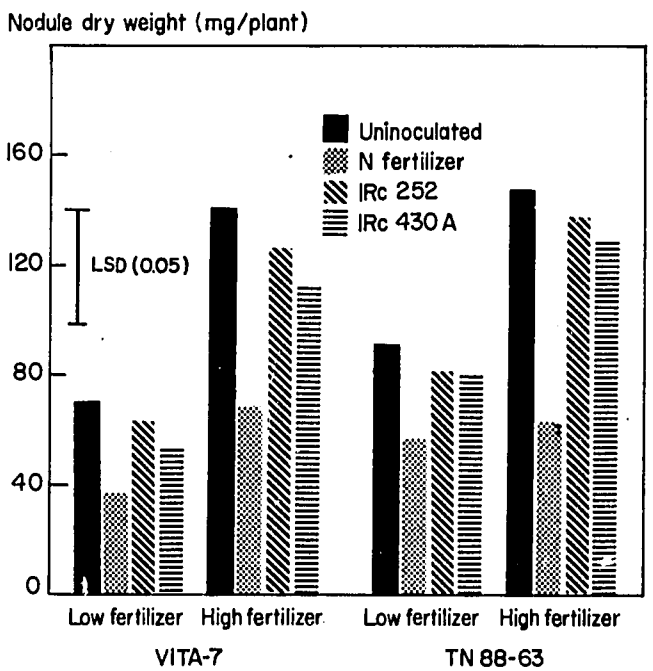


Figure 18. Nodulation of cowpeas at different soil fertility levels, Maradi, Niger, 1982.

Numbers of rhizobia, especially of cowpea rhizobia in the root zone (0 to 15 cm) six weeks after planting, were significantly higher in fields cropped to cowpeas (Table 52). It thus appears that cowpeas build up the population of compatible rhizobia in the rhizosphere.

Samples collected at a depth of 5 to 15 cm contained more cowpea rhizobia than those from the surface soil (0 to 5 cm), especially at IITA, where the cowpea rhizobia were approximately three times more numerous in samples from 5 to 15 cm deep than in samples from 0 to 5 cm (Table 52). This difference was expected since the surface soil layer (0 to 5 cm) is subjected to various deleterious changes in temperature and moisture. There were few rhizobia in samples collected at a depth of 15 to 30 cm, and seasonal variation in rhizobia counts in that soil layer was always significant.

Differences in *Rhizobium* populations were highly significant, the cowpea rhizobia being 10 times more numerous than the promiscuous rhizobia (so called for their ability to infect soybean cultivars exhibiting symbiotic promiscuity). *R. japonicum*, which is specific for the American soybean cultivars, had the smallest population at all three locations, confirming that American soybean cultivars must be inoculated with elite strains of *R. japonicum* in tropical soils.

The investigation of the size and seasonal variation in *Rhizobium* populations in Maradi soils was continued during 1981 and completed this year. The annual rainfall in Maradi in 1981 was 412.9 mm, distributed over the period from May to September. The maximum daily temperature was 43°C from 19 to 21 April, and the annual mean temperature was 27.2°C.

Soil samples were collected from fields cropped with cowpeas and under natural fallow. Fields were sampled during the dry season (29 April), at the beginning of the cropping season (9 July), during the season (27 August) and at the end of the season (30 September). Rhizobial populations were enumerated by the MPN method, using plastic pouches for the plant infection test. The cowpea cultivar VITA-7 and the soybean cultivars TGm 119 and 294-4 were used as hosts for cowpea rhizobia, promiscuous rhizobia and *R. japonicum*, respectively.

Populations of cowpea rhizobia were the largest throughout the year and those of *R. japonicum* the smallest (Table 53). Rhizobial numbers, especially of cowpea and promiscuous rhizobia, were high in the surface layer of the soil (0 to 15 cm). Population densities of those rhizobia increased slightly at all depths in both fields at the beginning of the cropping season and were retained throughout the season, particularly in the upper layer of the soil (0 to 15 cm). This increase could have been caused by higher soil

Table 52. Variation in population sizes of cowpea and soybean rhizobia according to location, cropping and soil depth, 1980

	Rhizobium group			
	Cowpea rhizobia	*R. japonicum*	Promiscuous rhizobia	Mean
	number per gram of dry soil			
Maradi, Niger	780	4	208	331
Onne, Nigeria	6,314	3	871	2,396
IITA	24,162	134	1,949	8,748
Mean	10,419	47	1,009	
LSD (5%) for:				
Locations	5,264			
Rhizobium groups	5,264			
Interactions	9,118			
Cropped to cowpeas	18,913	92	1,395	6,800
Uncultivated	1,924	2	623	850
LSD (5%) for:				
Fields	4,298			
Rhizobium groups	5,264			
Interactions	7,445			
Soil depth				
0 to 5 cm	9,706	9	1,509	3,741
5 to 15 cm	20,137	130	1,430	7,232
15 to 30 cm	1,413	2	89	502
LSD (5%) for:				
Soil depths	5,264			
Rhizobium groups	5,264			
Interactions	9,118			

Note: The numbers listed for cropping and soil depths are averages for all three locations.

Table 53. Seasonal variation in population sizes and in spatial distribution of indigenous rhizobia, Maradi, Niger, 1981

	Rhizobium			Depth, cm			
	Cowpea	Promiscuous	*R. japonicum*	0 to 5	10 to 15	25 to 30	Total
During dry season							
Cropped	2,483	840	19	604	2,093	645	3,342
Uncropped	<401	<66	<24	<6	427	58	<491
Beginning of cropping season							
Cropped	5,569	3,686	<6	2,823	4,856	1,582	9,261
Uncropped	—[a]	—	—	—	—	—	—
During cropping season							
Cropped	2,544	—	<6	1,023[b]	1,355[b]	172[b]	2,550[b]
Uncropped	2,675	1,117	<8	641	2,264	895	3,800
End of cropping season							
Cropped	<174	<115	<6	100	189	<6	<295
Uncropped	680	36	<50	134	179	453	766

Note: Population sizes are cell numbers per gram of dry soil.
[a]Not determined.
[b]Sum of population sizes of cowpea rhizobia and *R. japonicum* only; other totals are for all three groups of rhizobia.

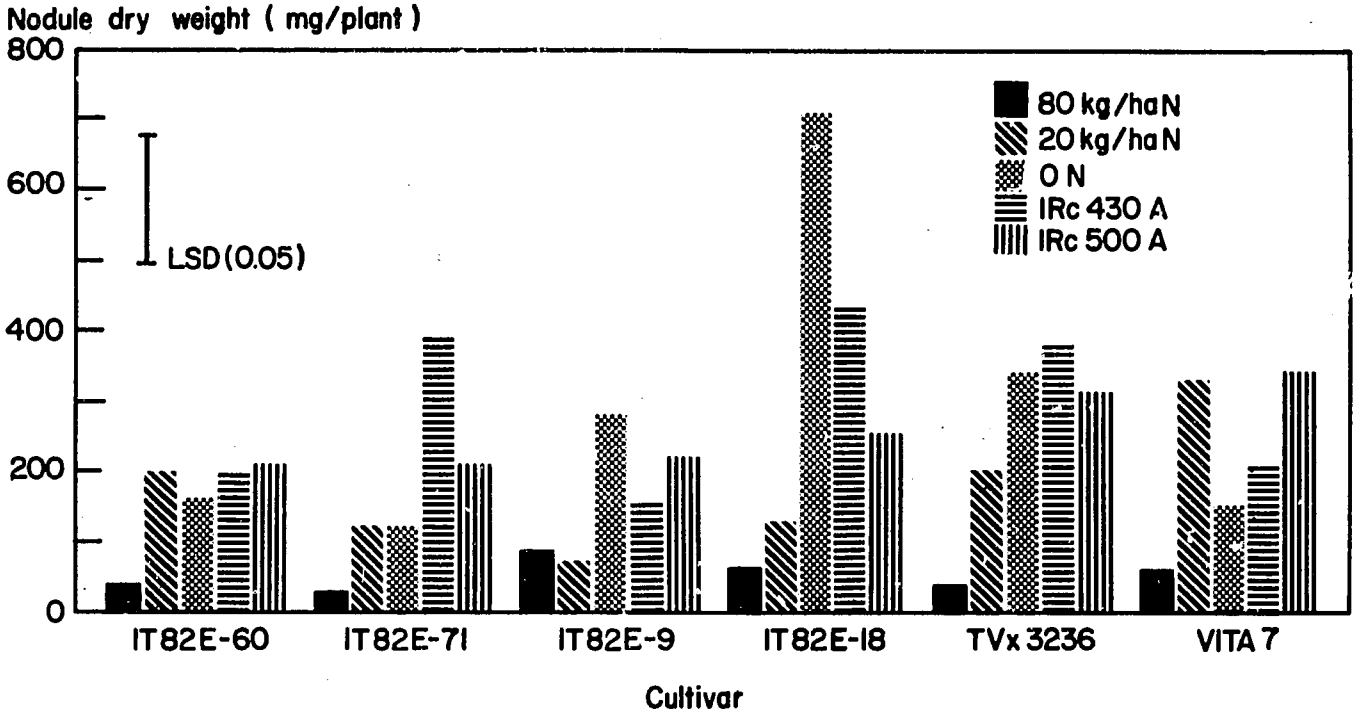


Figure 19. Effect of nitrogen source on nodulation of early maturing and intermediate maturity cowpea cultivars at six weeks after planting, IITA, 1982.

moisture content, lower temperatures, and addition of organic materials from increased plant growth. Little difference in spatial distribution and seasonal variation was observed for *R. japonicum*. The enumeration of indigenous rhizobia in Maradi soils during 1982 is in progress.—*S. Asanuma, A. Ayanaba and K. Mulongoy*

Effect of Nitrogen Fertilizer and Rhizobium Inoculation on Cowpeas

Four early maturing cultivars, TVx 3236 and VITA-7 were grown either with *Rhizobium* inoculation or with urea N to test the ability of inoculated strains to improve early nodulation and yield of symbiotic plants and to determine the effects of starter N (20 kg/ha). We tested inoculants from two single strains, IRc 430A and IRc 500A. In laboratory and greenhouse trials, both showed superior ability to form early, effective symbioses with cowpeas.

Four weeks after planting, inoculation with IRc 430A and IRc 500A significantly increased nodule number and dry weight in all cultivars compared to that of uninoculated plants. Growth of plants inoculated with IRc 430A was comparable to that with the highest N treatment, although IRc 500A reduced growth, compared to that of the uninoculated treatment.

Six weeks after planting, shoot growth in all treatments was similar, and nodulation in uninoculated treatments had generally increased compared to that in inoculated treatments. Both N treatments, however, still depressed nodulation. There were significant differences between cultivars

Table 54. Effect of urea-N and inoculation with different *Rhizobium* strains on early maturing cowpeas, IITA, 1982

Treatment	Shoot dry weight 24 DAP,[a] g/plant	Nodule dry weight 24 DAP, g/plant	No. of nodules per plant 24 DAP	Ureide production 24 DAP	Ureide production 41 DAP
Uninoculated.	1.9	102.7	10	2.2[b]	3.0
20 kg N/ha . . .	1.8	49.3	6	2.0	3.4
80 kg N/ha . . .	2.1	52.8	7	2.7	3.6
Inoculated:					
IRc 430A . . .	2.1	145.5	14	2.9	4.2
IRc 500A . . .	1.4	131.7	15	2.4	3.5
LSD (5%)	0.4	36.6	4	0.4	0.6

[a]Days after planting.
[b]Ureide production was measured by a simple colorimetric spot test, which qualitatively estimates allantonate levels in the plant on a scale of 0 to 6, corresponding to 0 to 64 mM Na-allantonate.

in nodulation by indigenous and inoculated strains (Figure 19). Nodule dry weights in IT 82E-18 were greatest in the uninoculated treatment; IRc 430A significantly increased nodulation of IT 82E-71; and IRc 500A increased nodulation of VITA-7. Nodule dry weight correlated well with nodule number ($r = 0.79$). Plant growth was affected by drought throughout the experiment, and as a result yields were low. Cultivars IT 82E-60, 82E-71 and 82E-9 averaged 475 kg/ha; IT 82E-18, TVx 3236 and VITA-7 averaged 950 kg/ha.

A spot test for ureide production was done four and six weeks after planting (Table 54). Ureide levels in all cultivars rose over that period. In both spot tests, inoculated plants, especially those inoculated with

IRc 430A, had higher ureide levels than either the uninoculated or 20 kg N/ha treatments. But in plants given 80 kg N/ha ureide, production was comparable to that in well nodulated plants, even though fertilizer N greatly reduced nodule number and weight.

Rhizobium strain IRc 430A increased early nodulation and initial growth of early maturing cowpeas. Plants inoculated with it had similar growth four weeks after planting and about the same yield at harvest as plants given 80 kg N/ha and showed high ureide production. Further studies need to be carried out under nonlimiting conditions.—*S. Asanuma, A. Ayanaba and B.B. Singh*

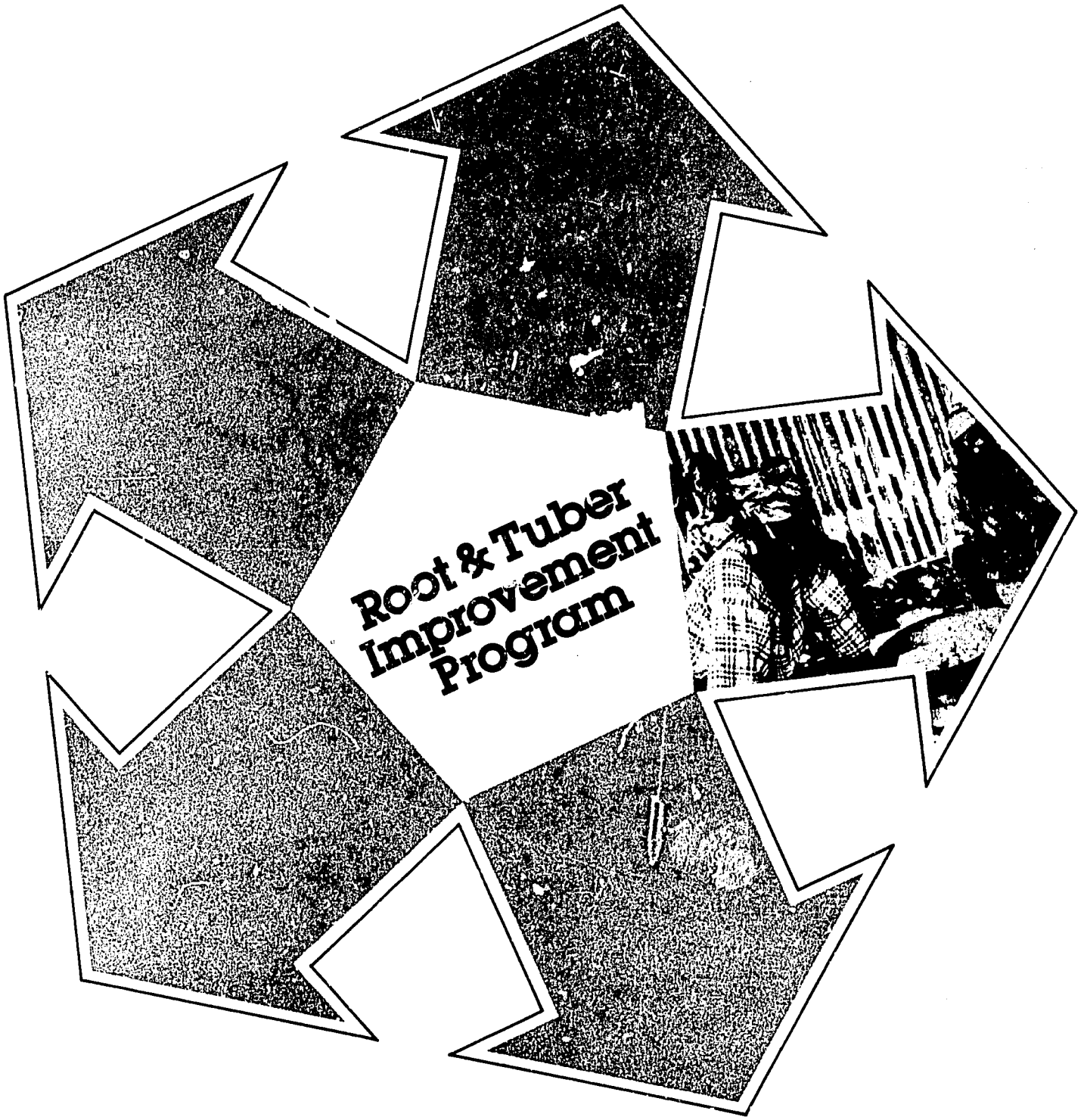
Studies on a Cowpea Cross-Inoculation Group

In continuation of studies on population sizes of cowpea rhizobia in soils at IITA and Fashola, Nigeria (IITA, Annual Report for 1981), rhizobial isolates were physiologically characterized, and inoculation trials were conducted to evaluate the symbiotic effectiveness of those isolates under field conditions at the two locations.

Acid tolerance (measured by ability to grow on agar plates at pH 4.5) was influenced by temperature, phosphorus level, and strain origin. A higher proportion of isolates from grain legumes (72%) than from forage legumes (36%) were acid tolerant, particularly those from IITA. Acid sensitivity was increased by increasing temperatures from 30° to 37° C, and lowering phosphorus levels from 1,000 to 5μM. The low P treatment is representative of P levels commonly found in the soil solution. Of the 98 isolates tested, 29% were tolerant of low P at pH 4.5.

Three grain legumes (cowpeas, groundnuts and pigeon peas) and three forage legumes (*Centrosema*, *Leucaena* and *Psophocarpus palustris*) were inoculated with isolates from each legume grown in the field at IITA and Fashola. Uninoculated treatments with and without nitrogen fertilizer were included. At both locations, *Leucaena* did not nodulate with isolates from other legumes or with native rhizobia, whereas nodulation and effective symbioses in other legumes did occur with any of the isolates tested and with indigenous rhizobia. Cowpea yield at IITA was improved by N fertilization and by inoculation with a cowpea rhizobial isolate. The growth of forage legumes at Fashola was much poorer than at IITA. Further studies of soil fertility are in progress.

The residual effects of the *Rhizobium*-legume symbiosis on soil fertility were measured by growing maize after harvesting the legumes. Maize growth was greatest following cowpeas or groundnuts. Nodule typing to evaluate competitiveness and survival of inoculated strains is in progress.—*A. Ayanaba and M. Mafuka*


Root & Tuber
Improvement
Program

THE ROOT AND TUBER Improvement Program (TRIP) is engaged in the improvement of four root crops—cassava, yams, sweet potatoes and cocoyams—that are basic in the diet of most people in the less developed tropical nations. These crops are the main source of food for the rural and urban poor (although crops such as yams are often the preferred food and command a premium price) and production of them is the main livelihood of many small scale farmers. Improvement in production would thus greatly benefit both producers and consumers.

The ultimate goal of TRIP's scientific team is to develop improved varieties that have pest and disease resistance, produce high and stable yields, give superior economic returns to the producer, and have good consumer acceptance. An essential part of the scientists' work is to transfer this technology to farmers by training scientists from national programs and by providing close and continuous support. In 1982 the program made significant progress both in crop improvement and technology transfer.

Cassava

Cassava, because of its importance in the African diet and its social and economic significance, continued this year to receive highest priority. The most pressing problems with this crop at present are the mealybug and green spider mite, which are causing devastating crop losses all across Africa. We are hopeful that these losses can be checked through a combination of biological control and breeding of resistant varieties.

Success in mass culturing and field establishment of natural enemies of the mealybug has justified projects for large-scale rearing of these enemies and distribution of them on the ground and by aerial drop if this method proves to be feasible. Since distribution will be done in cooperation with national programs, much emphasis is being placed on training of nationals in biological control methodology.

High priority is also being given to incorporation of resistance to the mealybug and green spider mite into cassava varieties that already have genes for resistance to cassava mosaic disease and cassava bacterial blight as well as good agronomic quality.

Other important projects in cassava research are the screening of germplasm for resistance to anthracnose disease and tuber improvement work aimed at reducing HCN content and improving starch quality.

Genetic Improvement

Since the beginning of IITA's cassava breeding program in 1971, significant progress has been made in developing high yielding varieties with resistance to both cassava mosaic disease and bacterial blight (Figure 1). These improved varieties are undergoing yield trials at various locations in Nigeria and are being sent in both seed and tissue culture form to national programs in Africa for multiplication and distribution to farmers.

Variety Trials

Yield trials of 12 IITA improved varieties were conducted without fertilization at three locations in Nigeria—Onne, IITA and Mokwa—that represent a wide range of environmental conditions. Onne is located in the high rainfall zone and has sandy, poor soil; Mokwa is in the dry savanna; and IITA represents the region of moderate rainfall and soil fertility. Trials of common cassava varieties were discontinued at these locations this year because of an outbreak of cassava green spider mite (CGM) and cassava mealybug (CM).

TMS 50395 performed outstandingly at all locations, producing the highest average fresh yield (26 t/ha), followed by TMS 40081, TMS 4(2)0267 and TMS 50207. TMS 50395 yielded more than 4.6 times the yield of the standard variety, 60506, which was formerly the best Nigerian variety and was used as a parent at the outset of IITA's breeding program. TMS 30337 and TMS 4(2)0267 performed well under high rainfall, sandy soil conditions. The IITA improved varieties outyielded the standard variety at all locations.

TMS 50395 also showed resistance to both cassava mosaic disease (CMD) and cassava bacterial blight (CBB) as well as tolerance to both CGM and CM. The

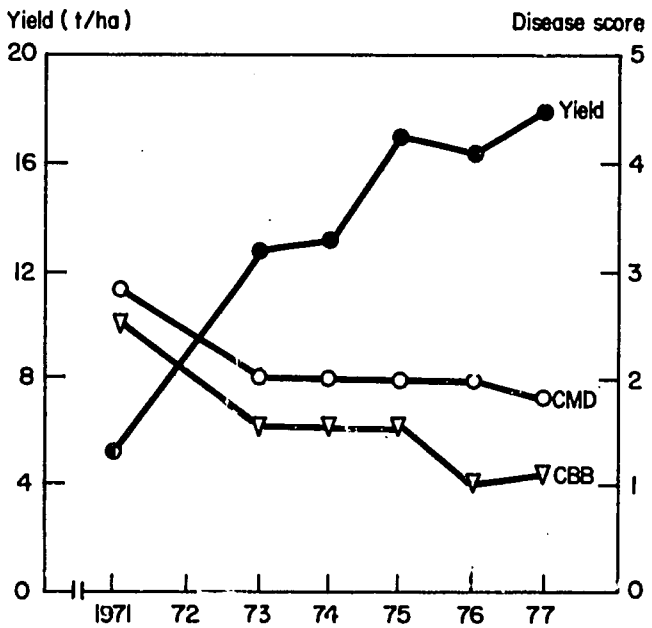


Figure 1. Mean yield and disease resistance scores of improved varieties since the beginning of IITA's cassava improvement program.

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Tables 1. Performance of cassava varieties at various locations in Nigeria, 1981–82

Variety	Fresh yield, t/ha				Percent dry matter	Dry yield t/ha	Disease resistance[a]		Pest resistance[a]		Gari quality[b]	Garification rate, %
	IITA	Mokwa	Onne	Avg.			CMD	CBB	CGM	CMB		
TMS 50395	27.3	32.0	18.4	25.9	25.5	6.6	1.8	1.7	2.0	2.0	G	16
TMS 40081	20.1	13.8	14.4	16.1	26.9	4.3	1.9	1.4	4.0	2.0	G	15
TMS 4(2)0267....	12.1	14.5	19.4	15.3	32.1	4.9	2.0	1.4	2.5	2.3	G	20
TMS 50207	18.5	11.2	16.0	15.2	25.8	3.9	2.1	1.7	3.3	2.5	VG	18
TMS 30337	17.4	5.0	20.7	14.4	25.8	3.7	2.3	1.7	3.8	2.0	M	16
TMS 30001	14.4	15.5	11.8	13.9	29.1	4.0	1.8	1.6	4.0	2.5	G	21
TMS 30211	12.3	12.0	14.6	13.0	26.8	3.5	1.9	1.5	3.8	2.2	G	14
TMS 30572	16.6	7.1	14.3	12.7	30.1	3.8	2.0	1.7	3.3	2.0	VG	19
TMS 30555	10.1	15.9	11.0	12.3	28.6	3.5	2.1	1.8	3.3	1.8	G	18
TMS 4(2)1443....	12.0	2.6	13.7	9.4	29.3	2.8	2.1	1.8	4.0	2.8	VG	21
TMS 50193	13.0	2.4	18.4	11.3	27.6	3.1	2.1	1.4	3.3	1.5	P	13
60506 (check)....	5.6	3.0	8.3	5.6	25.7	1.4	2.7	2.5	4.0	3.0	M	12
LSD (5%)	5.35	9.15	6.20	4.05	0.57	1.12	0.08	0.10	0.81	0.56		5.7
S.E.	1.86	3.17	2.15	1.44	0.20	0.39	0.03	0.04	0.28	0.19		1.8

[a]Resistance to cassava mosaic disease (CMD), bacterial blight (CBB), green spider mite (CGM) and mealybug (CMB) was rated on a 1 to 5 scale, where 1 = no damage and 5 = severe damage.
[b]Gari quality was rated as follows: VG = very good, G = good, M = moderate and P = poor.

quality of gari made from the tuberous roots of this variety was rated as good. The variety had a lower percentage of dry matter and a lower garification rate than did other IITA improved varieties. But its total dry yield was the highest of the varieties tested.

TMS 4(2)0267 had the highest average percentage of dry matter, 32.1%, followed by TMS 30572 with 30.1%. TMS 30001 (which had a lower cyanide content than the other varieties), TMS 4(2)1443 and 4(2)0267 had high garification rates, ranging from 20 to 21%. TMS 50207, TMS 30572 and TMS 4(2)1443 had very good gari quality (Table 1).

Multiplication and Distribution of Improved Varieties

During 1982 the highest yielding IITA variety, TMS 50395, and the CGM and CM resistant varieties TMS 4(2)1425 and TMS 60142 were multiplied on 20 ha in cooperation with the National Seed Service of Nigeria. The improved varieties will be supplied to state ministries and other public and private organizations in Nigeria for further multiplication and distribution.

Improved IITA breeding material in both seed and tissue culture form has been sent to many national cassava improvement programs in Africa for re-selection under their environmental conditions. Using this material, several national programs have developed and released their own improved varieties. The paragraphs below discuss some of the accomplishments of these programs this year.

Nigeria. Five improved varieties—TMS 30572, 30555, 30337, 30001 and 30211—have been rapidly multiplied and distributed to thousands of farmers through the National Accelerated Food Production Project (NAFPP), National Root Crops Research Institute, National Seed Service, state ministries of agriculture and private organizations. According to recent reports, these improved varieties are now planted on more than 80,000 hectares. They give farmers several advantages over the local, unimproved varieties: their yields are 50 to 300% higher and more stable because of their resistance to CMD and CBB; their more rapid canopy development speeds recovery from CM and CGM attack at the onset of the rainy season; they require only a third as much weeding; and they have better processing quality. Demand by farmers for planting material of these varieties was quite high in 1982 and is expected to increase in the years ahead.

Sierra Leone. The new varieties NUCASS 1, 2 and 3, yields of which range from 9.7 to 25.5 t/ha (two to four times the yield of the local variety Cocoa) were multiplied at five locations and distributed to local farmers with financial support from the U.S. Agency for International Development (USAID). In addition, a large quantity of select planting material was sent to Guinea.

Zaire. The National Manioc Program (PRONAM), which cooperates with IITA and is financed by USAID, has released two improved varieties—Kinuani (30085/28) and Kivuvu (30070/4)—that have performed well in multilocational tests in the last several years. Both were selected from IITA breeding material and are particularly resistant to CBB, which has caused severe yield reductions and unstable production in Zaire. Kinuani is also resistant to CGM. The two varieties, which have high consumer acceptance because of their good tuber and leaf quality, have been rapidly multiplied on a large scale and distributed to extension agencies and farmers.

Gabon. In 1981 and 1982, four improved varieties were increased by more than 400,000 cuttings and

distributed to several thousand farmers through extension agencies. During 1982 the government of Gabon sent planting material of the improved varieties, CIAM 76-6, 76-7, 76-13 and 76-33, to Congo, Equatorial Guinea and São Tomé. These varieties were selected from IITA breeding material that was introduced in Gabon through a Food and Agriculture Organization (FAO) project during 1976.

Rwanda. A large number of IITA improved breeding families were introduced in seed form in 1978. Selections were made based on the performance of these families in subsequent years. The 10 most promising clones are now being multiplied for distribution to farmers. Their yield potential is 20 to 50 t/ha, compared to 8 to 15 t/ha for local varieties. This work is being carried out by the Rwandan National Root Crop Improvement Program, which is financed by Canada's International Development Research Centre (IDRC).

Liberia. Three varieties--CARICASS 1, 2 and 3—have been released in this country. All were selected from IITA improved breeding material. Their yield potential is 30 to 50 t/ha; they are resistant to CMD; and their consumer acceptance has been rated as good. The Liberian cassava project is financed by IDRC.

Cameroon. The Cameroon National Root Crop Improvement Program (CNRCIP) has selected several promising clones from IITA breeding material under high rainfall and poor, sandy soil conditions and continues to evaluate others. The program cooperates with IITA and is financed by IDRC and Belgium's General Administration of Cooperation for Development (AGCD).

Pubescence in CGM Resistance

In the pubescent varieties TMS 60142 and TMS 4(2)1425, CGM resistance has been attributed to the tiny hairs on the leaves of young shoots. The former variety is both more pubescent and resistant than the latter. In order to clarify the relationship between the pubescence character and CGM resistance in the segregating families, nine crosses were made between pubescent types, between nonpubescent and pubescent types, and between nonpubescent types. During the dry season, when CGM is severe, individual plants in each family, some showing the pubescence character and others not, were evaluated subjectively for CGM damage on a 1 to 5 scale, with 1 being most resistant and 5 most susceptible. For each cross combination, the x^2 test was used to determine if CGM resistance scores depend upon the pubescence character. The results are summarized in Table 2.

The x^2 values were all highly significant for all crosses involving pubescent types, except the cross TMS 30572 × TMS 4(2)1425. This finding indicates that CGM resistance is associated with the pubescence character. The average scores of the pubescent segregants were lower than those of nonpubescent plants for all the crosses in which pubescent varieties were parents. The pubescent plants of families from crosses between pubescent types had the lowest average CGM scores, with 2.5 for TMS 60142 × TMS 60142 and 3.1 for TMS 60142 × TMS 4(2)1425. The nonpubescent plants of all crosses with pubescent parents also had high average CGM scores, ranging from 3.9 to 4.7 regardless of the cross combination, and their average scores were similar to those of the crosses between nonpubescent types.

These results suggest that pubescence is the primary character responsible for CGM resistance in the crosses tested. This character appears to be regulated by more than one gene, with a partial recessive effect. The genes responsible for pubescence were not in a homozygous state in the pubescent parents used. It could thus be concluded that pubescence is a heritable character and that CGM resistance can be improved by genetically incorporating the pubescence character into high yielding but CGM susceptible varieties.

Staff members of the Root and Tuber Improvement Program with agricultural workers from Togo visiting a successful Nigerian farmer who is growing IITA improved cassava varieties.

IITA improved cassava growing in a village near Ibadan.

Table 2. Relation between the pubescence character and CGM resistance in nine families of crosses between parents with varying degrees of pubescence, IITA, 1982

Cross and pubescence	CGM resistance score[a] 1	2	3	4	5	Total	Average score	X^2	Probability
Pubescent with pubescent types									
TMS 60142 × TMS 4(2)1425									
Present	0	16	23	10	6	55	3.1	34.6	$p<0.01$
Absent	0	0	2	7	18	27	4.6		
TMS 60142 × TMS 60142									
Present	0	6	4	1	0	10	2.5	21.9	$p<0.01$
Absent	0	0	0	5	10	15	4.7		
Nonpubescent with pubescent types									
TMS 30372 × TMS 60142									
Present	0	9	7	21	16	53	3.8	53.7	$p<0.01$
Absent	0	2	24	162	178	366	4.4		
TMS 30572 × TMS 4(2)1425									
Present	0	15	15	23	3	56	3.3	49.4	$p<0.01$
Absent	0	5	57	136	45	243	3.9		
TMS 30001 × TMS 4(2)1425									
Present	0	5	5	7	4	21	3.5	32.2	$p<0.01$
Absent	0	0	7	38	53	98	4.5		
TMS 30001 × TMS 60142									
Present	0	5	10	5	3	23	3.3	10.3	$p<0.05$
Absent	0	2	8	5	17	32	4.2		
TMS 30555 × TMS 4(2)1425									
Present	0	1	0	20	17	38	4.4	7.5	$p<0.25$
Absent	0	1	2	76	123	202	4.5		
Nonpubescent with nonpubescent types									
TMS 30572 × TMS 30001									
Present	0	0	0	0	0	0	—	—	—
Absent	0	0	0	20	25	45	4.6		
TMS 30572 × TMS 30555									
Present	0	0	0	0	0	0	—	—	—
Absent	0	0	2	13	21	36	4.6		

Note: The X^2 test was used to determine dependence between the pubescence character and CGM resistance scores.
[a]CGM resistance was rated on a 1 to 5 scale, where 1 = most resistant and 5 = most susceptible.

Effect of Drought Stress on CGM Resistance

During the dry season, CGM damage and drought stress were rated subjectively in plants of variety TMS 30572 planted along a contour under different soil moisture regimes. A total of 20 samples, each consisting of five plants, were taken at random in the field. CGM damage and drought stress were rated on a 1 to 5 scale, with 1 being the least and 5 the greatest damage. CGM damage scores were related to drought stress ratings with a correlation coefficient of $r = 0.76$, indicating that drought stress increased CGM damage.—*S.K. Hahn and E.M. Chukwuma*

Entomology

IITA's program for biological control of the cassava mealybug (*Phenacoccus manihoti*, MAT-FERR.) was continued more or less according to plans outlined in the IITA Annual Reports for 1980 and 1981. The principal activities of the program this year were to follow up on 1981–82 releases, make new releases, carry out mass culture of beneficial insects, explore for and introduce new natural enemy species, conduct detailed studies on the bionomics of CM and its exotic natural enemies, investigate host plant-insect interactions, and prepare for the Africa-Wide Project for Biological Control of Mites and Insect Pests in Cassava (AP-BC).

Both CM and CGM have continued to spread throughout the African cassava belt (Figures 2 and 3). At present, some 4.5 million ha are infested with one or both pests. The annual loss is currently estimated to be some $1,800 million, not including the leaf vegetable protein and planting material lost. The rapid spread of and tremendous losses caused by these pests have prompted IITA to speed up mass production of beneficial insects, which have shown promising results in natural enemy release trials, in preparation for the AP-BC.

Follow-up on Previous Releases of Natural Enemies

The methodology of these releases was described in the IITA Annual Report for 1981. Figure 4 compares the population density of CM in a field where natural enemies were released with that in a field without natural enemies over a cassava growing period of 17

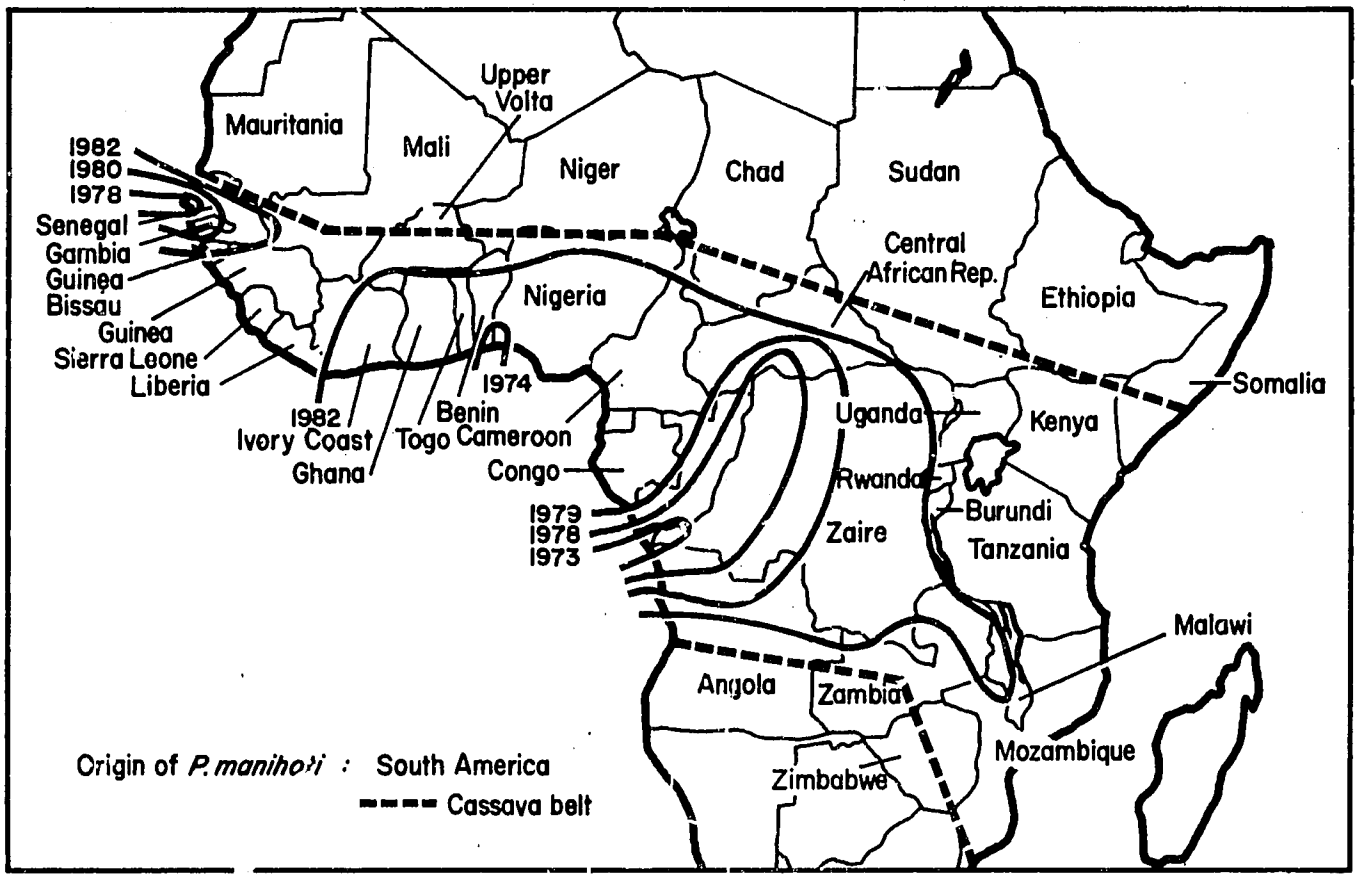


Figure 2. Spread of cassava mealybug (*Phenacoccus manihoti*) between 1973 and 1982.

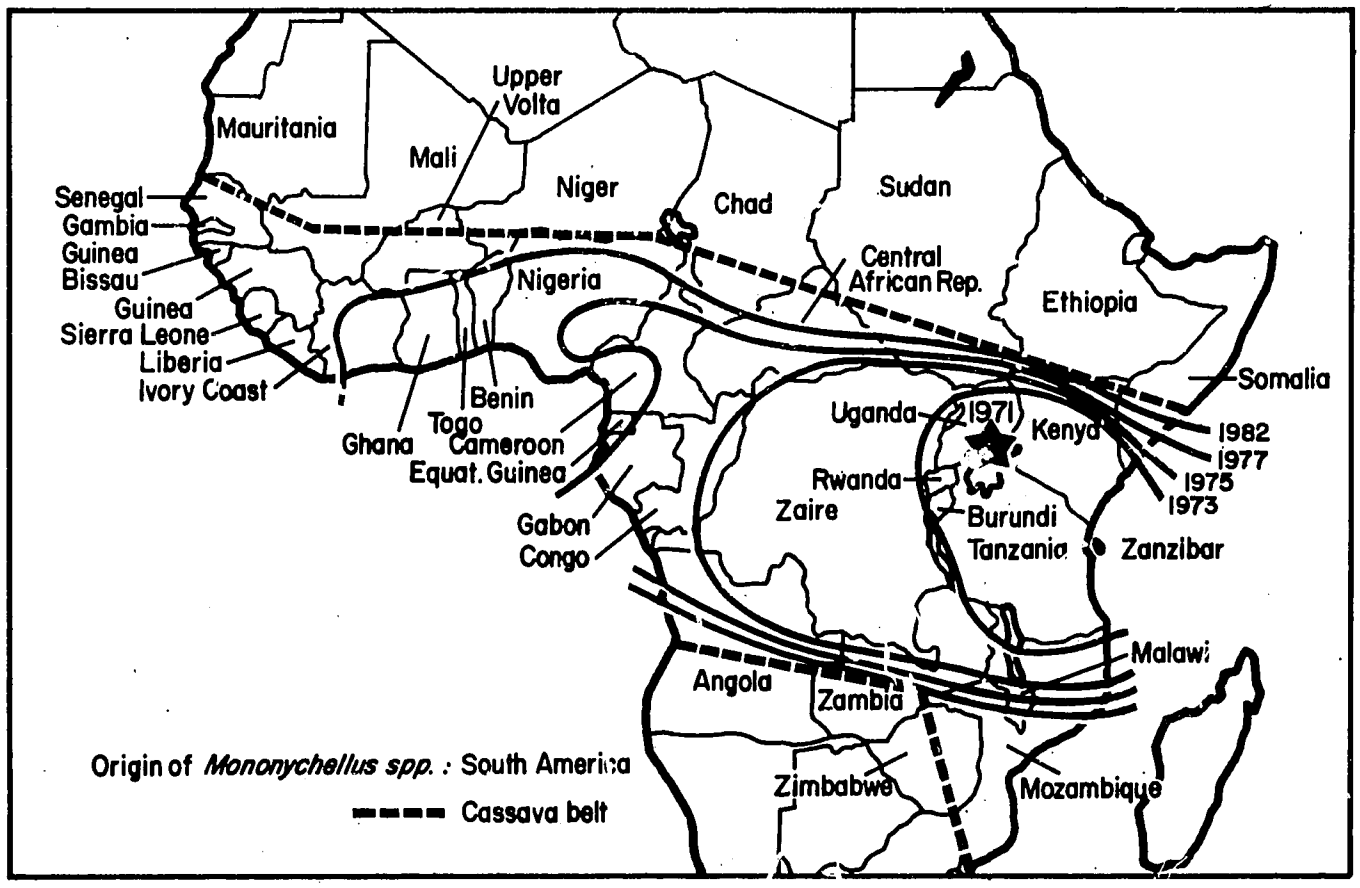


Figure 3. Spread of cassava green spider mite (*Mononychellus* spp.) between 1971 and 1982.

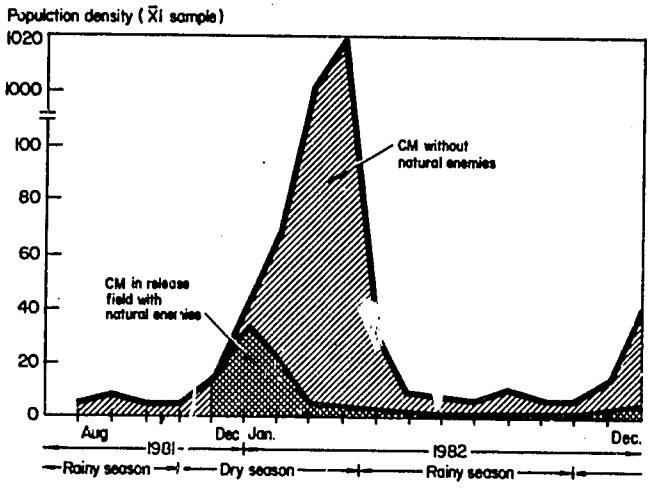


Figure 4. Population density of cassava mealybug with and without release of natural enemies, IITA, 1981–83.

months. The CM population in control fields increased drastically in March, but that in the release field dropped significantly within two months below the low level that is normal during the rainy season. From March 1982 through January 1983, the CM population remained at the very low level of 1 to 5 mealybugs (all instars) per terminal shoot, which is roughly half the usual, low, sustaining population density during the rainy season.

There has been a shift in the numbers of each natural enemy species present. From December 1981 to February 1982, *Scymnus* sp. was the predominant species, and *Apoanagyrus lopezi* occurred only in relatively small numbers. But between March 1982 and January 1983, *A. lopezi* became the predominant species. The first release experiment with *Scymnus* sp. and *A. lopezi* showed the difference in their potential for CM control. At high CM population densities, *Scymnus* sp. predominates, as is usual for coccinellidae. *A. lopezi*, although present when the CM population is high, provides most of the control after the CM population has been brought down from damaging levels to subeconomic levels. In future releases, only *A. lopezi* will be released where the CM population is low and both *Scymnus* sp. and *A. lopezi* where it is high.

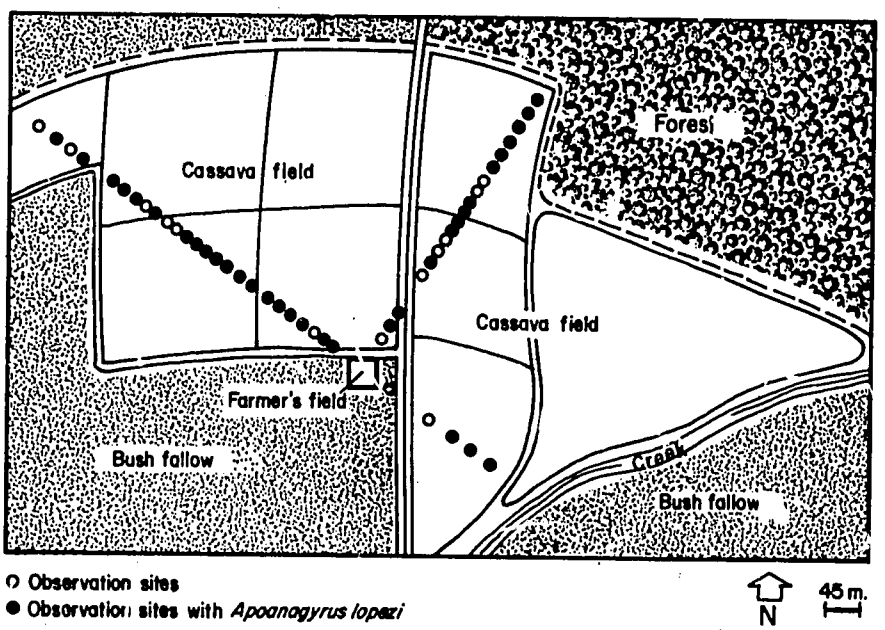
At IITA these two beneficial insects have spread as far as 2 km from the area of release within 12 months. Under farmers' field conditions, the natural spread might be reduced since fields are usually smaller and are surrounded by fallow land and/or forest. Natural enemies will be carried out of old fields into new ones on the cuttings to assure continuous control in every colonized clearing—*H.R. Herren and K.M. Lema*

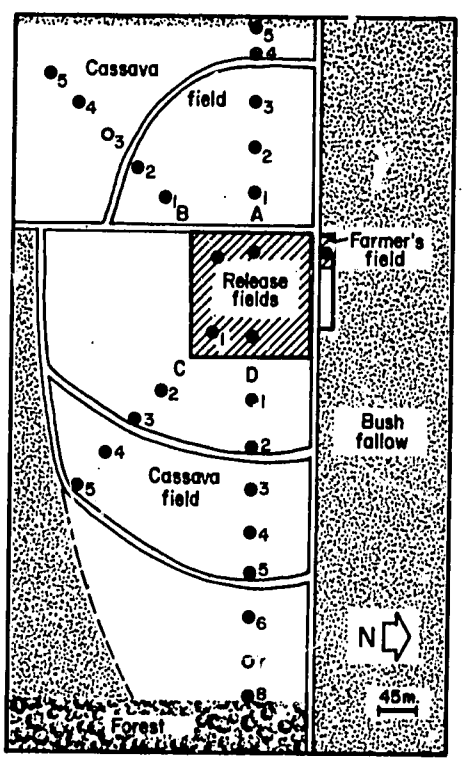
New Releases of Natural Enemies

From October to November 1982, releases of *Scymnus* sp. and *A. lopezi* were made in farmers' fields. In two plots (0.25 and 0.3 ha) at the Texagri farm in Abeokuta, Nigeria, the natural enemies got established within six weeks, and after only 8 to 10 weeks had practically eliminated CM from the field. They spread to neighboring fields until they were stopped by fallow land and forest, by which time they covered a total cassava area of 32.4 ha (Figure 5).

Natural enemies were released, either as adults carried to the field in petri dishes or as immature insects (with a few adults) on infested cassava plants. At Abeokuta, 1,500 adult *Scymnus* and 2,050 *A. lopezi* were released on three occasions, and an unknown

Figure 5. Dispersal of *Apoanagyrus lopezi*, an exotic parasitoid of the cassava mealybug, in two release fields near Abeokuta, Nigeria, 1982–83.





number of both species were released on infested plants discarded from the mass cultures.

Releases were also made in Zaire during July 1982 at four locations in Bas Zaire. *Scymnus* sp. and *A. lopezi* were reared at IITA and carried as adults to Zaire for these releases; the total number of insects released was 15,000. The beneficial insects are now expected to spread from the small, 1/10-ha release fields both passively (by means of cuttings or wind) and actively. It has been reported that both species are now established at one location near Kinshasa.

For 1983 experimental, large-scale ground and aerial releases are planned in several African countries. These tests should provide all the necessary information for releases in all CM and CGM infested areas included in the AP-BC.—*K.M. Lema and H.R. Herren*

Mass Culture and Release of Beneficial Insects

Three predator species, *Hyperaspis notata*, *Hyperaspis ?jucunda* and *Scymnus* sp., and one parasitoid species, *Apoanagyrus lopezi*, were mass multiplied throughout 1982. Because of limited space and rearing problems, only *Scymnus* sp. and *A. lopezi* were multiplied for release; the others were used for bionomics studies. The latter will be multiplied for release as soon as our new laboratory is available. It will contain five rooms 18 m^2, with 60 cages in each.

The rearing techniques used were host plant production, CM mass culture and mass culture of beneficial insects. Six weeks after planting of four two-to-three-node cuttings, the cassava plants reached the ideal infestation size. The young potted plants were placed in screened cages 40 cm × 50 cm × 60 cm and inoculated with first instar CM. After five to seven weeks, the CM population had built up to more than 1,000 per pot of four plants and was ready to be inoculated with natural enemies. The cage capacity was four to five pots. Upon emergence the beneficial insects were collected with aspirators, packaged in plastic vials or petri dishes with a supply of 10% sugar water or honey solution on blotting paper, and transported to the fields for release.

When CM population density is very low, as during the rainy season, whole potted plants are transported to the field. Each pot is placed under a cassava plant to allow parasitized, but not yet dead, mealybugs to crawl onto field grown cassava plants. It is not uncommon for some mealybugs to start reproducing and continue for a few days before they are killed by the parasitoid larvae. That they do so is particularly fortunate in areas where the CM population is low, because it guarantees that there will always be a few CM around to serve as host insects for natural enemies.—*H.R. Herren and K.M. Lema*

Exploration for New Natural Enemies

When it was discovered in 1981 that Paraguay and Bolivia are the natural home of *Phenacoccus manihoti*, exploration for natural enemies was concentrated in those countries. In 1982 two entomologists were stationed in Paraguay and have made collection trips there and in Bolivia.

Release of the parasitoid *Apoanagyrus lopezi* in Zaire.

Production of cassava plants in insect proof greenhouses for mass culture of mealybugs.

The exploration work has been very fruitful; so far 11 species of natural enemies have been found and identified: *Apoanagyrus lopezi*, *Anagyrus* sp., *Acerophagus* sp., *Hyperaspis notata*, *Olla V-nigrum*, *Scymnus* sp., *Diomus* sp., *Nephus* sp., *Chrysopa* sp., *Sympherobius* sp. and *Ocyptamus* sp. *A. lopezi*, *H. notata*, *Scymnus* sp., *Diomus* sp., and *Sympherobius* sp. have already passed through quarantine at the Commonwealth Institute of Biological Control (CIBC), London, and in Nigeria and are now being mass cultured at IITA for in-depth bionomic studies and for test releases. Many new species of natural enemies are expected to be found during new

explorations in Brazil. Since that country is most probably the center of origin of CM, the chances are good that the greatest diversity of natural enemies will be found there.—*H.R. Herren, B. Loehr and A.M. Varela*

Influence of Constant Temperatures on Population Growth of CM

Preovipositing cassava mealybugs from crawlers (first instar mealybugs) that had been used in life cycle studies were chosen for life table experiments. Potted cassava plants (of IITA clone 30001) were infested with crawlers, and four plants were placed in Conviron E15 growth chambers, each set at a different temperature (20°, 23.5°, 27° and 30.5°C) and a relative humidity of 65 to 75%, with a 12-h photophase. Twenty female mealybugs were placed in each chamber. After oviposition started each mealybug was observed every 24 h until it died. The eggs were removed with a camel hair brush and counted under a binocular microscope. Mortality of the immature stages was negligible.

Fertility and longevity data were used to construct the survival and fertility tables for particular ages and to calculate the following statistics: (1) x, the age of individuals in days; (2) l_x, the proportion of individuals still alive at age x; (3) m_x, female offspring per female (only female offspring are produced by *P. manihoti*); (4) gross reproductive rate or number of female eggs per average female, not taking into account survivorship; (5) net reproductive rate (R_0) or number of female progeny per female per generation ($R_0 = l_x m_x$); (6) r_m, intrinsic rate of natural increase calculated from the formula $\Sigma e^{-r_m x} l_x m_x = 1$; (7) generation time (T) or mean length of a generation from birth of parents to birth of offspring ($T = l_n R_0 / r_m$); and (8) finite rate of increase (λ) or multiplication per female per unit time ($\lambda = e^r m$).

Table 3 shows the influence of temperature on demographic statistics of the cassava mealybug. There was an inverse relation between adult longevity and temperature. The adult life span was highest at 20°C and decreased sharply as the temperature increased. Survivorship curves are shown in Figure 6. At each experimental temperature, all resemble Pearl's type I curve, with very little mortality at younger ages but increasing mortality as mealybugs get older. The time required for the population to reach 50% mortality (LT50), which also expresses the effect of temperature on longevity, was estimated from survivorship curves. This statistic also decreased with increasing temperature.

Except at 20°C the daily mean fertility (m_x) was highest on the first day of the reproductive period and declined thereafter (Figure 6). At 20°C daily fertility was highest on the second day of the reproductive period. The total mean fertility was highest (584.65 eggs per female) at 20°C and lowest (425.30 eggs) at 30.5°C. The oviposition period was greatly affected by temperature. It was longest (37.35 days) at 20°C and shortest (17.05 days) at 30.5°C (Table 3).

The different rates of population increase are also shown in Table 3. The gross reproductive rate reached a peak (695.02 eggs per female) at 23.5°C, whereas the net reproductive rate (R_0), which is the gross reproductive rate corrected for survivorship, reached its peak at 20°C. The mean generation time

Table 3. Effect of constant temperatures on demographic statistics of *Phenacoccus manihoti* reared on cassava, IITA, 1982

Statistics (X ± S.E.)	Temperature, C 20°	23.5°	27°	30.5°
Number of observations.....	20	20	20	20
Mean adult longevity, days...	38.40 (±1.78)	22.75 (±1.31)	19.95 (±0.87)	18.35 (±0.81)
No. of days until 50% mortality ...	37.5	21.5	19.0	19.0
Mean fertility, eggs per female ..	584.65 (±29.43)	571.55 (±42.28)	443.45 (±21.98)	425.30 (±25.88)
Mean oviposition period, days	37.35 (±1.81)	21.40 (±1.31)	18.60 (±0.83)	17.05 (±0.82)
Gross repro. rate, offspring fem.	656.20	695.02	482.77	458.97
Net reproduction rate, offspring/fem./generation ..	584.65	573.36	443.25	426.30
Innate daily rate of increase	0.114	0.169	0.185	0.182
Generation time, days	55.89	37.58	32.94	33.27
Finite rate of increase per week	2.21	3.26	3.65	3.45

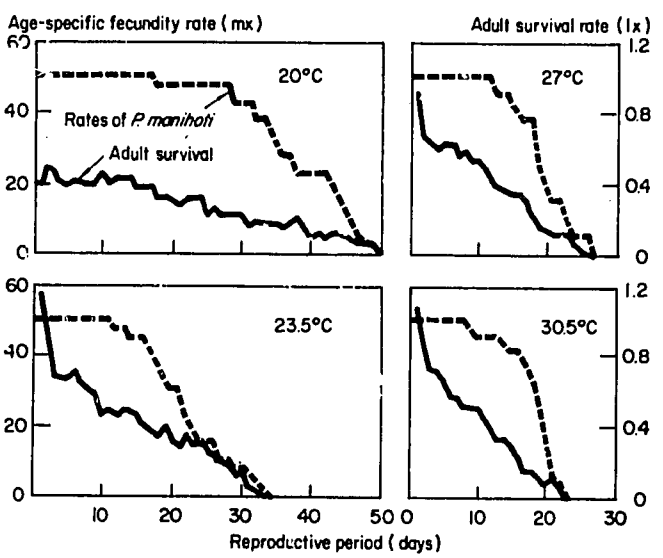


Figure 6. Effect of temperature on age-specific fecundity and adult survival rates of *Phenacoccus manihoti*, IITA, 1982.

was also inversely related with temperature but was higher at 30.5° than at 27°C. The intrinsic rate of increase was lowest (0.114) at 20°C and highest (0.185) at 27°C. The weekly finite rate of increase rose from 2.21 at 20°C to 3.65 at 27°C before decreasing to 3.45 at 30.5°C (Table 3).

The inverse relationship observed between adult longevity and temperature can be explained by the fact that longevity is generally inversely proportional to the intensity of life or metabolic rate of an insect. A higher rate of metabolism and activity at high temperatures causes the insect to reach senescence and die earlier than at low temperatures. Oviposition was maximum at 20°C because the adult life span is longest and the reproductive period is prolonged at that temperature.

The innate capacity for increase and other related statistics determined in laboratory studies are based on the assumption of an ideal environment that differs from natural situations. It is, therefore, difficult to apply laboratory results directly to field populations, which are under the influence of natural enemies, have limited food and space, and are exposed to adverse weather. This statistic is nevertheless a useful bioclimatic index that provides a good estimate of the maximum rate of increase a population can attain and of the range of temperatures within which a species can persist and increase in number.

The results of this experiment indicate that 27°C was the optimal temperature for population growth of *P. manihoti*; the highest value of r_m was observed at that temperature. The results also suggest that *P. manihoti* can persist and increase in number between 20° and 30.5°C; the value of r_m in that range was greater than zero. However, the decline in the value of r_m and the increase in the value of T at 30.5°C may indicate that constant temperatures above 30.5°C are unfavorable for development and population growth of the cassava mealybug. The net reproductive rate at those temperatures was high. This may explain the capacity of *P. manihoti* to build up its population rapidly to explosive levels in the field during the favorable dry season.—*K.M. Lema and H.R. Herren*

Bionomics of Two CM Predators

These bionomics studies are concerned with the developmental periods of the immature stages and with the fecundity and life span of the adults. Five-hour-old eggs from each of the two predators (*H. notata* and *Sympherobius notata*) were placed individually in separate petri dishes. Each egg was surrounded with ovisacs and other stages of CM. The petri dishes were then placed in Conviron Model E15 growth chambers under constant temperatures of 16.5°, 20.0°, 23.5°, 27.0°, 30.5° and 34°C and a fluctuating temperature of 22° to 30°C (Φ26.8). Daily observations were made on the various developmental stages of the three predators.

This research is still in progress. So far, data have been collected on the mean and range of developmental periods (Table 4), rate of development, lower temperature threshold and thermal constants required to complete the development of each stage. We also have data on the daily oviposition rate, fecundity and fertility, gross and net rate of reproduction, instantaneous and finite rate of increase, and generation time, which will be published upon completion of the research.—*H.R. Herren and H.D. Nsiama She*

Table 4. Mean duration of developmental periods of immature stages of cassava mealybug predators at various temperatures, IITA, 1982

	Constant temperature, C						Fluctuating temperature (22° to 38°C)
	16.5°	20.0°	23.5°	27.0°	30.5°	34.0°	
	days (number of individuals)						
Hyperaspis notata							
Egg	15.0(61)	10.2(75)	6.9(84)	5.0(24)	...[a]	0[b] (143)	6.4(73)
Instar 1	4.0(15)	3.8(15)	—[c]	2.0(20)	...	2.1(11)	—[c]
Instar 2	4.0(14)	2.5(15)	—	1.9(20)	...	1.7(8)	—
Instar 3	—[c]	3.1(14)	—	2.0(20)	...	2.3(3)	—
Instar 4	—	7.3(13)	—	4.5(20)	...	—[c]	—
Pupa	—	—[c]	—	10.3(20)	...	—	—
Egg to adult	—	—	—	21.1(20)	...	—	—
Sympherobius notata							
Egg	12.4(56)	8.6(71)	6.0(104)	...[a]	...[a]	8.0(115)[d]	7.0(44)
Instar 1	6.9(12)	4.0(15)	3.1(15)	...	...	2.5(14)	3.1(14)
Instar 2	4.6(11)	2.6	2.3(15)	...	...	2.3(12)	2.3(14)
Instar 3	—[c]	—[c]	8.0(14)	...	...	2.3(10)	8.6(10)
Pupa	—	—	9.8(12)	...	...	9.7(7)	
Egg to adult							

[a]Experiment not yet set up.
[b]100% mortality.
[c]Experiment in progress.
[d]First instar larvae were transferred at hatching from 23.5° to 34°C since freshly hatched larvae had 100% mortality at 34°C.

Host Plant-Pest Interactions

Research on host plant-pest interactions is of primary importance in biological control, or in any pest control program for that matter, because it establishes the time and manner in which the damage occurs, the plant's reaction to the damage, and the effect of this reaction on mite and insect pests and eventually on the natural enemies of those pests.

Understanding host plant-pest interactions better enables us to analyze the impact of biological control since it permits us to separate the effects of biotic and abiotic factors on yield losses. These losses depend not only on the pest's population density, but also on the plant's resistance to water stresses, its vigor, its age when attacked, the age structure of the pest population and other factors.

Because of the complexity of these interactions, mathematical models are being developed that will enable us to quantify and understand more clearly the interactions between the host plant, the pest insects, their natural enemies and the environment. These models can also be used to make control actions, such as release of natural enemies, as effective as possible.

The purposes of the research being undertaken are to develop a growth model for cassava, assess pest damage in relation to planting time, age of the plant when attacked and environment, and to develop a sampling plan for CM and CGM.

For development of the model, two varieties of cassava were selected—a glabrous variety, 30572, and a pubescent one, 60142. The varieties were planted on 15 July 1982 and 15 September and 15 April 1983, each in four plots, with 600 plants per plot (600 m^2 plus border rows). The treatments are: infestation before first branching, infestation after first branching, infestation after second branching and insecticide sprays to keep control plots insect free throughout the growing period.

For the phenology model, data on internode length and leaf size are being gathered weekly from 10 representative plants in the control treatment. In each of the four treatments, five plants are collected each month (roots, stem and leaves) for assessment of dry matter and of the number and distribution of CM. Every week soil samples are collected to determine the soil moisture. The climatological data for the experiment are taken from the IITA weather bulletin. This research is still in progress; the results will be published after completion of a one-year growing cycle.—*H.R. Herren and F. Schulthess*

Africa-Wide Project for Biological Control

Because such promising results have been achieved with the release of exotic natural enemies of CM at IITA, an Africa-wide project has been designed, and funds are now being sought for it. The International Fund for Agricultural Development (IFAD) has helped greatly in preparation for the five-year project. It will involve biological control of CM and CGM in the entire area over which the two pests have spread, which includes 4.5 million ha throughout the African cassava belt. The exotic natural enemies will be mass reared at IITA and released by air and from the ground in all countries requesting them. The project will also provide training in biological control practices for 56 entomologists.—*H.R. Herren*

Pathology

Etiology of Anthracnose

The objective of this study was to determine the role of *Pseudotheraptus devastans*, a sap feeding bug commonly found on cassava, and of *Colletotrichum gloeosporioides* f. sp. *manihotis* in severe outbreaks of cassava anthracnose disease (CAD).

The following treatments were applied to one-month-old plants of the clone TMS 30001: (1) inoculation by the inoculum (1×10^4 spores per ml) spray method, (2) inoculation followed by *P. devastans* feeding (three bugs per plant), (3) feeding followed by inoculation, (4) feeding alone, and (5) no feeding and no inoculation as a control. The plants were arranged in a completely randomized block design, with four replications (five plants per treatment). The percentage of cankers infected, length of the cankers and amount of defoliation were recorded for two weeks from the fourth day after plants were treated.

The control plants remained completely healthy throughout the period of observation. *P. devastans* feeding followed by *C. gloeosporioides* f. sp. *manihotis* inoculation and the reverse caused a significantly higher percentage of cankers to be colonized by the fungus than did other treatments (Table 5). Plants on which the fungus alone was applied showed no typical anthracnose cankers. When bug feeding

Table 5. Effect of *C. manihotis* inoculum and *P. devastans* feeding upon infected cankers on cassava plants, IITA, 1982

Treatment	Percentage of cankers infected after: 4 days	8 days	12 days	Length of cankers, mm[a]
P. devastans feeding alone	0.1	1.1	15.5	11.9
P. devastans feeding + *C. manihotis* inoculation	82.0	93.9	99.4	18.0
C. manihotis inoculation + *P. devastans* feeding	69.4	89.5	96.2	14.9
C. manihotis inoculation alone	0	0	0	0
Control	0	0	0	0
F ratio	383.4**	135.4**	274.1**	167.5**
LSD (5%)	1.6	6.3	3.6	2.8

**Significant at the 1% level.
[a]Each value is the mean of four replications and indicates the canker length four days after plants were treated.

occurred before inoculation, the cankers were longer than those of plants in which either the fungus was applied before bug feeding or *P. devastans* feeding was the only treatment.

At the end of the test, no significant difference was observed in defoliation between inoculation alone (80.5% defoliation), inoculation followed by feeding (80.8%), and feeding followed by inoculation (81.5%). With those treatments defoliation was, however, significantly higher than in the control (0%) and with *P. devastans* feeding alone (3.9%).

Fungal inoculum alone was not sufficient to explain the severe canker observed, since it occurred only when the inoculum was combined with *P. devastans*. The extreme severity of the disease is probably due to physiological alterations of tissues, some of which may play an important role in predisposing plants toward CAD infection.—*K.A. Muimba, M.O. Adeniji and E.R. Terry*

Screening for Anthracnose Resistance

An in vitro method was designed and assayed for developing a reliable and rapid method of screening cassava for resistance to CAD. Since the pathogen shows a high degree of variability, it was necessary to build up a large collection of pathogen isolates and evaluate their variability to determine which isolates should be used for screening and to detect physiological specialization.

Green cassava stem pieces about 8 cm long were cut from plants growing in the field, surface sterilized by dipping them in 95% ethyl alcohol for one minute, and inoculated by depositing 4-mm discs of an actively growing colony of the fungus on a group of three punctures made in the internodal region with a needle heated to red. The inoculated stem pieces were arranged in humid chambers that were placed in an incubator at 27°C under a 12-h photoperiod. The size of developing lesions was determined by measuring their largest diameter one and two weeks after inoculation. After preliminary experiments to work out the details of the method, it was assayed on 11 cassava clones, using three *Colletotrichum* isolates as inoculum.

Out of a collection of *C. gloeosporioides* f. sp. *manihotis* isolates collected at IITA, 22 were selected for their variability on the basis of morphological and cultural characters and inoculated in vivo to three clones (TMS 30001, 30572 and 30555). The cassava was planted in pots and inoculated 53 and 100 days after establishment by puncturing the stems with a hot needle and covering the punctures with a 5-mm disc of actively growing mycelium. Plants that were punctured but not inoculated served as the control. The experiment was arranged in a split-split-plot design and replicated four times. The length of the lesions induced by the fungus was measured with a vernier 5, 12 and 32 days after inoculation.

Twenty-one of the isolates used in the variability experiment were inoculated in vitro as described above on stem pieces of the cultivars TMS 30001, 30572 and 30555. The statistical design was the same as for the in vivo study. The stem pieces were well preserved and retained good sprouting ability. No stem rot was recorded before canker development. Lesions extended rapidly during the first seven days, after which their development slowed and stopped. Lesion size varied considerably among the different cassava clones (Figure 7). The average lesion tended to be longer on TMS 30572 and TMS 30555 and shorter on TMS 30001 and Isunikankiyan. The other cultivars showed intermediate results. Detailed statistical analysis was difficult because of the high variability among treatments. It appeared that the variable being studied was not normal. Work is in progress on larger samples to reduce variability and study variable distribution.

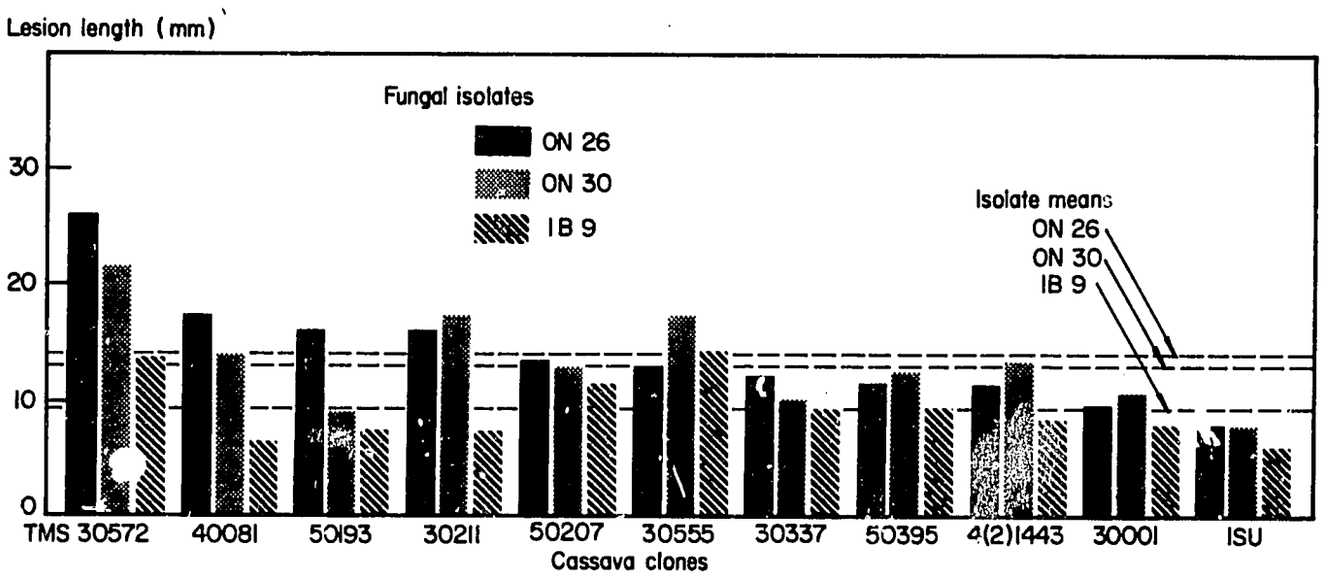


Figure 7. Response of 11 cassava clones to in vitro inoculation with three isolates of *Colletotrichum gloeosporioides* f. sp. *manihotis*. The data indicate lesion size seven days after inoculation.

The average lesion size induced in vivo by the isolates ranged from 5.8 to 7.5 mm (LSD = 0.9, P = 0.05). Although there were significant differences between isolates, the lesions were small compared to the cankers found under natural conditions. These results are consistent, however, with previous reports on similar experiments and can be attributed to the difficulty of maintaining suitable environmental conditions for disease development throughout the experiment and also to incomplete knowledge of the factors involved in symptom expression.

The cultivar 30572, which had an average lesion size of 7.1 mm, was significantly more susceptible than 30555 and 30001, which had 6.1- and 6.2-mm lesions, respectively (LSD = 0.3, P = 0.05). The younger plants were found to be significantly less susceptible, with average lesion sizes of 5.9 mm, than the older ones, which had 7-mm lesions (LSD = 0.8, P = 0.05).

The average lesion size induced by the 20 isolates in vitro ranged from 4.8 to 10.2 mm. Correlation between the results of in vitro and in vivo screening was low (r = 48, significant at the 5% level) if all the 20 isolates are taken into consideration. If one isolate that failed to induce canker in vivo is disregarded, the correlation coefficient is 0.67, significant at the 1% level (Figure 8).

The conditions for successful in vitro inoculation of cassava stems with *C. gloeosporioides* f. sp. *manihotis* have been defined, and preliminary experiments have shown clonal differences in host response. This method still requires further standardization, and correlation between the results of in vivo and in vitro studies must be further investigated.

Variability between pathogen isolates has been confirmed. Isolates have also been collected from other parts of Nigeria (Onne and Umudike) and will be compared to Ibadan isolates.—*B. Lame, J.P. Goffart, T. Ikotun and D. Perreaux*

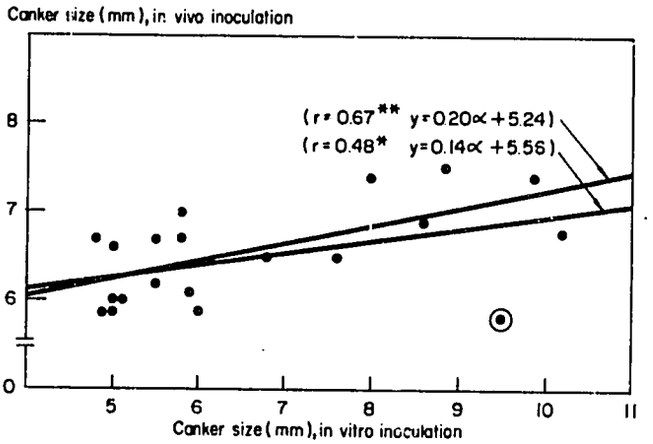


Figure 8. Scatter diagram of canker sizes induced by 20 isolates of *Colletotrichum gloeosporioides* f. sp. *manihotis* in vivo and in vitro, IITA, 1982.

Inoculum Thresholds in Screening for Resistance to Bacterial Blight

In a host/pathogen interaction study, various populations of *Xanthomonas campestris* pv. *manihotis* were inoculated in three cassava varieties of different CBB resistance levels, and disease development was evaluated. Varieties TMS 30572, TMS 30001 and Isunikankiyan were stem puncture inoculated with 72-hour-old pv. *manihotis* suspensions containing 10^8, 10^6, 10^4 and 10^2 cells per ml. Controls were inoculated with sterile distilled water. The inoculated plants were maintained in an air-conditioned room at a nighttime temperature of 25°C, daytime temperature of 30°C and average humidity of 80% for six weeks, after which disease development was evaluated. The experiment had a complete block design with two treatments replicated five times.

The minimum inoculum level for the pv. *manihotis* isolate used was found to be 10^4 cells per ml. Below that level there was no symptom expression. Inoculum levels of 10^6 or more are suitable in screening for resistance.

Wilt and defoliation increased with inoculum concentration in all varieties. The degree of wilt and defoliation depended on the level of resistance, particularly in observations made from above the point of inoculation (Figure 9). In observations made below the point of inoculation, there was no significant difference between the varieties tested in wilt and defoliation. This may have been due to interference by natural defoliation of lower leaves. The overall effect of inoculation on wilt and defoliation is shown in Table 6. Defoliation and wilt above the point of inoculation and in the plant overall increased significantly with increases in inoculum concentration. This finding suggests that wilt and defoliation alone, particularly above the point of inoculation, can be used in screening for resistance to CBB under controlled conditions.—*S.K. Asiedu, E.R. Terry, R.L. Pelletier and D. Perreaux*

Virology

A geminivirus, isolated from cassava plants with mosaic disease by mechanical inoculation on *Nicotiana benthamiana*, was purified from this test plant, yielding pure and concentrated virus preparations. Leaves of infected *N. benthamiana* showing the characteristic symptoms of infection were harvested 15 days after inoculation. The tissue was homogenized in a 0.2 *M* phosphate buffer (pH 7.8) with EDTA and mercaptoethanol and clarified with chloroform. After precipitation with ammonium sulfate and one centrifugation cycle, the virus was further purified by centrifuging twice on a 10 to 40% linear sucrose gradient.

Two rabbits were immunized by intramuscular injection of the virus preparations at weekly intervals, followed by one intravenous injection. Small quantities of antiserum were obtained with a

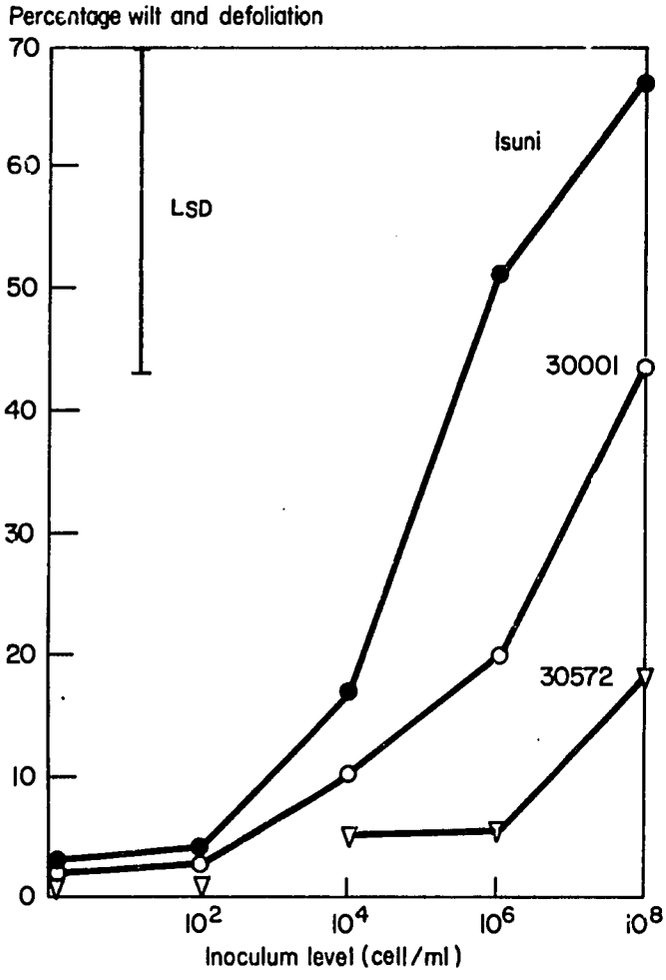


Figure 9. Relation between percent wilt and defoliation above the point of inoculation in cassava varieties and different inoculum levels in *Xanthomonas campestris* pv. *manihotis*, IITA, 1982.

Table 6. Effect of different inoculum levels of *Xanthomonas campestris* pv. *manihotis* on wilt and defoliation in cassava plants, IITA, 1982

Inoculation level, cells per ml	Percent wilt and defoliation: Above inoculation	Below inoculation	Overall
10^8	43.0 a*	21.3 a	35.9 a
10^6	25.7 b	33.8 a	28.4 ab
10^4	10.7 b	32.7 a	21.9 b
10^2	1.8 c	26.1 a	11.5 c
Water (control)	1.4 c	23.0 a	10.6 c

*Means followed by the same letter in a column are not significantly different at the 1% level. Each value is a mean of 75 observations in each of two experiments.

titer of 1/128 in agar gel diffusion tests with purified virus (0.9% (wt/vol) agarose in 0.01 *M*. ammonium molybdate, pH 7.8, with 0.001 *M* EDTA and 0.1% NaN_3). The same results were obtained using an extract of *N. benthamiana* tissue infected with the geminivirus; however, no reaction was seen when an extract of cassava plants with mosaic disease was used. Presumably, this is due to a very low concentration of the isolated geminivirus in cassava.

All attempts to transmit the geminivirus from *N. benthamiana* to healthy cassava seedlings by mechanical inoculation, needle pricking or injection failed. After mechanical inoculation and injection of healthy cassava seedlings with an extract from cassava plants showing mosaic symptoms, mosaic symptoms appeared on 1 out of 10 seedlings inoculated.

Several attempts to purify the geminivirus from diseased cassava were unsuccessful, although the different fractions obtained during the purification showed infectivity when tested on *N. benthamiana*. In all attempts a fraction was obtained that had short, rod-shaped particles of various lengths, with a diameter of approximately 10 nm and a coarse substructure. This fraction showed maximum absorption at a wavelength of 280 nm. These particles, which probably consist of protein, have been reported to be present in diseased as well as in healthy cassava plants.

In one purification attempt, using infected cassava materials, particles were also observed that ranged in length from 800 to 2,000 nm, had a diameter of approximately 18 nm, and were coarse in structure. It could not be established whether they consist of protein only or whether they occur in diseased plants only.—*J.W.M. van Lent*

Agronomy

Effects of Age and Size of Stakes on Tuberization and Initial Growth

To study the effects of age and size of cuttings on tuberization, stem cuttings were made from one-year-old plants of TMS 30595. The cuttings were divided into three age classes corresponding to the basal, intermediate and upper portions of the plant. Cuttings 10 cm, 20 cm, and 30 cm long, having two to three buds, four to five buds and six to eight buds, respectively, were obtained from the cuttings of each age class. The upper cuttings had a diameter of 0.8 to 1.2 cm, the intermediate 1.5 to 2.5 cm, and the basal 2 to 3 cm. Cuttings were singly planted at an angle of about 45° in 10 kg of topsoil in plastic pots. The experimental design was a complete randomized block with three replications. Sampling was begun 10 days after planting and continued at 10-day intervals for 90 days. Anatomical studies were carried out on thin root transections from each root to identify tuberous root initiation.

The results show that stem cuttings taken from basal portions and having a length of 20 or 30 cm and a diameter of 2 to 3 cm had a higher sprouting rate, number of stems per stand, number of tuberous roots, tuberous root diameter, and shoot and root dry weight. A similar trend was observed in plants from intermediate cuttings 30 cm long and 1.5 to 2.5 cm in diameter (Table 7). The final sprouting rates were 98.3% at 20 days after planting for intermediate cuttings 30 cm long, 99.4% at 19 days for basal

Table 7. Effect of age and size of cuttings on tuberization and initial growth of cassava plants, IITA, 1982

Treatment	Days to final sprouting	Final sprouting, %	Tuber initiation, days after planting	No. of stems	No. of tuberous roots	Diameter of tuberous roots, mm	Shoot dry weight, g per plant	Root dry weight, g per plant
Cuttings from upper portions:								
10 cm long	27	84.3	70	1.0	1.9	3.9	60.2	5.9
20 cm	27	87.4	70	1.2	2.4	3.7	76.2	6.2
30 cm	26	92.2	60	1.8	2.7	3.8	87.3	7.2
Cuttings from intermediate portions:								
10 cm long	26	94.7	60	1.0	2.3	4.5	96.4	8.9
20 cm	23	94.9	60	1.4	2.8	4.9	119.2	9.2
30 cm	20	98.3	40	2.4	4.1	8.4	134.7	11.7
Cuttings from basal portions:								
10 cm long	22	96.2	50	1.1	2.9	4.7	126.4	9.4
20 cm	19	99.4	40	2.4	4.8	9.2	160.2	14.6
30 cm	18	100.0	40	2.7	5.9	10.5	169.4	16.4
LSD (5%)	2.5	3.6	8.7	0.48	0.94	1.9	26.4	2.6
S.D.	3.6	5.1	12.4	0.68	1.33	2.6	37.3	3.6

Note: Cuttings from upper portions were 0.8 to 1.2 cm in diameter, those from the intermediate 2.0 to 2.5 cm, and those from the basal 2.5 to 3.0 cm.

cuttings 20 cm long, and 100% at 18 days for 30-cm basal cuttings.

The highest tuberous root number at final harvest, 5.9 per plant, was achieved by 30-cm cuttings from basal portions. The average tuberous root diameter and shoot and root dry weights were also greater for plants from 30-cm basal cuttings than from the others. The average root dry weight was 16.4 g per plant, and the average tuberous root diameter was 10.5 mm. Cuttings from upper portions had reduced sprouting rates, numbers of tuberous roots, tuberous root diameters, and shoot and root dry weights. The maximum sprouting rates, which ranged from 84.3 to 92.3%, were achieved between 26 and 27 days after planting. The average number of tuberous roots was 1.9, 2.4 and 2.7 for upper cuttings having lengths of 10 cm, 20 cm and 30 cm, respectively. The average tuberous root diameter ranged from 3.7 to 3.9 mm.

Tuberization began earliest (40 days after planting) in plants from 20- and 30-cm basal cuttings and in plants from intermediate cuttings 30 cm long. But tuberization was delayed in plants from upper cuttings and did not begin until about 70 days after planting in plants from 10- and 20-cm cuttings.—*I.N. Kasele and S.K. Hahn*

Effect of Daylength on Tuber Formation

Cassava is grown between latitudes 30°N and 30°S. Within that zone daylength varies from about 10 hr, 13 min, to about 14 hr, 15 min. Cassava developed at IITA (lat. 7° 25′N), where daylength ranges from about 11 hr, 33 min, to about 12 hr, 43 min, may perform differently when grown at higher latitudes. An experiment was set up to study the effects of daylength on tuberous roots, flowering and other plant characteristics.

Five daylength treatments were used: (1) 8 hr (2) approximately 12 hr (natural daylength at Ibadan), (3) 16 hr, (4) 8/16 hr (plants were switched from 8-hr daylength 35 days after planting to 16-hr daylength), and (5) 16/8 hr (plants were switched from 16-hr daylength 35 days after planting to 8-hr daylength). Light exposure was extended by use of fluorescent lamps and shortened by rolling portable tables into a dark room.

The varieties used were, 58308, TMS 30395, TMS 30001, TMS 30572, TMS 50395 and Isunikankiyan. The first two varieties were regarded as early flowering, the second two as intermediate and the last two as late flowering. They were planted on 1 April 1980 and the experiment was terminated on 30 September 1980. Data on the effect of daylength upon the number of tuberous roots and the fresh and dry weights of the tuberous roots in those varieties are contained in Table 8.

The early flowering varieties, 58308 and TMS 30395, produced a significantly larger number of tuberous roots and higher tuberous root weights under the 8-hr daylength than under the natural and 16-hr daylength. However, the late flowering varieties, TMS 50395 and Isunikankiyan, produced more tuberous roots under the 8-hr and natural daylength but the highest tuberous root weights under natural daylength.

The number of tuberous roots, and fresh and dry weights of tuberous roots produced by TMS 30001 and TMS 30572 were not significantly different under the 8-hr, 12-hr (natural), 16-hr, 8/16-hr and 16/8-hr daylength treatments. It was concluded that these two varieties are insensitive to daylength.—*J.A. Otoo and S.K. Hahn*

Relation Between Agronomic Traits and Tuberous Root Yield

The rate at which genetic improvement of cassava can be achieved depends upon the associations

between tuberous root yield and other important agronomic characters. A study of these associations was carried out at IITA, using six different populations with large genetic variation. Two of the populations were planted in 1979, and the remaining four were planted in 1980. A randomized complete block design with four replications was used.

Observations were made on 21 traits: fresh tuberous root yield, number of tuberous roots per plant, tuberous root size, dry matter and starch content in tuberous roots, total cyanide content in both tuberous root and leaves, number of nodes to the branching point, branching height, number of days to flowering, plant height at flowering, resistance to CMD and CBB, angles of first and second forking branches, stem girth, plant height at harvest, canopy width, number of first forking branches, total number of branches per plant, and number of stems per stand.

Two traits were considered as associated if they had significant correlations of the same sign in at least four populations. Tuberous root yield had significant and genotypic correlations with number of tuberous roots per plant, tuberous root size, stem girth, canopy width, total number of branches per plant, and plant height at harvest (Table 9). It had a negative correlation with number of days to flowering. The number of tuberous roots and tuberous root size were associated with the same traits as tuberous root yield. Total HCN in tuberous roots was associated only with total HCN in leaves (r = 0.45, 0.44, 0.50 and 0.51, significant at the 1% level).—*N.M. Mahungu, H.R. Chheda and S.K. Hahn*

Table 8. Effect of daylength on cassava tuber formation, IITA, 1980

Treatment	No. of tuberous roots	Fresh wt. of tuberous roots, g	Dry wt. of tuberous roots, g
58308 and TMS 30395 (early flowering)			
8-hr daylength	5.67	150.37	39.97
12-hr	1.83	47.76	14.88
16-hr	0.17	1.70	0.37
8/16-hr	2.00	67.96	19.83
16/8-hr	4.83	87.69	20.15
LSD (5%)	2.20	61.86	18.14
TMS 30001 and TMS 30572 (intermediate flowering)			
8-hr daylength	4.83	191.28	47.32
12-hr	4.83	201.08	54.38
16-hr	2.67	154.64	44.25
8/16-hr	3.67	236.97	64.50
16/8-hr	6.50	150.20	37.65
LSD (5%)	—[a]	—	—
TMS 50395 and Isunikankiyan (late flowering)			
8-hr daylength	3.33	110.20	24.98
12-hr	3.00	194.37	47.05
16-hr	0.67	37.88	8.48
8/16-hr	2.00	46.94	9.42
16/8-hr	3.67	85.29	18.30
LSD (5%)	1.93	84.54	20.39

[a]Not significant.

Quality Evaluation

Cassava contains hydrogen cyanide (HCN), usually in the form of cyanogenic glucosides, which release HCN on hydrolysis. Consuming cassava that has not been properly prepared can cause acute poisoning. A wide variety of traditional processing methods have been developed in Africa mainly for eliminating HCN. A study was carried out to determine the residual cyanide in the final products made from tuberous roots and leaves.

Tuberous roots of cassava were harvested from four IITA improved varieties, TMS 50395, 30572, 30555 and 30001, which vary widely in their HCN content. Five-kg samples of fresh tuberous roots from each variety were processed to make several products and 800-g samples of leaves were made into pondu, which is very popular as a leafy vegetable in central Africa. Gari was made through peeling, grating, fermenting for two days, dewatering and frying. Chikwange was made through fermenting, sieving, steaming, kneading and boiling of the pulp. Ntuka was made by fermenting and steaming the pulp. Fufu (Zaire) was made through fermenting, sun drying, milling and cooking. Attieke was made by peeling, grating, mixing of the grated pulp with previously fermented pulp at a ratio of 3 to 1, adding oil and salt, and sun drying. Plakali was made in the same way as attieke, except that oil and salt were not added. Oyoko was made by mixing the grated pulp with fermented pulp at a ratio of 3 to 1, followed by steaming. Pondu was made by blanching the fresh young leaves in hot water (70°C) for two to five minutes, followed by pounding, dewatering and cooking for one hour. The cyanide content of samples

Table 9. Correlations between yield and agronomic traits in six cassava populations, IITA, 1979 to 1981

Agronomic traits	r values for cassava populations					
	1	2	3	4	5	6
No. of tubers per plant	0.86**	0.97**	0.91**	0.71**	0.94**	0.47**
Tuber size	0.85**	0.83**	0.54**	0.68**	0.99**	0.48**
Stem girth	0.94**	0.35**	0.92**	0.67**	0.79**	0.44**
Canopy width	0.60**	0.46**	0.64**	0.57**	0.99**	0.55**
Number of branches	0.79**	0.50**	0.79**	0.42**	0.74**	0.33**
Plant height	0.60**	−0.03	0.44**	0.49**	0.79**	0.57**
Days to flowering	0.30**	0.20*	−0.39**	−0.54**	−0.33**	−0.30**

**Highly significant at the 1% level.
*Significant at the 5% level.

of these products was determined by the automated enzymatic assay method. The results are summarized in Table 10.

In general, total HCN in the products was reduced by 70 to 100%. But free HCN, although it was reduced in some products, was actually increased in others. In cassava products that had undergone thorough fermentation before being processed to make such products as chikwange, fufu (Zaire) and ntuka, both total and free HCN were almost totally eliminated.

Total HCN was reduced by 83 to 96% in such products as gari, attieke, plakali and oyoko that had been peeled and grated before processing. Total HCN in gari was reduced by 83% to 98% when it was stored for four months under ambient conditions, and in eba, a cooked form of gari, total HCN was reduced by almost 100%. Free HCN was reduced to very low levels in attieke, plakali and gari stored for four months. However, the free HCN in fresh gari was increased by 98% and in oyoko by 5%, compared with that in fresh peeled tuberous roots. In fufu (Ghana), which was made through boiling followed by pounding, total HCN was reduced by about 81% and free HCN by 57%. Merely boiling the tuberous roots of high HCN varieties did not reduce HCN sufficiently. This processing method by itself should therefore be used only with low HCN varieties.

In Nigeria fufu, which is made by soaking peeled whole, fresh tuberous roots in water for one day, followed by steaming and pounding, total HCN was reduced by about 96% and free HCN by 46%. In konkonde, which is made by soaking fresh tuberous roots and then sun-drying, milling and cooking them, total HCN was reduced by 96% and free HCN by 86%. Pondu had about 96% less total and no free HCN.

The general pattern that emerged in this study was that certain insufficiently processed products contained a considerable quantity of HCN but that other well processed products, particularly those that have been fermented, contain very little HCN that can be detected chemically.—*N.M. Mahungu, Y. Yamaguchi and S.K. Hahn*

Yams

In IITA's yam improvement program, researchers are concentrating on the white yam (*Dioscorea rotundata*) and water yam (*D. alata*), the two most important species. Their main aim is to find resistance against foliage diseases and the nematode rot complex. The latter is a particularly serious threat to good quality and extended storability of tubers. Viruses are also a major problem with yams. Since the crop is vegetatively propagated, both problems are quite persistent and drastically reduce storability, field establishment and yields.

Considerable work was done this year on seed yam technology and evaluation of breeding lines, several of which were tested at IITA and in Cameroon in cooperation with the Cameroon Root Crop Improvement Program. IITA seed yam technology is being well received at the farm level and is proving to be highly economical. Efforts to further improve this technology are continuing. Much work remains to be done on developing techniques to promote early, uniform establishment and to reduce labor.

Table 10. Content of hydrogen cyanide (HCN) in traditional African cassava products made from IITA improved varieties, 1982

	Total HCN, mg/100 g of fresh weight[a]						Free HCN, mg/100 g of fresh weight[a]					
Product	TMS 50395	TMS 30572	TMS 30555	TMS 30001	Mean	Percent reduction[b]	TMS 50395	TMS 30572	TMS 30555	TMS 30001	Mean	Percent reduction[b]
Peeled, fresh tuberous root	23.48	15.85	13.53	10.68	15.89	0.00	0.51	0.86	0.51	0.70	0.65	0.00
Attieke	0.51	0.86	0.51	0.70	0.65	95.91	0.06	0.10	0.03	0.10	0.07	89.23
Boiled tuberous root	5.42	4.02	6.39	3.32	4.79	69.85	0.64	0.69	0.79	0.67	0.70	+ 7.69
Chikwange	—[c]	—	—	—	—	100.00	—[c]	—	—	—	—	100.00
Eba (from 4-month-old gari)	—	—	0.02	0.04	0.02	99.87	—	—	0.01	0.01	0.01	98.46
Fufu (Ghana)	4.37	2.96	2.78	2.27	3.10	80.49	0.42	0.29	0.21	0.21	0.28	56.92
Fufu (Nigeria)	0.79	0.74	0.75	0.58	0.72	95.47	0.52	0.43	0.16	0.28	0.35	46.15
Fufu (Zaire)	0.04	—	—	0.03	0.02	99.87	—	—	—	—	—	100.00
Gari (freshly fried)	2.22	1.83	4.18	2.42	2.66	83.26	1.02	0.80	1.67	1.40	1.22	+87.69
Gari (after 4 months storage)	0.30	0.32	0.32	0.21	0.29	98.17	0.30	0.30	0.21	0.23	0.26	60.00
Konkonde	0.71	0.78	0.78	0.60	0.72	95.47	0.27	0.05	—	0.05	0.09	86.15
Ntuka	0.05	0.02	0.04	0.01	0.03	99.81	0.05	0.02	0.04	0.01	0.03	95.38
Oyoko	1.11	1.48	1.98	1.28	1.46	90.81	0.51	0.58	0.94	0.68	0.68	+4.62
Plakali	0.87	0.53	0.19	0.51	0.53	96.66	0.12	0.08	0.03	0.05	0.07	89.23
Fresh leaves	305.00	155.00	142.50	—	201.00	0.00	8.24	3.35	2.95	—	4.85	0.00
Pondu (cooked leaves)	10.63	6.82	8.15	—	8.53	95.76	—	—	—	—	—	100.00

[a]Initial weight of tuberous roots was 5 kg per replication per product.
[b]Reduction is expressed as a percentage of the total/free HCN in peeled, fresh roots and fresh leaves.
[c]No HCN detected (less than 0.01 mg/100 g of fresh weight).

Genetic Improvement

Yield Trials

Several lines of *D. rotundata* and *D. alata* were evaluated in a staked uniform yield trial and an advanced yield trial at IITA. In the uniform trial, there were 10 lines of *D. rotundata* and 6 of *D. alata*. The advanced trial had 13 of the former and 11 of the latter. The trials were in a randomized complete block, with three replications for *D. rotundata* and four for *D. alata*. Plants were spaced 1 m × 1 m in single 11-m rows in the advanced trial and in double 11-m rows in the uniform trial. The *D. rotundata* plants were subjectively evaluated for virus damage and the tubers for nematode damage, and *D. alata* plants were rated on scorch damage. For yield evaluations only the inner 10 plants were weighed at harvest eight months after planting. The consistency index was used to measure inconsistency resulting from changes in the ordering of the genotypes from one year to the next.

The performance of *D. rotundata* in these trials is given in Table 11. The clone Abi gave the best yield and percentage of tubers marketable. Only one hybrid line, RM7-21-248, gave a better yield than the Nwapoko check clone. In the advanced trial, the highest yielding clone was RM7-4-198, with 41.8 t/ha and 95% marketable tubers. It also had a low virus damage score. RM7-3-168 had the lowest nematode damage score. Most lines had high scores for nematode damage, which is still a major cause of poor storage.

The performance of *D. alata* is given in Tables 12 and 13. Thirty percent of the variation in the performance of clones was attributable to clone × year interaction and 25% to the clones. Both types were significant. TDa 251 gave the highest mean yield for three years. TDa 310, 5 and 204 were fairly consistent in their performance over the years; TDa 297 was least consistent.

Although genotypes showed much variability in yield from year to year, such was not the case with the scorch score, which remained relatively stable over the years for each genotype. The difference in genotypes accounted for over 70% of the variation. TDa 291 and TDa 297 showed the highest level of resistance to scorch.

Table 11. Performance of white yams in uniform and advanced yield trials, IITA, 1982

Clone	Yield, t/ha	Percentage of tubers marketable	Damage scores[a] Nematode	Virus
Uniform trial				
Abi	41.5	84.9	3.0	1.6
RM7-21-248	29.8	46.0	3.3	2.0
Nwapoko (check)	21.8	65.5	4.3	3.3
TDr 148	21.1	48.0	5.0	3.3
TDrS-4002-C226	20.6	57.5	4.3	2.7
TDr 820	17.6	68.9	5.0	3.7
TDr 819	17.1	26.3	5.0	2.3
R17-167-531	16.8	25.4	4.3	2.6
Boki	12.0	45.7	4.3	2.6
W512	8.8	39.8	5.0	2.6
Mean	20.7	50.7	4.4	2.7
LSD (5%)	9.2	30.0	1.1	1.2
S.E.	±3.1	10.1	0.4	0.4
Advanced trial				
RM7-4-198	41.8	95.6	3.3	1.7
RM7-3-168	37.7	96.8	2.3	1.7
RM7-4-177	36.3	83.4	4.6	2.3
Gbangu	28.4	100.0	4.0	2.7
R18-370-790	27.6	89.7	5.0	3.0
R18-177-12	22.4	77.1	4.6	3.7
Nwapoko (check)	21.5	78.1	4.6	3.0
TDrS-4002-9	16.5	58.6	5.0	3.7
TDrs 831	16.3	60.9	5.0	3.0
W4-B58	16.0	46.6	5.0	3.7
RB6-114-1049	15.1	69.0	5.0	3.7
TDr 830	12.8	97.4	3.3	3.3
Ausuku	11.9	97.8	5.0	3.0
Mean	23.4	80.9	4.4	2.9
LSD (5%)	14.3	32.9	1.1	1.4
S.E.	±4.8	11.3	0.4	0.5

[a]Damage was evaluated subjectively on a 1 to 5 scale, where 1 = no visible symptoms and 5 = severe symptoms.

Seed Yam Production

Two *D. rotundata* cultivars were evaluated for their efficiency in producing seed yams. Cut pieces of 100 to 150 g were treated with ash and allowed to dry

Table 12. Performance of water yam clones in uniform yield trials, IITA

Clone	Yield, t/ha 1980	1981	1982	Mean	Scorch score[a] 1980	1981	1982	Mean	Consistency index
TDa 251	49.7	25.2	30.3	35.1	2.7	4.2	3.1	3.3	1.2
TDa 204	37.4	29.9	26.7	31.3	3.2	4.0	3.2	3.4	0.6
TDa 5	31.1	24.5	26.4	27.3	2.8	4.1	3.2	3.3	0.6
TDa 297	14.8	30.2	29.1	24.7	1.5	1.5	1.9	1.6	2.6
TDa 310	25.5	18.6	22.3	22.2	2.6	2.6	2.8	2.7	0.6
TDa 291	26.5	16.1	23.1	21.8	1.4	1.6	1.6	1.5	1.0
Mean	30.8	24.1	26.3	27.1	2.34	2.99	2.61	2.65	
LSD (5%)	9.6	12.6	4.6	9.8	0.49	0.50	0.52	0.57	
S.E.	3.2	4.2	1.5	4.4	0.16	0.16	0.17	0.25	

[a]Scorch damage was evaluated subjectively on a 1 to 5 scale, where 1 = 0 to 20% symptoms and 5 = severe symptoms.

Table 13. Performance of water yam clones in advanced yield trials, IITA, 1982

Clone	Yield, t/ha	Scorch score[a]
TDa 309	34.3	3.7
TDa 316	32.7	3.4
TDa 67	29.4	4.3
TDa 167	28.4	4.7
TDa 308	23.4	4.5
TDa 315	23.0	4.1
TDa 200	22.8	3.6
TDa 302	21.8	2.9
TDa 314	17.1	2.9
TDa 300	16.5	4.6
TDa 199	14.9	4.8
Mean	24.0	3.9
LSD (5%)	18.5	0.9
S.E.	±5.8	0.3

[a]Scorch damage was evaluated subjectively on a 1 to 5 scale, where 1 = 0 to 20% symptoms and 5 = severe symptoms.

before planting. The planting sites were plowed and ridged by conventional methods (with ridges 1 m apart), and the setts were planted 50 cm apart in rows, with 240 setts per plot in three replications. One treatment was traditional field cultural practices without herbicide. The second treatment was a modified staking system that consisted of arched, half-inch PVC pipes supporting 4-in plastic mesh and included the use of herbicide. The herbicide, a mixture of Cotoran and Dual, was applied pre-emergence at the rate of 2 kg a.i/ha immediately after planting. The third treatment also included herbicide application but no staking. Black and white polyethylene plastic mulch was placed on one plot after germination.

The soil temperature and moisture were monitored in the plots toward the end of the rainy season until harvest. Temperature was measured with soil thermometers placed 5 cm deep on the crest of the ridges in plots of one replicate. Readings were taken at 0900 and 1400 hours. Soil moisture samples were taken from four locations in each of the mulched and unmulched plots. Soil moisture was expressed as a percentage on an oven dry basis. Soil samples were also taken at harvest to determine the nematode population.

Table 14. Effect of improved and traditional cultural practices on seed yam yield, IITA, 1982

Treatment	Yield, t/ha
Abi	
Herbicide + modified staking	14
Herbicide + no staking[a]	16
Traditional practices	10
Nwapoko	
Herbicide + modified staking	10
Herbicide + no staking	3
Plastic mulch	10

[a]Resulted in a net cash benefit of more than $2,000/ha.

The yield from herbicide treated plots was higher than that in hand weeded plots (Table 14). The yield of Nwapoko with herbicide and no staking was lowest. This cultivar is less vigorous and grows slower than Abi, which was able to establish a canopy after one weeding. Since Nwapoko still lacked a good canopy at that time, weeds were able to compete with it successfully. In addition to its early establishment, Abi also has resistance to virus and other field diseases.

Modified staking allowed plants to form a canopy, which subsequently suppressed weeds. The PVC pipes and plastic mesh proved to be good material for staking. Since they are not damaged by termites, they can be reused for several years. The bamboo stakes were readily infested with termites before harvest.

The plastic mulch gave good weed control throughout the growth cycle of the yams and had no adverse effects on the plants. Measurements of soil temperature showed that bare soil had the highest average afternoon temperature (40.7°C ± 5.3°). Under bare plastic mulch the soil temperature was 36.2°C ± 2.1°. With plastic mulch and a yam canopy, the soil had an average afternoon temperature of 33°C. The profile of the difference in temperature between morning and afternoon is shown in Figure 10.

Once the soil moisture in plots without mulch had been reduced, the plants shed their leaves, and afternoon soil temperatures increased. Some plants with plastic mulch still had green leaves at harvest. The mean soil moisture content under plastic mulch one week before harvest was 6.7%, which was significantly different (at the 1% level) from the moisture content of unmulched soils (2%). Plastic mulch had no adverse effect on the tubers. Termites, mealybugs and nematodes were present in negligible quantities in all plots. The root-lesion nematode, *Pratylenchus sefaensis*, was found under plastic mulch and could be a problem in the long run if a proper rotation is not used.

Although yield differences were marginal (except in the case of Nwapoko with herbicide and no staking), the monetary value of the labor saved and of the increased yield were appreciable. Technology for efficient production of healthy seed yams is being further evaluated. The use of healthy, clean seed yam tubers results in early, uniform establishment and gives high yields.

True seeds of several *D. rotundata* families, which had been direct seeded or transplanted to well-prepared seedbeds, produced seed-yam size tubers ranging in weight from 100 to 1,200 g and yielded up to two and a half times more than the traditional system (Table 15). In addition to producing tubers of uniform size, these families also responded positively to denser plantings. The potential for producing seed-yam size tubers from true seeds seems high and will be tested further.—*M.N. Alvarez, S.K. Hahn and F.E. Caveness*

Pathology

Studies on the etiology of *Dioscorea alata* foliar necrosis disease, also referred to as yam scorch or yam anthracnose, were continued this year. Particular attention was paid to a possible association between the onset of tuberization and the severity of foliar necrosis.

Five *D. alata* clones were planted at two dates (12 April and 7 June) and harvested at 3-week intervals, starting 20 weeks after planting and ending at 29 weeks. The experiment was arranged in a randomized complete block design and was replicated two times (40 treatments with six plants per treatment). Fresh yield, root dry matter content, harvest index and percentage of scorched leaves (estimated from a sample of 200 randomly selected leaves per treatment) were recorded at each harvest.

As found in previous studies, TDA 297 and 291 were significantly less susceptible to the disease than the other cultivars. Symptom prevalence gradually increased for the different harvesting times and was significantly more severe when planting was delayed. Foliage damage generally progressed with dry matter accumulation in root and tuber formation and was significantly correlated with root dry matter content (0.60) and harvest index (0.79) at the 1% level. There was no correlation between leaf damage and fresh yield.

Although these results do not indicate that tuberization is itself responsible for foliar necrosis, they do suggest that tuber development and dry matter accumulation permit the disease to occur. The real causes of the disease are not yet fully understood and need further examination. It has been reported that yam foliar necrosis is normally associated with *Colletotrichum gloeosporioides* infection. In preliminary studies at IITA, however, a rather large proportion of the symptoms were not found to be associated with this fungus.—*D. Perreaux*

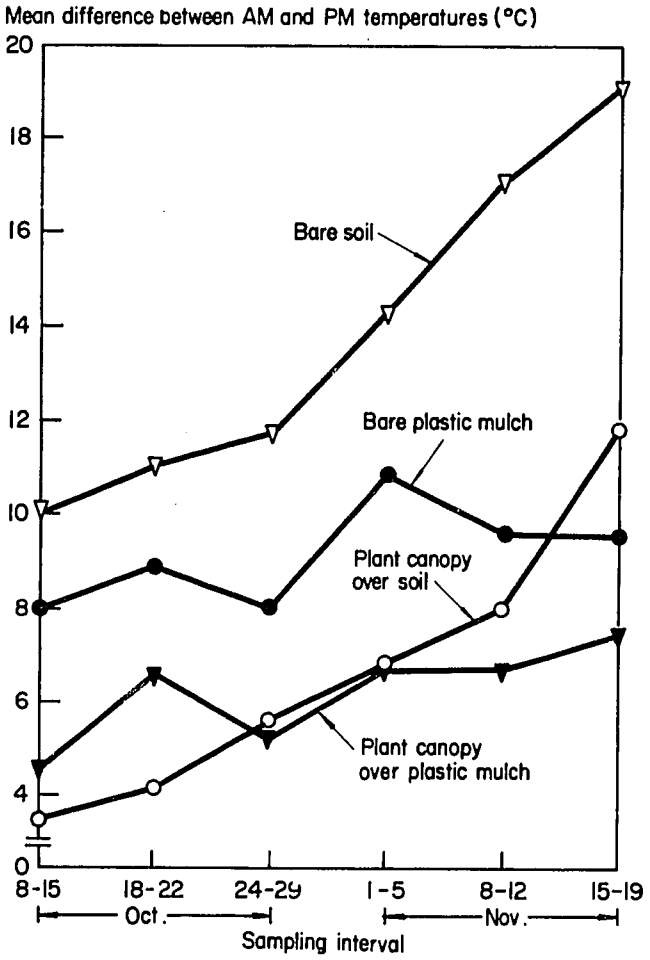


Figure 10. Mean difference in soil temperatures at a depth of 5 cm between 9 am and 2 pm, IITA, 1982.

Table 15. Performance of promising yam families grown from true seeds in well-prepared seedbeds, IITA, 1982

Family number	Yield of marketable seed yams, t/ha	Percentage of seed-yam size tubers
W 370	42	70
W 33	27	50
W 56	22	45
W 71	18	30
Okumodu (check)	15	25

Virology

Dioscorea alata Vein Yellowing

From obviously affected plants of *Dioscorea alata* showing various kinds of vein yellowing and chlorotic mottle symptoms, no virus could be isolated by inoculation of several *Nicotiana* species, including *N. benthamiana* and a number of other solanaceous test plant species. This was in spite of the apparent presence of a potylike virus indicated by electron microscope studies of numerous samples from diseased plants from IITA's experimental fields. It is not likely that yam mosaic virus (YMV), isolated from *D. rotundata*, is the virus responsible for the symptoms in *D. alata* since when YMV was inoculated to *D. alata* seedlings it could be readily recovered from those plants by means of back inoculation to *N. benthamiana*. Except for mild vein yellowing in 1 plant of the 15 inoculated, no obvious symptoms, however, were observed in *D. alata*. Apparently, under natural conditions, *D. alata* does not become infected with YMV although it is susceptible to this virus.

Dioscorea esculenta Virus

Occasionally, some scattered vein yellowing was observed on *D. esculenta*, which otherwise looks mostly clean and unaffected by viruses. From three out of six samples from *D. esculenta* showing mild vein yellowing symptoms, a virus was isolated by inoculation of *N. benthamiana* that in host range

features as well as serologically was very similar to and perhaps identical with YMV as it occurs in *D. rotundata*.—*H.W. Rossel*

Yam Mosaic, Mottle and Leafstrapping

Dioscorea rotundata and D. cayenensis are apparently always infected with a virus belonging to the potyvirus group. The virus was transmitted mechanically by sap inoculation and by aphids in a nonpersistent manner. The virus was successfully transmitted to *Nicotiana benthamiana*, which showed initial vein clearing followed by systemic mottling. *Nicotiana benthamiana* proved to be a good host for virus propagation and a good source of virus for purification.

As reported in the IITA Annual Report for 1981, diseased yam plants showed various types of symptoms, such as green vein banding, strapping, mottling and yellowing. In all cases many particles of approximately 775 nm that are typical of viruses in the potyvirus group were observed.

Last year we reported that an antiserum was produced, using virus preparations purified from *N. benthamiana* leaves artificially inoculated with the virus from *D. rotundata* plants showing mosaic symptoms. In order to compare the different isolates, two more antisera were produced against two other isolates from plants showing strapping symptoms and from plants showing mottling symptoms. The virus from yam plants showing strapping symptoms and from plants showing mottling was individually transmitted to *N. benthamiana*. The virus was purified as reported in the IITA Annual Report for 1981. Antisera to mottling and strapping isolates were prepared by injecting rabbits intramuscularly each week for five weeks with purified virus suspensions, emulsified with an equal volume of Freund's incomplete adjuvant, followed by two intravenous injections. The rabbits were bled at weekly intervals 10 days after the last injection.

Electron micrograph of a purified preparation of a virus occurring in yams (4,500×).

Serological relationships were determined by SDS agar gel diffusion tests. The Immunodiffusion medium contained 0.8% Noble agar, 1% SDS and 0.5% sodium azide. In serological tests the isolates from plants with different symptoms reacted identically and formed a confluent band. Apparently, mottling and leaf strapping symptoms are either manifestations of the same virus or are caused by other, so far unidentified, agents.—*G. Thottappilly*

Sweet Potatoes

The sweet potato weevil, *Cylas puncticollis*, continues to be a problem in sweet potato production, especially during the dry season. A source of resistance to the weevil has been identified at IITA, and efforts are now being made to increase the resistance level of the crop. Good progress has been made in increasing yield, and combining drought tolerance with weevil resistance and high yield continues to receive high priority. The same type of work is being carried out in cooperation with the Cameroon National Root Crop Improvement Program (CNRCIP).

The two major sweet potato weevil species in the world are *Cylas formicarius* and *C. puncticollis*. The former is found in the Americas, Asia and East Africa and the latter only in Africa. In West Africa only *C. puncticollis* has been reported. However, taxonomic studies by G.W. Wolfe reveal that *C. brunneus* also occurs in West Africa. Crosses between *C. puncticollis* and *C. brunneus* have not been successful, confirming that they are two different species.

Ten sweet potato lines were tested at IITA and other locations throughout Nigeria. A randomized complete block design with four replications was used for each test. Each plot had two rows 10 m long, with 1-m spacing between rows and 0.3 m within rows. Information on line × location interaction effects was obtained from analysis of variance for the combined data. The consistency index was used to measure inconsistency resulting from changes in the ordering of the genotypes from one environment to the next.

The highest yielding line across environments was TIS 9265, followed by TIS 2498 (Table 16). TIS 2498 was more consistent (had a lower consistency index) than TIS 9265 across the locations tested. The clone with the best index was TIb 4, which was also the lowest yielder at almost all locations. Weevil and virus scores are shown in Table 16.

The mean square attributable to lines was highly significant. Locations accounted for 70% of the total variation and the interaction of line × location was highly significant ($P < .01$).

In Cameroon TIS 2544 and TIb 1, a highly acceptable clone, gave the highest yield across four locations.

Table 16. Performance of sweet potato lines at various locations in Nigeria, 1982

	Yield, t/ha						Weevil score[b]						Virus score[b]						
Line	A	B	C	D	E	Mean	A	B	C	D	E	Mean	A	B	C	D	E	Mean	CI[a]
TIS 9265	53.7	5.3	10.9	9.6	7.8	17.5	0.0	1.0	1.0	0.3	0.0	0.4	0.0	0.5	0.0	1.8	0.0	0.4	2.28
TIS 2498[c]	45.2	3.6	2.8	10.0	7.3	13.9	1.0	0.0	0.8	0.0	0.0	0.4	0.0	0.0	0.0	2.0	0.0	0.4	1.92
TIS 8401	29.6	5.4	7.5	9.8	9.7	12.9	0.0	0.3	0.8	0.0	0.0	0.3	0.5	0.0	1.0	1.0	0.0	0.5	1.48
TIS 70357	21.8	3.8	10.0	15.0	8.3	11.8	0.3	0.8	1.0	0.0	0.5	0.5	0.8	0.0	0.5	0.0	0.0	0.3	2.38
TIS 8441	26.9	0.5	4.9	14.5	8.2	11.0	0.0	0.3	1.5	0.3	0.0	0.4	2.8	3.3	1.0	2.0	0.0	1.8	2.70
TIS 8524	29.6	2.2	5.1	9.8	8.1	10.9	0.5	0.0	1.5	0.0	0.0	0.5	1.5	0.0	0.5	3.0	0.0	1.0	1.52
TIS 8504	22.2	7.9	3.3	9.8	4.8	9.6	0.3	0.3	0.0	0.0	0.8	0.3	0.3	1.0	0.0	3.0	0.3	0.9	2.88
TIS 70399	26.8	2.5	1.9	7.9	7.0	9.2	0.0	0.3	0.5	0.0	0.0	0.2	0.0	0.0	3.0	2.8	0.0	1.2	1.14
TIS 8266	21.6	2.5	1.7	11.8	4.3	8.4	0.3	0.0	1.0	0.3	0.0	0.3	0.5	0.5	2.3	2.3	0.5	1.2	2.77
TIb-4[c]	19.3	1.9	1.4	3.5	5.8	6.8	1.3	1.0	1.5	0.0	0.3	0.8	0.8	1.8	3.8	3.5	0.0	1.8	0.89
Mean	29.7	3.5	4.9	10.9	7.1	11.1	0.4	0.4	0.9	0.07	0.15	0.4	0.7	0.7	1.2	2.1	0.1	0.9	
LSD (5%)	8.2	5.9	4.4	3.1	3.8	6.6	0.8	0.9	1.4	0.4	0.6	1.1	1.1	1.1	1.2	1.4	0.5	1.2	
S.E.	±2.8	2.0	1.5	1.1	1.3	2.7	0.3	0.3	0.5	0.1	0.2	0.4	0.4	0.4	0.4	0.5	0.1	0.5	

Note: The test locations were A, IITA; B, Jos; C, Mokwa; D, Onne; and E, Zaria.
[a]Consistency index.
[b]Weevil and virus damage were evaluated subjectively on a 0 to 5 scale, where 0 = no visible symptoms and 5 = severe symptoms.
[c]TIS 2498 was used as a high yielding control and TIb-4 as a low yielding control.

Wooden propagation boxes filled with topsoil were planted with weevil resistant sweet potatoes and a susceptible check in the screenhouse. Ten vine cuttings were planted in each plot with spacing of 10 cm × 10 cm and five replications. Box 1 was maintained under stress conditions of about 30% available moisture (measured with gypsum blocks 5 cm deep) and was infested with sweet potato weevils. Box 2 was kept weevil free by insecticide application and was watered regularly to maintain 100% available moisture.

One week after planting, the boxes were infested with weevils. The plants were harvested 20 days later, and the mean number of punctures and larvae per stem was recorded. The fresh and dry weight of the vine and leaves were measured in the stressed and unstressed environments and expressed as a ratio. Stress conditions in the screenhouse reduced plant size and increased foliage loss. TIS 3030 had the highest leaf dry weight and TIS 3017 the highest vine dry weight under stress conditions at 30 days after planting. TIb 4 had the fewest stem punctures, while TIS 2532 had the most. TIS 3017 had the fewest larvae per stem (Table 17).—*M.N. Alvarez and S.K. Hahn*

Cocoyams

Genetic Improvement

The cocoyam root-rot-blight complex (CRRBC) continued to receive much attention in the Cameroon National Root Crops Improvement Program (CNRCIP). Many crosses were made among promising lines for seed production, and investigations were begun on the pollen behavior of the yellow type, which is resistant to CRRBC. Working together, CNRCIP and IITA produced several thousand seeds, which will serve as the source population for 1983. Yield trials were conducted at both institutions, and a crop production package for the reduction of CRRBC was tested at CNRCIP.

Ten cocoyam lines were tested in an advanced yield trial at IITA. They were planted in plots with single, 11-m rows at spacing of 1 m × 1 m in a randomized complete block design with three replications. Nine months after planting, the inside 10 plants were harvested and evaluated for yield, and the harvest index was calculated. The results are shown in Table 18. The highest mean yield was 9.6 t/ha at IITA. The highest yield from CRRBC infested land was 4.17 t/ha at Njombe in preliminary trials. A yield of 19 t/ha was obtained at Ntui in an area that was free of CRRBC. The difference in yield between crops at Njombe and Ntui could be attributed to the disease. Njombe had a high incidence of CRRBC, whereas Ntui was disease free throughout the cycle of the experiment.

Observations on cross pollination of the yellow biotype revealed that pollen from cultivated cocoyams will germinate. Examination of the staminate portion showed that the pollen grains produced had very low fertility. The percentage of good pollen, determined by staining, ranged from 3 to

Table 17. Effect of drought and high weevil population on growth of weevil resistant sweet potato lines in the screenhouse, IITA, 1982

Clone	Relative leaf growth[a]	Relative stem growth[a]	Mean no. of larvae per stem	Mean no. of stem punctures per vine
TIb-4[b]	1.66	0.92	0.6	1.8
TIS 2532 ..	0.98	1.19	0.6	3.4
TIS 3030 ..	0.69	0.89	0.8	2.6
TIS 3017 ..	0.97	1.14	0.2	2.8
Mean.....	1.06	1.03	0.55	2.65
LSD (5%) .	1.60	1.03	0.61	1.54
S.E.....	±0.52	0.33	0.25	0.66

[a]Expressed as a ratio of the stressed trial to the control trial.
[b]Weevil susceptible.

Table 18. Performance of selected cocoyam lines, IITA, 1982

Line	Yield, t/ha	Harvest index	No. of leaves	Leaf area per plant, m²
XI-9-281	9.6	0.44	4	0.51
XI9-9-454	9.6	0.27	4	0.66
XI9-9-419	9.4	0.24	4	0.62
TXS 23	8.5	0.36	4	0.72
XI9-9-287	8.2	0.19	5	0.80
XI9-9-452	7.1	0.38	4	0.51
XI9-9-284	6.8	0.30	4	0.75
XI9-9-451	6.5	0.26	4	0.58
XI9-9-426	6.3	0.19	4	0.74
TXS 18	4.4	0.28	4	0.42
Mean	7.6	0.29	4.3	0.63
LSD (5%)	3.0	0.13	0.5	0.32
S.E.	±1.0	0.04	0.2	0.11

8%. On account of low fertility, the pollen grains did not dehisce naturally. The lack of seed set from crosses between cultivated *Xanthosoma* and the yellow biotype could be the result of the poor fertility of the yellow type, which may be further aggravated by incompatibility barriers.—*M.N. Alvarez and S.K. Hahn*

Agronomy

Cocoyams, *Colocasia esculenta* (L.) Schott, are grown throughout the tropics and subtropics. Since the rainfall in these regions is not always well distributed throughout the year, the crop often experiences plant water deficits. To gather information on the response of cocoyams to soil moisture conditions, a study was carried out in which the water table was maintained at different depths in a soil profile.

The experiment was conducted during the dry season of 1981–82 in field lysimeters packed with surface sandy loam soil (Apomu series) at a bulk density of 1.4 g/cm³. Two suckers, one each of two cocoyam cultivars (TCe 23 and TCe 36), were planted in each lysimeter. The plants were uniformly fertilized with N, P and K fertilizers.

Four weeks after planting, five treatments were imposed: (1) WT_{15}, in which the water table was maintained at a depth of 15 cm, (2) WT_{30}, (3) WT_{50}, (4) WT_{70} and (5) WT_{no}, in which no water table was present. Treatment 5 was the control; it was irrigated on alternate days with an amount of water equal to the mean pan evaporation during the dry season (4.5 mm/day). Treatments were replicated three times in a randomized block design. Stomatal resistance and leaf water potential were measured periodically.

Figure 11 indicates that the stomatal diffusion resistance of the cultivars went through nearly identical daily cycles. There was an early morning low and a gradual buildup till sunset and a rapid rise after dark, resulting from the usual stomatal closure. The depth of the water tables made no apparent difference in stomatal diffusion resistance.

The leaf water potential of both cultivars decreased rapidly in the daytime, and the minima were observed around 1515 hours (Figure 12). Leaf water potential was lower for both TCe 23 and TCe 36 in the WT_{15} treatment. It increased for both cultivars in the WT_{50} treatment. The TCe 23 control plants behaved like those under WT_{50} and the TCe 36 plants like those in WT_{15}. When leaf water potential was at its minimum (1515 hours), leaves did not wilt in any of the treatments. Recovery of leaf water potential began toward the evening.

The evapotranspiration rate of the cocoyams (EVT) varied according to the open pan evaporation (E_o) and the depth of water table (WT) according to the equation, $ET = 0.50 + 0.76\ E_o - 0.01\ WT$ ($R = 0.92$ and $R^2 = 0.85$), where ET and E_o are weekly means in centimeters per day and WT is in centimeters.

The average evapotranspiration rate for the period of measurement (89 days) was 0.77, 0.52, 0.34 and 0.17 cm/day in the WT_{15}, WT_{30}, WT_{50} and WT_{70} treatments, respectively. The average potential evaporation rate for the same period was 0.51 cm/day.

The plant height of TCe 23 and TCe 36 decreased significantly with increasing water table depth (Table 19). This decrease was accompanied by a statistically insignificant trend toward smaller leaf area.

As shown in Table 19, fresh corm yields of TCe 23 were significantly higher (334.1 g/plant) under WT_{15} than WT_{70} (152.2 g/plant), whereas the response of TCe 36 to a higher water table was insignificant. As expected, total water use decreased as the water table was lowered, and water use efficiency (grams of corm produced per liter of water expended)

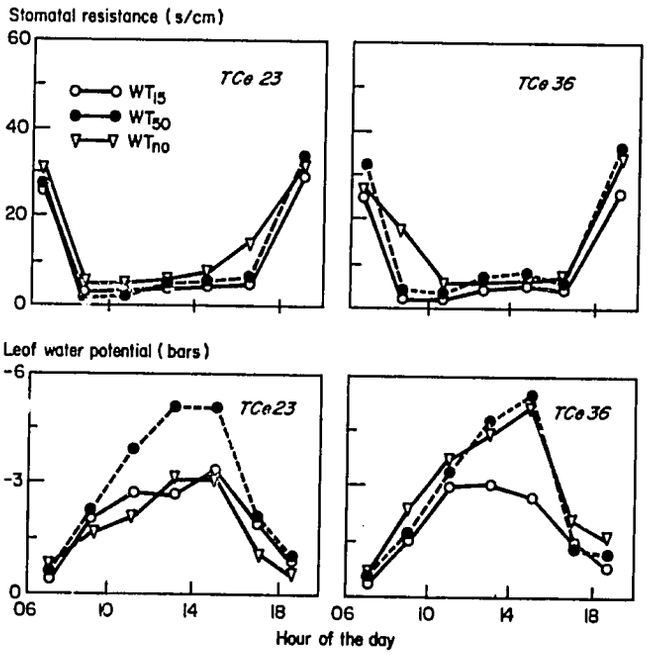


Figure 11. Diurnal changes in stomatal resistance and leaf water potential of two cocoyam cultivars for different water table depths, IITA, 1982.

Table 19. Effect of water table depth on cocoyams, IITA, 1982

Water table depth	Average plant height, cm		Fresh corm yield, g/plant		Water use, l	Water use efficiency, g/l
	TCe 23	TCe 36	TCe 23	TCe 36		
15 cm	48.2 a*	57.8 a	334 a	246 a	182	3.2
30 cm	49.0 a	45.8 ab	265 ab	187 a	122	3.7
50 cm	35.8 b	35.8 bc	211 ab	161 a	81	4.6
70 cm	33.7 b	26.0 c	152 b	118 a	39	6.9
No water table	49.7 a	55.2 ab	333 a	180 a		
LSD (5%)	12.1	19.1	173	169		

*Averages followed by the same letter do not differ at the 5% level of significance.

increased. The yield model indicates that corm yield was related exponentially to water table depth with a negative exponent. Fresh corm yield increased linearly with increases in leaf area (Y (g/plant) = 55.5 + 0.10 LA).

From these data it is clear that a high water table of 0 to 15 cm or very regular resupply of moisture, as in the control treatment, is essential for maximum growth and corm production of cocoyams. The varieties differed very little in their responses to lower water tables, although leaf size and changes in daily leaf water potential showed some relation to water table.—*B.S. Ghuman and R. Lal*

Nematology

Root-knot nematodes are common throughout the tropics and subtropics and are becoming an increasingly serious threat to good crop growth as the land is farmed more intensively. An integral part of IITA's root crops improvement program is to screen its germplasm collection systematically for resistance to nematodes. A total of 55 sweet potato lines have shown good resistance in greenhouse retesting to the root-knot nematodes *Meloidogyne incognita* race 2 and *M. javanica*. The resistant lines will be further tested under field conditions.

In greenhouse testing of white yam (*D. rotundata*) germplasm, the cultivar Abi showed only light root-knot galling on the tubers from both *M. incognita* race 2 and *M. javanica*. Juveniles of *M. javanica* were recovered from the soil but not for *M. incognita*. The reniform nematode, *Rotylenchulus reniformis*, and the root-lesion nematode, *Pratylenchus sefaensis*, reproduced only to a limited extent on Abi. There were no symptoms of nematode attack or reproduction on the other seven yam lines tested. The spiral nematode, *Helicotylenchus pseudorobustus*, did not reproduce or survive on any of the yam lines. Carryover infections of the yam nematode, *Scutellonema bradys*, were recovered from tubers in five of the eight yam lines tested.—*F.E. Caveness*

Tissue Culture

The principal objective of the tissue culture unit is to render improved varieties of cassava, yams and sweet potatoes insect pest and disease free, so that they can qualify for plant quarantine certification and be moved through international quarantine barriers. The unit also multiplies improved varieties and preserves vegetative germplasm.

Cassava

During 1982 the major focus of tissue culture work on cassava was meristem culture for elimination of diseases and international distribution of material. Six varieties with resistance to the cassava mealybug and green spider mite were successfully regenerated by the meristem culture method in combination with thermotherapy, as described in the IITA Annual Report for 1979. Four cassava varieties that were regenerated from meristem culture in 1981 were indexed and then certified by plant quarantine authorities at Ibadan in 1982. These varieties carry sources of resistance to the mealybug and green spider mite and are low in cyanide content. These and the eight varieties previously certified are now available for distribution.

A total of 26 consignments of disease free cassava in tissue culture form were delivered to 19 countries, 18 of them in Africa (Figure 13). The handling of tissue culture material upon arrival in recipient countries has improved as a result of a root crop tissue culture training course that took place late in 1981. Reports from the recipient countries indicate that the materials received are either being multiplied or are still being evaluated.

Sweet Potatoes

In its work on sweet potatoes, the tissue culture unit concentrated this year on meristem culture for eradication of diseases, germplasm conservation and international distribution of tissue culture materials. Seventeen sweet potato varieties were successfully regenerated by means of meristem culture, as described in the IITA Annual Report for 1979. Eight varieties were indexed, tested and then certified by the plant quarantine authorities at Ibadan for exportation.

In virus indexing of the meristem culture material, a test involving grafting to an indicator plant, *Ipomoea setosa* was used along with Serological Specific Electron Microscopy (SSEM). Two disease

agents are known to be involved in the sweet potato virus disease complex (SPVD); one is transmitted by aphids, the other by whiteflies. Either agent alone is latent in sweet potatoes, but in combination the two cause severe SPVD symptoms. Vine cuttings from test plants regenerated through meristem culture were approach grafted to cuttings of an SPVD-susceptible sweet potato clone that had been preinfected either with the whitefly- or aphid-transmitted agent. The test plants were observed for SPVD symptoms to determine whether disease agents were present.

In 1982, 23 consignments of disease free sweet potato clones were delivered to 20 countries throughout the world, of which 14 are in Africa, four in Asia and two in the Caribbean. Reports from our cooperators indicate that the materials they received are now either being multiplied or evaluated.

An additional 100 sweet potato varieties are now being maintained in tissue culture form in a slow-growth medium at a low incubation temperature. A total of 500 accessions of sweet potato germplasm are now maintained in vitro. To test the stability of the clonal characteristics of the germplasm stored in vitro, several clones, selected at random, were multiplied and grown in the field for comparison with clones that had been maintained in the field. Morphological characteristics of the tops, such as leaf shape, pigmentation of vine, petiole length and pubescence, and characteristics of the roots, such as skin and flesh color, were found to be stable. —*S.Y. Ng*

Figure 12. Distribution of IITA disease free cassava during 1982.

Culture room at IITA for conservation of germplasm.

Cytogenetics

In breeding programs wild species have been receiving increasing attention as an additional source of desirable characters such as resistance to diseases, insect pests, and drought. The chances of success in recombining desirable genes of a wild species with those of a cultigen depend largely on the pairing relationships of their chromosomes. In the segregating generations from interspecific hybrids, strikingly different and new types can evolve. Further, genetically controlled meiotic modifications, resulting in the production of 2n gametes among the clones/hybrids, can be exploited in the production of polyploids. A knowledge of the ploidy status of the species/clones/hybrids and of their cytogenetic behavior is thus essential. For that reason, the cytogenetical aspects of cassava, sweet potatoes, cocoyams and yams were investigated at IITA during 1982.

Cassava

Crosses Between Cassava and Wild Species

A family of hybrid plants was raised from seeds of the cross, cassava (*Manihot esculenta*) × *Manihot dichotoma*, a wild species. Morphological characters of these hybrids, such as leaf shape, nodal features of the stem, height at first branching, branching habit and flowering were recorded.

For a meiotic study, buds were fixed in 3:1 alcohol-propionic acid and two days later were transferred to 70% alcohol for storage. Smears were made in 2% propionocarmine. Meiotic stages were analyzed from the pachytene stage onward. Pollen fertility was estimated by staining the pollen grains from freshly dehisced anthers with propionocarmine. Pollen grains that were full and stained well were counted as fertile; the empty, nonstained grains were considered sterile. Two to five flowers per plant were examined for pollen fertility, and the mean fertility of the parents and hybrids was determined.

Based on morphological characters, particularly leaf shape, the hybrids can be grouped into two classes, cassava type and wild type. The number of plants that flowered and the pollen fertility of these two types are given in Table 20.

The chromosome number of the parents, cassava (30555) and *M. dichotoma*, was determined to be 2x = 36. Meiosis was studied in both plants and found to be normal, resulting in high pollen fertility. At metaphase I in pollen mother cells (PMCs), 18 bivalents were observed (see accompanying photograph). The mean chiasma frequency at that stage was determined to be 26.4 in cassava and 22.1 in *M. dichotoma*.

In the hybrids also, the chromosome number was determined to be 2x = 36. Meiotic behavior of chromosomes in 5 to 10 plants from each pollen fertility group was studied to determine the causes of variation in pollen fertility. In hybrids showing 100% pollen sterility (in 25 to 50 PMCs observed from each plant), the chromosomes remained as univalents (36 I) at M-I (see photograph). To ascertain whether the univalent condition is due to desynapsis or asynapsis, pachytene chromosomes in a few PMCs were observed in which the chromosomes remain as univalents. These plants exhibited asynapsis. Subsequent stages of meiosis were irregular, resulting in dyads, triads and polyads with one to many micronuclei and leading to pollen sterility.

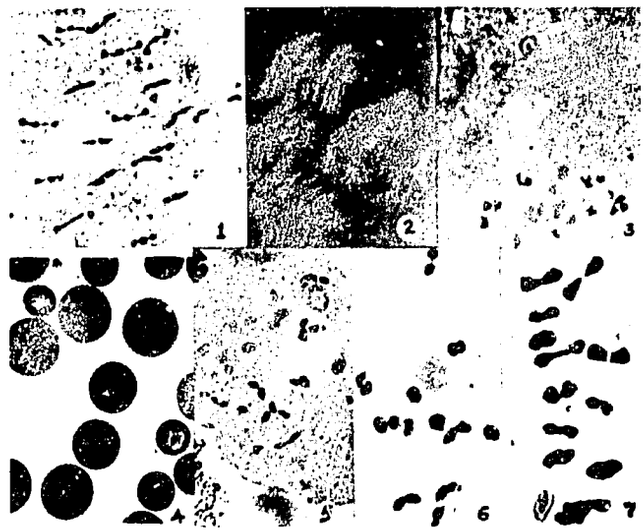
In hybrids with 5 to 50% pollen fertility at M-I, 18 bivalents were observed. The mean chiasma frequency per PMC varied in these plants from 21.1 to 24.4 (range, 18 to 26). At anaphase I a dicentric bridge and an acentric fragment were observed in 20 to 35% of the PCMs (see photograph). In a few PMCs in these hybrids, unequal separation of chromosomes, such as 17 to 19, was observed at A-I. These hybrids also produced 0.3 to 4.5% "giant pollen grains," which are presumed to be 2n gametes. The hybrids with 70% or more pollen fertility exhibited normal meiosis, with 18 bivalents at M-I; normal separation of chromosomes at A-I and normal second divisions led to high pollen fertility.

There were no detectable morphological differences between the asynaptic and normal plants. All the asynaptic plants were crossed with normal cassava. No seeds were obtained either in the crosses or under open pollinated conditions. The ovules of these plants were not functional.

Regarding the asynaptic condition in some of the hybrids, the question arises as to why there is a gradation in pairing frequency from regular bivalent formation to complete asynapsis. A probable explanation is the gene dosage effect. Lack of chromosome homology does not explain asynapsis, since a majority of plants of the same population showed regular bivalent formation. Nor do environmental conditions account for the differences in pairing, since the plants were grown under similar conditions and fixations for meiotic studies were made on the same day. The asynaptic plants isolated thus seem to owe their origin to a gene dosage effect.

Table 20. Data on hybrid cassava plants, IITA, 1982

	Cassava type	Wild type (*dichotoma*)	Total
No. of plants	122	63	185
No. of plants flowered	93	56	149
Pollen fertility, %			
0	19	—	19
5 to 20	3	3	6
21 to 35	2	15	17
36 to 50	5	17	22
51 to 70	9	9	18
71 and above	34	—	34
No. of plants checked for pollen fertility	72	44	116



(1) 18 bivalent chromosomes at metaphase I in *M. dichotoma*; (2) 36 univalent chromosomes at metaphase I in a hybrid plant; (3) a bridge and fragment at anaphase I in a hybrid; (4) pollen grain of varying sizes in tetraploid sweet potatoes; (5) nine trivalent, four bivalent and seven univalent chromosomes at diakinesis in *Colocasia*, TCe-36; (6) 13 bivalent chromosomes at diakinesis in *Xanthosoma*, TXS-13; and (7) 13 bivalent chromosomes at metaphase I in *Xanthosoma*, TXS-426.

The dicentric bridge and acentric fragment that occurred at A-I in some hybrids are due to a paracentric heterozygous inversion. This type of A-I configuration is produced by single crossovers and three strand doubles within the inversion loop as well as by two- and four-strand double exchanges in which one crossover has taken place in the proximal region between the centromere and the inversion and a second crossover has occurred within the inversion loop.

F_1 hybrids were backcrossed with cassava (TMS 30555 and 30572). About 1,735 flowers were pollinated. The percentage of fruit set was lower among the *dichotoma* type hybrids than in the cassava types. The seeds are now being collected.

Manihot chlorostica is a wild species having some disease and insect resistance and drought tolerance. Its chromosome number has been determined to be 2x = 36. This species was used as a pollen parent in interspecific crosses of cassava. A total of 1,120 flowers were pollinated. The seeds are now being collected.

Production of Polyploids

Since polyploids are usually better yielders than diploids and since there can be differences in the response of different cultivars to polyploidy, four promising clones of cassava, TMS 30001, 30555, 30572 and 50395, were selected to induce tetraploidy. Tetraploids are being produced to make triploids, which are reported to be superior in many crop plants to the diploids or tetraploids, especially when the economically important yield component is not the seed. Once superior tetraploids and triploids are isolated, they can be perpetuated without major difficulties since cassava is a vegetatively propagated crop.

Sprouting axillary buds are treated with 0.5% aqueous colchicine solution for 24 to 48 hours and then covered with cotton wool. The buds and cotton wool are kept moist with colchicine solution. Later, the treated buds are washed thoroughly with water. The tetraploids can be identified by their leaf shape, thickness and color. Their ploidy status will be confirmed when they flower.

Anther culture

Haploid plants are valuable in genetic, cytological and breeding research. Since they are in a hemizygous state, when their chromosomes are doubled, either naturally or by colchicine treatment, a homozygous diploid results. Thus, homozygosity can be achieved in one generation, whereas with conventional breeding techniques it takes five or six generations. The study of meiosis in haploids has contributed somewhat to tentative theories about basic chromosome numbers in many genera. One method of producing haploids is by anther culture. Some plant species produce plantlets directly from the microspores, while others produce a callus first, which is then transferred to a differentiation medium for regenerating plants.

Anther culture was begun at IITA this year to produce haploids in cassava. Flower buds containing pollen grains at the uninucleate stage were collected and stored at 8°C for a minimum of three days before being cultured. The culture media used were M and S basic media with 2,4-dichorophenoxy acetic acid (2,4-D) (10^{-2m}), sucrose (30 gm/l), agar (8 gm/l) and kinetin (10^{-1m}). They were adjusted to pH 5.8 before sterilization. The cultures were kept at 25° to 26°C and exposed to light with an intensity of 3,000 lux for 12 hours a day. Callus formation was observed three weeks after culturing the anthers. The calluses are being multiplied for later transfer to a differentiation medium.

Sweet Potatoes

Sweet potatoes (*Ipomoea batatas*) are hexaploid, having 2n = 6x = 90 chromosomes. The majority of the species in the genus are diploids (2x = 30) and a few are tetraploids (2n = 4x = 60). Some of these species can be useful in the improvement of agronomically important characters such as disease and insect resistance. Because of their high potential, a few species were collected and their ploidy status determined (Table 21). Now they are being used to produce interspecific sweet potato hybrids. Two accessions of tetraploid sweet potatoes produce 10 to 20% dyads. These plants also produce "giant pollen" (see photograph). An average of 10 to 15% of such pollen grains was observed, although their frequency varies from flower to flower.

Table 21. Chromosome numbers of various sweet potato species

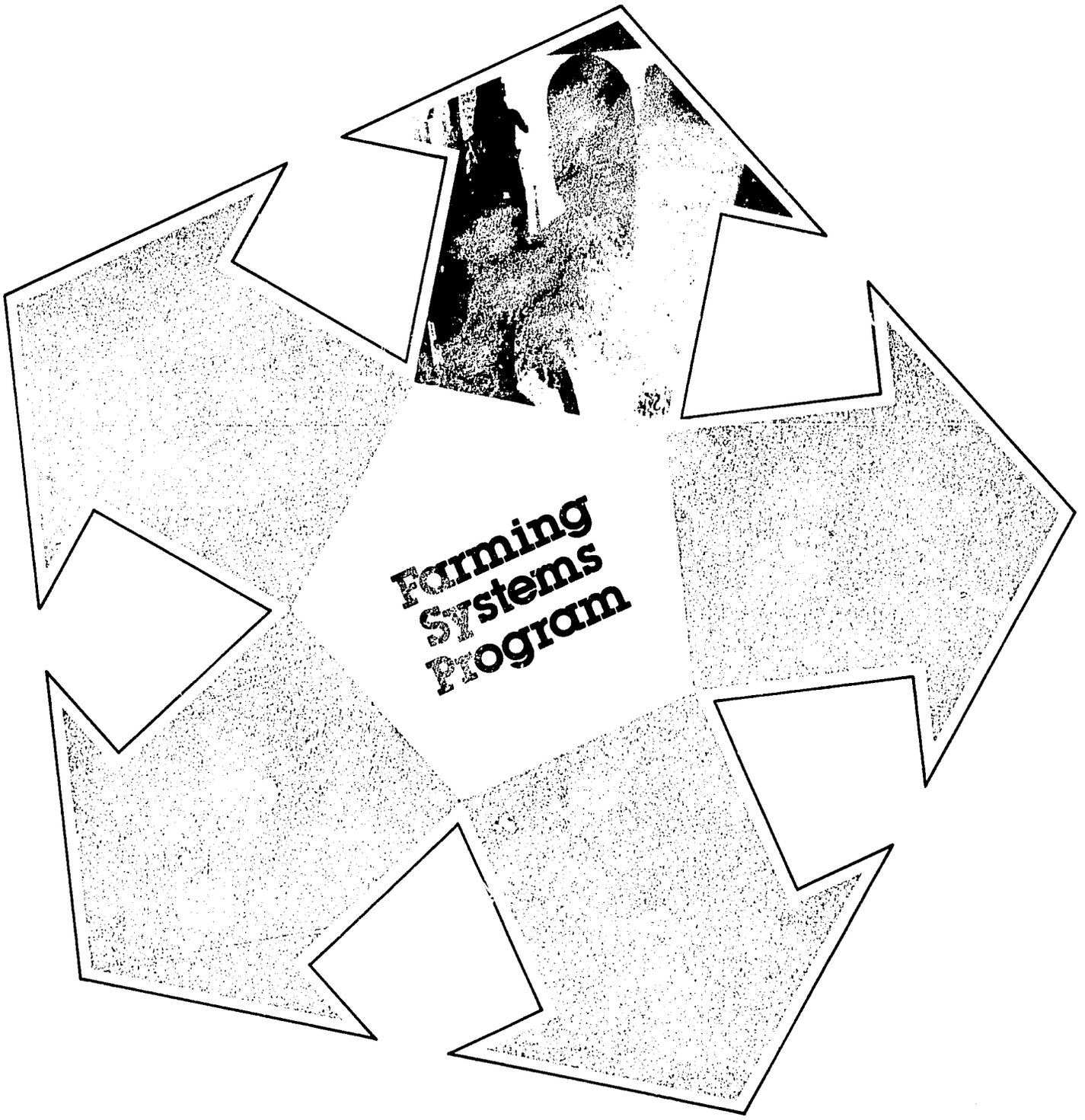
Species no.	Species	Chromosome number
1	*Ipomoea lacunosa*	30
2	*Ipomoea trifida*	30; 60
3	*Ipomoea tiliacea*	60
4	*Ipomoea littoralis*	60
5	Tetraploid sweet potatoes (five accessions)	60
6	Seeds from the cross, sweet potatoes × K-221	60
7	*Ipomoea batatas* (sweet potatoes)	90

Cocoyams

The two most important cocoyams are *Colocasia esculenta* and *Xanthosoma* spp. Genetic variability in this crop is limited because both male and female sterility are prevalent. Although there are many causes of this sterility, it is attributed mainly to different cytogenetical phenomena such as polyploidy, structural hybridity, desynapsis and abnormal tapetal development. Cytological screening of the clones and identification of polyploids will enable us to plan appropriate breeding strategies for these vegetatively propagated species. It should also reveal the causes of sterility and provide an opportunity for assessing the effect of polyploidy on tuber yield.

Cytological screening of clones of *C. esculenta* revealed that accessions TCe-23 and TCe-36 (see photograph) are triploids (2n = 3x = 42). The high sterility of these clones can be attributed to meiotic irregularities such as high trivalent frequency (7 to 10 per PMC), irregular separation of chromosomes at A-1 and presence of laggards. The clone TCe-23 was found to exhibit desynapsis. Both the triploid clones are superior yielders.

In *Xanthosoma* sp. collections, the yellow cocoyam TXS-11 was found to be a tetraploid (2n = 4x = 52). The clones TXS-17, TXS-23, TXS-42b and TXS-427 are diploids with 26 somatic chromosomes. At diakinesis and M-I (see photograph), 13 bivalents were observed in PMCs.—*K.V. Bai*



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IN RECENT YEARS the multidisciplinary research of IITA's Farming Systems Program has been dedicated to improving or finding a substitute for the traditional bush fallow agricultural system. Although this system is in balance with the ecology and prevents permanent destruction of land resources, it is inefficient and low in productivity. Using this system, farmers cannot keep pace with population growth and increasing demand for food.

Research projects that address this central concern continue to be the mainstay of IITA's Farming Systems Program. This work is now being complemented, though, by a major research effort generally referred to as on-farm adaptive research. In this research methodologies are being developed for identifying on-farm production constraints and for designing and implementing adaptive research programs in which technology from IITA and other sources will be tested in cooperation with farmers and development workers. This work, now being carried out in Nigeria, Ivory Coast and Cameroon on a preliminary basis, involves a sizeable portion of the program's scientists not only in field research, but also in the meetings and training events related to this regional effort.

This new concern led during 1982 to two crucial and highly successful meetings at IITA. The first brought together about 40 scientists from all over the world to discuss their experience in various aspects of on-farm farming systems research from both the socioeconomic and agronomic viewpoints. The symposium resulted in a valuable exchange of ideas and data, and a consensus was reached about the essential features of this research and about the great value it could have in the creation of adapted and acceptable technologies for the small farmers of the developing world.

The second workshop was sponsored jointly by IITA, the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Institut de Recherches Agronomiques Tropical (IRAT) and Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ). Its aim was to bring together farming systems researchers from all over West Africa to exchange ideas and create a farming systems research network for the region. This independent organization has now been established and promises to be a valuable asset to scientific exchange in West Africa.

Another important event for IITA's Farming Systems Program this year was the first International Symposium on Land Clearing and Development, which was held and organized by IITA with assistance from the United Nations Development Programme (UNDP), U.S. Agency for International Development (USAID) and Swedish Agency for Research Cooperation (SAREC). The meeting brought together about a hundred scientists, development experts, and government workers to evaluate experiences with clearing and developing tropical forest areas over the last decade. It also led to the formation of the International Committee on Land Clearing and Development (ICLCD), which was charged with publicizing the views and concerns adopted by the symposium and with forming a coordinating body for the improvement of land clearing and development in the tropics.

Three important special projects made their influence felt for the first time in 1982. The nitrogen utilization project being carried out with the Institute for Soil Fertility in the Netherlands established two large experiments at Onne in the high rainfall region of Nigeria and yielded valuable information in its first year. A joint research project with the International Fertilizer Development Centre in the United States was also successful in its first year of fundamental studies on nitrogen and phosphorus uptake from soils in the humid and subhumid tropics.

Finally, in the first phase of the hydromorphic or wetlands project, executed jointly with the Institute for Land Reclamation and Improvement in the Netherlands, it was discovered that the total available wetland area in West Africa is much greater than estimated in recent development studies. It thus seems quite realistic that the development of these wetlands, which in general are considerably more productive than the more typical soils of the region, could contribute substantially to increasing food production in the sub-Sahelian region.

In 1982 the Farming Systems Program placed greater emphasis on appropriate equipment, mulch production and management, and socioeconomic studies and laid the foundation for a new, major multidisciplinary effort to study constraints in large scale crop production. The West Bank catchment is being used for this purpose. It was clear from the 1981 and 1982 data from the West Bank experiment that the tillage versus no-tillage treatments completely overshadowed the residual effects of the original forest clearing methods. This pioneering trial was therefore abandoned and transformed for the 1983 crop season.

The IITA rotary injection planter was successfully adapted for medium scale operations with low horsepower tractors and is probably at a stage now where any further development must be left to other initiatives. Utilization of this equipment in medium to large scale operations has shown that the next requirement for expansion by small farmers is rapid and timely harvesting, which will receive high priority in IITA's agricultural engineering section for the next few years.

In research on plantains and cooking bananas, good progress is being made in production agronomy. But the threat of invasion by the black sigatoka

fungus in West Africa (it has already been reported in Gabon and Cameroon) may require that we change our priorities in research on this very important food crop. Meetings have been held with scientists from the Caribbean area and with interested donors to discuss a worldwide program for improving these species with special emphasis on development and introduction of materials with resistance to the black sigatoka fungus. The threat of this disease has also led to the introduction of meristem culture technology at IITA and a training program to create a network of competent scientists who can participate in an Africa-wide network for development of plantains and cooking bananas.

Soil Management and Land Development

Wetlands Characterization and Evaluation

The increasing demand for rice as a staple food in tropical Africa during the past decade necessitates more intensive utilization of suitable wetlands (inland valley swamps) for rice cultivation. In western and central Africa, a limited number of these lands are currently being used to grow rainfed rice without water control. Seasonal deep flooding frequently damages the crops during the early stage of growth. Iron toxicity is common in many inland valleys, where seepage flow contains a high concentration of ferrous iron.

Research during 1982 focused on seventeen selected wetlands sites in southern and southeastern Nigeria. Soil profiles representative of the land forms were described and sampled for laboratory analysis and evaluation. Present land use at each study site was also described. Three types of wetlands have been identified in this region: (1) the small inland valleys, termed fadamas (5 to 40 ha), in the savanna region of central Nigeria (near Bida), with predominantly coarse textured soils derived from Cretaceous sandstones; (2) the extensive Anambra River flood plains and terraces near Adani in southeastern Nigeria, with medium to fine textured soils derived from Tertiary shales; and (3) the small to medium sized inland valleys or swamps (20 to 100 ha) near Bende in the humid region of southeastern Nigeria, with fine textured soils derived from Tertiary shales.

Soil Characteristics

Soil depth and texture, chemical properties and nutrient status, clay mineralogy, water holding characteristics, depth and seasonal variation of groundwater table, flooding hazards, and toxicities (Fe, for example) are being analyzed and evaluated. Some properties of selected pedons are given in Table 1.

Bida fadamas. With few exceptions the hydromorphic soils of the inland valleys in central Nigeria have a sandy texture, low pH, low cation exchange capacity and low organic matter content (Table 1.) The mineral in the clay fraction is predominantly kaolinite. Most soils show strong mottling, indicating seasonal fluctuation of the groundwater table, and they have a very low soil nutrient status. High soil permeability and fluctuating groundwater tables

Table 1. Properties of selected hydromorphic soils from inland valleys near Bida and Bende and from Anambra River alluvial plains near Adani, Southern and Central Nigeria

Depth, cm	Horizon	Sand, %	Silt, %	Clay, %	pH (H_2O)	Organic C, %	Exchangeable cations, meq/100 g Ca	Mg	K	Na	Al	H	Cation exchange capacity, meq/100 g	Bray P-1, ppm
Arenic Tropaquept, Gara Fadama, Bida														
0–10	Ap	68	30	2	4.2	1.10	0.96	0.15	0.13	0.07	0.68	0.04	2.10	9.6
10–23	A2	72	26	2	4.2	0.27	0.85	0.06	0.06	0.04	0.49	0	1.55	12.0
23–42	B2	50	38	12	4.1	0.58	1.60	0.27	0.05	0.04	0.86	0	2.82	1.8
42–80+	C1	50	46	4	4.3	0.32	0.41	0.08	0.06	0.03	0.61	0	1.22	2.2
Plinthic Tropaquult, Lower Terrace, Adani														
0–4	Ap	14	72	14	4.2	1.78	0.60	0.48	0.16	0.06	1.86	0.68	3.94	3.9
4–7	A12	18	56	26	4.9	1.12	1.10	2.42	0.22	0.06	1.18	0.28	5.98	1.2
7–20	B1	16	50	34	4.6	0.77	0.90	3.38	0.16	0.06	2.90	0.88	8.52	0.6
20–80+	B2	18	48	34	4.6	1.42	0.80	4.28	0.25	0.06	3.94	1.31	10.74	0.4
Typic Tropaquept, Flood Plain, Adani														
0–12	Ap	16	38	46	4.3	1.54	6.60	5.45	0.38	0.15	0.75	0.04	13.77	1.5
12–37	B2	14	38	48	5.4	0.58	6.80	6.45	0.35	0.18	0.14	0	13.94	0.6
37–60	B3	14	38	48	5.6	0.95	7.60	6.70	0.35	0.19	0.18	0	15.02	0.6
60–100+	C	20	38	42	5.5	0.60	7.00	6.80	0.29	0.21	0.21	0	14.54	0.5
Eutric Tropaquept, Inland Swamp, Isi-Ugwu, Bende														
0–13	Ap	18	33	49	4.6	4.56	23.10	4.42	0.41	0.11	0.35	0.06	28.59	4.5
13–35	B2	14	35	51	5.5	2.13	26.30	4.82	0.33	0.10	0.09	0	31.69	2.2
35–65	B3	14	35	51	5.7	0.58	24.40	4.50	0.31	0.09	0.14	0	21.45	1.2
65–100+	C	14	35	51	5.4	0.36	24.60	4.67	0.33	0.10	0.06	0.09	30.86	0.9

increase losses of fertilizer nutrients through leaching. Research should be conducted in these fadamas on water control and fertilizer management to ensure a moderate but stable crop yield. High yielding cultivars may not be suited to such poor quality soil.

Adani plain. The wetlands of the Anambra River alluvial plains consist of two land units, the floodplain and the lower terrace. Because of the high risk of deep flooding, most of the floodplain is not presently cultivated. On the lower terraces, however, extensive schemes for growing irrigated and partly irrigated rice on a total area of approximately 5,000 ha have been developed by the federal and state governments in cooperation with the Japanese government and World Bank. The area may contain 20,000 to 30,000 ha of potential rice land along the Anambra River.

The area comprises two major soil types, depending upon physiography. Analytical data on two selected pedons from the Adani wetlands are given in Table 1. Soils (mainly Tropaquepts) on the floodplain are formed from recent alluvium, as indicated by their high clay and silt contents, high levels of exchangeable Ca, Mg and K, and slightly acidic soil reaction. Moreover, subsoil horizons include many small soft Fe/Mn concretions but very few gravel sized iron stones, or laterite. In general, soils in the floodplain have relatively high fertility status. Intensive rice cultivation would require moderate N and P application and good water control.

Soils on the lower terraces are medium textured and well developed. Their clay content, cation exchange capacity and nutrient status are considerably lower than that of soils on the floodplain. The soils are mainly Typic and Plinthic Tropaquults. Iron toxicity symptoms (bronzing and oranging) appear in patches of the rice crop where drainage is poor. With good fertilizer management and the use of small dosages of lime, soils of the lower terrace can be developed into more productive rice land.

Bende inland swamps. The Bende area consists of undulating land forms with small residual hills formed from sandstones. The valleys or swamps are mostly U shaped and are underlain by Tertiary shales. Unlike the Bida area, the small inland valleys in Bende have steep side slopes; thus, no hydromorphic soils are found in the foot slopes of the toposequence. The size of these inland valleys ranges from 20 to 100 ha.

The hydromorphic soils in these areas are generally characterized by high organic matter content, weak acidity, fine texture, high exchangeable Ca, Mg and K, and a montmorillonitic clay mineralogy (Table 1). The pedon is classified as a Eutric Tropaquept and has a blocky structure and high base status. It is the most fertile rice soil among the pedons observed in the wetland areas in southern and southeastern Nigeria. Several inland valleys in the Bende area have been developed for irrigated or

Characterization of hydromorphic soils in central Nigeria.

rainfed lowland rice cultivation. The grain yield of the 1982 crop of paddy rice was more than 5 t/ha, with moderate rates of N and P application. Varying degrees of Fe toxicity symptoms on rice are also observed in the Bende wetlands.

Iron Toxicity in Inland Valleys

Iron toxicity in inland valleys and swamps has frequently been reported in rice in West Africa. It is believed that this phytoxicity of Fe is caused mainly by the high concentration of ferrous iron (Fe^{++}) in seepage or groundwater. A field study was started in 1982 in a small inland valley (20 ha) near Bende to characterize the source and dynamics of ferrous Fe in relation to seepage flow and seasonal fluctuation of the groundwater table.

Field observations showed that severe iron toxicity (indicated by bronzing in rice) occurred mainly near the seepage outlets in one of the small side valleys (Figure 1). Soils in the iron toxic area are very poorly drained, appearing grayish, and have very few mottles in the subsoil horizons. The soil moisture regime in this area remains saturated from June to December.

Hydromorphic soils in the nontoxic area have good structure in the surface layer and many mottles, which extend to a depth of more than 100 cm in the subsoil. It is clear that the groundwater table in the nontoxic area drops to below 100 cm and allows oxidation to take place during part of the year.

Piezometers were installed along a transect from the foothill to the main stream, covering both the Fe toxic and nontoxic areas of the valley (Figure 2). The groundwater table at each piezometer was recorded weekly, and soil solution samples were withdrawn once a week for analysis of soluble Fe (mainly ferrous) and nutrient ions. The groundwater table at various piezometer sites monitored between August and December is shown in Figure 3.

Fluctuation in the groundwater table during the growing season is related to topography and the

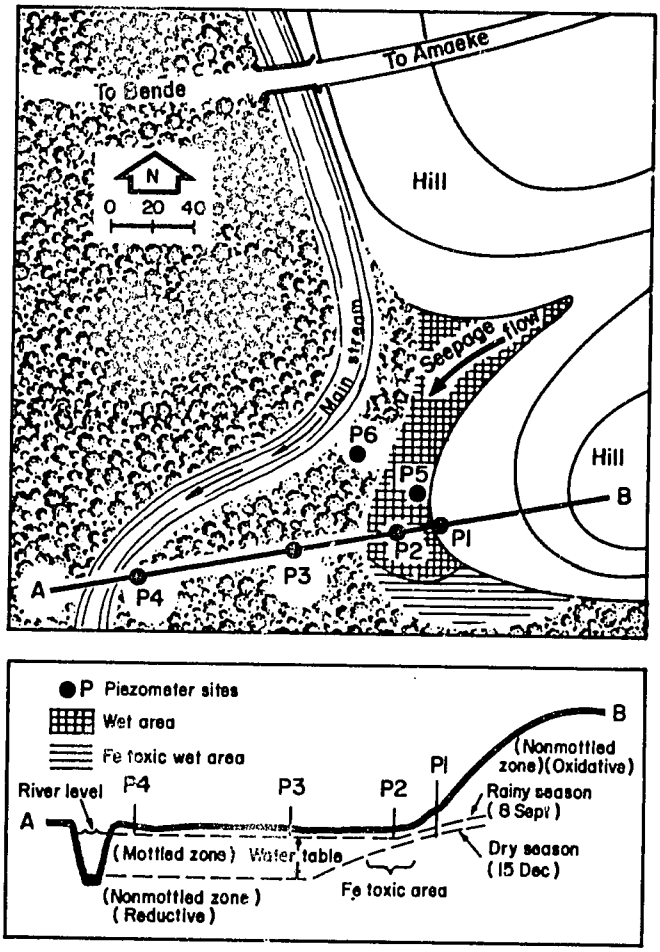


Figure 1. Map and cross section showing an iron toxicity field in an inland valley near Bende, Nigeria, 1982.

seepage and groundwater flow. Four piezometers were installed along the direction of seepage flow (piezometers 1 to 4). Groundwater data indicated that soils in the iron toxic area (piezometers 2 and 5) remain saturated or flooded throughout the growing season. Their soil solutions contain high levels of ferrous iron, ranging from 20 to 50 ppm (Figures 2 and 3). The highest soluble Fe content was observed in water samples taken from piezometer 5. The high Fe content is apparently the result of this piezometer's proximity to the source of seepage flow and to continuous flooding.

The groundwater table in the nontoxic area fluctuates markedly during the growing season, as shown by the data from piezometers 3 and 4. Soluble Fe content in the soil solution in the nontoxic area was much lower, ranging from 0 to 5 ppm.

Analysis of data collected throughout the year indicates that the groundwater table in the valley bottom land varies greatly in depth between the rainy and dry seasons. During most of the rainy season, it remains near the surface. The surface soil is thus enriched by the Fe rich seepage water, causing toxicity in the area near the outlets of the seepage flow. During the dry season, starting at the end of November, the groundwater table drops gradually to the level of the main stream (piezometers 4 and 6). Seepage flow from the side valley also diminishes during the dry season, and a slight drop of the groundwater table in the Fe toxic area allows oxidation to take place in the surface layer during some part of the dry season.

Although the Fe toxicity problems of inland valleys and swamps are common, their extent and severity depend largely upon the volume of seepage flow, the source and concentration of ferrous Fe in the seepage water, the groundwater table, and the drainage condition of the valley bottom land below the seepage flow.

The hydromorphic soils of the inland valleys near Bende are among the most productive soils for lowland rice cultivation in Nigeria. It is estimated that severe Fe toxicity occurs in about 5 to 10% of the total area study site. Reclamation of this area could be achieved by the construction of a small drainage canal to lead Fe rich seepage water into the main stream. The Fe toxic area is presently being used for screening rice cultivars for tolerance to Fe toxicity.—*T. Kosaki and A.S.R. Juo*

Soil Degradation

Alfisols

The decline in soil productivity of the kaolinitic Alfisols at IITA as a result of continuous cultivation has become a serious problem. On land newly cleared from secondary forest, cassava fresh tuber yields of 30 to 40 t/ha were at one time frequently obtained on large plots without fertilizer, and maize yields of 5 to 6 t/ha with moderate NPK application were not uncommon during the first few years after clearing. Such yields have become increasingly rare on fields that have been under continuous, mechanized cultivation for more than ten years.

During 1981–82, a soil fertility survey was made of the main farm blocks at IITA. Maps showing the extent of chemical and physical soil degradation and the nutrient status of the soil are being prepared. The results of this survey will be used in making recommendations for soil fertility restoration and future soil management.

Of the soil properties analyzed, the ones that changed most significantly were soil pH, organic matter and exchangeable Mg (all of which decreased) and bulk density in the surface horizon, which increased. Information about the degraded area and remarks on land management are given in Table 2.

Over half the total area of the experimental farm on the East Bank at IITA should be put under a planted fallow or a mulch farming system to restore adequate levels of organic matter and soil biological activity. Approximately 10 to 15% of the total area of the East Bank has been severely acidified, and magnesium deficiency and/or manganese toxicity may limit normal crop growth. These acidified lands should be returned to planted fallow with deep rooted shrubs to recycle the subsoil calcium. An initial

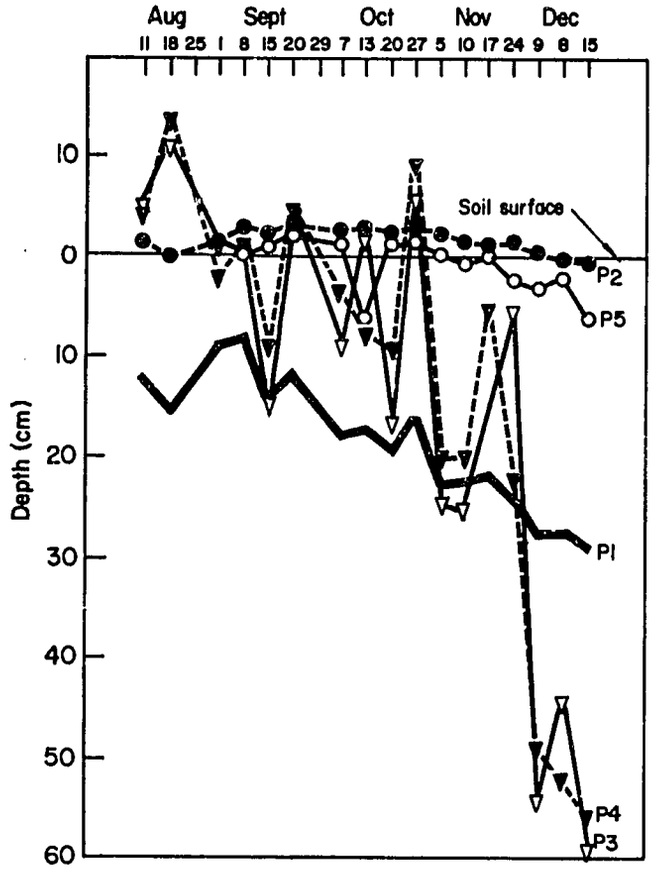


Figure 2. Seasonal fluctuation of the groundwater table and flooding at various observation sites in an inland swamp near Bende, Nigeria, 1982.

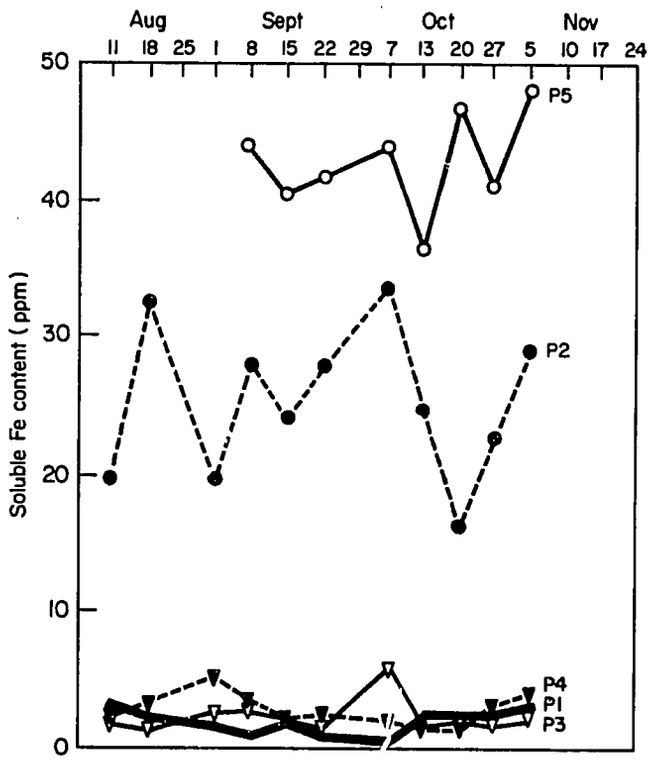


Figure 3. Seasonal fluctuation of dissolved iron in soil solution sampled at various piezometer sites in an inland swamp near Bende, Nigeria, 1982.

application of a small amount of dolomitic lime may also be required to facilitate seedling establishment.

Systematic monitoring of soil properties in selected long-term experimental plots (Figure 4 and Table 2) has shown that the extent of soil degradation depends upon the cropping systems and soil management practices. Land under continuous cereal cropping acidified at a much faster rate than that in a rotation of maize, cowpeas and cassava or in mixed cropping of maize and cassava. Continuous cropping greatly increased bulk density and reduced soil organic matter in the surface soil of all three land management systems. Fields planted in no-till maize with a residue mulch cover maintained a slightly higher level of organic matter than fields plowed by tractor.

The decline of soil organic matter and exchangeable Mg in the surface soil (monitored in a long-term continuous cropping experiment) was most striking, particularly when the crop residues were removed after each harvest (Figure 5). Acute Mg deficiency symptoms appeared on young maize plants after the fifth year, particularly on plots where crop residue was removed. This implies that even for the relatively high base-status Alfisols additional inputs of Mg fertilizer and lime may be required after several years of continuous cropping.

Data collected over a ten-year period have shown that the rate of decline in Mg was more rapid than that of Ca and K. This finding is in agreement with the ion exchange selectivity sequence of soils dominated by kaolinitic clay minerals. The loss of

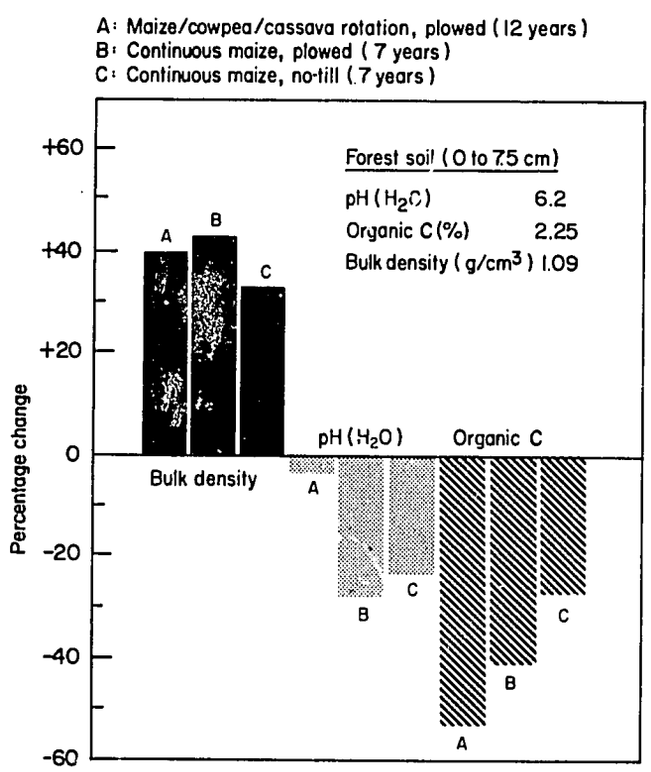


Figure 4. Changes brought about by continuous cropping in the surface layer of Alfisols at IITA, 1982.

Mg from the surface soil is caused primarily by a reduction in the cation exchange capacity, which results from a decline in soil organic matter. This loss is also caused in part by increased acidity in the surface soil. Most of the Mg is leached into the groundwater because the kaolinite dominated subsoil horizons have little capacity to absorb it.

A comparison of soil organic matter and pH levels in cultivated soils with those in soils under natural and planted fallow has shown the need for including an effective fallow phase in the cropping cycle to maintain adequate soil organic matter levels and to prevent rapid soil acidification (Table 3). Research on the management of the highly erosive kaolinitic Alfisols for food crop cultivation should strongly emphasize cover crop rotation and the inclusion of economic tree crops.

Table 2. Information on degraded soils at IITA's experimental farm at Ibadan, 1982

Soil condition[a]	Percentage of total area	Remarks
pH (H_2O): <5.0	15	Possible Mn toxicity in legumes; low rates of lime may be required. The land should be placed under cover crops, shrub fallow or alley cropping.
Organic carbon: <1.0 %	60	Severe N and S deficiencies in cereal crops. We recommend residue mulch farming with proper crop rotation, including cover crops. Alley cropping should be practiced on land with a slope greater than 4% or on land occupying the lower part of the toposequence.
Exchangeable Mg: <0.5 meq/100 g	35	Mg fertilization may be required to maintain adequate cationic balance

[a]Under secondary forest the surface soil (0 to 15 cm) properties were as follows: pH (H_2O), 6.0 to 6.9; organic C, 1.5 to 2.3%; and exchangeable Mg, 0.9 to 1.8 meq/100 g.

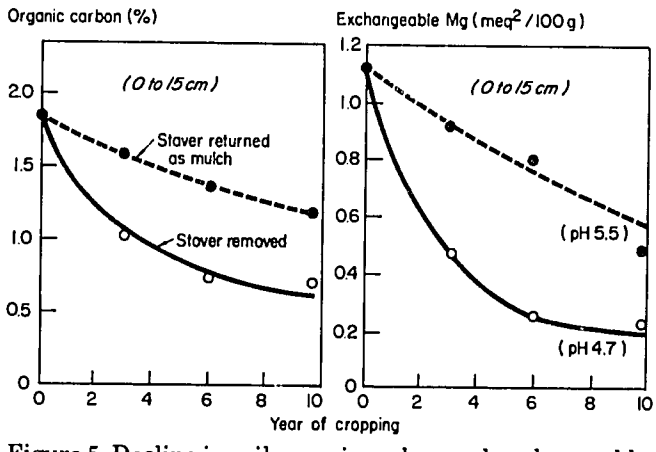


Figure 5. Decline in soil organic carbon and exchangeable magnesium in the surface layer of a forest Alfisol as a result of continuous maize cropping with and without crop residue mulching, IITA, 1982.

Ultisols

Changes in soil properties of the strongly acidic Ultisols (Typic Paleudult) under continuous cultivation at IITA's high rainfall substation at Onne were also monitored in selected experimental plots. The most pronounced change was the soil compaction in a field that had been under tractor cultivation for seven years, as shown by the increase in bulk density of both surface and subsurface horizons (Figure 6). Improved surface drainage on such fields is needed to minimize runoff and erosion during heavy rain storms. Establishing alley cropping systems on severely compacted fields is recommended to improve water infiltration. Liming and residue burning would be beneficial for the establishment of leguminous shrubs, which would supply adequate Ca and Mg and eliminate Al toxicity.

Continuous cultivation has also resulted in a decline of soil organic matter in the surface soil, compared with that in soil under forest vegetation. There was little difference in organic C content between the plowed and no-till and mulched fields under the perhumid conditions of Onne. The slightly higher pH values of the cultivated soils were due to a liming applied seven years ago at a rate of 1 t/ha.

The relatively high level of organic carbon (1.8%) and the low pH values (3.7) in the surface horizons under forest vegetation are common properties of highly weathered acid soils in the high rainfall tropics. Because most nutrient cations, such as Ca, Mg and K, are being held by the forest biomass, the soil organic matter becomes predominantly Al saturated and strongly acidic.

Table 3. Effects of continuous cropping compared with those of natural and planted fallow, IITA, 1972–1982

Treatment	Organic C, % 0 to 7.5 cm	Organic C, % 7.5 to 15 cm	pH (H_2O) 0 to 7.5 cm	pH (H_2O) 7.5 to 15 cm
Fallow (no fertilizer)				
Bush regrowth	2.81	1.05	6.3	6.0
Guinea grass (ratooned twice a year)	2.56	1.26	6.6	6.5
Leucaena (ratooned once a year)	2.68	1.12	6.1	5.9
Pigeon peas (ratooned or replanted once a year	1.79	0.84	5.1	5.0
Cropping (fertilizer, no-tillage)				
Maize/cassava mixed, residue mulched	1.28	0.80	5.4	5.5
Maize, residue mulched	1.58	1.01	4.6	4.8
Maize, residue removed	0.80	0.65	4.3	4.2
Soybeans, residue mulched	0.81	0.45	4.7	4.4
LSD (5%) for comparing:				
Treatments	0.33		0.26	
Depths	0.15		0.13	

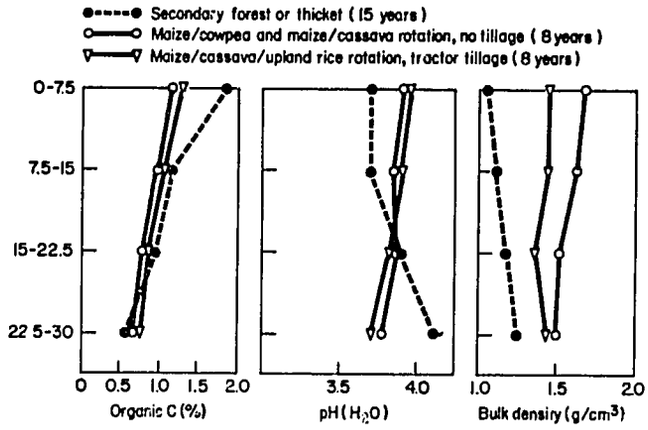


Figure 6. Effect of cultivation on some properties of a forest Ultisol, Onne, Nigeria, 1982.

Residue burning on strongly acidic Ultisols and Oxisols during forest clearing is beneficial in that it neutralizes soil acidity and permits quick release of nutrients such as Ca, Mg and P from plant residues.—*A.S.R. Juo and C. van der Meersch*

Soil Erodibility

Several attempts have been made to assess the erodibility of soil. Although it is best estimated by the unit plot technique under natural conditions, this method is expensive and time consuming. In other studies, nomograms have been developed that can predict relative erodibility from measurable soil properties both under natural and simulated conditions. These methods need to be tested on tropical soils.

Soil erodibility is a function of both the detachability and transportability of a soil and can be evaluated by various laboratory methods, although it is not known whether the various detachability indices are appropriate for tropical soils. In this study the correlation between various detachability indices and soil erodibility, as measured by rainfall simulation, is being evaluated for some Nigerian soils. These measurements of soil erodibility will be compared with estimates obtained by using the nomograph. For many erosion studies, simulated rainfall has great advantages over natural rainfall. It produces results more rapidly and efficiently and provides the desired information under more controlled conditions. However, the characteristics of natural rainfall must be simultated as accurately as possible, and in order for the results to be interpretated properly, the limitations of the method must be clearly established.

The rainfall simulator being used in this experiment was developed at the Laboratory of Soil Physics of the State University of Ghent, Belgium, by Gabriels et al. The main part is an applicator tank with 96 drop formers placed spirally in the bottom of the tank. The intensity of the rain is controlled by changing the hydrostatic head above the drop formers.

In order for the results to be valid, the rainfall simulator has to reproduce accurately a given intensity of rainfall for the different soils. After preliminary testing an intensity of 9 cm/h was selected, which could be reproduced with less than 5% variation. This high intensity was selected because it represents the more severe rainfall conditions for testing the erodibility of the soil.

The test procedure is as follows. The sample is placed carefully into the soil pan in a 5-cm layer over a screen covered with cheesecloth. Infiltration is measured by the outflow from holes in the bottoms of the pans, which are tilted at a 9% slope. Splash erosion is collected on splash boards placed at each side of the pans. Samples of runoff material and splash and infiltration water are taken at five-minute intervals. The runoff samples are filtered under suction, and the amount of soil and runoff water are measured. The samples are stored for further analyses. Samples of infiltration water are analyzed for nutrient losses. The soil sample (air-dry) is subjected to a one-hour rain, allowed to come approximately to field capacity and then subjected to 80 minutes of rain.

Fifty-six topsoil samples were taken at 27 different locations in Nigeria. These soils come from different agro-ecological regions of the country and have contrasting physical and chemical properties. The samples have been air dried without sieving. Since this study is still in progress, only the results for one soil sample can be given. The intensity of the rain was 8.17 cm/h for the dry and 9.00 cm/h for the wet run. Differences in rainfall intensity were due to differences in hydraulic head in the reservoir. The comparison between the wet and dry run was made to determine the magnitude of the effects of antecedent soil moisture content on splash and sheet erosion.

Results for the different soils will provide a basis for comparing the various detachability indices that will be examined (instability index, Henin index, wet sieving, water stable aggregates, dispension ratio, etc.). These tests are now being conducted for the 56 soil samples collected. In the near future, we plan to use a field rainfall simulator for comparing laboratory results with in-situ measurements.—*A. Vanelslande, R. Lal and D. Gabriels*

Organic Residues and Fertilizers

Most of the field experiments on organic residues and fertilizers were carried out at four sites in Nigeria: the IITA main station at Ibadan on an Egbeda series soil (Oxic Paleustalf); IITA's substation at Ikenne on an Alagba series soil (Oxic Paleustalf); IITA's substation at Onne on an Ultisol (Typic Paleudult); and Mokwa, which has a very sandy Oxic Paleustalf.

Effect of Plant Residue Mulching and Burning

Burning of plant residues is part of seedbed preparation in traditional farming systems. The

effects of this practice on soil productivity and crop performance have never been adequately studied. Two trials were started in 1978 on an Alfisol (Oxic Paleustalf) at Ikenne and on an Ultisol (Typic Paleudult) at Onne to investigate the effects of annual burning of plant residues before each main season planting. The trials included a study on the effects of mulching with the residues. The experiments were carried out through 1982, using a split-plot design with four replications. A maize cowpea annual rotation has been used throughout that period.

At Onne on the Ultisol, the main season maize yield declined to low levels without fertilizer and liming in the fifth cropping year. With an application of N, P, K, Mg and Zn, the burned plots gave slightly higher yields than the mulched plots, but when lime was also added every other year, the mulched plots gave higher yields. Results from five years showed that with minimum tillage, application of N, P, K, Mg and Zn, biannual liming, and annual rotations, high maize yields of over 3.0 t/ha can be sustained on the acid Ultisols at Onne.

The 1982 maize crop in the Ikenne trial produced much lower yields than in previous years primarily because of poor rainfall (Table 4). Though burning and mulching did not differ significantly in their effect on yield, the mulched treatment gave a slightly higher yield with NPK application.

The burned plots had a higher percentage of plant establishment. The lower plant establishment in the mulched plots was due mainly to rodent damage. But even though the plant stand was decreased by over 20%, the yield of the mulched plot was equal to or slightly higher than that of the burned plots. It is therefore likely that higher yields could be obtained from the mulched plot if the plant stand were improved.

Measurements of the physical properties of the soil showed that under minimum tillage, the bulk density remained low with both residue mulching and burning (1.11 g/cc compared to 0.95 g/cc for the bush plot). There was more earthworm activity in the mulched than in the burned plot.—*B.T. Kang*

Table 4. Effect of plant residue management and fertilizer on main season maize (TZPB) yield, Ikenne, Nigeria, 1982

Fertilizer treatment	Yield, kg/ha: Residues mulched	Residues burned	Mean
Control	2,507	2,499	2,503
PK	3,632	3,798	3,715
NK	2,788	3,117	2,953
NP	3,948	3,524	3,736
NPK	4,056	3,899	3,978
NPK, mg and Zn	4,105	3,943	4,024
Mean	3,506	3,463	

LSD (5%) for comparing:

Residue management means	739
Fert. treatments under same residue mgmt	576
Fert. treatments under different residue mgmt	885

[a]Mean plant stand of maize with residue mulched was 77.0% and with residue burned 95.9%, with an LSD (5%) of 11.2%.

Leaf Decomposition

Psophocarpus palustris and *Gliricidia sepium.* Decomposition of leaves of these species was studied at IITA on flat land cleared of vegetation and litter. Fresh bipinnate leaves of gliricidia and trifoliates of psophocarpus were collected and dried at 50° to 60°C in an oven. Subsamples (about 60 leaflets) were weighed and confined in insect proof nylon bags 30 cm × 40 cm of 32 mesh size and nylon nets of 2-cm mesh size.

For each legume, bags and nets were secured in the field during the rainy season in a four-replication split-plot design, with three pesticide treatments (control without pesticide, 0.15% thiodan and 0.1% benomyl) as the main plots and sampling time as the subplots. The latter consisted of five randomly set bags and five nets. Every 10 days one bag and one net were collected in each subplot for each legume. They were dried at 60°C until constant weight. Loss of dry weight and changes in N and P content were then determined in each sample.

The weight loss in nets of psophocarpus was 1.4 times more than in bags (Figure 7). Insects, physically screened from the bags, apparently played an important role in biodegradation of leaves of this legume. This finding was corroborated by the slow decomposition of psophocarpus leaves in nets treated with thiodan. However, because the rate of weight loss was higher in nets of psophocarpus leaves treated with insecticide than in bags, one could assume that thiodan was not totally effective in suppressing the insects or that its toxicity was not maintained throughout the experimental period. Other factors may have been involved, such as removal of pieces of leaves by wind and rain.

Comparison of weight loss in bags and nets of gliricidia leaves and the effect on this loss of thiodan indicate that insects were unimportant in biodegradation of leaves of this legume (Figure 7). Figure 7 also shows that benomyl retarded decomposition of leaves, particularly of psophocarpus, in the nets. Isolation of fungi colonizing both gliricidia and psophocarpus indicated qualitative differences between treatments; these were observed in the microscope and were indicated by mycelia and spore color on acidified potato dextrose agar plates.

Figure 8 shows that after 20 days decomposing leaves of psophocarpus contained less than 50% of their initial N and P. The same trend was observed for gliricidia. The rapid rate and large extent of N and P loss are important considerations when these legumes are to be used as live mulch or in alley cropping. Thiodan and benomyl had little effect on N and P loss but stimulated P immobilization.

Another experiment was conducted in the dry season to assess the effect of rainfall on the loss of dry matter and N during decomposition of *P. palustris*

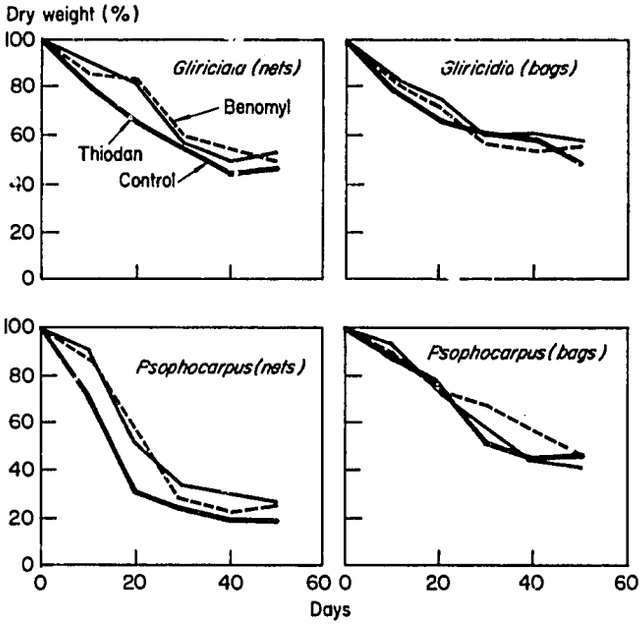


Figure 7. Effects of benomyl and thiodan on the dry weight of decomposing leaves of *Gliricidia sepium* and *Psophocarpus palustris* in nets and bags (expressed as a percentage of the initial weight), IITA, 1982.

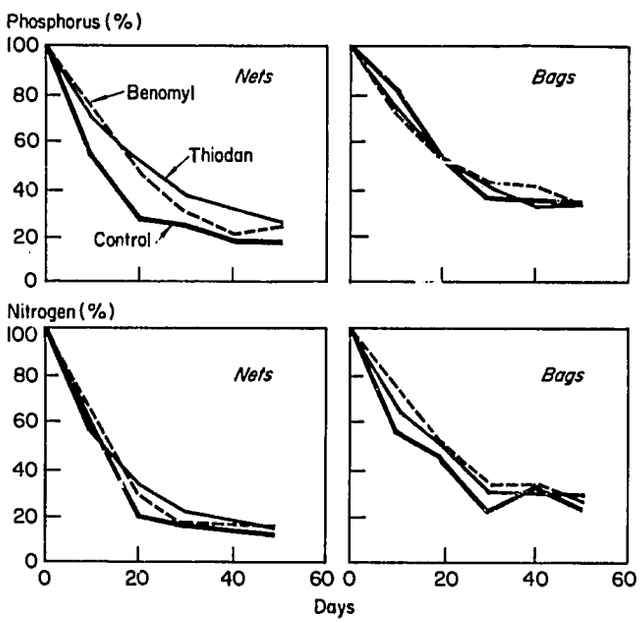


Figure 8. Effects of benomyl and thiodan on nitrogen and phosphorus content of decomposing leaves of *Psophocarpus palustris* in nets and bags (expressed as a percentage of the initial nitrogen and phosphorus content), IITA, 1982.

leaves. A four-replication split-plot design was used, with irrigation (equivalent to 0 and 8 mm rainfall per day) as the main plot and pesticide treatment (control, thiodan and benomyl) as the subplot. From five bags and five nets of leaves, one bag and one net were collected every 10 days.

Irrigation accelerated the loss of dry matter and N in the bags (Figure 9). This loss was reduced in the presence of thiodan and benomyl, confirming that insects and fungi participate in the decomposition of

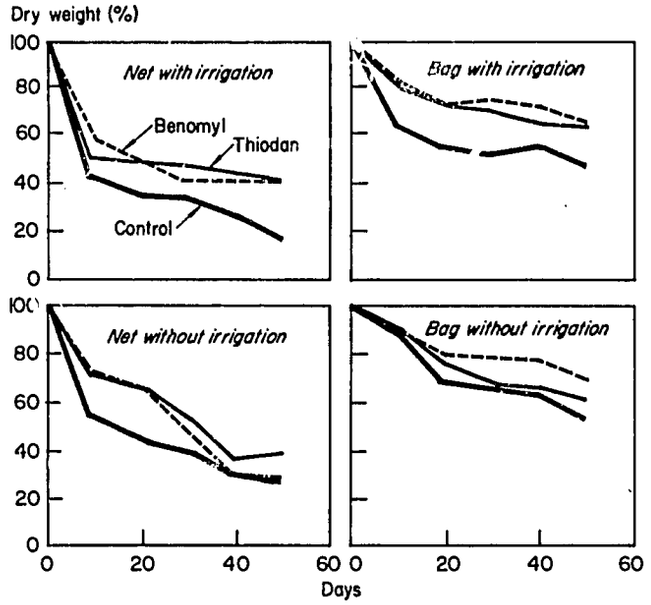


Figure 9. Effect of irrigation and pesticides on dry matter during decomposition of leaves of *Psophocarpus palustris*, IITA, 1982.

psophocarpus leaves. Dry matter and N content decreased faster in nets than they did in insect proof bags because plant materials are removed from the former by insects and wind and more are lost during handling. Because of the high rate of dry matter loss in nets, the effects of irrigation and pesticides were not evident.

Other plant species. The decomposition of leaves of selected plant species was studied at IITA and Onne to determine their potential as a source of nitrogen and as mulch materials. Leucaena and psophocarpus decomposed more rapidly than the other species (Table 5). The leaves of the latter had only 6% of their original N content after six weeks of decomposition at Onne and 21% at IITA. Because of its high N content and its fast growth and decomposition rate, *P. palustris* is appropriate for live mulch systems. Leaves of gmelina, cassia, acioa, treculia and centrosema are also adequate for that purpose. Of these, centrosema, and to a lesser extent, gmelina and cassia, could serve as sources of nitrogen as well.—*K. Mulongoy*

Nitrogen Response With Different Cropping Systems

An experiment was carried out at Onne on land that had been in bush fallow (mainly *Anthonata* and *Alchornea*) for over 12 years. The plot was hand cleared (not destumped) and partially burned before cropping, as is done by traditional farmers in the area. The trial was conducted using a randomized complete block design with four replications.

The response of maize to nitrogen was very significant (Figure 10). Monocropped maize (at a population of 40,000 plants/ha) responded significantly to N rates of up to 135 kg N/ha. Maize (at a

Table 5. Field decomposition of leaves of selected plants, IITA and Onne, Nigeria, 1982

Species	% dry matter after 6 wk of decomp. IITA	% dry matter after 6 wk of decomp. Onne	Percent N before decomposition	No. of days until 50% N loss IITA	No. of days until 50% N loss Onne
Gmelina arborea	78.9	77.9	2.23	>42	>42
Cassia siamea	79.7	94.4	2.66	>42	>42
Acioa barteri	87.2	88.7	1.74	>42	>42
Treculia africana	81.2	76.5	1.99	>42	>42
Gliricidia sepium	64.0	61.2	3.80	21–22	12
Leucaena leucocephala	61.5[a]	21.6[a]	3.35	26–27	22
Psophocarpus palustris	64.7	21.8	5.96	11–12	6–7
Centrosema pubescens	83.1	72.7	4.44	19–20	11
LSD (5%)	12.3	18.0	1.60	4	3.5

[a]The low dry weight may have resulted from loss of leaves during handling.

plant population of 10,000 plants/ha) intercropped with cassava (at a population of 10,000 plants/ha) gave lower yields under the low light intensity conditions at Onne. The low yields were caused by the shading effect of the vigorously growing cassava crop, which may also have been the reason that maize responded significantly only to the lower nitrogen rate of 45 kg N/ha. Additional nitrogen applications gave no further yield increases, and yield actually seemed to decrease at the highest N level of 180 kg/ha.—*A. van der Kruijs, J. van der Heide and B.T. Kang*

Evaluation of Nitrogen Sources

A trial was conducted at Onne on cropped land using a randomized complete block design with four replications. Nitrogen was applied in three dosages. Maize yield responded significantly to nitrogen up to a rate of 135 kg N/ha on this heavily cropped land (Figure 11). Though maize yield was not significantly affected by method of nitrogen application or by nitrogen sources in this trial, it appears that ordinary urea is slightly better than urea supergranules or CAN.

An experiment was conducted on cropped land at Ibadan to test the effectiveness in a no-tillage system of urea, urea supergranules, and calcium ammonium nitrate placed by various methods. The experiment was carried out using a complete randomized block design with three replications.

Prilled urea was less effective when broadcast or surface banded than when applied in a band and covered or applied in a hill (Table 6). Yield increased significantly when prilled urea was applied at a rate of 120 kg N/ha in a band and covered and when it was applied at the lower rate of 60 kg N/ha in a hill. With calcium ammonium nitrate, broadcast application also appears to be least effective. Calcium ammonium nitrate significantly increased yield when applied at 120 kg N/ha in a band at the surface or when covered and also at the lower rate of 60 kg N/ha when applied in a hill. Urea supergranules significantly increased yield when applied at a rate of 120 kg N/ha in a hill.

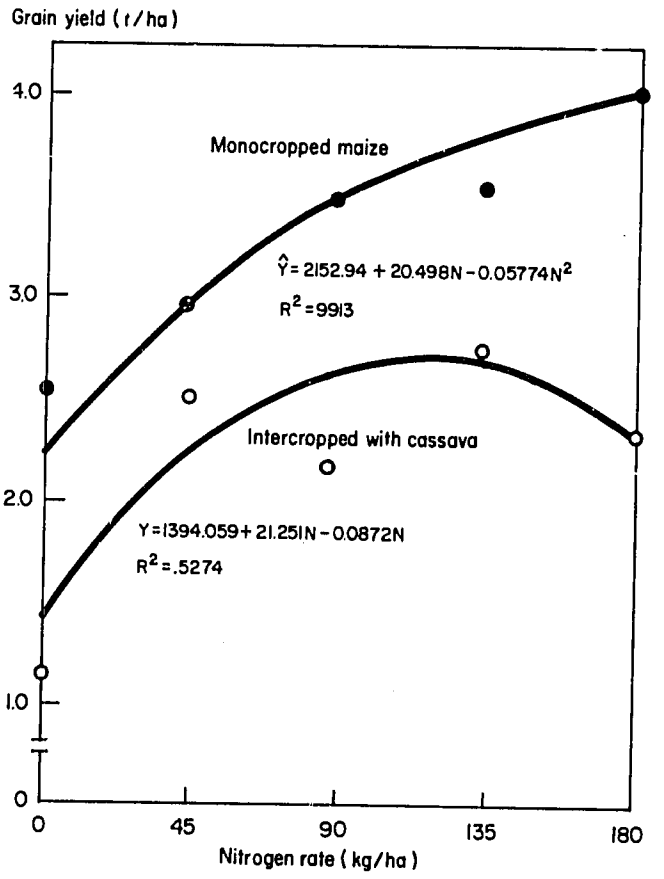


Figure 10. Effect of nitrogen rates on yield of monocropped and mixed cropped maize on newly cleared land, Onne, Nigeria, 1982.

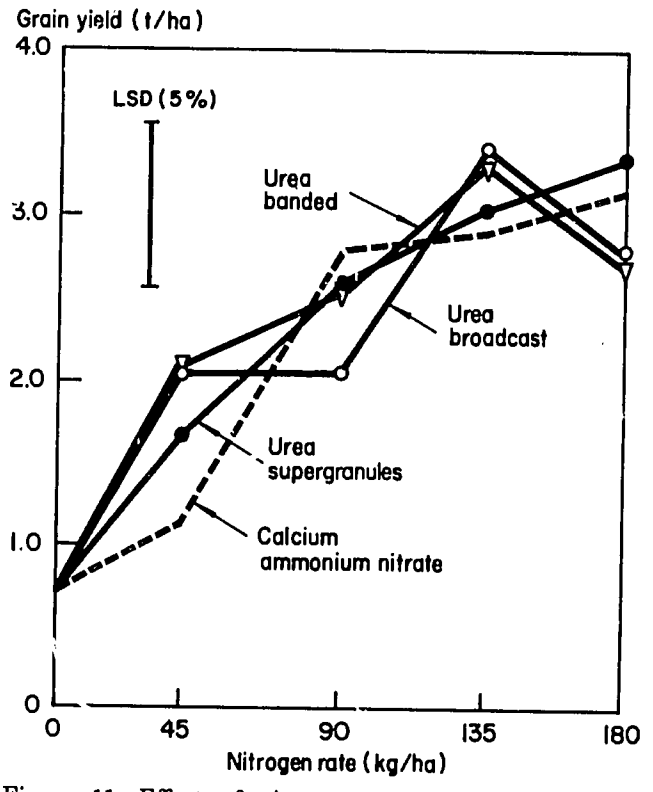


Figure 11. Effect of nitrogen sources and placement methods on maize yield, Onne, Nigeria, 1982.

With hill placement prilled urea, calcium ammonium nitrate and urea supergranules appeared to be equally effective, though urea supergranules have the advantage of easier handling and application. The lower effectiveness of surface applied urea and calcium ammonium nitrate may be due to surface runoff and, with urea, possibly to volatilization, as was observed in earlier trials.—*B.T. Kang, A. van der Kruijs and J. van der Heide*

Phosphorus Requirement of Cowpeas

The phosphorus requirement of three early maturing cowpea varieties (IT 82-32, 82E-9 and 82E-60) and one intermediate maturing variety (VITA-6) was studied at Ikenne. The surface soil had a low Bray P-1 level of 4.2 ppm. The experiment was set up in a randomized complete block design with four replications.

Despite the low initial soil phosphorus status, the four varieties did not respond to phosphorus application. The three early maturing varieties had significantly higher mean yields than VITA-6 (505 kg/ha). Of the three, IT 82E-9, which is black seeded, gave the highest seed yield of 1,210 kg/ha. All four varieties nodulated well at Ikenne. Phosphorus application significantly increased nodule numbers and weights at three weeks after planting. However, at six weeks after planting, phosphorus application had a significant effect only on nodule number, not on nodule weight. At that time, there were no significant differences in dry nodule weight between VITA-6, IT 82E-32 and IT 82E-9; all three varieties showed significantly higher dry nodule weight than IT 82E-60. —*B.T. Kang, A. Ayanaba and B.B. Singh*

Nitrogen and Potassium Response of Cassava

A nitrogen-potassium trial begun in 1980 with four cassava varieties on a Typic Paleudult at IITA's Onne substation was repeated in 1982. The experiment had a factorial design with four replications.

All four varieties showed some dieback and tuber rot at harvest. The low yields of TMS 4488 and TMS 30377 were due mainly to a high percentage of missing plants and tuber rot caused by the high rainfall at Onne (Table 7). Yield analysis showed significant differences between varieties. TMS 30572 gave the highest tuber yield, with a mean of 21.0 t/ha, followed by TMS 30555, 4488 and 30337 with mean yields of 18.4, 17.5 and 13.3 t/ha, respectively (Table 7). TMS 30555 gave the lowest tuber yield of the four varieties in the first trial.

Statistical analysis of the nitrogen and potassium responses showed no significant differences in tuber yield. However, as observed in the first crop, the average tuber yield tended to be higher with potassium application, particularly for TMS 30572 and TMS 30555 (Table 7). Data on the dry matter percentage of the tubers showed a significant increase with potassium application and a decrease with nitrogen.—*B.T. Kang and A.S.R. Juo*

Table 6. Effect of nitrogen source and placement method on maize (TZPB) Yield, IITA, 1982

Method and rate of nitrogen application	Prilled urea	Calcium ammonium nitrate	Urea, super-granules
Broadcast		*kg/ha*	
60 kg/ha	3,341	3,574	—
120 kg/ha	3,580	3,698	—
Surface banded			
60 kg/ha	3,148	3,500	—
120 kg/ha	3,624	3,919	—
Banded and covered			
60 kg/ha	3,570	3,441	—
120 kg/ha	4,033	4,073	—
Hill			
60 kg/ha	3,710	3,710	3,668
120 kg/ha	4,068	4,068	3,989
Control (no nitrogen)	3,108		
LSD (5%)	601		

Table 7. Nitrogen and potassium response of cassava varieties, Onne, Nigeria, 1982

Treatment, kg/ha		Tuber yield, t/ha				
N	K	TMS 30572	TMS 30555	TMS 4488	TMS 30337	Mean
0	0	14.6	17.1	20.8	14.4	16.7
50		16.4	17.4	21.6	11.7	16.7
100		17.8	15.9	13.4	10.8	14.5
150		15.3	16.7	14.1	13.1	14.8
0	50	18.0	22.3	17.8	12.4	17.6
50		20.4	18.1	16.9	18.0	18.4
100		24.4	16.6	14.2	5.9	15.3
150		25.1	12.9	22.8	7.3	17.0
0	100	24.9	22.5	18.4	9.7	18.9
50		25.3	15.5	16.0	12.2	17.3
100		23.5	18.8	21.1	13.8	19.3
150		20.7	18.0	17.8	23.5	20.0
0	150	23.4	23.8	16.9	16.2	20.1
50		23.8	20.0	11.3	18.2	18.3
100		20.3	19.1	20.5	14.7	18.7
150		21.6	19.6	16.9	11.3	17.4
Mean		21.0	18.4	17.5	13.3	
LSD (5%)				2.55		

Sources and Management of Phosphorus and Nitrogen

The International Fertilizer Development Centre (IFDC) and IITA started a cooperative research program in 1982 to find better, more economic sources of phosphorus and nitrogen fertilizers and to study their management in the humid and subhumid tropics of Africa. One alternative being considered to the expensive soluble P fertilizers is direct application of phosphate rock to some acid soils. This option has received much attention for several reasons. First, extensive areas in developing countries are characterized by acid soils that are high in phosphorus fixing capacity. Second, where deposits of phosphate rock exist, it takes much less capital investment and foreign exchange to use the rock for direct application than to import soluble fertilizers.

In using phosphate rock, one has to recognize the importance of soil pH since acid conditions are required for dissolution of basic calcium phosphate. Direct acidulation of phosphate rock, using a fraction of the sulphuric acid needed to produce single superphosphate, yields a P fertilizer that combines many of the desirable properties of the soluble P source and the P rock. These intermediate products developed by IFDC are referred to as partially acidulated phosphate rock. Their effectiveness is much less dependent on soil pH.

Little is known about the fate of fertilizer nitrogen applied to field crops such as maize in the humid and subhumid tropics of Africa. The use of ^{15}N as a tracer allows us to quantify accurately the utilization of fertilizer N by the crop, retention of it by the soil, and the amount of it lost from the soil-plant system. Incorporation of ^{15}N in different fertilizer treatments will help identify N sources or management practises that favor N utilization by the crop and reduce N losses.

The first series of experiments was established at Ikenne and Mokwa, Nigeria. Mokwa is in the southern Guinea savanna, where the rainfall is monomodal and averages 1,500 mm over five to seven months of the year. The soils at the experimental site are sandy, and the downward movement of clay within the profile makes the subsoil higher in clay. The clay is predominantly kaolonitic. The soils are Paleustalfs, with rather low cation exchange capacity and organic matter content.

Ikenne is in the subhumid forest zone, which receives an average of 1,500 mm of rainfall per year in a bimodal pattern. The soils at the experimental site are sandy, and the clay content increases with depth. The clay fraction is mainly kaolinitic and contains iron and aluminum oxides. Leaching is more intense there than in the savanna. The base saturation on the undisturbed topsoil is very high but decreases with increasing depth. These soils are Oxic Paleustalfs.

The objectives of the joint IFDC/IITA phosphorus experiments are to determine the effectiveness of finely ground Togo phosphate rock in food crop production, the effectiveness of partially acidulated Togo phosphate rock as a source of both phosphorus and sulfur for food crops and the most appropriate phosphorus fertilizer sources for improving food crop production economically.

Different rates of phosphate materials, including partially acidulated rock (with sulfuric acid) prepared at IFDC, were used in experiments at both Ikenne and Mokwa. The treatments included (1) phosphate rock applied annually, (2) phosphate rock applied at three times the rate of the annual application, (3) 25% partially acidulated phosphate rock, (4) 50% partially acidulated phosphate rock, (5) single superphosphate and (6) triple superphosphate.

Sources 1, 3, 4, 5 and 6 were applied at the rates of 0, 30, 60 and 90 kg P_2O_5/ha. All the phosphorus fertilizers were broadcast and incorporated to a depth of 3 to 5 cm. Nitrogen, magnesium and zinc were applied at 120 kg N/ha, 10 kg Mg/ha and 2 kg Zn/ha. The urea applied in treatment 5 was labelled with 5% ^{15}N to permit construction of the fertilizer N balance. The maize variety TZPB was planted at spacing of 75 cm × 25 cm during the major season in plots of 8 m × 4.5 m. The treatments were replicated five times in a randomized complete block design. Atrazine was applied to control weeds. In the minor season (Ikenne) or after maize had started silking (Mokwa), cowpea variety VITA-5 was relay planted at Mokwa and sequentially planted after maize at Ikenne. The cowpea crop did not receive any additional fertilizer.

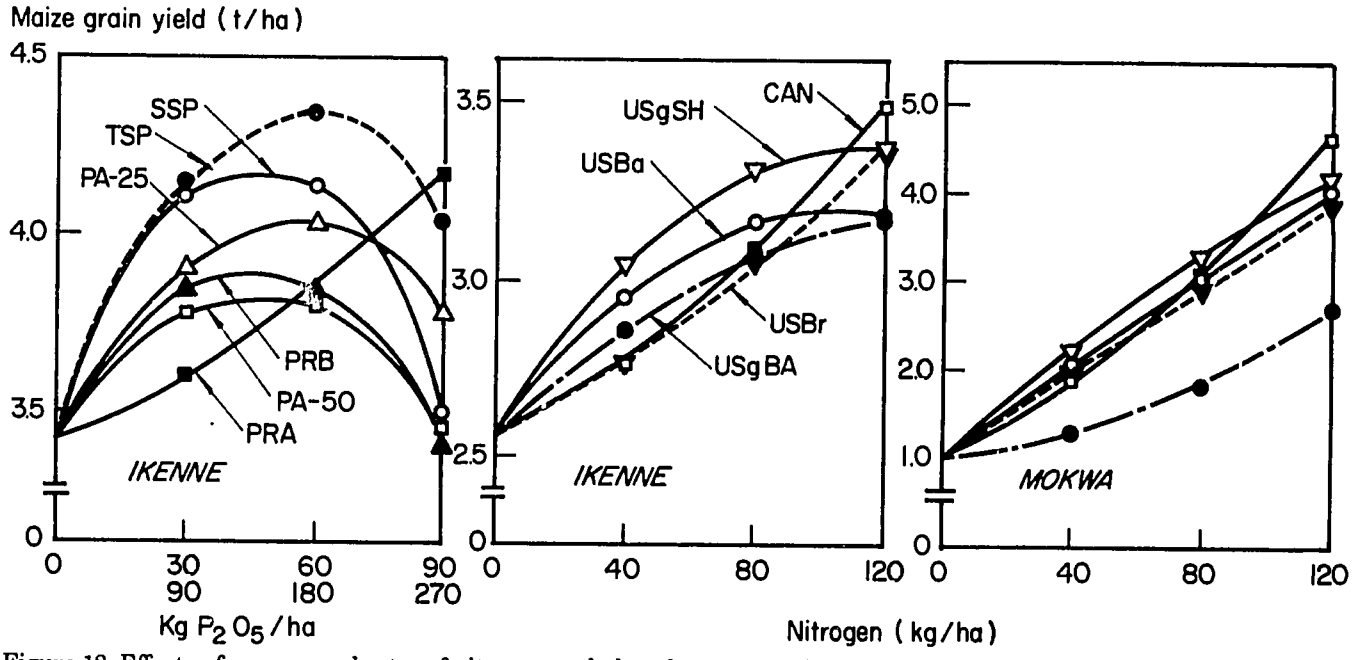


Figure 12. Effects of sources and rates of nitrogen and phosphorus on maize yield at two locations in Nigeria, 1982.

At Mokwa, phosphorus application had no effect on maize yields or on the P content of the maize index leaves. At Ikenne there were no increases in P content of the maize index leaves but maize yield did respond to phosphorus (Figure 12). At both locations cowpea yield did not respond to phosphate application. Growth and yield of the cowpea crop at Mokwa was markedly reduced because of the shading effect of the maize. Generally, cowpea yields at Ikenne were higher because the crop was sequentially planted there.

Since there was so little response to P, these experiments did not permit a proper evaluation of the phosphate sources. The experiments will be continued to evaluate residual effects, and new ones will begin at sites known to be responsive to P. The fertilizer N balance has not yet been constructed but will be once plant and soil samples have been analyzed for ^{15}N. Both experiments will include a second ^{15}N balance experiment next year.

Nitrogen trials were laid out at Mokwa and Ikenne to compare the N efficiency of various N sources and fertilizer management practices (modified products such as urea supergranules were tested) and to determine the utilization of N in maize/cowpea relay cropping systems (Mokwa) and the residual effect of N applied to maize on cowpeas in maize/cowpea sequential cropping (Ikenne).

In two experiments different sources and ways of managing IFDC's modified nitrogen fertilizers were examined in the field. The treatments were as follows: (1) calcium ammonium nitrate (CAN) was split and broadcast into the soil, one-third at two weeks after planting and two-thirds at six weeks; (2) urea was split and broadcast just as in 1; (3) urea was split and banded 6 cm deep and about 8 cm from each row marked with a hoe, one-third at two weeks after planting and two-thirds at six weeks; (4) urea supergranules were split and placed on the hill (one-third was spot placed in each hole 6 to 8 cm deep and about 8 cm from maize hills two weeks after planting, and two-thirds was spot placed at six weeks); and (5) urea supergranules were all placed in holes 6 to 8 cm deep and about 8 cm from maize hills at two weeks after planting.

The nitrogen rates for all the sources and management practices were 0, 40, 80, and 120 kg/ha. A basal application of phosphorus and potassium was made at planting at a rate of 90 kg P_2O_5/ha and 90 kg K_2O/ha. No fertilizer was applied to the succeeding cowpea crop. All the treatments were replicated five times in a randomized complete block design. The index leaves were sampled at silking for the maize tissue and at midflowering in the cowpea trial.

At Ikenne the nitrogen levels in the index leaves were not significantly different. They were very high, averaging around 3.47%, probably because the site had been under fallow. Maize yields responded significantly to N in the first season. At Mokwa the percent N of the maize index leaves greatly increased (Figure 13), and yield responded well to increased fertilizer N application (Figure 12).

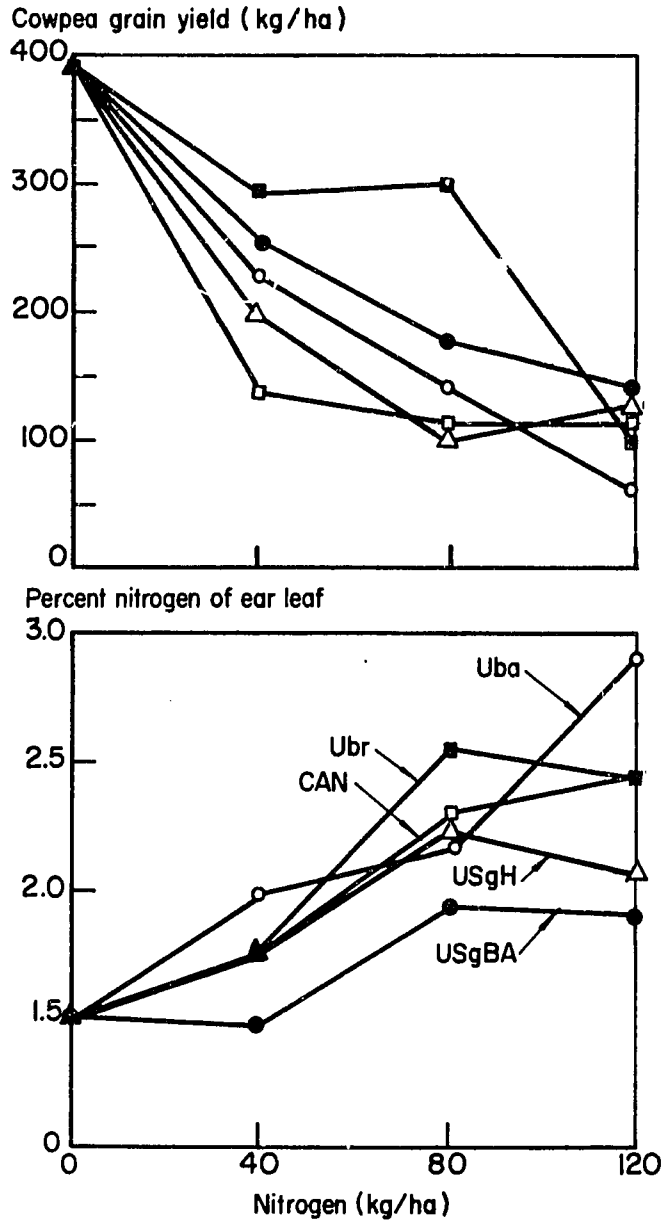


Figure 13. Effects of sources and rates of nitrogen on cowpea yield, Mokwa, Nigeria, 1982.

These experiments seem to indicate that split application of N improves maize yield. However, full evaluation of the various N sources and management practices requires further chemical (^{15}N) and statistical analysis.

Cowpea yield did not respond to N application at Ikenne. At Mokwa higher nitrogen rates resulted in higher maize yield, causing the maize crop to shade the cowpeas during their early growth and reducing cowpea yield (Figure 13). The highest cowpea yields were in the control (no nitrogen) plots where there was low maize growth.—*S.K. Mughogho*

Leaching and Utilization of Nitrogen

Rapid loss of fertilizer N through leaching is a major constraint on crop growth in the frequently highly permeable soils of the humid tropics. Field and

lysimeter studies were continued this year to evaluate leaching and crop utilization of different N sources.

Nitrogen leaching and recovery. Field experiments on leaching and crop recovery of N from different N fertilizers were conducted at Onne, which is in the perhumid region and has an annual rainfall of 2,400 m. Two cropping sequences, maize (first season) and upland rice (second season) and upland rice/maize were used. Three N sources were applied: urea, calcium ammonium nitrate (CAN) and ammonium sulfate (AMS). N rates were 150 kg/ha for maize and 120 kg for rice in split applications.

The results of these experiments from the first cropping season of 1982 (March to June) are given in Table 8. Judging from yield and N recovery by the crop, urea was a better source of N than CAN and AMS for first season maize. The three N sources made no significant difference in yield of upland rice, although rice plants recovered considerably more N from AMS than from CAN and urea.

Because of the poor growth and yield of second season maize and upland rice, the three N sources made no significant difference in yield and N recovery. The poor growth and yields were due partly to severe stem borer damage. Upland rice also had poor grain filling in the second season (July to October).

The estimated total recovery of applied N by the crop and soil (0 to 120 cm) at the end of the first cropping season (Table 8) showed that for upland rice ammonium sulfate gave the highest total recovery (71%) whereas for maize total N recovery from urea (61%) was considerably higher than from CAN and AMS.—*Y. Arora and A.S.R. Juo*

Nitrogen fertilizer efficiency. A field experiment was begun in 1982 on an Alfisol (Egbeda Series, pH 5.8), to determine the efficiency with which maize uses nitrogen from three sources—calcium ammonium nitrate (CAN), urea and ammonium sulfate (AMS)—and to study the long-term effect of the three sources on soil acidification under two cropping systems, a maize/maize and a maize/cowpea rotation. In cooperation with the IFDC, microplots with ^{15}N labelled CAN and urea were established in the field. The rate of N application was 150 kg N/ha.

Yields of maize and cowpeas are given in Table 9. The first season maize (TZPB) responded significantly to N application, but the N source had no significant effect on maize yield. The results of ^{15}N analysis showed that maize (grain plus stover) recovered 33% of the N from urea and 50% from CAN, indicating that the latter was the more efficient N source for maize growing at Ibadan.

Second season maize suffered severe drought stress resulting from poor rainfall distribution in 1982 and did not respond significantly to N application. The average yield of second season cowpeas (VITA-1) was about 1 t/ha without fertilizer application.—*Y. Arora, A.S.R. Juo, P.L.G. Vlek and S. Mughogho*

Calcium cyanamide as a nitrogen fertilizer. Calcium cyanamide ($CaCN_2$) has been unpopular with farmers of the temperate regions because of its slow rate of breakdown and transformation into nitrate in the soil. However, these characteristics may be beneficial for excessively well drained soils in the high rainfall tropics. In lysimeter and greenhouse experiments conducted during 1982, the rate of leaching and effectiveness of $CaCN_2$ as a source of N was evaluated for crops grown in a well-drained acid Ultisol (Typic Paleudult) at Onne.

A laboratory leaching study, using undisturbed soil columns (12 cm in diameter and 100 cm deep) of the Onne soil (pH 4.3), showed that CAN had the highest leaching rate, urea a somewhat lower rate and calcium cyanamide the lowest after the columns had been leached with 2,400 mm of water through a rainfall simulator over a period of 42 days (Figure 14). The rate of application was 24 meq N per soil column. Only a small amount of NH_4-N was found in the leachate, accounting for about 3% of the total amount of N added to the soil. Most of the NH_4-N was still retained in the soil column after leaching, indicating that NH_4-N was released from calcium

Table 8. Effect of nitrogen sources on leaching and utilization of fertilizer nitrogen by maize and rice, Onne, Nigeria, first season, 1982

Nitrogen source	Yield, kg/ha	Percentage of applied N recovered in grain and stover	Total percentage of N recovered by crop and soil (0-120 cm)
Maize (TZPB)			
Control	1,130	—	—
CAN	3,070	23	49
Urea	4,562	51	61
AMS	3,929	27	50
LSD (5%)	658	13	—
Upland rice (ITA 118)			
Control	974	—	—
CAN	2,978	30	50
Urea	2,441	29	36
AMS	2,612	40	71
LSD (5%)	417	17	—

[a]Nitrogen was applied at a rate of 150 kg/ha for maize and 120 kg/ha for rice.

Table 9. Effect of nitrogen source on maize and cowpea yield and recovery of nitrogen by maize, IITA, 1982

N source	Yield, kg/ha: First season maize	Second season maize	Cowpeas	% N recovered by first season maize
Check	2,177	1,054	1,124	—
CAN	4,407	1,419	925	50.1
Urea	3,878	1,334	1,001	33.7
AMS	4,342	1,222	921	—
LSD (5%)	722	ns	ns	—

[a]No fertilizer was applied to second season cowpeas. In both seasons maize received 150 kg N/ha in two split applications.

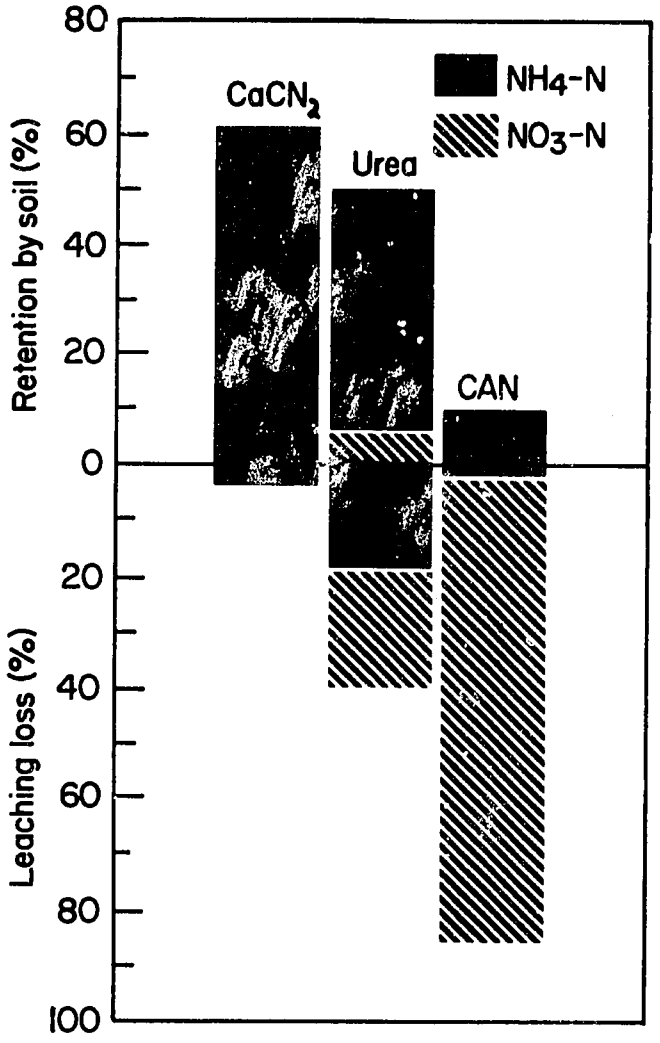


Figure 14. Leaching and retention of NH_4-N and NO_3-N from three different nitrogen sources (expressed as a percentage of total nitrogen added to the undisturbed soil columns), IITA, 1982. The soil columns were leached with 2,400 mm of water.

cyanamide slowly during its breakdown in the soil. The absence of nitrate in both the leachate and soil suggests that nitrification of NH_4-N was inhibited by the presence of appreciable amounts of free cyanamide in the soil during the six-week period.

In greenhouse and lysimeter studies of the Onne soil (limed to pH 6.0), calcium cyanamide was evaluated as a source of N for plants. In the greenhouse study, calcium cyanamide was compared with CAN and urea on upland rice and maize. The application rate was 150 mg N/kg of soil. Urea and CAN were applied at sowing. Calcium cyanamide was applied at one week and again at two weeks before sowing and at sowing to determine the time required for its breakdown and to eliminate its herbicidal effect on seed emergence. The plant dry matter yield of five-week-old plants (Figure 15) showed that calcium cyanamide (applied one week before sowing) was just as effective as urea and CAN in the greenhouse, where leaching of urea and CAN was prevented.

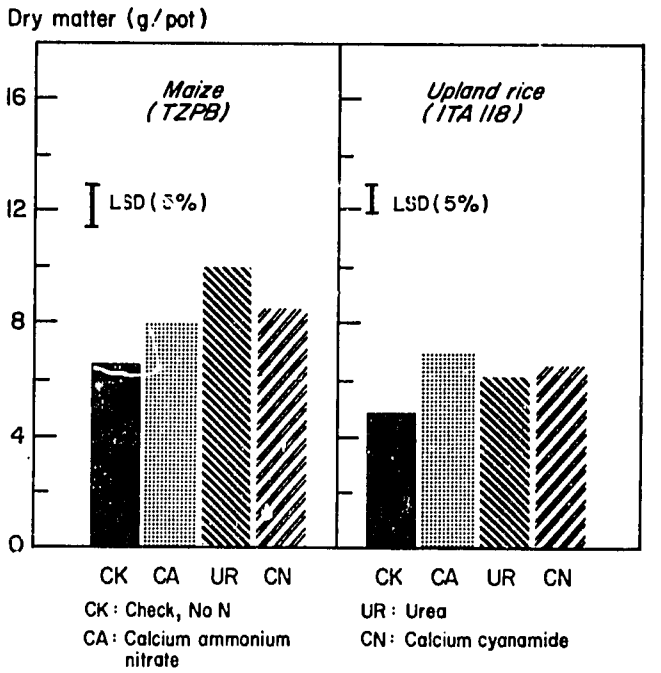


Figure 15. Dry matter yield of five-week-old maize and rice seedlings that received 150 mg N/kg of soil from three nitrogen sources, IITA, 1982.

In the lysimeter study conducted at Ibadan, using monolith lysimeters with Onne Ultisol, N leaching and utilization of calcium cyanamide and urea by upland rice were compared under a simulated Onne rainfall regime. An amount equivalent to 150 kg N/ha was added to each lysimeter (three replications). Urea was applied in three splits, and $CaCN_2$ was applied two weeks before sowing to allow sufficient time for its breakdown and transformation into NH_4-N and NO_3-N. The surface soil (0 to 10 cm) also received 3 t/ha of powdered $Ca(OH)_2$ four weeks before sowing, and soil pH was raised from 4.3 to 6.0, as measured at the time of sowing. Yields and amount of N leaching, given in Table 10, show that for upland rice grown under simulated high rainfall conditions $CaCN_2$ was just as effective as urea, even though it was applied only once before planting.

Because of its "resistance" to leaching and its usefulness as a preplant herbicide, calcium cyanamide may prove to be a superior nitrogen fertilizer for food crop production in the humid tropics.—*J.L. Pleysier, Y. Arora, A.S.R. Juo and T.L. Lawson*

Seedbed Preparation and Tillage

Effects of Tillage and Residue Mulches on Soil Properties

A long-term tillage experiment was begun in 1971 to compare no-tillage and conventional tillage, with and without mulch consisting of crop residues. The plots have been cropped continuously to maize, with two crops per year. Twenty-four maize crops were grown in succession through the end of 1982. This year a study was done on differences between the

Table 10. Leaching of mineral nitrogen and yield of upland rice in monolith lysimeters, IITA, second season, 1982

Nitrogen source (7,500 mg N per lysimeter)	Grain yield, g/lysimeter	Straw yield, g/lysimeter	Drainage	Amount of NO_3-N in leachate, mg[a]	ETM,[b] mm
Urea, three split applications	106	178	241	3,192	603
$CaCN_2$, one appl. 2 wk before sowing.	94	135	236	2,841	607
LSD (5%)	ns	ns	ns	ns	ns

[a]The content of NH_4-N in the leachate was negligible, and the total amount was less than 1% of NO_3-N.
[b]Maximum evapotranspiration over the growing period.

various treatments in some soil physical properties. Undisturbed core samples were taken at 10-cm intervals to a depth of 80 cm, and moisture retention and total porosity were analyzed. The pH curves are shown only for the 0-to-10-cm and 10-to-20-cm layers (Figure 16).

Regardless of the mulch treatment, the moisture retention of the untilled soil at a depth of 0 to 10 cm was greater than that of the conventionally tilled soil. The edaphologically significant soil moisture retention at 1 bar suction and a depth of 0 to 10 cm was 45% for no-tillage with mulch and 44% without, and 34% for conventional tillage treatments with mulch and 29.6% without. The total porosity at a depth of 0 to 10 cm was 49.6 and 48.0% for no-tillage and 39.2 and 38.4% for conventional tillage. These data show that the no-tillage treatments had a greater available-water storage capacity than the plowed treatments and that storage capacity is improved by residue mulch.

The pF curves for soil at a depth of 10 to 20 cm were not as clear as those for soil at 0 to 10 cm (Figure 16). Nevertheless, the soil from the no-till plots retained more moisture than that from plowed plots at most suctions. This favorable moisture retention with the no-tillage system is probably due to the higher organic matter content in the surface layer, the better soil structure and the higher earthworm activity, which result in better maize yields under a no-tillage system.—*R. Lal and O. Opara-Nadi*

Tillage and Fertilizer Interaction in Upland Rice

Experiments on upland rice were conducted both at Ibadan and Onne to investigate the effects of different tillage methods on the water and fertilizer use efficiency of the variety ITA 118. Three tillage methods were used: (1) conventional tillage involving plowing and harrowing, (2) no-tillage with chemical weed control, and (3) no-tillage plus straw mulch at 4 t/ha. There were three fertilizer treatments: (1) a control without any fertilizer, (2) 45 kg N, 6.5 kg P and 7.5 kg K/ha and (3) 90 kg N, 13 kg P, and 15 kg K/ha. All no-till plots were treated with paraquat at the rate of 2.5 l/ha one week before

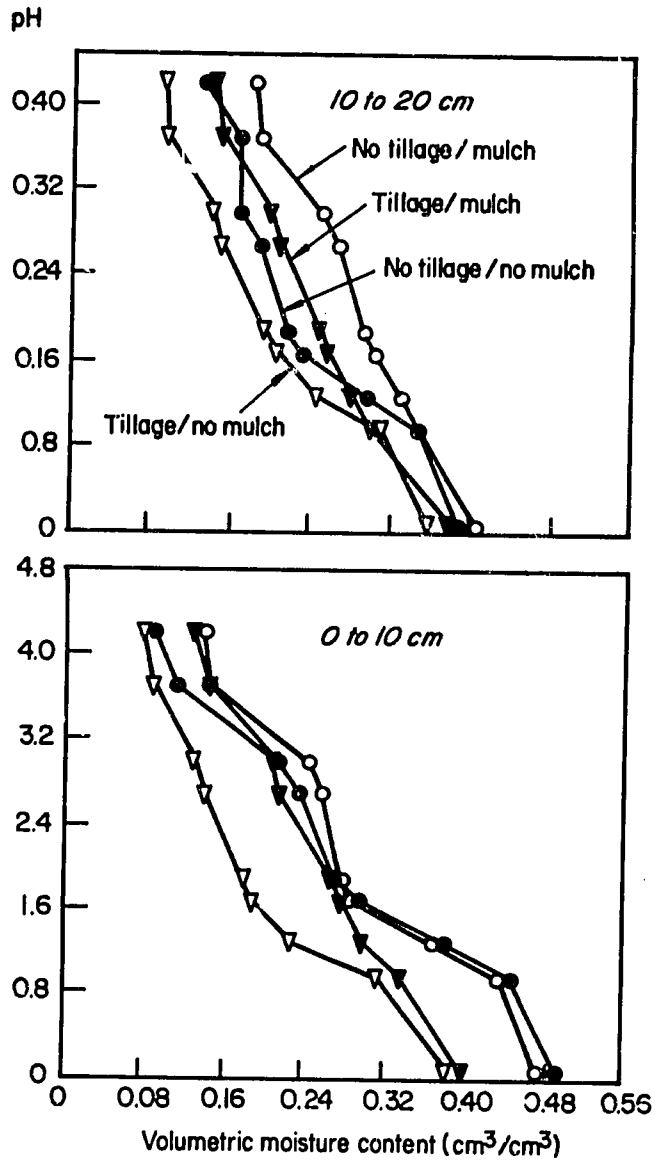


Figure 16. Effects of tillage methods and mulching on pF curves, IITA, 1982.

seeding. The experiment had a split-plot design with three replications. The tillage treatments were the main plots and fertilizer treatments the subplots. ITA 118 was seeded at spacing of 25 cm between and 20 cm within rows. Postemergence weed control in all plots was achieved through the application of Stam F34 at a rate of 4 kg/ha.

The rice yields at Ibadan and Onne are shown in Figure 17. At Ibadan yields were significantly affected by tillage methods, fertilizer levels and the interactions between them. The conventional tillage system yielded more than the no-tillage, with and without mulch, by 34 and 25%, respectively. The response to fertilizer was also much higher in the conventional tillage plots. It should be noted that this experiment was conducted on plots that had been cultivated by conventional tillage for about 10 years and were in poor condition.

Rice yields at Onne were higher than at Ibadan, and the general trends in the response of the crop to

good fertilizer management and the use of small dosages of lime, soils of the lower terrace can be developed into more productive rice land.

Bende inland swamps. The Bende area consists of undulating land forms with small residual hills formed from sandstones. The valleys or swamps are mostly U shaped and are underlain by Tertiary shales. Unlike the Bida area, the small inland valleys in Bende have steep side slopes; thus, no hydromorphic soils are found in the foot slopes of the toposequence. The size of these inland valleys ranges from 20 to 100 ha.

The hydromorphic soils in these areas are generally characterized by high organic matter content, weak acidity, fine texture, high exchangeable Ca, Mg and K, and a montmorillonitic clay mineralogy (Table 1). The pedon is classified as a Eutric Tropaquept and has a blocky structure and high base status. It is the most fertile rice soil among the pedons observed in the wetland areas in southern and southeastern Nigeria. Several inland valleys in the Bende area have been developed for irrigated or

side valleys (Figure 1). Soils in the iron toxic area are very poorly drained, appearing grayish, and have very few mottles in the subsoil horizons. The soil moisture regime in this area remains saturated from June to December.

Hydromorphic soils in the nontoxic area have good structure in the surface layer and many mottles, which extend to a depth of more than 100 cm in the subsoil. It is clear that the groundwater table in the nontoxic area drops to below 100 cm and allows oxidation to take place during part of the year.

Piezometers were installed along a transect from the foothill to the main stream, covering both the Fe toxic and nontoxic areas of the valley (Figure 2). The groundwater table at each piezometer was recorded weekly, and soil solution samples were withdrawn once a week for analysis of soluble Fe (mainly ferrous) and nutrient ions. The groundwater table at various piezometer sites monitored between August and December is shown in Figure 3.

Fluctuation in the groundwater table during the growing season is related to topography and the

tillage methods and fertilizer levels were somewhat different (Figure 17). Conventional tillage outyielded no-tillage with and without mulch. The fertilizer responses were highest with conventional tillage, followed by no-tillage with mulch. These experiments will be continued at Onne and Ikenne in 1983. To the yield data will be added observations on root growth and water uptake.—*M. Ogula, R. Lal and K. Alluri*

Nitrogen Requirements in Conventional Tillage and No-Till Systems

Investigations begun several years ago on the nitrogen requirement in tilled and no-till systems were continued in 1982. One trial, begun in 1978, is being carried out in the forest zone at Ikenne on an Alfisol (Oxic Paleustalf) and another, begun in 1979, is being conducted in the derived savanna at Ogbomosho on an Entisol (Psammentic Usthorthent). Both trials have a split-plot design with four replications.

The 1982 maize crop yielded very poorly, particularly at Ogbomosho, because of uneven rainfall (Table 11). There was no significant difference in yield resulting from tillage treatments at Ikenne. Nor did the crop respond significantly to nitrogen treatment. At Ogbomosho, despite the extremely low yields, the no-till treatment yielded less than the tilled plots, as in previous years. At Ogbomosho continuous maize cropping caused a pronounced decline in soil nutrient status under both tillage systems.—*B.T. Kang and N.C. Navasero*

Tillage and Residue Management

Another experiment on the effects of tillage and residue management on an Alfisol was carried out at Mokwa in central Nigeria. Maize and sorghum were the test crops. The trial had a split-plot design with four replications. In the first year, only partial residue management treatments (including burning, mulching and removal of residue) were imposed because the land had been under a short grass fallow. Maize and sorghum growth was slightly depressed in the mulched plots, but there were no significant yield differences. The tillage treatments (strip, conventional, manual and no-tillage) had no significant effect on maize and sorghum yields.—*B.T. Kang and E.N.O. Iwuafor*

A Screenhouse Method For Studying the Effects of Tillage on Crop Performance

A screenhouse trial was conducted with an acid Ultisol to determine the effect of mixing to various surface oil depths (one of the effects of tillage) on crop performance. Four soil mixing depths and four liming rates were compared, using a randomized complete block design with four replications. Soil core samples from depths of 0 to 30 cm were collected from a bush fallow plot at IITA's Onne substation, using aluminium tubes with an inner diameter of 12.5 cm.

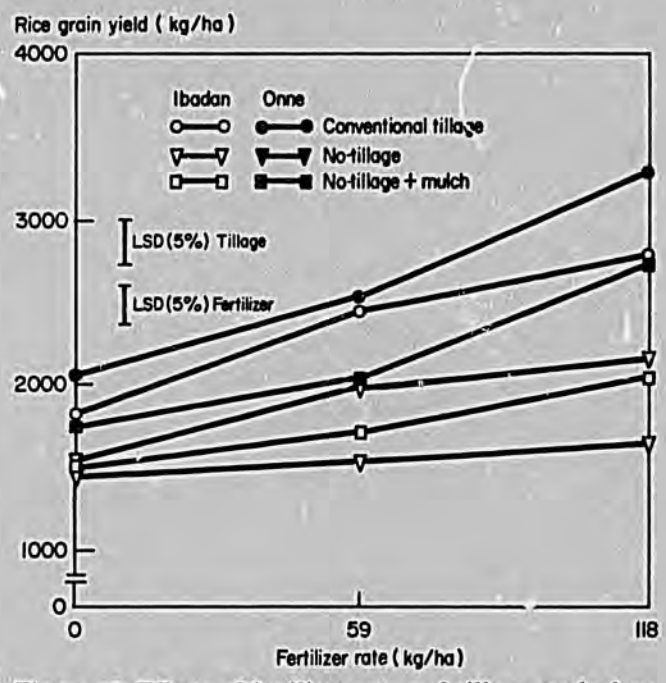


Figure 17. Effects of fertilizer rate and tillage method on yield of upland rice, Ibadan and Onne, Nigeria, 1982.

The tubes also served as pots for growing the maize. N, P, K, Mg, Zn and plant ash were added to all the treatments.

With no lime mixing of the surface soil up to a depth of 20 cm had no significant effect on the maize plants (Figure 18). However, mixing the soil to a depth of 30 cm significantly depressed maize dry weight. Under no tillage maize dry yield increased significantly with application of 0.5 t of lime per hectare. As the depth of soil mixing was increased to 10 and 20 cm, the lime rates required to increase maize dry matter yield significantly also increased to 1.0 and 2.0 t/ha, respectively. Mixing the soil to a depth of 30 cm caused a significant response only to the first increment of the 0.5 t of lime per hectare; further increases in lime rate did not improve maize growth. It appears that deep tillage in the highly acid

Table 11. Effect of tillage and nitrogen rate on maize yield at two locations in Nigeria, 1982

N rate, kg/ha	Ikenne			Ogbomosho		
	Tilled	No-till	Mean	Tilled	No-till	Mean
			kg/ha			
0	2,915	3,147	3,031	122	48	85
30	3,456	3,519	3,487	756	380	568
60	3,538	3,716	3,626	899	722	810
90	3,656	4,017	3,836	1,149	967	1,058
120	3,621	3,874	3,747	1,170	877	1,023
150	3,806	3,961	3,883	1,326	1,156	1,241
Mean	3,498	3,705		903	691	
LSD (5%) between:						
Tillage means				606		205
N rate means				368		183
N rate with same till. trtmt.				521		259
N rate with diff. trtmt.				752		306

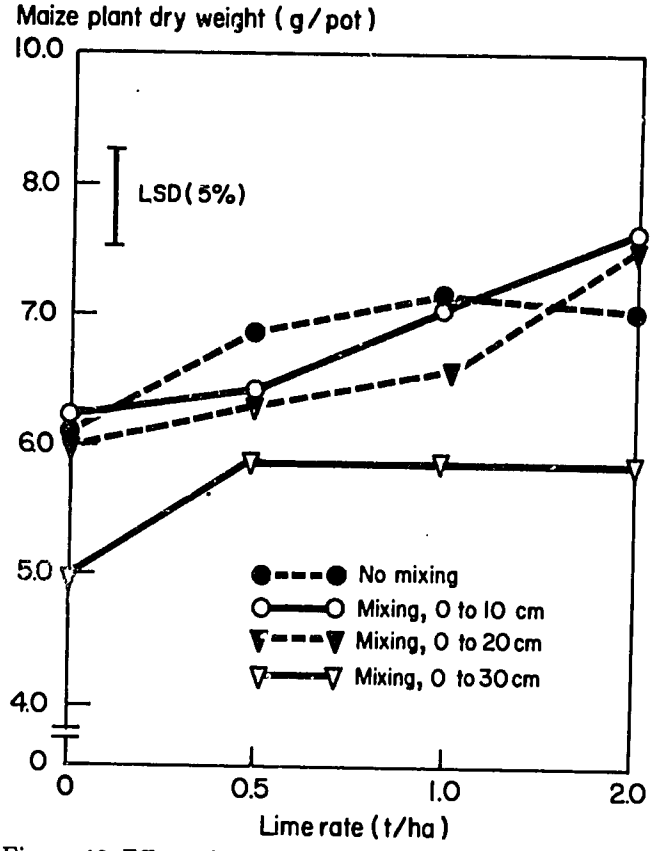


Figure 18. Effect of mixing depth in the surface layer of a highly acid Ultisol on the lime response of maize, Onne, Nigeria, 1982.

Ultisol may have undesirable chemical effects on the performance of maize. The higher acidity and Al saturation of the subsoil may have been the principal cause of this phenomenon.—*B.T. Kang and A. van der Kruijs*

Minimum Tillage Trials

Soil compaction becomes a serious problem on kaolinitic soils under no-till systems when tractors are used for planting and harvesting. While agronomists are studying crops and fallows that could alleviate soil compaction, the engineering section is conducting a long-term study to test different conservation tillage practices for their ability to avoid or alleviate compaction and allow sustained crop production in a no-till system.

The field experiment has six tillage treatments that cause minimum disturbance of the surface soil: (1) a continuous no-till system using a four-row no-till planter, a 10-m boom sprayer, a broadcast fertilizer applicator and a side-dress fertilizer applicator; (2) a continuous no-till system with hand-operated equipment, including a rolling injection planter, a hand-pulled 4-m pneumatic knapsack boom sprayer and a manual fertilizer applicator; (3) tillage at a depth of 25 cm with a Paraplow once a year just before planting in the first season (the no-till system of the first treatment is used in the second season); (4) tillage at a depth of 25 cm with a Paraplow once every two years just before planting the first season crop, followed by no-till as in the first treatment during the next three seasons; (5) planting every season with a chisel planter, using a chisel depth of 20 cm; and (6) strip tillage 10 cm wide and 13 cm deep in front of the planter.

The field used for the study had been cropped to maize, and weeds had been controlled chemically for four years without any tillage. The lightweight farmobile was used for the first three years, and in the fourth large-scale, mechanized no-tillage was employed. The design of the experiment is a randomized complete block with six treatments replicated eight times. Maize (TZESR-W) was planted in the first season on 2 June 1982. Uniform fertilizer applications and herbicide treatments were used on all parts. Observations are being made on soil water infiltration (double-ring system), weekly soil moisture, yield, soil bulk density and soil chemical properties.

In the paraplow treatment, yields were significantly higher than the others at the 5% level (2,734 kg/ha for once a year and 2,661 kg for once every two years), but treatments 1, 5 and 6 gave no significant differences. The hand-operated no-till treatment yielded the least (1,998 kg/ha). The yield response appears to be related to the amount of soil disturbance caused by the tillage method. The greater the disturbance, the higher the yield. Thus, the paraplow resulted in almost total soil loosening, and the chisel planter disturbed the soil a little more than strip tillage. The no-till system with tractor planter disturbed a very narrow line of soil, while the hand-operated no-till planter caused the least disturbance.

The chisel setup for the chisel planter, which was made at IITA, left a shallow trench because not all the soil chiseled aside fell back into the cut. The planter then planted the seeds in this narrow trench, making it difficult to control planting depth.

The low yields were most likely due to late planting, a relatively low rate of N application and the choice of TZESR-W, a short duration variety of rather low yield potential. As the experiment continues, we will determine whether the no-till hand treatment improves soil conditions and crop performance when no tractor or equipment passes over the plots. The paraplow treatment resulted in good production in the first crop, but its overall effects can only be determined after the experiment has been carried out over several seasons.—*C. Garman and A.S.R. Juo*

Ridged Seedbeds for Soybeans

The soils in Benue State, a major soybean growing area in the northern savanna region of Nigeria, are loose and sandy Alfisols. In the growing season there (May to October), heavy rains often wash soybean seeds and seedlings away from the usually ridged seedbeds and cause the seedbeds to collapse. Sometimes farmers leave the prepared seedbeds to settle during the first couple of rains before planting

soybeans. The erosion hazard in this area is high, and the rainfall, often torrential, occurs in a monomodal pattern.

A simple experiment involving four methods of seedbed preparation was begun at the Yandev station of Ahmadu Bello University. Ridges, normally 24 cm high, were flattened by levelling off the top to form beds 6 cm and 12 cm high. These were compared with flat, harrowed plots and with undisturbed ridges 24 cm high. The treatments were arranged in a randomized complete block and replicated four times.

The data in Table 12 show the benefits of a firm seedbed for soybeans in the loose sandy Alfisol that is characteristic of the Yandev area. The significant reduction in yield in the undisturbed ridges was due not to poor stands, but to a short drought spell after planting in July, which very likely caused higher moisture stress on the young soybeans in the loose ridges.

Tillage Systems and Mulch for Soybeans

A tillage and mulch experiment with soybeans was begun in 1981 and repeated in 1982 on a field at Yandev with a slope of 12%. The field was covered with a mixture of *Imperata cylindrica* and *Stylosanthes*. The legume covered about 20% of the total stand. This vegetation was killed with paraquat before seedbed preparation.

The experiment compared various land preparation methods: standard beds 1 m wide along a slope (control), ridges along the slope, ridges across the slope and no-till. In the beds and ridges, tied and untied furrows were compared. Some of the no-till treatments were mulched at 4 t/ha, and others were not. The experiment had a randomized complete block design with four replications.

Soybean yields were generally low, even where establishment was 90 to 100%. Growth was stunted as a result of dwarfing, which we suspect was caused by virus and serious moisture stress, particularly in 1981. The coefficient of variation in 1981 was 27% and in 1982, 42%. The replanted, mulched plots (100% establishment in 1982) outperformed the average by 53% because of the better moisture regime under organic cover. In 1981, when establishment in the mulched plot was very poor, the mean yield in the no-till plot was reduced about 33% below that of the control, which is about the same as the reduction in soybean establishment (31%) in those plots.—*H.C. Ezumah and E.A. Kueneman*

Tillage for Upland and Lowland Bunded Rice

Although rice is rapidly gaining importance in the African diet, research information on the most desirable agronomic practices for different ecosystems is rather scarce. Tillage requirements vary for upland and flood irrigated rice and differ according to the physical and chemical properties of the soil. Experiments were carried out to determine the effects of different methods of seedbed preparation on growth and yield of rice under upland and irrigated conditions.

Lowland bunded rice. The effect of three methods of seedbed preparation and of two soil moisture regimes was investigated in an experiment with a split-plot design and three replications. The moisture regimes were the main plots and methods of seedbed preparation the subplots. The three methods were compaction with a roller, puddling involving both dry and wet plowing, and no-tillage with chemical weed control. The soil moisture regimes were rainfall and irrigation to ensure continuous flooding. Root growth, grain yields and yield components were measured.

Upland rice. Experiments on upland rice were conducted at IITA's Onne substation. The effects of three tillage methods (compaction, no-tillage and conventional plowing) were studied with and without mulch. The effects of these treatments on establishment, root growth, grain yield, and yield components were examined in a randomized block design with three replications.

In the lowland bunded rice trial, which was carried out on a sandy coarse textured soil at IITA, the rice yield was higher on compacted soil than under other methods of seedbed preparation (Table 13). Yield was also significantly greater from continuously flooded than from rainfed plots. Compaction of these sandy soils decreases total porosity and macroporosity and therefore decreases losses caused by water percolation and leaching of plant nutrients. Under rainfed conditions, however, compaction restricts root growth and lowers yields, especially when soil

Table 12. Effects of seedbed preparation method on soybean yield, Yandev, Nigeria, 1982

Plot preparation	Yield, kg/ha	Plants per m²
Ridges undisturbed (control), 24 cm high	1,781 b	20
Ridges flattened, 12 cm high	1,963 ab	20
Ridges flattened, 6 cm high	2,022 a	20
Flat, harrowed plots	2,169 a	18
C.V., %	5.3	

[a]Yields followed by the same letter within the column are not significantly different.

Table 13. Effect of seedbed preparation method on yield of lowland rice under continuous flooding, Onne, Nigeria

	Rice yield, t/ha		
Treatment	First season of 1981	Second season of 1981	First season of 1982
Compacted	7.9 a	4.1 a	7.6 a
Puddling	6.6 b	3.5 b	5.1 b
No-tillage	5.9 b	3.3 b	5.6 b

Note: Figures followed by the same letter are statistically the same at the 5% level of probability.

moisture is a limiting factor.—*L. Ogunremi, R. Lal and O. Babalola*

Measuring Soil Compaction

In gravelly, highly variable soils in the tropics, it is difficult to assess soil compaction by routinely measurable soil properties (bulk density and penetrometer resistance, for example) that can be related directly to crop responses such as root growth, water uptake and yield. A study was conducted in cooperation with the Universities of Dar es Salaam and Copenhagen to develop more suitable criteria for measuring soil compaction in relation to plant response.

An experiment was begun in September that related compaction to crop response at three levels of soil compaction as main plots, to two levels of tillage (no-tillage and conventional plowing) as subplots, and to three crops (maize, cowpeas and soybeans) as sub-subplots. All treatments were replicated three times. The three compaction levels were 0, 2 and 4 passes of a tractor-mounted, two-ton roller. All crops were seeded on 16 September 1982 and received a uniform application of fertilizer (120 kg N, 26 kg P and 30 kg K/ha for maize and 30 kg N, 26 kg P and 30 kg K for legumes).

The results so far indicate that the saturated hydraulic conductivity measured on cores using a constant head permeameter was influenced greatly by soil compaction and tillage methods. The effects of compaction were present to a depth of 10 cm in plowed treatments and 15 to 20 cm in no-till treatments. At each level of soil compaction, saturated hydraulic conductivity in the no-till plots was generally higher than that in the plowed treatments often by 50 to 150% (Table 14). The high level of soil compaction decreased soybean emergence by 10% and reduced the number of leaves and leaf area index by 45% under conventional tillage 34% under no-till in cowpeas, and by 33 and 11% in soybeans. The plant height of the severely compacted treatment was also reduced, by 21 and 9% in maize, 15 and 12% in cowpeas, and 26 and 16% in soybeans under the conventional plowing and no-till treatments, respectively.

Table 14. Effect of soil compaction and tillage on saturated hydraulic conductivity and penetrometer resistance, IITA, 1982

Soil depth cm	Conventional tillage			No-tillage		
	No passes	Two passes	Four passes	No passes	Two passes	Four passes
			cm/hr			
0 to 5	76.9	32.8	22.5	123.5	57.2	22.5
5 to 10	66.4	37.2	35.5	121.2	62.4	30.9
10 to 15	44.0	89.4	45.1	109.4	99.0	57.5
15 to 20	36.7	123.0	52.2	102.9	124.1	74.0
Penetrometer resistance, kg/cm	—	2.98	4.22	1.70	3.05	3,53

Table 15. Effect of tillage and compaction on maize, cowpea and soybean yield, IITA, 1982

Compaction level	Maize		Cowpeas		Soybeans	
	No-till	Conv. till.	No-till	Conv. till.	No-till	Conv. till.
			t/ha			
No passes	5.9	6.9	1.3	1.3	1.0	1.9
Two passes	3.8	4.6	1.0	0.9	0.7	1.4
Four passes	2.9	3.3	0.8	0.8	0.5	1.1
LSD (5%):						
Comp. for same till.	1.1		0.3		0.2	
Comp. for diff. till.	3.2		0.8		0.4	

The yield of crops was also affected by soil compaction treatments (Table 15). Cowpea yields were 1.00, 0.72 and 0.61 t/ha under conventional tillage and 1.00, 0.82 and 0.66 t/ha under no-tillage for the control, two passes, and four passes of the roller, respectively. This implies that at the same level of compaction cowpea yield was reduced more by the conventional than by the no-tillage system. The reductions in yields of maize and soybeans are also shown in Table 15.—*B. Kayombo, R. Lal and H.E. Jensen*

Tillage and Soil Compaction

Soil compaction is thought to be one of the problems of continuous, mechanized crop production and is often observed to be very severe at points where farm machinery turns. In the heavily weathered tropical soils, with their low-activity clays and low organic matter contents, compaction problems can become a major obstacle to better agricultural production. A study was begun during October 1982 in cooperation with the University of Göttingen, to quantify soil compaction caused by mechanized and manual farming operations under no-tillage and conventional plowing systems. Soil compaction will first be characterized by evaluating soil physical properties (bulk density, porosity, pore size distribution, penetration resistance, water transmission characteristics, etc.) and then related to root development and proliferation and crop performance.

In the first experiment, root growth of maize (TZE) was investigated under no-tillage and conventional plowing managed by manual and mechanized operations. Manual operations included clearing, seeding, spraying, fertilizer application and harvesting. In the mechanized system, all these operations were performed by tractor driven implements. The experiment had a randomized split-plot design with four replications. Crop yields have not yet been measured.

The penetrometer resistance of plowed and no-till soil, measured 10 weeks after seeding, seemed to indicate that the different tillage methods caused varying degrees of compaction. Plowed plots were more compacted than no-tillage plots, especially at depths of 5 and 20 cm. As a result, the no-till plots had a higher root density in the surface 0-to-5-cm layer,

and the roots went down to 55 cm, compared with only 30 cm in plowed plots.

Under the no-till system, the root density and penetrometer resistance varied according to whether manual or mechanized farm operation methods were used. There were more roots in the surface horizons of manually operated than in mechanized no-till treatments. This differential root distribution is related to the higher penetrometer resistance in the surface layer of mechanized than in manual treatments.—*H. Franzen, R. Lal and W. Ehlers*

Land Clearing

Saturated Hydraulic Flow in Soil After Land Clearing

Tropical forests are being cleared by different methods for agricultural and industrial purposes. These methods greatly change the soil's physical properties, particularly bulk density and water retention and transmission properties. A study was conducted to examine the influence of different land clearing methods on water movement through disturbed soil cores. Chloride, rather than a dye or radioactive material, was used as a tracer to follow the depth of wetting front.

Undisturbed soil cores were taken from the 0-to-20-cm layer of an Alfisol sandy clay loam (Egbeda series) under forest and from plots cleared by manual, traditional, tree pusher and shear blade methods. The plots had been under a no-till system for three years.

The soil cores were first saturated with 0.01 N $CaSO_4$ solution, which was immediately replaced by 0.1 N $CaCl_2$. At the same time, samples of leachate were collected for analysis. The saturated cores were weighed at the end of a run for pore volume determination. These procedures were repeated for reconstituted cores for which soil samples were collected from depths of 0 to 5, 5 to 10 and 10 to 15 cm in each plot. These were air dried and packed in columns in their natural order of occurrence. Stones were not discarded and helped to pack the soil in columns at its field bulk density.

The chloride breakthrough for undisturbed cores collected from the manually cleared field show that the anion appeared in the affluent immediately after $CaCl_2$ was applied to the soil surface (Figure 19). This indicates relatively high flow through large, continuous soil pores. In the repacked columns, chloride appeared at a later stage, showing a relative lack of macropores in the soil samples.

The undisturbed cores from the shear blade treatment showed very similar flow characteristics, with an initial slight delay in chloride recovery (Figure 19). The displacement of the initial solution in the repacked column was nearly identical to that of the repacked columns from the manual treatment.

The results on chloride recovery in undisturbed soil cores from the other treatments are given in Table 16. Values for saturated hydraulic conductivity and bulk density are also included. The dominant flow in all cases was through the larger pores, indicated by a pore volume of less than 1 to reach $C/C_0 = 0.5$. Saturated hydraulic conductivity was highest in soil under traditional farming, and mean bulk density was lowest.

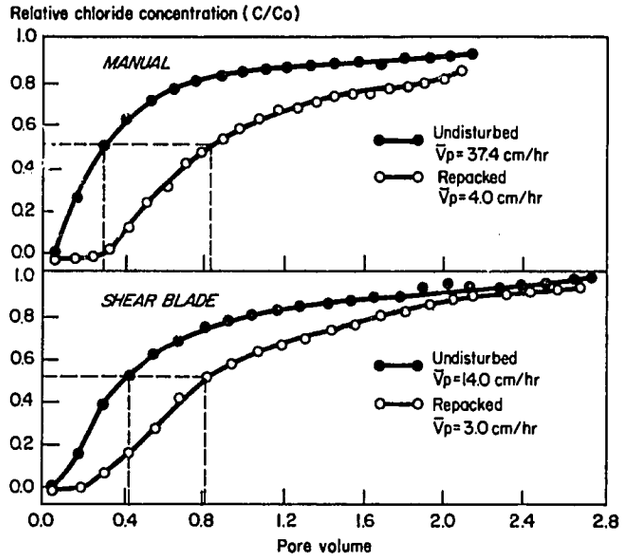


Figure 19. Chloride breakthrough curve for undisturbed and repacked soil cores under saturated flow for manual and shear blade clearing treatments. V_p is the average pore water velocity and C/C_0 is the ratio of influent concentrations, IITA, 1982.

From these results it appears that the method of land clearing has a considerable influence on water movement and saturated hydraulic conductivity in cleared soils. These changes reflect the compaction that occurs after forest vegetation is cleared from leached tropical soils. This compaction, which one might call structural collapse, changes pore size distribution considerably, decreasing the large and increasing the small pores. As a result, hydraulic conductivity is seriously decreased with obvious consequences for the ability of these soils to absorb

Table 16. Effect of land clearing on chloride leaching, saturated hydraulic conductivity and bulk density, IITA, 1982

Land clearing method	Pore volume to reach: 0.5 C/C_0[a]	0.9 C/C_0[a]	Saturated hydraulic conductivity, cm/hr	Mean bulk density,[b] g/cm³
Forest (control)	0.59	1.48	80.4	1.35
Traditional farming	0.60	1.64	85.4	1.26
Manual	0.26	1.48	35.4	1.61
Shear blade	0.40	1.90	13.3	1.76
Tree pusher	0.40	1.84	20.8	1.70

Note: For a leaching run, two undisturbed soil cores from a depth of 0 to 20 cm were collected.
[a]Ratio of effluent to influent chloride concentration.
[b]Stones were included.

rainfall without erosive runoff.—*B.S. Ghuman and R. Lal*

Effects of Land Clearing on Hydrological Properties

A study was begun in 1979 to assess the effects of land clearing methods and tillage systems on runoff and erosion, soil and microclimate, and crop yield.

Six land clearing methods and tillage systems were evaluated on individual watersheds of 3 to 4 ha each with two replications. The methods were traditional bush clearing, manual clearing followed by no-tillage, manual clearing followed by conventional tillage, shear blade followed by no-tillage, tree pusher/root rake followed by no-tillage and tree pusher/root rake followed by conventional tillage. All conventionally tilled watersheds were terraced for protection against runoff and erosion. In the no-tillage watershed, the previous crop residues were kept as a mulch, and herbicides were applied.

In 1982 the two conventionally tilled watersheds cleared with tree pusher/root rake attachments and one of the manually cleared, unterraced watersheds were taken out of maize production and seeded to the leguminous cover crop *Mucuna utilis* for soil restoration. Accelerated soil erosion in these treatments had resulted in rapid soil degradation and caused severe yield reductions. All the remaining watersheds were sown to a maize/cowpea rotation.

Soil hydrological properties. The soil moisture retention characteristics, determined by tensiometric measurements and gravimetric moisture determinations, were significantly affected by the methods of land clearing and soil management after clearing. The data indicate that the soil in the traditional farming plot retained high moisture at low suctions and less moisture at high suctions (Figure 20). The reverse was the case with soil from a plot cleared by tree pusher/root rake attachments and conventionally tilled during three successive years of cropping. For example, moisture content at a depth of 0 to 10 was 48, 40, 14 and 13% by volume for pF values of 0, 1, 3 and 4, respectively, in the traditionally cleared plot, compared to 40, 38, 20 and 19% in the tree pusher/root rake plot.

These results indicate a predominance of macropores in the traditional farming plots and of micropores in the mechanically cleared and conventionally tilled treatment. The total porosity was also 8% more in the traditional than in the conventional tillage treatment. For the traditional farming treatment, soil moisture characteristics determined in the field agreed with laboratory results. But field determined moisture contents at any suction were generally lower than the laboratory values for the tree pusher/root rake treatment (Figure 20).

Diurnal changes in soil moisture profile. Tensiometric and gravimetric soil moisture measurements were made at hourly intervals from 0800 to 2200 hours at depths of 5 and 10 cm. There were three tensiometers at each depth, and the data presented are the average of three separate measurements. At 5 cm no marked differences were found in diurnal soil moisture patterns between the different clearing and tillage treatments. There was a slight tendency for the soil in the traditional farming treatment to dry up slower than in the other plots. This tendency was greatly magnified at 10 cm, as shown in Figure 21. The traditional farming watershed still has a large number of trees (mainly oil palms). It is logical

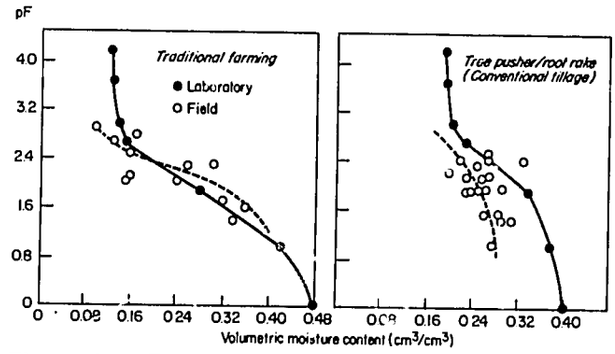


Figure 20. pF curves determined in situ and in the laboratory for two methods of land development, IITA, 1982.

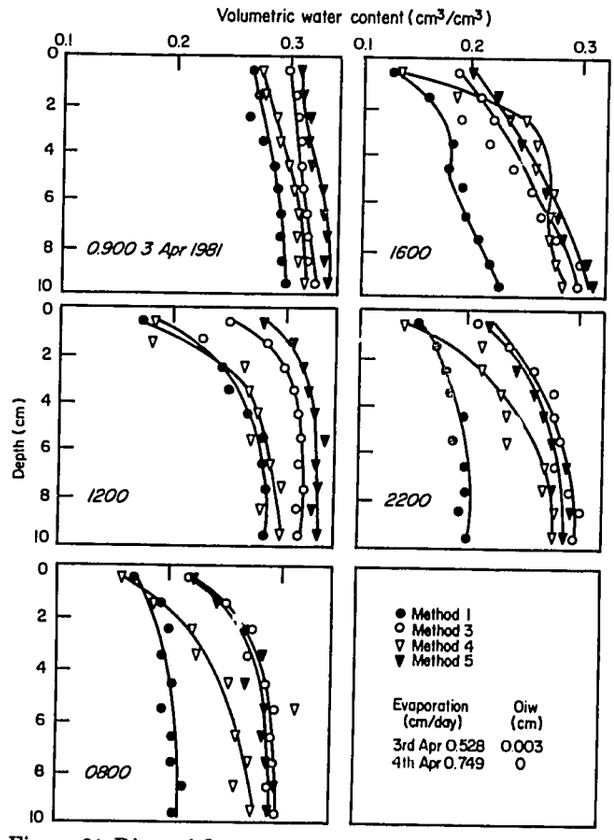


Figure 21. Diurnal fluctuations in volumetric soil moisture content for different methods of land clearing and tillage systems, IITA, 1982.

to conclude that shading, low soil and ambient temperature, the insulating effect of mulch and vegetative cover, low runoff and evaporation losses, and the high soil moisture retention capacity of the soil in traditional farming plots are responsible for this favorable moisture condition.

Four-hourly changes in the soil moisture profile (shown in Figure 21) varied significantly according to the method of land clearing and tillage. As indicated by their low soil moisture suction (discussed above), traditional treatments were observed to have high soil moisture content. The increase in evaporative demand during the day caused a progressive decline in soil moisture content in the upper 5 cm, although the most significant decrease was observed in the 0-to-3-cm layer. Regardless of the land clearing and tillage methods, the lowest soil moisture content in the surface layer was observed from 1200 to 1600 hours. Measurements at 2200, and on the following day at 0800 hours showed that the soil moisture content of the surface layers was higher than at 1600 hours (Figure 21). This increase in soil moisture content can be attributed to the temperature reversal during the night and subsequent dew and to the condensation of soil water vapor within the upper soil layers, probably at the expense of soil moisture in the 5-to-8-cm layer. The agronomic significance of this phenomenon, if it occurs widely, needs to be determined.

Regardless of the method of land clearing, no-tillage outyielded the conventional tillage system (3.3 t/ha compared to 2.4 t). Shear blade clearing followed by no-till led to better crop performance than did other methods of land clearing. Maize yield from the manually cleared no-tillage treatment equalled that from the shear blade treatment for the same time of clearing. One of the reasons for the stable and high yields of the shear blade treatments is that less water runoff and soil erosion take place in those treatments and the decomposing root channels of the perennial crops provide avenues through which maize roots can penetrate subsoil horizons and reach moisture and nutrient reserves.—*O. Opara-Nadi and R. Lal*

Cropping Systems and Management

In 1982 increased attention was given to cropping systems and management. We expect to give this subject even more emphasis in the future as we reorient the large-scale experiment on the West Bank at IITA. This study was originally designed to determine the effects of various land clearing and management practices on erosion, soil-water relations, soil degradation and crop performance. Beginning in 1983 the experiment will center on a number of cropping patterns, involving a wide variety of crops, and their effects on soil productivity, runoff and erosion, and farm management economics.

Multiple Cropping and Rotations

Maize/Cassava Intercropping

The effects of maize and cassava architecture on the microenvironment of maize and cassava grown in association were monitored by IITA's farming systems agroclimatologist. Since moisture and insolation limit crop production in the southern parts of West Africa, plant modifications that make moisture and sunlight more available should improve the yield of component crops in mixed cropping systems, particularly those with a multi-story canopy structure. To determine the extent to which this is so, maize and cassava varieties with the following plant architectures were studied: a spreading cassava variety (TMS 30572) whose leaf area indices (total plant leaf area divided by the land area it occupies) at Ibadan at two, four, six and eight months were 0.3, 2.0, 6.5 and 5.0, respectively, and a relatively erect type (TMS 30001) with leaf area indices of 0.25, 1.50, 3.30 and 2.10 at the same ages. The leaf area indices of TMS 30572 at those ages were 20, 33, 97 and 138% higher than those of 30001 (Figure 22).

Two varieties of maize were used, a spreading type (TZPB) and a relatively erect type (Kewesoke) with narrower leaves. The leaf area index of TZPB eight weeks after planting was 5.2, which indicated that it had a 27% higher leaf area than Kewesoke, whose leaf area index at the same age was 4.1. The two cassava varieties and two maize varieties were established in a split-plot design with two maize populations (30,000 and 60,000) and one cassava population (10,000). The cassava varieties were the main plots.

As reported in the IITA Annual Report for 1981, no pronounced differences in soil moisture were observed under the different crop combinations, although the light transmitted through the upper canopy of Kewesoke to the interplanted cassava was 5 to 10% higher than the amount transmitted through TZPB. With an increase in maize population from 30,000 to 60,000 plants/ha, the percentage of light transmitted decreased by 15% for Kewesoke and 9% for TZPB.

Cassava type had no significant effect on maize yield. TZPB, which has superior yielding ability, yielded 49% more than Kewesoke. Slight increases in the yield of each maize variety were obtained by doubling the maize populations (30,000 to 60,000). The relative yields of intercropped maize, based on monocrop performance, ranged from 80 to 99% for TZPB and 84 to 102% for Kewesoke. Since these differences are not significant, it can be concluded that the cassava had no effect on maize yield, regardless of the cassava or maize architecture.

Increasing maize populations to 60,000 plants/ha can cause significant differences in cassava root yields in a cassava/maize intercrop. Cassava intercropped with the spreading maize variety, TZPB, especially at a high population (60,000 plants/ha),

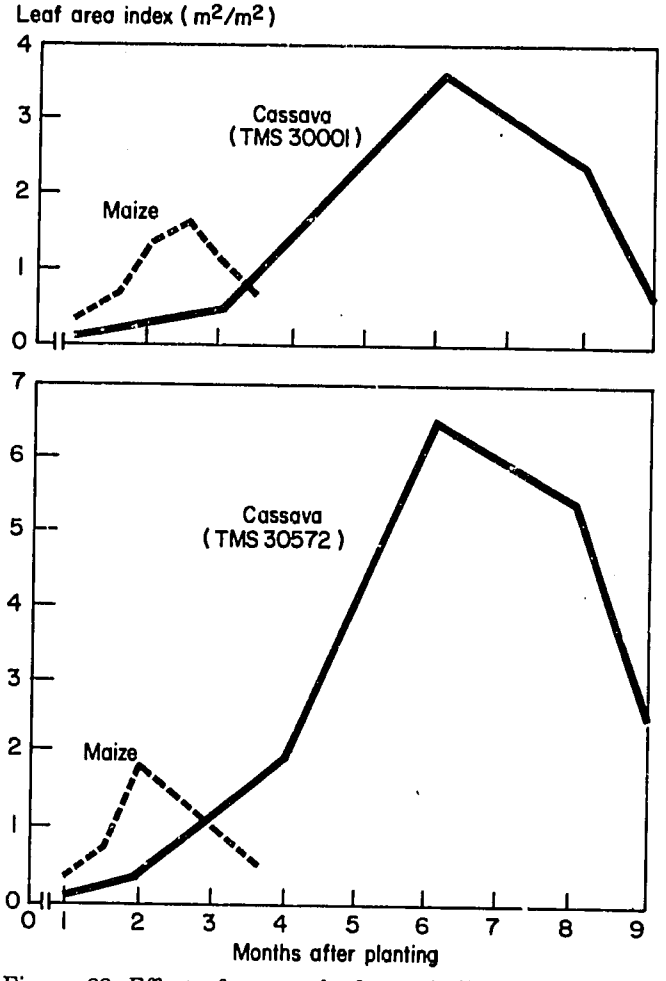


Figure 22. Effect of age on leaf area indices of different varieties of cassava and maize grown in a mixed cropping system, IITA, 1982.

yielded less than cassava with relatively erect maize (Table 17). Higher light reception is therefore associated with higher root yield by cassava intercropped with maize. The amount of light received and the resulting differences in root yields of a given cassava variety are affected by maize architecture. Thus, the 5 to 10% higher light transmission to cassava by Kewesoke as reported in 1981 resulted in a mean increase of 32% in root yield of TMS 30572.

Experiments were begun in 1981 to determine the effects on the performance of maize and cassava of including Egusi melon and okra in maize/cassava intercropping systems. Changes in microenvironmental factors at specific growth stages were monitored in the field and greenhouse. The layout had a split-block factorial design with three replications. Two cassava cultivars with different growth habits and yield potentials (TMS 30572 and TMS 30001) made up the main plot treatments, while the intercropping systems formed the subplots. The plant population of the cassava was 10,000 plants/ha in 1981 and 1982, that of the maize (TZPB) 20,000 plants in both years, that of the okra (V45) also 20,000 plants, and that of the melon 20,000 plants in 1981 and 10,000 in 1982.

Monitoring of the microenvironment showed that melon and okra did not significantly reduce the photosynthetically active radiation received by cassava, whereas in the cassava/maize intercrop, cassava received significantly less light. Cassava yields were significantly reduced by maize and by three combinations of cassava, melon and okra. The reduction in cassava yield caused by including maize in the intercrop was about the same as that resulting from okra and melon combined (Table 18).

These results agree with those of the maize/-cassava experiment reported above in that a significantly lower amount of light was transmitted to maize by cassava between 4 and 10 weeks of growth. Fresh root yield of cassava was also significantly decreased. The magnitude of light received does not explain the significant reduction in cassava root yield in the cassava/okra/melon intercrop (Table 18). The results of this experiment and of the one on cassava/maize intercropping clearly show that cassava does not reduce maize yield when the two are intercropped (Tables 17 and 18). Maize with cassava sometimes yields more or as much as maize alone. This is due in part to their wide differences in time of maturity (more than a year for cassava and 90 to 120 days for maize) and to the fact that maize and cassava do not compete during their periods of optimum vegetative development (Figure 22). But the high maize yields also suggest that it may be deriving some benefit from the intercropping with cassava.—*H.C. Ezumah and T.L. Lawson*

Mechanization in Maize/Cassava Intercropping

A major consideration in mechanizing maize/cassava intercropping is the consequences of damage done by maize harvesting machines to cassava. To test the reaction of cassava to this damage, the damage anticipated was simulated by cutting back the cassava stem to various heights—0 (control), 40, 60 and 80 cm—at the time of maize harvest. The experimental design was a randomized complete block with four replications.

The growth parameters (plant height, leaf index, branching and stem diameter) measured at harvest showed no significant differences between treatments, indicating that the cassava was able to regenerate its aboveground parts between maize and cassava harvest. However, the plants recovered only at the expense of tuber development. The number of tubers per plant and yields per hectare were significantly reduced by all cuttings (Table 19). In a trial carried out last year, cutting had no significant effect on yield. Thus, the extent to which cutting influences plant recovery and yield may depend on prevailing climatic conditions. Because there were no significant differences between cutting heights, it appears that machines causing similar damage within the height range used should be acceptable if the increased efficiency outweighs the cassava yield loss.—*G.F. Wilson and P.S.O. Okoli*

Table 17. Effects of cassava and maize architecture on yield, IITA, 1982

Maize variety	Cassava variety TMS 30572: Cassava yield, kg/ha	Maize yield, kg/ha	Total relative yield	Cassava variety TMS 30001: Cassava yield, kg/ha	Maize yield, kg/ha	Total relative yield
TZPB						
30,000 plants/ha	15,700	3,054	1.62	12,650	3,461	1.65
60,000 plants/ha	10,900	3,793	1.59	8,650	3,589	1.45
Kewesoke						
30,000 plants/ha	19,020	2,034	1.84	13,340	2,170	1.63
60,000 plants/ha	14,510	2,628	1.82	11,920	2,239	1.57
Means	15,025	2,877		11,640	2,865	
Monocrop cassava	18,030		1.00	16,910		1.00
Monocrop maize (TZPB)		3,838				
Monocrop maize (Kewesoke)		2,580				

LSD (5%)	
Maize varieties	592 (s)
Cassava varieties	4,920 (ns)
Maize pop. on maize yield	376[a]
Maize pop. on cassava yield (same var.)	3,791 (s)

[a]Significant only with TMS 30572.

Effect of Moisture Cycle on Cassava

A previous study on declining yields of cassava with increased severity (duration and intensity) of the dry season before harvest (IITA, Annual Report for 1980) indicated that the longer the moisture cycle, in proportion to the growing season (from planting to harvest), the higher the yield. The results also indicated that cassava is similar to other crops in that it requires favorable moisture throughout its growing cycle to reach maximum yields.

To confirm these deductions, differential irrigation, simulating moisture cycles of different duration, was applied to two cassava varieties (TMS 30555 and TMS 30572). Treatments were applied to whole blocks, with each cassava plot replicated three times within each block. Planting was done at the beginning of the 1981 cropping season (mid-April). Three moisture regimes were imposed after the end of the rains on 31 October and two blanket irrigations of all plots were done on 20 November and 1 December. In treatment 2 no more irrigation was applied. Treatment 2 received additional weekly irrigation through 31 December, and the additional irrigation in treatment 3 continued through 5 March 1982. The crops were sampled for fresh root yield on 2 December (before the additional irrigation treatments) and harvested in mid-March 1982.

The results for both varieties show that there was no significant difference in yield per plant before these treatments were imposed (Figure 23). At final harvest, however, yield differences between treatments 1 and 3 were significant, and the difference in mean yield per plant was highly significant.

These results confirm that the productive potential of these cassava varieties declines in increasingly dry areas. They also indicate the need for varieties with growth cycles that are more compatible with seasonal moisture cycles. Such varieties would permit harvesting at the end of an annual moisture cycle, leaving the land free for use at the onset of the next cycle.—*T.L. Lawson*

Maize/Cowpea Intercropping

The varying growth habits of cowpea varieties affect their usefulness in mixed cropping systems. Cowpeas are usually the minor crop in mixtures with other crops, especially in Africa. Research was begun in 1981 on maize/cowpea and cassava/cowpea systems to evaluate the performance of these mixtures under

Table 18. Yield of cassava and maize intercropped with okra and melon, IITA, 1982

Crop mixture	Cassava fresh root yield, t/ha	Crop mixture	Maize yield, t/ha
Cassava only	25.46 a	Maize only	2.96 b
Cassava/maize	19.40 b	Maize/cassava	3.17 ab
Cassava/okra	26.63 a	Maize/okra	3.07 b
Cassava/melon	22.03 ab	Maize/melon	2.96 b
Cassava/okra/melon	18.55 b	Maize/okra/melon	3.43 a

Note: Means in the same column followed by the same letter are not significantly different at the 5% level of probability.

Table 19. Effect of cutting height on cassava yield, IITA, 1982

Cutting height, cm	Number of tubers per plant	Tuber yield dry weight, t/ha
Control	9.7	17.6
80	7.3	14.2
60	7.2	13.1
40	7.2	13.1
LSD (5%)	1.7	2.2
C.V., %	13.2	9.7

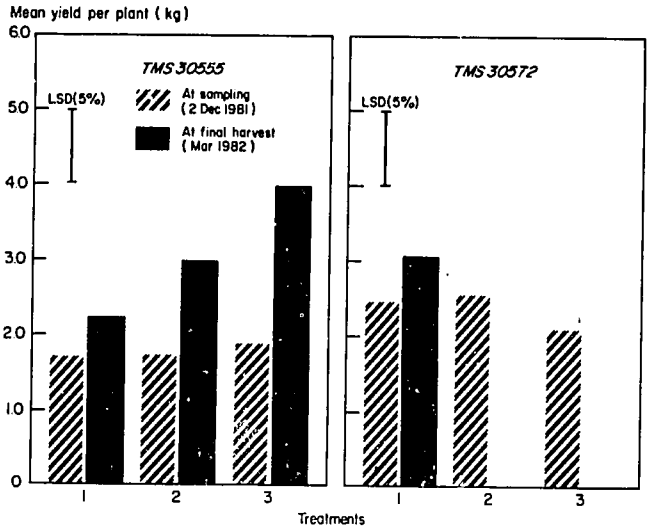


Figure 23. Effect of the duration of a favorable moisture cycle on cassava yield, IITA, 1982.

different conditions. In 1982 an early maturing cowpea variety developed by IITA scientists was used in mixed cropping experiments.

A 60-day erect cowpea (IT 82E-60) and a standard variety (VITA-5) were grown in four planting patterns with a late (TZPB) and an early (TZESR) maize variety. The patterns were (1) cowpeas arranged in alternate rows with maize; (2) two rows of cowpeas, 40 cm apart, planted between adjacent rows of maize; (3) cowpeas and maize in the same row; and (4) cowpeas and maize in the same row but with a second crop of cowpeas relay planted with maize soon after harvest of the first crop. The maize rows were 1 m apart, and within-row spacing was 25 cm. A fifth pattern, the control, was monocropped maize also planted at spacing of 100 cm × 25 cm. The seeding rate of cowpeas was 120,000/ha at planting. VITA-5, which has a spreading growth habit, was thinned to 60,000; IT 82E-60 was left unthinned. Fertilizer (15-15-15) was applied at a rate of 200 kg/ha. Insects were controlled by spraying at 22 and 40 days after planting. Harvesting frequency was based on the maturity of each variety.

With neither of the cowpea varieties in any of the cropping patterns and seasons, was the yield reduction of intercropped maize below that of monocropped maize (Table 20). Maize yields were higher than normally expected for TZPB in the long, first season but normal in the short, second season. Since yield differences resulting from differences in planting patterns were not significant, planting patterns should probably be selected on the basis of factors other than yield.

Monocrop cowpea yields were significantly higher than mixed crop yields (Table 20). Differences in planting pattern caused no differences in cowpea yield. Since cowpeas do not reduce maize yield, it is highly advantageous to intercrop maize with cowpeas, particularly during the second season, when the yield advantage, expressed as the total relative yield, could be as high as 25%, compared with about 4% during the first season.

As expected, cowpeas matured faster during the drier second season than in the first (Figure 24). During both seasons, it took only two harvests to pick over 90% of the total yield of the early cowpea variety, IT 82E-60, regardless of the planting pattern. In contrast, three or four harvests were required for VITA-5 during the first season, especially in the monocrop and double-row planting patterns.—*H.C. Ezumah, B.B. Singh and S.R. Singh*

Cassava Canopy Structure in Intercropping

Cassava is a main component of mixed cropping systems in many parts of the humid tropics. Previous studies have shown that competition for light is a

Table 20. Effects of planting pattern on yield of maize and cowpeas, IITA, 1982

Planting pattern	First season (April planting)				Second season (August planting)			
	Maize yield, kg/ha	Cowpea yield, kg/ha	Combined yield, kg/ha	Total relative yield	Maize yield, kg/ha	Cowpea yield, kg/ha	Combined yield, kg/ha	Total relative yield
	TZPB and VITA-5				**TZESR and VITA-5**			
Maize only	6,420		6,420	1.00	2,430		2,430	1.00
Cowpeas/maize in alternate rows	6,060	517	6,577	1.46	2,270	690	2,960	1.62
Double-row cowpeas between two maize rows	6,160	487	6,647	1.45	2,280	860	3,140	1.80
Cowpeas in same row as maize	5,590	614	6,204	1.49	1,190	750	2,740	1.57
Cowpeas and maize in same row/cowpea relay	5,510	551	6,061	1.42	2,100	840	2,940	1.70
Cowpeas only		992	992			1,000	1,000	
	TZPB and IT 82E-60				**TZESR and IT 82E-60**			
Maize only	6,420		6,420	1.00	2,430		2,430	1.00
Cowpeas/maize in alternate rows	6,120	510	6,630	1.35	2,370	590	2,960	1.52
Double-row cowpeas between two maize rows	5,880	640	6,520	1.43	1,930	880	2,810	1.59
Cowpeas in same row as maize	5,640	680	6,320	1.42	1,840	780	2,620	1.47
Cowpeas and maize in same row/cowpea relay	5,550	680	6,230	1.40	1,850	720	2,570	1.41
Cowpeas only		1,260	1,260			1,100	1,100	
LSD (5%) variety × planting pattern	900	223	206		830	200	154	

major factor in the relative productivity of the component crops in the mixtures (IITA, Annual Reports for 1980 and 1981). In one study comparing the microclimate of the canopy of cassava having strap leaves with that of cassava having normal leaves (TMS 30001), it was found that there may be some advantage to growing the former in association with low growing crops.

In a followup experiment, cowpeas (TVx 3236) were interplanted within these two types of cassava to determine the response of cowpeas to differences in microclimate, particularly light, under the cassava canopies, the possible effects of these differences on cowpea insect pests, particularly pod bugs, and the implications of these differences in pest control.

The mixed crop plots were laid out in a randomized complete block with three replications. The monocropped cowpea control plots were laid out in a separate block. Half of each plot was sprayed for major cowpea pests twice during the growing season with Decis at 15 to 20 g a.i./ha and Thiodan at 500 g a.i./ha. Thrips and *Maruca* were assessed based on flower sampling, and pod sucking bugs were counted visually.

The differences in light transmission through the cassava canopies were comparable to those previously observed. But the trend was somewhat different because of less favorable moisture conditions in 1982 and a consequent poorer rate of growth. Cowpeas in the strap leaf cassava yielded up to 92% of the monocrop yield; the corresponding yield with normal leaf cassava was only 40% of the control because less light was transmitted to the intercrop (Figure 25). Second season cowpea yields were very low in both mixtures (14 and 5% of the control) mainly because of excessive shading (Figure 26). For the sprayed cowpeas, the relationship between yield and light incident on the crop is expressed as follows: $Y = 1{,}043/[1 + 17.892e^{(0.11343x - 0.00237x^2)}]$ ($R = 0.96$).

Air temperatures within the strap leaf canopy near the top of the cowpeas were close to those of the monocrop cowpeas and up to 20°C higher than the values observed in the canopy of TMS 30001. The reverse was true of the relative humidity. The soil moisture was generally higher under the normal leaf cassava/cowpea combination during the early phases of growth. These results agree with those previously obtained in pure stands of the two cassava types (IITA, Annual Report for 1981).

The merits of the strap leaf cassava in intercropping systems are evident from these results. As in previous studies, rapid decline in the yield of interplanted crops is closely related to a narrow drop in light intercepted from about 75 to 60% of the prevailing global radiation. Given the differences in the light transmission characteristics of the two cassava canopies, the potential advantage of incorporating the strap leaf character into some popular varieties is obvious. This type of cassava offers a wide range of possibilities in the development of mixed crop production systems.—*T.L. Lawson and L.E.N. Jackai*

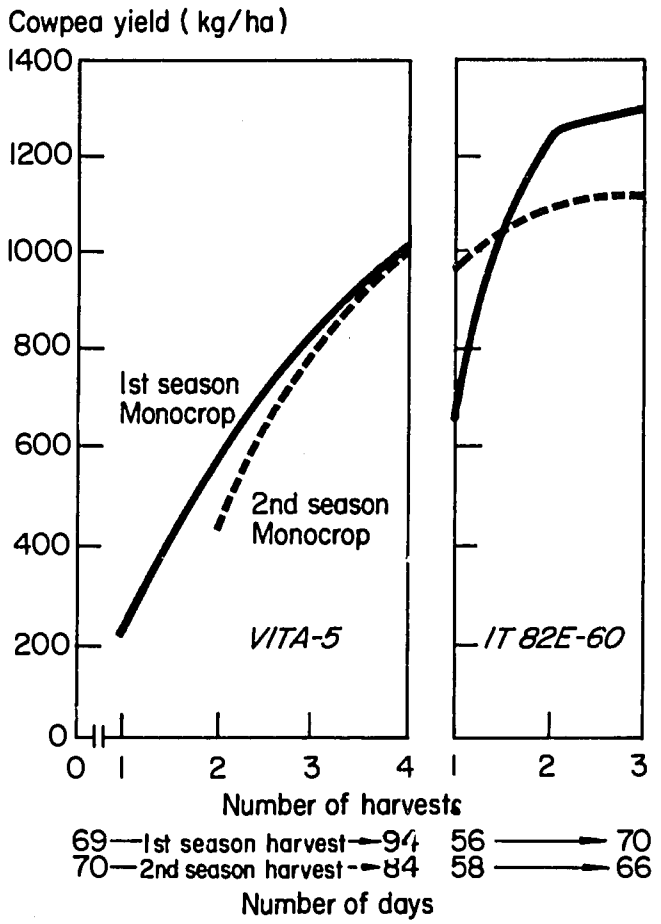


Figure 24. Effect of planting pattern on yield and rate of grain maturity of cowpeas, IITA, 1982.

Weed Management

Chemical Control of Fallow Vegetation

A study was begun to evaluate a range of herbicides and herbicide mixtures for control of perennial weeds after bush fallow clearing and to identify preplant herbicides that do not create residue problems in the crops. The experiments were conducted at four locations, representing: (1) typical woody perennial bush regrowth, (2) the mixed perennial grasses and broadleaves of the tropical rain forest and (3) the mixed perennials of the savanna.

One experiment was carried out at IITA on a site that had been under no-tillage farming for three years. After that cropping period, the residual fallow vegetation consisted of woody perennials such as *Alchornia laxiflora*, *Ficus exasperata*, *Combretum hispidum*, *Hippocratea pallens*, *Newbouldia leavis* and *Albizia* spp. Control of these perennial weeds was assessed qualitatively by visual ratings and quantitatively from samples taken at the beginning of the study and after maize harvest from fixed

quadrats along a transect in each plot. The design was a randomized complete block with five replications. The preplant herbicides were applied so that maize could be planted within two weeks after treatment, but planting was delayed over two weeks by a sudden dry spell. A supplemental paraquat spray was applied at the rate of 0.5 kg/ha as a blanket treatment in all plots to kill new seedling weeds before planting maize. Annual weeds were controlled by a preemergence application of a tank mixture of metolachlor plus pendimethalin (2.0 + 1.5 kg/ha). Soil samples were taken at intervals to assess the residual activity of the preplant herbicides. These samples were used in bioassays involving maize, cowpeas and rice as test crops.

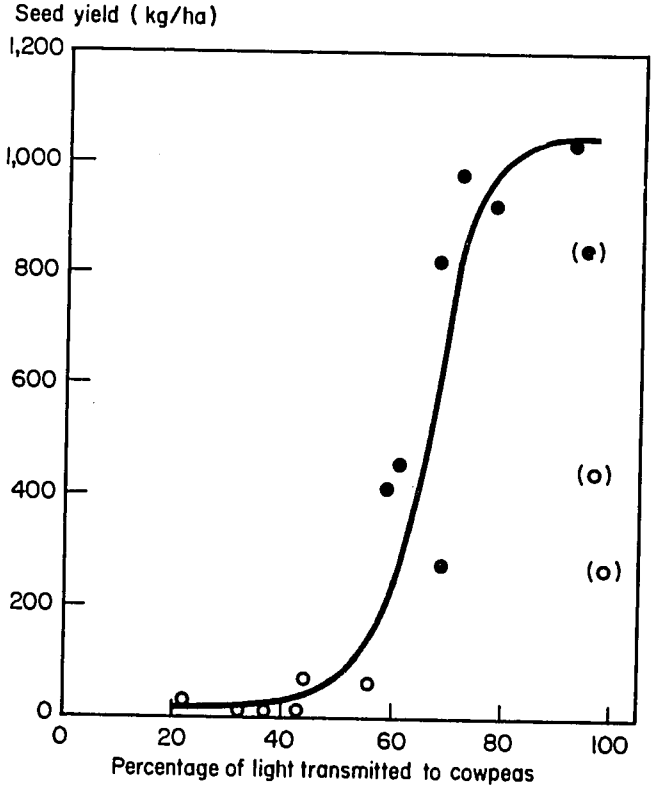


Figure 25. Relation between cowpea yield and percent global radiation incident on the crop through a cassava canopy, IITA, first season, 1982.

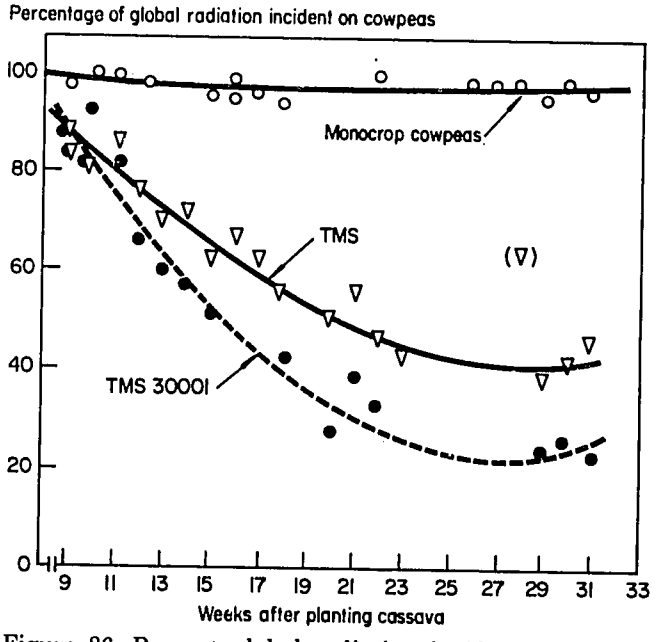


Figure 26. Percent global radiation incident on monocropped cowpeas and cowpeas mixed with strap leaf (TMS X) and normal leaf (TMS 30001) cassava, IITA, 1982.

Data on the effects of the preplant herbicides are shown in Table 21. Glyphosate (2.0 kg/ha) applied sequentially with 2,4-D (2.0 kg/ha) gave the best control of all perennial weeds and performed significantly better than when the two herbicides were applied as a tank mixture. Treatments that killed less than 60% of the perennial weeds (based on actual stand count) were considered ineffective in reducing the regrowth of woody perennials. Although crops can be planted immediately in fallows sprayed with glyphosate or paraquat, other preplant herbicides such as amitrole and tank mixtures such as glyphosate plus 2,4-D or dicamba plus 2,4-D proved to be toxic to cowpeas and rice planted within the first week after applying the preplant herbicides. However, residues of these herbicides disappeared from the soil within four weeks at this site.

The second experiment at IITA was located in two-year bush regrowth that had been slashed twice. The vegetation consisted of perennial broadleaves and grasses. The dominant broadleaves were *Eupatorium odoratum*, *Deinbollia pinnata*, *Combretum hispidum*, *Alchornia laxiflora* and *Ficus exasperata*. The main perennial grass weed was *Panicum maximum*. The design and methodology of the experiment were similar to those reported above, except that each plot was split into two, one with maize and the other with cowpeas. A preemergence spray of pendimethalin (2.0 kg/ha) was applied to control *Rottboellia*

Table 21. Effect of preplant herbicides on woody perennials in a no-till system, IITA, 1982

Treatment and rate, kg a.i./ha[a]	Percentage of perennials killed	Maize population	No. of cobs per ha	Maize yield, kg/ha
Glyphosate (3.6)	79	25,100	27,900	2.9
Glyphosate (2.0)	76	25,000	27,900	3.0
Glyphosate (2.0) followed by 2, 4-D (2.0)	84	24,700	25,800	2.9
Glyphosate (2.0) + 2, 4-D (2.0)	46	23,800	26,000	2.8
Glyphosate (2.0) + 2, 4-D (1.0)	59	29,400	29,900	3.1
Amitrole (4.0)	40	21,800	22,100	2.5
Dicamba (1.5) + 2, 4-D (2.0)	54	22,700	25,900	2.7
Slashing	33	21,900	21,500	2.4
Paraquat (1.0)	33	26,400	27,800	3.0
Paraquat (1.0) followed by slashing[b]	46	26,100	29,200	3.1
LSD (5%)	26	6,500	5,800	0.5

[a]All herbicide treatments were preplant foliar sprays.
[b]Slashing was done two weeks after the paraquat treatment.

Table 22. Effect of preplant herbicides on bush regrowth in a slashed two-year fallow, IITA, 1982

Treatment and rate, kg a.i./ha	Weed control rating[a] *Alchornia laxiflora*	*Combretum*	*Eupatorium*	*Ficus*	*Hippocratea*	*Panicum maximum*	Percentage of woody perennials killed	Cowpea yield, kg/ha	Maize yield, t/ha
Glyphosate (3.6)	63	50	80	—	40	80	51	788	3.78
Glyphosate (2.0)	60	57	74	20	37	85	50	688	4.36
Glyphosate (2.0) + 2, 4-D amine (1.0)	63	83	79	40	37	80	46	870	4.57
Glyphosate (1.5) + 2, 4-D amine (1.0)	55	78	69	30	35	70	47	691	3.53
Glyphosate (0.7) + 2, 4-D amine (1.0)	45	67	69	47	10	53	36	599	2.06
Glyphosate (1.5) + fosamine (6.0)	45	10	49	55	20	80	45	551	3.53
Glyphosate (1.5) + dicamba (1.5)	45	75	68	—	25	80	42	703	3.81
Fluazifop-butyl (2.0) + 2, 4-D ester (2.0)	30	80	73	60	30	73	49	739	3.63
Fluazifop-butyl (1.5) + 2, 4-D ester (1.0)	36	80	64	20	33	60	37	443	2.84
Fluazifop-butyl (1.5) + amitrole (2.0)	45	50	53	45	40	—	35	466	4.26
Fluazifop-butyl (1.5) + fosamine (6.0)	20	10	37	30	13	67	38	814	3.81
Amitrole (4.0)	35	35	39	30	40	30	66	560	3.88
2, 4-D amine (2.0)	43	67	68	60	20	0	43	585	3.50
Dicamba (3.0)	40	50	61	—	48	—	66	491	4.03
Picloram (0.1) + 2, 4-D (0.5)	40	50	63	20	20	0	54	425	4.30
Dicamba (1.5) + MCPA (2.0)	55	82	81	—	43	—	40	738	2.92
Dicamba (1.5) + 2, 4-D (2.0)	60	85	86	—	—	0	48	568	3.44
Dalapon (4.0) + 2, 4-D (2.0)	25	67	75	25	20	40	24	847	3.12
Slashing at planting	5	50	8	—	0	0	33	722	3.00
Paraquat (1.0)	20	0	16	—	0	30	44	337	2.30
LSD (5%)								348	1.83

[a]Weed control was rated on a 0 to 100 scale, where 0 = no control and 100 = complete control.

exaltata, which was common at this site. Other annual weeds were hand pulled from the plots at five weeks after treatment.

The results of this test showed that none of the herbicides gave satisfactory control of all broadleaves and grassy weeds (Table 22). Treatments that showed a wide spectrum of activity and merit further investigation are glyphosate plus dicamba and glyphosate and 2,4-D, applied either sequentially or as mixtures. Some herbicide mixtures, such as fluazifop-butyl plus 2,4-D or fosamine, gave promising control of perennial weeds, but they tended to persist far too long and could pose phytotoxic problems to commonly grown food crops. Generally, the ester formulation of 2,4-D was more effective on a cross section of woody perennials with pubescent (*Combretum* spp.) and nonpubescent (*Alchornia laxiflora*) leaves. Similar results were obtained in a two-year fallow of mixed perennial grasses and broadleaves at Ikenne, which is more representative of the subhumid forested tropics.

Table 23 shows the results of a similar study conducted at Ilorin in the southern Guinea savanna region of Nigeria. At that location, the major weeds are tall, tussocky perennial grasses such as *Andropogon gayanus*, *A. tectorum*, *Hyparrhenia involucrata*, *H. ruffa* and *Pennisetum* spp. These are generally burned during the dry season but survive to produce new flushes of growth at the onset of the rainy season. Another commonly occurring perennial grass is *Imperata cylindrica*. The regrowth of woody perennials is from such fire resistant species as *Daniellia oliveri*, *Butryospermum parkii*, *Terminalia glauscens*, *Isoberlinia*, *Cassia* and *Acacia* spp. Promising herbicides and mixtures were glyphosate plus 2,4-D, dicamba or fosamine; dalapon plus 2,4-D; and fluazifop-butyl plus fosamine. However, the last mixture persisted at toxic levels for up to four weeks after treatment. Table 24 shows the toxicity pattern of some preplant herbicides used in the Ikenne and Ilorin experiments. Many of the mixtures used at both sites were toxic to cowpeas and rice planted in soils sampled immediately and at two weeks after treatment. When maize was used as the test crop, some herbicides, such as fluazifopbutyl plus fosamine, were phytotoxic even when soils were sampled at four weeks after treatment.

In future research we will define specific rates and formulations for tank mixtures and closely monitor the aftereffects to ensure that products recommended not only control the preplant vegetation, but are also economical and safe to both the crops and ecosystems.

Performance of Preemergence Herbicides

Previous studies have shown that although many preemergence herbicides give good weed control after conventional tillage they result in poor control of annual weeds in no-tillage systems, even with a good kill of the preplant fallow vegetation. Preliminary work showed that mulches intercept some of the atrazine and metolachlor applied broadcast to the mulch and could reduce their effectiveness. The objective of these studies was to test the efficacy of some preemergence herbicides and their persistence

Table 23. Effect of preplant herbicides on perennial weeds, Ilorin, Nigeria, 1982

Treatment and rate, kg a.i./ha	Weed control 90 days after treatment[a] *Andropogon* spp./ *Hyperrhenia* spp.	*Dan-iellia*	*Imperata cylindrica*	Percentage of perennials killed	Crop injury 53 days after planting[a] Maize	Cowpeas	Maize yield, kg/ha
Glyphosate (3.6)	94	70	63	74	0	1	550
Glyphosate (2.0)	86	60	68	77	1	0	610
Glyphosate (2.0) + 2, 4-D (1.0)	91	45	68	66	3	13	520
Glyphosate (1.5) + 2, 4-D (1.0)	88	51	60	52	0	9	280
Glyphosate (0.7) + 2, 4-D (1.0)	83	53	30	32	0	5	760
Glyphosate (1.5) + fosamine (6.0)	91	55	58	65	0	0	520
Glyphosate (1.5) + dicamba (1.5)	83	79	55	62	0	0	900
Fluazifop-butyl (2.0) + 2, 4-D ester (2.0)	8	32	3	48	75	33	0
Fluazifop-butyl (1.5) + 2, 4-D ester (1.0)	0	40	5	33	25	10	0
Fluazifop-butyl (1.5) + amitrole (2.0)	3	25	27	33	5	0	30
Fluazifop-butyl (1.5) + fosamine (6.0)	85	70	65	76	0	3	1,020
Amitrole (4.0)	7	25	3	45	0	0	70
2, 4-D amine (2.0)	0	43	3	51	8	5	0
Dicamba (3.0)	0	90	3	70	10	6	10
Picloram (0.1) + 2, 4-D (0.5)	0	86	0	47	15	14	0
Dicamba (1.5) + MCPA (2.0)	0	58	0	52	20	13	0
Dicamba (1.5) + 2, 4-D (2.0)	0	80	3	72	23	15	0
Dalapon (4.0) + 2, 4-D (2.0)	70	55	30	41	0	1	690
Slashing at planting	0	13	0	35	3	0	0
Paraquat (1.0)	0	0	3	51	0	13	0
LSD (5%)							440

[a]Weed control and crop injury were rated on a 0 to 100 scale, where 0 = no weed control or crop injury, 30 = poor weed control and some injury and stand reduction, and 100 = all plants killed.

at different maize mulch levels.

Three field experiments involving four levels of mulch residues were carried out at the three locations mentioned in the no-tillage experiments reported above. Levels of maize stover used at the IITA site did not appear to affect control of annual weeds, which were predominantly *Euphorbia heterophylla* and *Brachiaria* spp. (Table 25). Weed control at various mulch levels was good across all herbicide rates, but it was significantly lower at the 15 t/ha mulch level than at lower mulch levels. Maize yield was also poorer at this high mulch level than at lower levels (Table 25). Results from the other sites were similar to those at the IITA site.

Bioassays showed that herbicides had reached treated soils at all levels of mulch. However, there are indications that herbicide interception is, as expected, most pronounced when low rates of herbicide are used. Similar trends were observed at the other sites. To improve annual weed control in no-tillage systems, it appears necessary to apply higher rates of preemergence herbicides than are used in conventional tillage systems to establish critical concentrations in the soil and inhibit weed seed germination.

Upland Rice Weed Control

Studies at IITA have shown that good weed control can be gotten in upland rice with a mixture of propanil plus fluorodifen or thiobencarb applied as a postemergence treatment within two to three weeks after planting. Proper timing of this treatment is a serious problem for many farmers in the tropics, especially those whose farms are located far from the homestead. This year selected rice herbicides (oxadiazon and propanil) just introduced in the region were evaluated for their suitability in pre- and postemergence weed control in upland rice.

Table 24. Toxicity of some preplant herbicides in a no-tillage system, Ikenne and Ilorin, Nigeria, 1982

Treatment and rate, kg a.i./ha	Maize (WAT)[a] 0	2	4	Cowpeas (WAT) 0	2	4	Rice (WAT) 0	2	4
Glyphosate (1.5) + fosamine (6.0)	†*		†						
Glyphosate (1.5) + dicamba (1.5)		†			*				†
Fluazifop-butyl (2.0) + 2, 4-D ester (2.0)	†*	†*	†				†*		†
Fluazifop-butyl (1.5) + 2, 4-D ester (1.0)	†*	†			*	†	†*		†
Fluazifop-butyl (1.5) + amitrole (2.0)		†			*		†		†
Fluazifop-butyl (1.5) + fosamine (6.0)	†						†*		†
2, 4-D amine (2.0)						†			†
Picloram (0.1) + 2, 4-D(0.5)				†*		†*			†
Dicamba (1.5) + 2, 4-D(2.0)		†		†*			†		
Dalapon (4.0) + 2, 4-D (2.0)		†		*			†		

Note: † (bioassay based on sample from Ikenne) or * (sample from Ilorin) indicates that dry matter of the test plants was significantly reduced. [a]Weeks after treatment.

The results are shown in Table 26. Uncontrolled weed growth significantly reduced tillering per plant, number of panicles per unit area and rice yield. Weeds were controlled best with a recommended herbicide such as propanil plus either fluorodifen or thiobencarb. A mixture of oxadiazon plus propanil was as effective as any of the standard mixtures containing propanil. Oxadiazon applied preemergence gave poor control.

Hydromorphic Rice Weed Control

In hydromorphic rice the effects of weeds are often more serious and herbicide efficacy is lower than under other methods of rice cultivation. In this study the performance of three promising rice cultivars was tested at varying row spacings and weed pressures. Each variable was used at three levels in a factorial treatment, with a completely randomized design. The treatments were replicated three times. The cultivars ranged in height from 104 cm (Adny 11), through 118 cm (ITA 118) to 170 cm for OS 6.

The results show that neither plant type nor interrow spacing could protect rice plants from the adverse effects of early weed interference. Yield was significantly reduced when rice was weeded only once, compared to when it was kept weed free (Table 27). The highest overall yields were obtained when the rice was grown at a row spacing of 30 cm. Intraspecific competition tended to reduce yield at 15-cm spacing, and weed interference reduced yield at 45-cm spacing. The taller OS 6 had fewer weeds than the other shorter cultivars at 90 days after spraying. The highest weed weight was observed in ITA 118. Weed weight was significantly lower at the 15-cm spacing than at the wider spacings (Table 28). The high weed biomass that resulted from weeding only once accounts for the significantly lower rice yield at this weeding frequency.

Yields of the dwarf variety Adny 11 were lowest at the 45-cm spacing when the crop was weeded only once, a common practice among rice growers in many parts of the tropics. However, this variety outyielded all other cultivars at that spacing if the rice was kept weed free. The low yields associated with low weeding frequency may explain in part why small farmers have been reluctant to accept the improved high yielding varieties. The semidwarf ITA 118 yields about as much (over 2.0 t/ha) as the popular OS 6 at low weeding frequency but has the advantage of not lodging as much. All cultivars performed well at the 30-cm spacing.

Weed Control in Cowpeas

In past studies at IITA, herbicides have been identified that control annual weeds in cowpeas, except for wild poinsettia (*Euphorbia heterophylla*) and iron weed (*Vernonia pauciflora*), the former of which is the major broadleaf weed in the subhumid region and the latter in the Guinea savanna of Nigeria. Two late-season field experiments were carried out to screen herbicides for control of these weeds in cowpeas and to identify weed management practices and assess crop performance in conventional tillage and no-till systems.

The two experiments were done at Mokwa in the Guinea savanna and at IITA, which is on the fringes of the tropical rain forest. The cowpea cultivar TVu 3236 was used at the Mokwa site and VITA-5 at IITA. The experimental design was a randomized complete block with four replications. Herbicide treatments and application rates are listed in Tables 29 and 30.

At Mokwa good to excellent grass control was obtained, but control of broadleaf weeds was generally poor (Table 29). Chloramben and linuron,

Table 25. Effect of maize stover mulch level and herbicide rate on weed control and maize yield, IITA, 1982

Mulch, t/ha	Herbicide rate, kg/ha 0	1 + 1	2 + 2	3 + 3	Mean
	Weed control, %				
0	45	97	100	100	85
5	43	90	98	96	82
10	40	95	94	99	82
15	43	81	88	94	76
Mean	43	91	95	97	
LSD (5%):					
Herbicide	4.5				
Mulch	4.5				
Herbicide × mulch	ns				
	Maize yield, t/ha				
0	4.80	5.18	5.13	5.04	5.04
5	3.23	5.40	5.17	5.04	4.71
10	3.91	5.46	5.14	5.22	4.93
15	3.58	4.81	4.61	4.69	4.42
Mean	3.88	5.21	5.01	5.00	
LSD (5%):					
Herbicide	0.54				
Mulch	0.54				
Herbicide × mulch	ns				

Table 26. Effect of weed control method on weed growth and performance of upland rice, IITA, 1982

Treatment and rate, kg a.i./ha	Weed dry weight, kg/ha	No. of rice panicles per m^2	Rice yield, kg/ha
Preemergence			
Oxadiazon (0.8)	964	82	1,216
Oxadiazon (1.0)	1,725	91	1,294
Postemergence			
Oxadiazon + propanil (2.4)[a]	1,646	95	966
Oxadiazon + propanil (2.0)	1,033	98	1,555
Oxadiazon + propanil (2.4)	378	130	2,035
Fluorodifen + propanil (3.0)	257	136	2,442
Thiobencarb + propanil (3.4)	477	139	2,138
Weed free	0	119	2,409
Unweeded check	4,072	61	85
LSD (5%)	141	34	582

[a]This treatment was applied 10 days after planting; all the other postemergence treatments were applied 15 days after planting.

each in combination with either metolachlor or pendimethalin, provided good control of all weeds up to about five weeks after treatment. After that period *Vernonia pauciflora*, a late appearing weed, became predominant, and only chloramben plus metolachlor gave satisfactory control. Oxyfluorfen plus either metolachlor or pendimethalin caused severe cowpea injury and stand loss, resulting in significant yield reductions.

Average weed growth in the untreated weedy plots at IITA was 2,643 kg/ha (Table 30). Chloramben alone and in combination with either metolachlor or pendimethalin provided satisfactory weed control. Bifenox and butachlor gave good control but caused heavy stand losses. Oxyfluorfen gave good control initially, but by five weeks after treatment, the plot was reinfested. Cowpeas usually recovered from the initial injury caused by this herbicide. None of the treatments in this trial controlled *Euphorbia heterophylla*.

The results indicate that preemergence applications must be supplemented later by other methods of weed control to remove early escapes. In future trials we will test the effectiveness of following a preemergence application with an interrow directed spray of suitable herbicides.

Table 27. Effect of cultivar, interrow spacing and weed control on rice yield in hydromorphic soil, IITA, 1982

	OS 6	ITA 118	ADNY 11	Spacing × weeding	Spacing
			t/ha		
15-cm spacing					
Weed free ...	3.4	3.3	3.9	3.5	
Two hoe weedings	2.8	2.7	3.1	2.9	3.0
One hoe weeding	2.7	2.3	3.1	2.7	
30-cm spacing					
Weed free ...	4.0	3.3	3.9	3.7	
Two hoe weedings	2.7	3.9	3.7	3.4	3.3
One hoe weeding	2.7	2.7	3.1	2.8	
45-cm spacing					
Weed free ...	3.6	3.6	4.1	3.8	
Two hoe weedings	2.7	2.6	2.9	2.7	2.8
One hoe weeding	2.2	2.3	1.5	2.0	
Cultivar means	3.0	3.0	3.2		
LSD (5%):					
For spacing, cultivars and weed control.				0.3	
For spacing × weed control				0.4	

Note: Means for weed control are as follows: weed free, 3.7 t/ha; two hoe weedings, 3.0 t/ha; and one hoe weeding, 2.5 t/ha.

Table 28. Effect of cultivar, interrow spacing and weed control on weed biomass and rice yield components, IITA, 1982

Treatment	Weed dry weight,[a] g/m^2	Rice dry weight,[a] g/m^2	No. of tillers per hill	No. of panicles per hill
Cultivar:				
OS 6	92.7	1.29	38.1	22.1
ITA 118	174.8	1.21	31.1	17.0
ADNY 11	110.1	1.09	53.1	41.2
Spacing:				
15 cm	21.8	1.30	34.7	20.1
30 cm	144.2	1.28	40.2	27.5
45 cm	211.6	1.01	47.4	32.7
Weed control:				
Weed free.....	0	1.42	47.9	32.6
Weeded twice ...	44.6	1.12	38.2	25.9
Weeded once....	333.0	1.07	36.3	21.9
LSD (5%).....	89.3	0.21	2.2	2.7

Note: Spacing × weed control interactions had a significant F test for weed dry weight and number of panicles per hill.
[a]At 90 days after spraying.

Mulches for Weed Control

Appropriate management of ground covers can be effective in soil conservation and weed control, and their organic mulches, dead or alive, can bring about long-term soil improvement and suppress weeds. Studies at IITA have shown that *Mucuna utilis* forms a good mulch for crop production. A study was carried out to test weed control with a residual mucuna mulch. The plot had been in mucuna fallow during 1981. The volunteer mucuna seedlings from seeds buried in the thick mulch were killed first with a broadcast application of paraquat (0.5 kg/ha). The design was a randomized complete block, with six treatments replicated four times. Maize was planted using a rolling injection planter in April 1982.

The results in Table 31 show that the mucuna mulch drastically reduced weed seedling population (two seedlings per square meter, compared to over 18,000 viable weed seeds per square meter of topsoil). A preemergence application of a formulated mixture of atrazine plus metolachlor (2.5 kg/ha) reduced it even further. The main problem was the smothering effect of volunteer mucuna plants on the maize. At harvest these covered 94% of the surface in the unweeded plot, causing 70% lodging of the maize and a yield reduction of 43% (Table 31). Paraquat as a directed spray did not prevent volunteer mucuna from having these adverse effects. Weeding once by hand pulling of volunteer mucuna at six weeks after treatment kept the population to a minimum.

The best yields were obtained in plots where volunteer mucuna and seedling weeds were controlled with postemergence application of 2,4-D (0.75 kg/ha) or with a formulated mixture of atrazine plus metolachlor (1.0 kg/ha). The mucuna mulch did not completely eliminate weeding but reduced the use of Primextra from 5.0 l/ha to 2.0 l/ha while protecting the soil from erosion and returning organic matter to the soil.—*I.O. Akobundu, J.A. Poku and M.A. Gowman*

Effect of Herbicides on Nitrification

To predict the inhibitory action of herbicides on microbial activity in the field, the effects of metolachlor, atrazine and fluometuron on the

Table 29. Effect of herbicide combinations on weeds and cowpea yield, Mokwa, Nigeria, 1982

Treatment and rate, kg a.i./ha[a]	All weeds, 2 WAT[b]	7 WAT *Veronia pauciflora*	7 WAT Grass weeds	At harvest *Veronia pauciflora*	At harvest Grass weeds	Yield at 12% moisture, kg/ha
Weed free	100	100	100	100	100	2,457
Metolachlor (2.0) + chloramben (1.5)	85	80	89	63	98	1,694
Metolachlor (2.0) + linuron (0.5)	63	64	85	16	96	1,611
Fluazifop-butyl (1.0)	0	10	95	6	98	1,491
Metolachlor + metobromuron (2.5)	60	56	71	13	94	1,491
Metolachlor (2.0) + chloramben (2.0)	80	65	84	15	96	1,455
Metolachlor (2.0) + linuron (0.25)	56	46	85	15	91	1,382
Pendimethalin (1.5) + linuron (0.5)	75	63	90	3	99	1,270
Pendimethalin (1.5) + chloramben (2.0)	80	59	88	18	99	1,215
Pendimethalin (1.5) + linuron (0.25)	85	60	90	8	99	1,184
Pendimethalin (1.5) + chloramben (1.5)	84	66	89	20	98	1,102
Metolachlor (2.0) + oxyfluorfen (0.3)	98	59	91	14	93	529
Pendimethalin (1.5) + oxyfluorfen (0.3)	98	68	91	26	95	513
Metolachlor (2.0) + oxyfluorfen (0.4)	98	75	83	9	73	393
Pendimethalin (1.5) + oxyfluorfen (0.4)	95	69	88	28	88	375
Weedy check	0	0	0	36	0	1,467
LSD (5%)						385

[a]All herbicides were applied preemergence to the crop and weeds, except fluazifop-butyl.
[b]Weeks after treatment.

Table 30. Effect of herbicide combinations on weeds and cowpea yield, IITA, 1982

Treatment and rate, kg a.i./ha[a]	Crop injury rating 2 WAT[b]	Crop injury rating 5 WAT	Weed control rating 2 WAT	Weed control rating 5 WAT	Weed dry weight, kg/ha	Yield at 12% moisture, kg/ha
Metolachlor + metobromuron (3.0)	5	10	67	43	1,160	914
Dinoseb (5.0) + chloramben (2.0)	0	0	75	49	1,145	862
Chloramben (3.0)	5	8	90	38	1,178	842
Pendimethalin (2.0) + chloramben (2.0)	3	5	93	48	1,120	858
Pendimethalin (2.0) + linuron (0.5)	8	3	74	50	1,383	774
Metolachlor (2.0) + chloramben (2.0)	10	3	96	48	1,370	753
Linuron (0.5)	8	5	79	23	2,090	735
Metolachlor (2.0) + oxyfluorfen (0.3)	60	23	93	61	865	734
Metolachlor (3.0)	10	13	81	33	1,575	734
Oxyfluorfen (0.3)	53	10	86	28	2,068	610
Butachlor (2.2)	45	40	61	33	1,885	592
Metolachlor (2.0) + bifenox (2.0)	75	55	91	53	1,485	631
Pendimethalin (2.0) + bifenox (2.0)	79	60	89	46	2,323	430
Bifenox (2.0)	84	70	98	40	2,173	447
Butachlor (1.7) + linuron (0.5)	28	25	73	40	1,890	389
Weedy check	0	0	0	0	2,643	575
LSD (5%)					91	318

[a]All herbicides were applied preemergence to the crop and weeds.
[b]Weeks after treatment.

number and activity of nitrifying bacteria were studied in soils from IITA, Mokwa and Onne. Three-hundred-gram samples of air-dried soil were mixed with the appropriate herbicides each at 0, 2, 20 and 100 ppm, representing, respectively, 0, 1, 10 and 50 times the normal rate of 3 kg a.i./ha. The soils were incubated for eight weeks in duplicate at near field capacity (16%) and at 30°C. At weekly intervals soil moisture was adjusted before collecting 5-g samples of the moist soil for nitrifier counts and mineral N content analysis. Bacteria counts were not performed in samples containing 100 ppm of the herbicides.

During the first week of incubation, microorganisms regained their activity following soil wetting, and ammonification of organic N took place readily. In the IITA soil, the number of nitrifying bacteria was high, and nitrification proceeded rapidly (Figure 27), but ammonium N accumulated in the acid Onne soil, which contained very few nitrifying bacteria.

The herbicides reduced the original population of nitrifying bacteria in the IITA soil (Table 32). At 20 ppm fluometuron was the most inhibitory; only 0.6% of the *Nitrosomonas* population and 5% of the *Nitrobacter* could be enumerated in the soil after

Table 31. Effect of *Mucuna utilis* dead mulch on weed control and maize yield, IITA, 1982

Time and rate of treatment, kg a.i./ha	No. of weed seedlings per 10 m^2[a]	No. of viable weed seeds per m^2 of soil[b]	Percent coverage by volunteer mucuna[c]	Maize: Percent lodging[c]	Maize: Yield, kg/ha
Primextra[d], preemergence at 2.5 kg	3.8	9,072	73	26	2,019
Primextra, four weeks after planting at 1.0 kg	16.3	18,144	30	13	3,055
Paraquat, six weeks after planting at 0.5 kg	13.8	23,587	81	70	2,230
2,4-D, five weeks after planting at 0.75 kg	18.1	16,330	26	13	3,168
Weeded once six weeks after planting	12.8	23,587	28	8	2,743
Unweeded check	16.9	18,144	94	70	1,745
LSD (5%)	8.1	8,164	21	19	542

[a]Weed seedlings were counted four weeks after planting.
[b]Based on average weight of 90,720 g/0.15 cubic m of topsoil (dry weight).
[c]Data on coverage and lodging were taken at crop harvest. Lodging is expressed as a percentage of total maize population.
[d]Primextra is the trade name of a formulated mixture of atrazine plus metolachlor.

Table 32. Effect of herbicides on number of nitrifying bacteria (log_{10}/g of soil) and mineralization of organic nitrogen (μg N/g of soil) in IITA and Mokwa soils, 1982

Herbicide treatment	*Nitrosomonas* IITA	*Nitrosomonas* Mokwa	*Nitrobacter* IITA	*Nitrobacter* Mokwa	NH_4-N IITA	NH_4-N Mokwa	NO_3-N IITA	NO_3-N Mokwa
No herbicide	3.94	2.92	4.02	3.46	4.65	3.88	50.95	30.27
Metolachlor								
2 ppm	3.57	3.36	3.77	3.38	4.31	4.19	53.23	23.40
20 ppm	3.62	3.66	3.42	3.57	4.25	3.52	55.39	31.25
100 ppm	ND[a]	ND	ND	ND	4.50	7.60	55.83	29.79
Atrazine								
2 ppm	3.59	3.31	3.76	3.48	4.58	3.31	49.27	30.77
20 ppm	3.30	3.88	3.69	3.45	4.90	3.69	52.04	32.13
100 ppm	ND	ND	ND	ND	4.10	3.88	57.33	30.83
Fluometuron								
2 ppm	3.65	3.39	3.88	3.67	4.17	3.85	47.19	38.60
20 ppm	2.83	3.51	3.55	3.36	3.40	3.25	48.83	41.65
100 ppm	ND	ND	ND	ND	4.44	5.04	56.96	42.71
LSD (5%)	0.211	0.211	0.12	0.115	1.25	1.12	3.02	3.71

[a]Not determined.

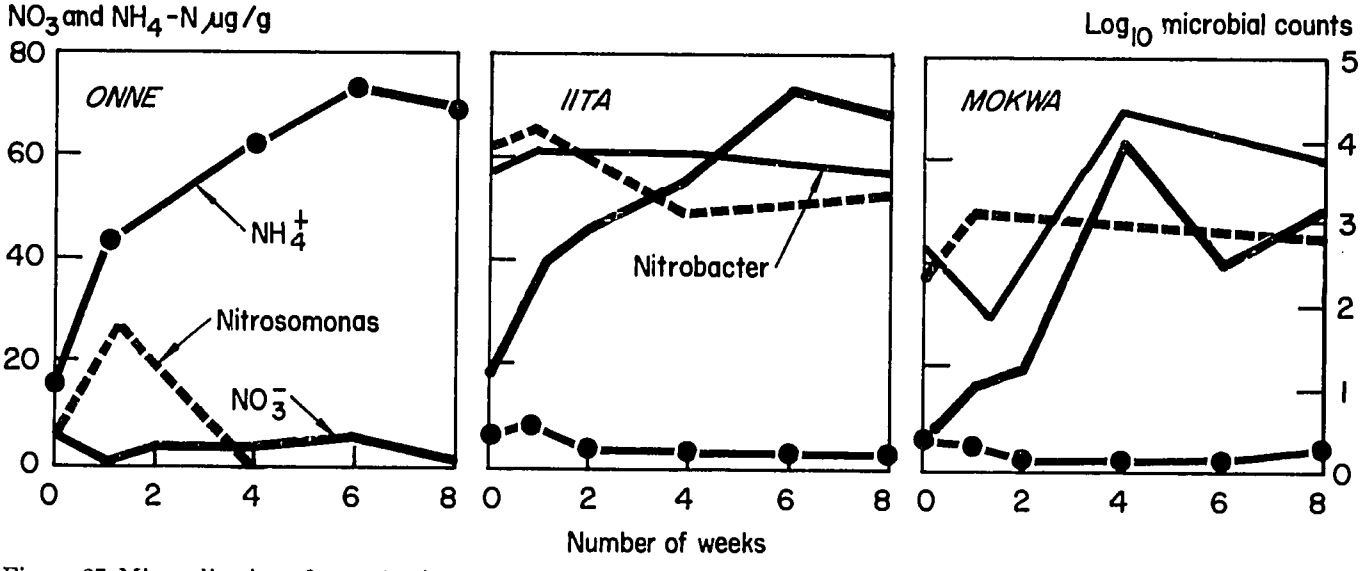


Figure 27. Mineralization of organic nitrogen and evolution of nitrifying populations in untreated soils (incubated at 30°C) from various locations in Nigeria, 1982.

eight weeks of incubation, as compared to untreated samples. However, the evolution of ammonium N was unaffected by the herbicides, and more nitrate N was found in soil samples treated with metolachlor, atrazine and fluometuron each at 100 ppm.

In the Mokwa soil, *Nitrosomonas* growth was

stimulated in the presence of the herbicides studied (Table 32). With 20 ppm of atrazine, the *Nitrosomonas* population was more than 45 times the population in the untreated sample after four weeks of incubation. Following an increase at one week, the number of *Nitrobacter* decreased in the presence of the herbicides more rapidly than in the untreated samples during the last seven weeks of the experiment. These effects of herbicide on nitrifying bacteria counts did not reflect the changes in N mineralization; accumulation of ammonium N was observed only in soil samples treated with 100 ppm of metolachlor or fluometuron, and more nitrate N accumulated in the fluometuron treatment.

In the Onne soil, fluometuron at 20 or 100 ppm depressed nitrification but not mineralization of organic N. The effect of the herbicides on nitrifying bacteria in this soil could not be evaluated since only a few nitrifiers were detected.—*K. Mulongoy and Y. Arora*

Agroforestry

Studies on alley cropping were continued in 1982 as part of IITA's effort to find improved alternatives to the traditional bush fallow system. In alley cropping food crops are grown in spaces between pruned hedgerows of shrubs or trees, which produce organic residue and recycle nutrients.

Maize/Cowpeas Intercropped with Leucaena

A trial was initiated in 1976 on a low fertility Apomu series soil (Psammentic Usthorthent) at IITA, using a continuous function design with four replications. In this trial the leucaena hedgerows were regularly pruned to a height of about 150 cm.

In 1982 the main season maize (variety TZPB) responded significantly to addition of leucaena prunings (Table 33). Yields were lower than in previous years in treatments where leucaena prunings were removed and no nitrogen was applied. The addition of prunings and nitrogen kept yields at previous years' levels.

The minor season cowpea (VITA-6) crop grew better in treatments receiving leucaena prunings, although this was not reflected in the yields (Table 33). High rainfall during the pod formation and drying period resulted in heavy pod borer infestation (in spite of regular spraying with pesticides) and low seed yield. Cowpea yield was not improved by tillage and actually declined in treatments receiving nitrogen fertilizer. The weed *Talinum triangulare* was a serious problem in cowpea plots, particularly the no-till plots, receiving leucaena prunings.

Tree Species for Alley Cropping

A trial was started in 1981 on an eroded Egbeda soil series (Oxic paleustalf) with low N and P status to compare *Gliricidia sepium*, *Leucaena leucocephala*, *Acio barterii* and *Alchornea cordifolia* for soil improvement and suitability to alley cropping and to test the effects of alley width and fertilizer application. The experiment has a split-split plot design with three replications.

The tree species were pruned to a height of 60 cm in 1982, the second cropping year. Before the first pruning at 11 months, height measurements showed large differences between species. Leucaena was the tallest at 3.6 m, followed by gliricidia at 3.2 m and alchornea at 2.1 m. Acioa was shortest at 0.6 m. Only small quanitites of dry prunings were produced in the second year by all four species, particularly acioa. Because of its irregular and slow growth, the amount of pruning from this species was negligible. Higher biomass was produced per unit area with a 2-m than with a 4-m alley width because of the higher tree population. With 4-m spacing leucaena produced more biomass than gliricidia, but with a 2-m alley gliricidia produced more. Leucaena and gliricidia produced more biomass than alchornea.

The growth of the four species was not affected by fertilizers applied to the companion crop. Large differences were also noticed between species in the composition of the prunings, as shown in Table 34. Gliricidia and leucaena prunings had higher contents of N, P, K, Ca and Mg than those of alchornea and acioa. Interestingly enough, both alchornea and acioa are widely grown as natural fallow by traditional farmers on the strongly acid soils in the humid zone where the cation supply is limited.

The effects of alley cropping on minor season cowpea (VITA-6) yields in 1981 are shown in Table 35. Yields responded well to residual fertilizer from the previous maize crop. Since the fallow hedges were not pruned in the first year of establishment, cowpea seed yield was lower with the 2-m alley width as a result of shading. Gliricidia depressed yield the most, followed by leucaena, alchornea and acioa in that order, which is more or less in line with the size and leafiness of the trees. With the 4-m alley spacing, alley cropping had no significant effect on the cowpea yields, though in the no fertilizer treatment alley cropping with gliricidia, alchornea and acioa tended to give higher cowpea yields.

Table 33. Effect of alley cropping maize and cowpeas with *Leucaena leucocephala*, IITA, 1982

Treatment[a]	Maize (TZPB) yield, kg/ha	Cowpea (VITA-6) yield, kg/ha
Tilled		
0 kg N/ha[b]	610	589
0 kg N/ha	2,096	608
40 kg N/ha	2,671	472
80 kg N/ha	2,911	481
No-till		
0 kg N/ha[b]	450	580
0 kg N/ha	1,566	528
40 kg N/ha	2,293	537
80 kg N/ha	2,423	494
LSD (5%)	437	152

[a]Nitrogen was applied to the first season maize crop.
[b]Leucaena prunings were removed from the plot.

Yields of maize (TZPB) during the 1982 main season are shown in Table 35. With both the 2-m and 4-m alleys, fertilizer application significantly increased grain yields. But when hedges were pruned periodically (acioa was pruned only once) during the main season of 1982, alley width had no significant effect on maize yield. It appears that gliricidia, which produced the largest amount of prunings in the second year of the trial, also had the highest yield response to alley cropping. With fertilizer application the alley cropped maize produced higher yields than the monocropped maize. It thus appears that on this eroded Alfisol the beneficial effects of alley cropping with leucaena, alchornea, acioa and particularly gliricidia are already being felt.

Leucaena Alley Cropping With Upland Rice

A trial with rice was set up at Ikenne on an Alagba soil series (Oxic Paleustalf) in 1981. The leucaena hedgerows were pruned to a height of 60 cm, and during 1982 a large amount of leucaena prunings and a high N yield were obtained. Addition of leucaena prunings and nitrogen had a striking effect on the growth and nitrogen status of the rice crop. However, a long drought spell during the flowering stage sharply reduced yields.

Lime and Phosphorus Response in Tree Species

A screenhouse trial was carried out to determine the suitability of certain tree species for alley cropping on acid soils. The Ultisol was collected at Amakawa in eastern Nigeria. The lime and phosphorus responses of three wooded species, *Calliandra caolothyrsus*, *Leucaena leucocephala* and *Sesbania grandiflora*, were tested in this pot trial.

All three species responded significantly to lime and phosphorus applications (Table 36). The mean dry weights with application of lime, at the rates of 0, 125, 250, 500, 1,000 and 2,000 ppm of $CaCO_3$ were 1.04, 1.53, 1.90, 2.22, 3.21 and 2.93 g/plant, respectively. Calliandra responded best to phosphorus, followed by leucaena and sesbania. Sesbania showed the highest response to lime, followed by calliandra and leucaena. It also appears that among the three tree species tested, leucaena variety K-26 still performs the best, with low or high lime and phosphorus inputs.—*B.T. Kang, G.F. Wilson, T.L. Lawson and D. Koudero*

Table 34. Nutrient composition of first prunings of various tree species 11 months after planting, IITA, 1982

Treatment	Percent					ppm	
	N	P	K	Ca	Mg	Cu	Zu
Gliricidia							
With fertilizer[a] ...	4.21	0.29	3.43	1.40	0.40	5.0	29.5
Without fertilizer .	4.00	0.28	3.33	1.60	0.42	7.5	29.0
Leucaena							
With fertilizer	4.33	0.28	2.50	1.49	0.36	21.0	32.0
Without fertilizer .	4.31	0.25	2.39	1.50	0.32	17.0	30.5
Alchornea							
With fertilizer	3.29	0.23	1.74	0.46	0.20	18.0	34.0
Without fertilizer .	2.83	0.23	1.71	0.45	0.20	14.5	31.0
Acioa							
With fertilizer	2.57	0.16	1.78	0.90	0.27	11.5	23.5
Without fertilizer .	2.38	0.15	1.94	0.81	0.30	7.5	24.5

[a]Applied to companion crop.

Alley Cropping and Microclimates

Studies at IITA have shown that alley cropping is a promising method of land and crop management. Further information is needed on the use of physical resources and competition for those resources in the alley cropping system. Without that information the efficiency of the system cannot be improved systematically.

Table 35. Effect of alley cropping on minor season cowpea yield and main season maize yield, IITA, 1982

Treatment	Control	Gliricidia	Leucaena	Alchornea	Acioa	Mean
			Cowpea (VITA-5) Yield, kg/ha			
2-m spacing, without fertilizer	904	388	765	740	1,043	768
4-m spacing, without fertilizer	1,048	1,619	1,133	1,626	1,637	1,412
2-m spacing, with fertilizer	842	403	629	781	1,011	733
4-m spacing, with fertilizer	1,829	1,698	1,519	1,535	1,457	1,608
Mean	1,156	1,027	1,012	1,171	1,287	
			Maize (TZPB) Yield, kg/ha			
2-m spacing, without fertilizer	1,343	1,943	1,111	1,154	1,249	1,560
4-m spacing, without fertilizer	1,619	2,221	1,203	1,527	1,620	1,638
2-m spacing, with fertilizer	2,360	3,471	3,471	2,776	2,823	2,980
4-m spacing, with fertilizer	2,684	3,471	3,377	3,285	3,378	3,239
Mean	2,002	2,777	2,291	2,186	2,268	

LSD (5%) between:	Cowpeas	Maize
Species	374	390
Spacings	279	318
Fertilizer treatments	148	556
Fert. treatments for same species	332	273
Species for same spacing and fert. treatment	681	888

[a]Fertilizer was applied at a rate of 90-40-40 kg/ha to the main season maize crop.

Light and moisture distribution were measured in an alley cropping experiment (reported on by B.T. Kang in the section on soil fertility) to analyze their characteristics and effects on crop yields. The incidence of light on crops close to the leucaena rows and on those farthest away (middle of the 4-m alleys) was measured with long-tube solarimeters before and after each pruning of the leucaena. Soil moisture was monitored once a week gravimetrically and with tensiometers and resistance moisture blocks.

Soil moisture content varied according to the position between the leucaena rows and was evidently influenced by rainfall patterns. No consistent trends could be detected through regular sampling in the middle of the rows and at both edges.

The percentage of global radiation incident on the crops near the hedges and at a maximum distance from them (2 m) is given in Table 37 for different periods before and after pruning of leucaena. It is evident that shading is a more serious problem in the early stages of growth and on the west side of the plot (east of the north-south oriented leucaena rows).

Timely pruning during this phase may be very important. In later stages the increase in maize height relative to that of the leucaena regrowth, considerable reduces shading. Since shorter statured crops such as cowpeas (planted during the second season in this experiment) do not have that advantage, more pruning may have to be done when those crops are included in the system (Table 37). The results point out the advantages of reducing pruning height to the lowest level possible. It is also clear that wider distances between leucaena rows decrease the area of excessive shading (relative to the total cropped area) and should therefore improve crop performance.—*T.L. Lawson and B.T. Kang*

Table 36. Effect of liming and phosphorus on dry matter yield of various tree species 14 weeks after planting, IITA, 1982

Phosphorus and lime rate	Shoot dry weight, g/plant			
	Calliandra	Leucaena	Sesbania	Mean
No P				
No lime	0.31	0.42	0.10	0.28
125 ppm	0.46	0.55	1.13	0.71
250 ppm	0.58	1.15	2.06	1.26
500 ppm	0.99	2.03	2.25	1.76
1,000 ppm	1.80	2.30	3.39	2.50
2,000 ppm $CaCO_3$	0.68	2.74	2.96	2.13
Mean	0.69	1.53	1.82	1.35
50 ppm P				
No lime	1.43	2.42	1.56	1.80
125 ppm	1.85	2.68	2.53	2.35
250 ppm	2.08	2.71	2.80	2.53
500 ppm	2.12	3.27	2.66	2.68
1,000 ppm	3.42	4.64	3.70	3.92
2,000 ppm $CaCO_3$	3.10	4.24	3.82	3.72
Mean	2.48	3.34	2.90	2.91
LSD (5%) between:				
Phosphorus means				0.22
Phosphorus means for same species				0.60
Lime trtmts. for same P trtmt. and species				1.75

Table 37. Shading effect of leucaena on alley cropped first season maize and second season cowpeas, IITA, 1982

	Percent radiation incident on crops			
	West side of plot[a]	Middle of plot[b]	East side of plot[a]	Mean
First season				
Before pruning		*percent*		
Early growth phase	42	66	50	53
Late growth phase	94	93	98	95
After pruning				
Early growth phase	84	92	91	89
Late growth phase	88	92	93	90
Second season				
Before pruning	41	82	49	57
After pruning	89	98	90	92

[a]Close to the leucaena rows.
[b]Midway between two leucaena rows.

Storage of Leucaena Seeds

The increasing use of the nitrogen-fixing tree *Leucaena leucocephala* for soil restoration warrants further study of its biology to develop efficient management techniques. One problem is the germination of seeds, which leucaena produces in large numbers when the land is recovered for cropping. To find solutions to problems such as this one, a series of studies on leucaena seed germination was initiated.

Freshly harvested (untreated) leucaena seeds were stored for up to six months under various conditions: in cold storage (less than −1°C), at ambient room temperature (22° to 28°C), in dry soil (25° to 40°C in a glass top screenhouse) and in a drying oven (40° to 45°C). At monthly intervals some seeds were removed from storage and tested for germination in moist sterile soil in pots each containing 100 seeds in a screenhouse. Each batch was treated as a completely randomized experiment with six replications.

Dry soil storage was the most effective germination stimulator (Figure 28). Germination increased sharply over the first two months and at a slower rate until the sixth month. In the drying oven germination increased dramatically in the first month, followed by an equally dramatic decline to 0% germination by the fifth month. Neither cold storage nor ambient room storage had a marked effect on germination over the six-month period.

It is important that dry soil, a common field condition in the tropics, should be the most effective in stimulating germination and may explain the large number of leucaena volunteer seedlings observed where a dry period of three or more months precedes the beginning of the rains. When dry soil storage was extended to 10 months, the germination percentage did not change significantly from that of the five-month storage period.

To determine the effect of temperature on germination, seeds were sown in moist sterile soil in

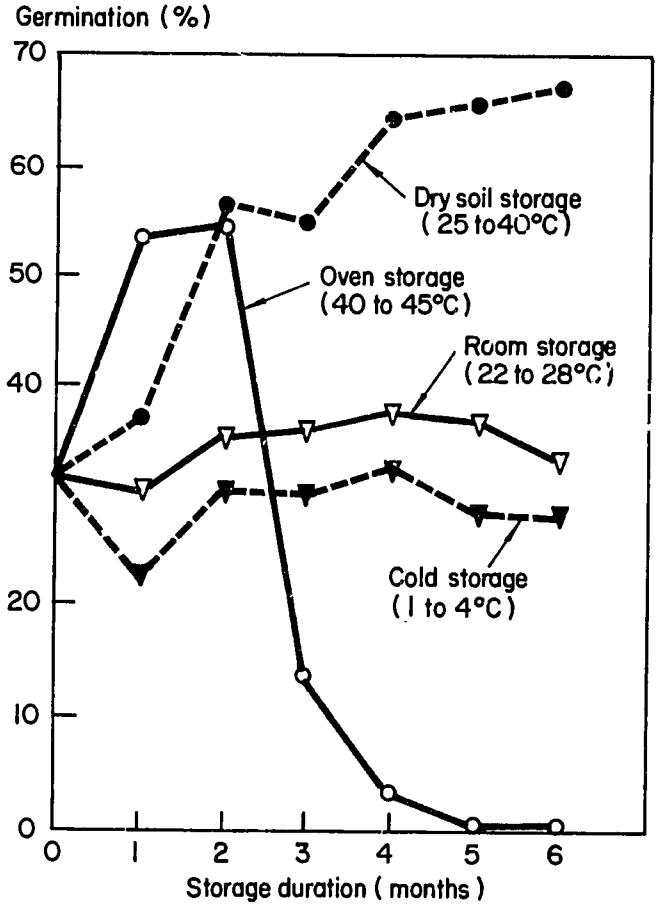


Figure 28. Effect of storage duration and conditions on leucaena seed germination eight weeks after planting, IITA, 1982.

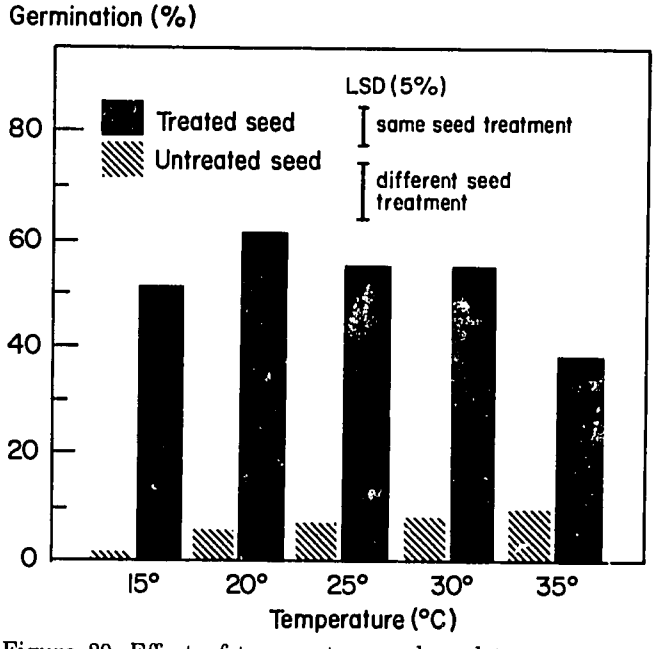


Figure 29. Effect of temperature and seed treatment on germination of leucaena seeds 14 days after planting, IITA, 1982.

clay pots and kept at 10°, 20°, 25° and 35°C for 28 days. One set of seeds was treated with hot water to break dormancy, while the other was untreated. The experiment had a split-plot design, with seed treatments as main plots and temperatures as subplots and six replications. Each subplot had 100 seeds. There was no germination at 10°C, but from 15°C the germination rate increased until 25°C and then decreased appreciably at 35°C. Total germination (Figure 29) was more or less the same between 15° and 30°C but was significantly lower at 35°C.

Weed Control After Leucaena and Natural Fallows

In addition to restoring the chemical and physical properties of the soil, a good fallow is expected to purify the field by reducing the population and effects of pathogens, insects and, most of all, weeds in succeeding crops. Though *Leucaena leucocephala* fallow reduces the population of many common weeds, leucaena itself can become the major weed after the fallow. The effect of leucaena as a weed on maize yield was compared to the effect of weeds after natural fallows during the same one-year period. The design of both trials was a split plot, with tillage (rotovation and no-tillage) as the main treatments and three levels of atrazine as the subtreatments.

After leucaena fallow the plot was alley cropped (alleys 2 m wide). The trees were cut back to 0.3 m, the trunks and large stems were removed, and the leaves and small twigs were left as mulch or green manure. With green manure, the leaves and twigs were incorporated during rotovation. In the tillage with mulch treatment, the land was rotovated before the mulch was added. With natural fallow, the plant cover, mostly grasses, was killed with glyphosate, and the residue was used as mulch or green manure. Fertilizer was not applied in either case.

After leucaena fallow tillage and plant residue management had no significant effect. Atrazine at only 3.0 kg a.i./ha controlled weeds significantly better than the control. With natural fallow tillage was slightly better than no-tillage, and both atrazine levels were significantly better than the control (Table 38).

In general, the maize yields were good, considering that fertilizer was not applied. The maize yield after leucaena fallow in the first season was low possibly because the leucaena was not given a third pruning and its regrowth partially shaded the maize during the grain filling stage. In the second season, the leucaena was pruned a third time. Direct comparison of the two fallows shows that there was less weed competition after leucaena fallow than after natural fallow. After leucaena weed control resulted in yield increases of 40% in the first and 70% in the second season. After natural fallow weed control increased yields 377% in the first and 263% in the second season. In reducing weed competition, leucaena fallow has an advantage over natural fallow dominated by grasses, where maize is grown after the fallow.

Fertilizer, Mulch and Green Manure in Alley Cropping

The effects of leaves and twigs pruned from *Gliricidia sepium* on maize yield were tested in an alley cropping system with 3.75-m spacing between rows. The leaves were used as mulch or green manure. The experiment had a split-plot design. The main treatments were NPK fertilizer (each applied at 60 kg/ha at planting plus 30 kg N/ha as a side-dressing four weeks later) and no fertilizer. The subtreatments were leaves and twigs as mulch and leaves and twigs incorporated as green manure. Maize was grown during the first season at spacing of 75 cm × 25 cm.

The fertilizer treatment gave significantly higher yields than the no fertilizer treatment. There were indications that using leaves as mulch or green manure had some beneficial effects, although the yield was not significantly different from that of the control. This trial will be continued to determine the cumulative effects of leaves as mulch and green manure over several seasons and years.—*G.F. Wilson and A.N. Atta-Krah*

Gliricidia Prunings as a Nitrogen Source

The effectiveness of *Gliricidia sepium* tops as a nitrogen source (applied fresh or after drying), compared to urea fertilizer, was tested on a sandy Apomu series soil (Psammentic Usthorthent), using maize as the test crop. A field trial was set up in a randomized complete block design with four replications. The urea nitrogen and gliricidia tops were applied (one-third of the N at planting and two-thirds two weeks after planting) in bands and then covered. All treatments received basal P and K dressings.

The maize yields were low because of erratic rainfall. Addition of urea and fresh gliricidia tops as fresh and dried materials at rates equivalent to 40 kg N/ha and 80 kg N/ha significantly increased maize yield (Figure 30). At the lower rate of 40 kg N/ha, gliricidia tops were less effective than urea. Though yield differences between fresh and dried gliricidia tops were not significant, the fresh tops appear to be more effective as a nitrogen source than the dry tops. The dry material, though, is easier to handle because it is less bulky.—*B.T. Kang*

Table 38. Effect of weed control on maize yield after leucaena and natural fallow (linear contrast for three values), IITA, 1982

	0 kg/ha	2.5 kg/ha	3 kg/ha	Effect Contrast	Effect Avg.
Leucaena fallow			*t/ha*		
First season.....	2.74	3.37	3.88	1.14	0.57
Second season.....	1.48	2.43	2.56	1.08	0.54
Natural fallow					
First season.....	0.95	4.53	4.53	3.58	1.78
Second season.....	0.68	2.40	2.47	1.79	0.90

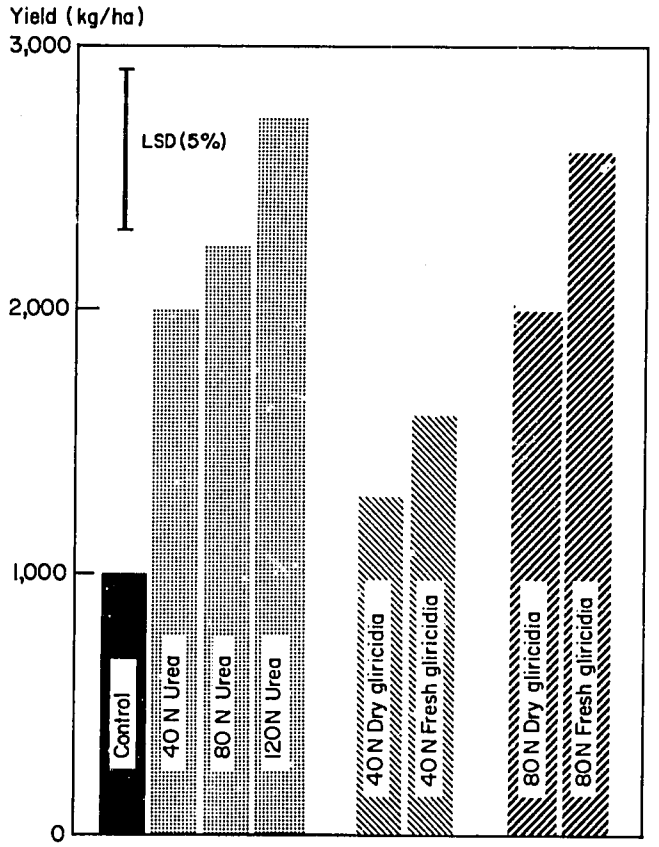


Figure 30. Effect of urea and *Gliricidia* nitrogen application on maize yield, IITA, 1982.

Leucaena/Maize/Yam On-Farm Trials

In addition to the objectives stated in previous IITA Annual Reports, the long-term on-farm trials of maize/yam alley cropping with *Leucaena leucocephala* had the following goals during 1982: (1) to check the suitability of leucaena stems as live in-situ stakes for yam vines under farm conditions; to observe farmers' problems with the management of yam/leucaena alley cropping; to assess farmers' perceptions of the system; and to obtain other feedback for further improvement of the system.

By the end of 1982, ten on-farm trials of leucaena/maize/yam alley cropping had been established, five of which were started in 1980, three in 1981 and two in 1982. The locations of the trials are Ijaye in Oyo State, Osara and Tawari in Kwara State and Yandev, Tyowanye and Zakibiam in Benue State. In addition, some alley cropping trials were started in 1982 in cooperation with the Ayangba and Ekiti-Akoko Agricultural Development Projects.

Most of these trials are located in the Guinea savanna, the midbelt of Nigeria, where yams are the predominant crop, though staking materials are quite scarce. For example, in Zakibiam, the center of yam production in Benue State and an area where farmers' specialization in yam production is probably the highest in Nigeria, farmers do not stake their yams. From informal surveys carried out in this area, it is clear that farmers understand the value of

staking yams. But because of the large hectareage under yam cultivation each year and the enormous amount of labor required to obtain the scarce staking materials, they choose not to stake their yams.

A simple experimental design consisting of a single replicate of yam/leucaena plot per farmer (with a control), is used in these trials. The farmers are taught that once the leucaena trees are well established, they should make heaps for yam cultivation between the leucaena rows and prune the leucaena trees at a height of about 1.5 m after planting the yams. They are instructed then to guide the vines so that they climb up the leucaena stems and to prune the live leucaena stakes regularly, leaving the tops and leaves as mulch for the yam crop. The trials are managed by the farmers under partial supervision by and with occasional advice from the cooperating researchers, who visit each trial at regular intervals to make the necessary observations.

As reported last year on the trials started in 1980, only one trial was fully established and ready for yam cultivation in early 1981. By 1982 five trials were ready for yam cultivation in Yandev and Zakibiam and have been put into production. The trial at Yandev, with its control, was planted to yams in May 1982. The farmer maintained the trial well by pruning the leucaena shoots regularly, and the yam vines grew vigorously as he guided them to climb up the live stakes. The farmer commented that the leucaena plot demanded too much attention and took too much labor to maintain. But he indicated that his wife was happy about the yam growth in the leucaena plot and that they were looking forward to seeing the yield.

Four of the trials under production are located at Zakibiam in the Ukum local government area. One of the farmers, after planting yam in March 1982, pruned the leucaena live stakes regularly and maintained the trial very well. Four of his neighbors were so impressed that they have requested leucaena seeds. But later in the season, the farmer pruned the live stakes less regularly, so the leucaena shoots started overgrowing and shading the yam vines before he could prune them again.

In the second trial at Zakibiam, the leucaena trees were burned down by a bush fire in January 1982, and when it was time for making yam heaps, the soil was so hard that the yam mounds had to be spaced wide apart. Yams were then planted so as to make use of dry stems as stakes. But during the heavy rains of June and July, many leucaena shoots sprang up from the stumps, and since the farmer did not prune the regrowth regularly, yam leaf production was not as high as in the other trials. Also, pruning of overgrown leucaena shoots appeared to disturb the yam vines. In the third trial at Zakibiam, the farmer was not able to plant yams in 1982 because of sickness, but he has finished making yam mounds and is ready to plant yams for the 1983 season.

The fourth trial at Zakibiam had the fastest growing and best established leucaena trees. The farmer planted late yams in 1981 in his leucaena plot

Land preparation in an alley cropping system.

along with the control and obtained good yields, although the tubers were not significantly better than those from the control plot. The farmer attributed the low yields of the leucaena plots to too much shading, which resulted from irregular pruning of leucaena and late planting of yams. He expects significantly better yields from subsequent crops.

After the farmer harvested yams, the leucaena shoots grew vigorously during the rest of 1982 and formed a closed canopy, keeping the ground free of weeds and the soil moist. The farmer explained that when leucaena was first introduced to him he was not convinced that trees could be interplanted with and benefit crops. However, he has been impressed by leucaena and has even told some of his friends about it. Two neighbors who have been impressed by this trial have requested leucaena seeds. But the farmer wishes to reduce the plant density of leucaena trees in his plot. The rest of the trials are still being established. The farmer at Osara wonders whether a tractor can operate through the leucaena hedgerows, and the farmers at Ijaye are reluctant to crop their plot for fear that it might cost them too much labor to manage the leucaena trees.

Observations of trials and comments by farmers indicate that further research is needed to adapt the system to farmers' conditions and capabilities. One problem is proper management of the system by farmers. The shoots of live leucaena stems used as in-situ yam stakes require pruning at regular intervals to prevent competition with the yam leaves for sunlight. The yam is an eight-month crop, lasting through both growing seasons, so about six prunings are required. If because of labor shortage or sickness, the farmer is forced to delay the prunings, the leucaena shoots are likely to depress both the vegetative growth and yield of the yams. Late pruning, when the leaflets are already large, also appears to damage the yam vines.

A second problem is determining the optimal

spacing between and within rows of the leucaena bushes. The early trials were planted at 2 m × 0.5 m and the later ones at 4 m × 0.5 m. In the former, farmers could make only one row of mounds, and even then some farmers complained that 2-m spacing is too narrow for their yam heaps. The 4-m row spacing seems more reasonable, although some farmers think it gives too high a proportion of trees per unit land. A third problem is mechanization of the alley cropping system for ploughing or pruning of the leucaena bushes to reduce labor requirements at peak periods, especially for the medium scale farmers.

In addition to pointing out problems that require further research, farmers have commented that leucaena/yam alley cropping has definite benefits. It provides inexpensive staking materials for yams. The yam crops in the leucaena plots look much better than those in the control plots. The leucaena controls weeds, especially *Imperata cylindrica*, and it keeps the soils moister and more friable. When farmers ploughed they found the soils in the leucaena plots to be softer and easier to plough than those in the control plots.

Leucaena also improves the fertility of the soil. Soil tests on these plots done in November 1982 indicate that since the last tests in June 1981 some soil chemical properties have improved significantly. Total nitrogen in the soil has increased by over 60%. The pH of the soil has increased by up to 8%, and the percentage organic carbon in the soil has also been raised.

Another benefit recognized by farmers (especially in the Guinea savanna) is that leucaena trees provide firewood and fencing materials. Two farmers indicated that they plan to increase the land under leucaena to 2 ha each. The fact that other farmers have taken an interest in leucaena at two of the locations and have requested seed is a further indication of the benefits of alley cropping with leucaena.—*D.S. Ngambeki*

Live Mulches and Cover Crops

Nitrogen Uptake in Live Mulch Systems

To evaluate the N contribution of *Psophocarpus palustris*, *Centrosema pubescens* and *Arachis repens* in live mulch systems at IITA, total N uptake was assessed at maize harvest in a newly established field and in another one that had been cropped continuously for six seasons. The latter was a three replication split plot with different types of land management and live mulches as the main plots and different levels of N fertilizer as subplots. Some parts of the plots were not weeded, others were kept clean, and some were weeded once.

The newly established field was a four-replication split plot with different types of land management and live mulch (only *C. pubescens* and *P. palustris*) as the main plots and N fertilizer rates as subplots. This field was weeded regularly. The effects of the different land management and live mulch treatments on soil properties and crop yield were reported in the IITA Annual Reports for 1979, 1980 and 1981. This discussion is concerned only with N data from the live mulch and unmulched plots that were conventionally tilled, received 0 or 120 kg N/ha, and were weeded or not as indicated.

The shoot dry weight of the cover crops averaged 4 t/ha, and root dry weights ranged from 0.4 to 2.65 t/ha. In both fields live mulches contained 89 to 161 kg N/ha at maize harvest, but their N contents exceeded 200 kg N/ha during the cropping season, and they were not affected significantly by N fertilization and weeding (Table 39).

In the newly established field, the N uptake by maize was about the same at 0 and 120 kg N/ha and was the lowest in centrosema plots. The N contribution from the cover crop (calculated as the difference between the N content of maize in live mulch plots and its N content in plots without live

Table 39. Nitrogen uptake and yield in a newly established and a long-term mulch plot, IITA, 1982

Treatment	Total N, kg/ha: Live mulch	Total N, kg/ha: maize	Amount of N contributed to maize by live mulch, kg/ha
New plot			
No N fertilizer			
No live mulch	0	34.0	0
Centrosema	95.0	9.2	−24.8
Psophocarpus	114.0	20.4	−13.6
120 kg N/ha			
No live mulch	0	38.0	0
Centrosema	116.0	16.0	−22.0
Psophocarpus	108.5	27.2	−10.8
LSD (5%)	64.0	13.6	18.4
Long-term plot			
Weed free, no N fertilizer			
No live mulch	0	60.0	0
Centrosema	99.0	39.2	−20.8
Psophocarpus	104.5	63.2	3.2
Arachis	160.5	37.2	−22.8
Weed free, 120 kg N/ha			
No live mulch	0	82.0	0
Centrosema	130.0	68.4	−13.4
Psophocarpus	89.0	108.8	26.8
Arachis	133.5	105.2	23.2
Weedy, no N fertilizer			
No live mulch	0	16.4	0
Centrosema	117.0	76.0	59.6
Psophocarpus	133.5	60.4	44.0
Arachis	156.0	29.2	12.8
Weedy, 120 kg N/ha			
No live mulch	0	49.2	0
Centrosema	120.5	83.6	34.4
Psophocarpus	102.5	98.0	48.8
Arachis	110.5	40.4	−8.8
LSD (5%)	78.0	38.0	28.4

[a]Values were calculated for a maize population of 40,000 plants/ha.

mulch was negative, indicating that the live mulch and main crop competed for N. This finding corroborated earlier observations that *P. palustris* and *C. pubescens* nodulated poorly at IITA and that their symbiotic N fixation was low.

In the long-term field, N uptake by maize was lowest in the weedy plots that had no live mulch and received no N fertilizer. Also, because weed control was poor in arachis, N uptake by maize was low in unweeded plots having this legume as live mulch. *A. repens* in weedy plots contributed the least N. The N contribution of *P. palustris* was generally superior, averaging 30.7 kg N/ha. This represents only a small fraction of the live mulch N, especially if the total litter produced from the legume over the cropping season is taken into consideration.—*K. Mulongoy and I.O. Akobundu*

Use of a Growth Retardant in Live Mulch Systems

The purpose of this study was to describe the growth patterns of *Psophocarpus palustris* and *Centrosema pubescens* as affected by CGA 47283, a growth retardant used to prevent these legumes from climbing and strangling associated crops in live mulch systems. The growth retardant was applied on the cover crops at rates of 0, 1 and 10 times the recommended rate of 2 kg CGA/ha. At the time of spraying, the legumes were 15, 30 and 45 days old. One, five and nine weeks after CGA application, the length of the main stem was measured, and the number of nodes and branches on this stem were counted.

Leaf burns were noted the second day after application of the growth retardant. These were more marked in the treatment that received 20 kg CGA/ha. The plants recovered in two or three weeks, but elongation of their main stem was visibly reduced. Five weeks after CGA application, the mean height of the main stem of psophocarpus sprayed with 2 and 20 kg CGA/ha was, respectively, 47 and 31% of that of unsprayed plants; for centrosema, 43 and 53% inhibitions were recorded for the corresponding treatments (Table 40). Only plants sprayed 15 and 30 days after planting were affected by the growth retardant. Nine weeks after application of CGA, growth inhibition persisted in centrosema plants that had been sprayed with 20 kg CGA/ha 15 days after planting and in psophocarpus plants that had received 2 kg CGA/ha at 15 days after planting or 20 kg CGA/ha at 15 and 20 days after planting. Thus, the inhibitory effect of CGA on main stem elongation was more marked on plants sprayed at an early growth stage, and psophocarpus was more sensitive to the chemical than centrosema.

Internode length was also affected by the growth retardant. One week after CGA application, internodes averaged 2.4 cm long for psophocarpus and 3.0 cm for centrosema, respectively, with no differences between CGA treatments. After four weeks the internodes of sprayed plants were about half the size of those on unsprayed plants. At that stage stem elongation was generally inhibited by CGA, but the formation of nodes was not. Sprayed plants produced greener and smaller leaves than those that received no CGA treatment. Nine weeks after CGA application, newly formed internodes on the main stem of sprayed plants were more than 5 cm long, but psophocarpus sprayed with 20 kg CGA/ha 15 days after planting showed 87% inhibition of internode elongation.

Table 40. Main stem length and dry weight of two legume species five weeks after application of a growth retardant, IITA, 198[illegible]

Plant stage at CGA application	CGA rate, kg/ha 0	2	20
Psophocarpus	**Main stem length, cm**		
15 days after planting	91.79	29.34	17.07
30 days after planting	138.96	57.29	34.07
45 days after planting	196.30	111.98	79.35
Centrosema			
15 days after planting	53.46	17.61	14.97
30 days after planting	86.76	34.93	23.12
45 days after planting	102.14	86.43	75.91
LSD (5%) for comparing means of:			
Psophocarpus, same CGA trtmt			43.83
Psophocarpus, diff. CGA trtmts			53.08
Centrosema, same CGA trtmt			30.65
Centrosema, diff. CGA trtmts			30.16
Psophocarpus	**Dry weight, g/plant**		
15 days after planting	38.39	36.07	13.49
30 days after planting	58.78	54.13	15.37
45 days after planting	75.98	61.32	32.28
Centrosema			
15 days after planting	52.88	33.83	22.66
30 days after planting	54.37	44.55	20.48
45 days after planting	61.47	60.10	33.43
LSD (5%) for comparing means:			
For same CGA treatment			20.0
For different CGA treatments			31.0

Shoot dry weight of the cover crops was evaluated five and nine weeks after CGA application, and nodulation of psophocarpus only was observed 8 and 16 weeks after application of the growth retardant. At five weeks 20 kg CGA/ha had caused 70% inhibition of dry matter production in 65-day-old plants of psophocarpus and 50% in centrosema (Table 40). Four weeks later all the plants that had been sprayed with 20 kg CGA/ha exhibited reduced dry matter production, compared to plants of the same age in the unsprayed control or in the treatment that received 2 kg CGA/ha. This pattern could not be predicted from the height and number of nodes and branches on the main stem since at that stage all these factors tended to be similar in the CGA and no CGA treatments. The small size of the leaves may account for the reduced dry weight in the CGA treatments.

At 8 and 16 weeks after application, the chemical retarded nodulation of psophocarpus when applied at 20 kg/ha. At a low rate (2 kg/ha), inhibition was

significant only on plants that were at least 14 weeks old at the time of sampling. The fact that CGA retards nodule formation and development suggests that it reduces the symbiotic N fixing ability of *P. palustris*, lessening its usefulness as an N source in live mulch systems. In the future we will evaluate the effects of CGA on fixing of atmospheric nitrogen by nodules.—*K. Mulongoy*

Soil Climatic Regimes in Live Mulch Systems

As part of a comprehensive evaluation of live mulch production systems, changes in soil moisture in different surface mulch/crop combinations were followed during both cropping seasons in 1982 (this study was a continuation of one reported in the IITA Annual Report for 1981). The objective was to assess the moisture regime and moisture availability under the system and to confirm the validity of previous results.

Those results indicated that there is considerable interplay between the amount, rate and frequency of rainfall and the observed moisture regimes. The trends observed then still hold. Moisture infiltration into the soil is evidently higher in mulch/crop combinations than with bare or poorly covered soil surfaces. The soil moisture content under live mulches also remains higher except after prolonged drying cycles. With regard to these properties, psophocarpus and maize stover are best, Arachis and no-till are often the worst, and centrosema and conventional tillage are generally in between.

There is evidence that the treatments interact with soil fertility (N fertilizer level) and soil type. The no-till treatment ranks high at high soil fertility on light soil (Apomu) and is also better than other treatments on a heavier soil (Egbeda) at lower fertility. For the same mulch/crop combination, soil moisture content is also higher, in most cases at a higher fertility on lighter soil.

As expected, much cooler soil temperatures prevail under live mulches (psophocarpus and centrosema), particularly during the dry season and early in the first season. Differences in weekly mean maximum temperatures may reach more than 10°C during the dry season and near 5°C during the early rains (Figure 31). These differences could have a considerable effect on biological activity in the soil during the dry season and possibly on seedling growth during the growing season.

On the basis of these and previous results, certain broad criteria may be used in choosing mulches for particular situations. First, heavy surface mulches are unsuitable in areas and during seasons with very light rainfall, even if rains are frequent. Second, actively growing live mulches do not appear suitable in areas or during seasons of erratic rainfall with prolonged periods of moisture depletion between rains. Live mulches should not be used if these periods last more than 10 to 15 days, depending on the soil type and amount of preceding rainfall. Finally, the moisture advantages of mulch/crop combinations are most effective in soils of adequate fertility.—*T.L. Lawson and I.O. Akobundu*

Crop Yield After Two Planted Fallows

A long-term trial on the effects of planted fallow trees on soil chemical properties and crop yield was begun in April 1981 on plots of *Acioa barterii* and *Gliricidia sepium* that had been established four years earlier. Each plot measured 8 m × 2 m, and the row spacing was 1 m. The experiment had a split-plot design with the fallow trees as whole plots and the fertilizer treatments (fertilizer versus no fertilizer) as subplots. The control was natural regrowth (mainly grass weed fallow). There were three replications.

A. barterii and *G. sepium* stands were pruned a second time to a height of 50 cm in April 1981, and the leaves and fine twigs were spread out evenly as a mulch in the plots. Weeds were controlled in *G. sepium* and in the control plots by application of paraquat. There were no weeds in the *A. barterii* plots. The test crops were maize in the first season and cowpeas in the second. Fertilizer (60 kgN/ha, 125 kgP/ha and 60 kgK/ha) was applied only to the first season maize. *A. barterii* regrowth was pruned once and that of *G. sepium* twice to prevent shading of crops. Changes in the amount of leaf residue were monitored at monthly intervals.

The *Gliricidia sepium* plots had the highest yields of first season maize (Table 41). Fertilized plots yielded significantly more than unfertilized plots in all fallow treatments. The cowpeas in the natural regrowth fallow yielded significantly more than that in other treatments, except unfertilized *G. sepium*. Cowpea yields were generally lower in 1982 than in 1981 because of a 24% deficit in precipitation.

The residue of *A. barterii* decomposed very slowly (Figure 32) and the persistent mulch it formed prevented weed growth and eliminated the need for weeding throughout the trial. Since weeding is often the largest labor input in bush fallow agriculture, the *A. barterii* fallow could free a large part of the labor force for expanding production. The mulch also protects the soil from erosion and adds to the soil organic matter content.—*G.F. Wilson and P.S. Okoli*

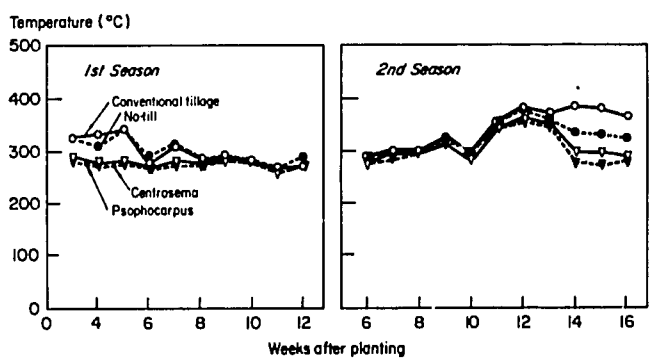


Figure 31. Trend in weekly mean maximum temperatures under different mulch/crop combinations and tillage methods, IITA, 1982.

Plantain Research

The major concern of farmers undertaking large scale production of plantains (*Musa* sp. AAB) is the rapid decline in yield after the first harvest. Previous studies have shown that a low soil organic matter content may be one of the main causes of this decline and that productivity can be maintained if organic material is applied frequently as mulch. Recent IITA plantain research has focused on the effects of mulches and on the development of efficient mulching techniques.

Table 41. Effect of planted fallow species on maize and cowpea yield, IITA, 1982

Treatment	*Acioa barterri*	*Gliricidia sepium*	Natural regrowth	Mean
First season		**Maize yield, t/ha**		
Fertilized	4.4	5.0	3.8	4.4
Unfertilized	3.1	3.7	2.7	3.2
Second season		**Cowpea yield, t/ha**		
Residual fertilizer	0.404	0.536	0.692	0.544
Unfertilized	0.408	0.628	0.631	0.556

LSD (5%) for comparing:	Maize	Cowpeas
Species	1.2	0.212
Fertilizer treatments	0.4	0.079
Fert. trtmts., same species	0.7	0.136
Fert. trtmts., diff. species	1.3	0.233
C.V., %		
Species	19.1	24.0
Fertilizer treatments	9.6	12.4

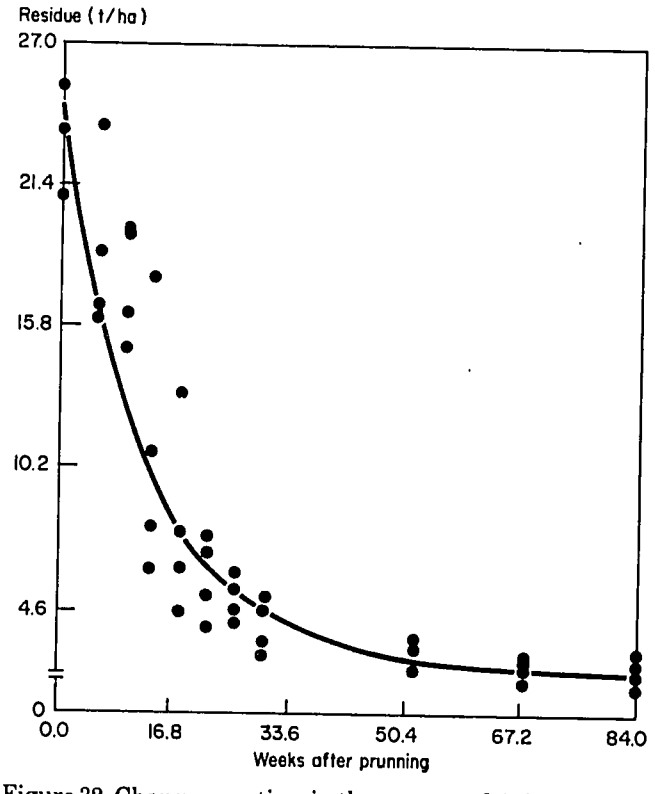


Figure 32. Change over time in the amount of *Acioa barterii* leaf residue, IITA, 1982.

Mulch and Inorganic Fertilizers

An experiment was started to examine the effects of mulch plus fertilizer, mulch alone, fertilizer alone and a control without mulch and fertilizer. Two plantain cultivars (a giant and a medium false horn) and a banana cultivar (paranta) were planted in a randomized complete block design with four replications. Fertilizer was applied at the rates of 300 kg N/ha and 500 kg K_2O/ha per annum in five equal applications over 10 months. Mulch from elephant grass (*Pennisetum purpureum*) was applied three times at a rate of 10 to 15 t/ha to give a total of 40 t/ha/yr (fresh weight).

The mulch plus fertilizer treatment was significantly better than the others in terms of early maturity, bunch weight and yield (Figure 33). The height of the first sucker increased with fertilizer but decreased with mulch. Judging from yield response, the giant false horn appears to be more tolerant than the other cultivars to low soil fertility. The medium false horn and paranta matured much earlier with mulch and fertilizer. These results agree with previous findings that mulch alone is often as effective or better than fertilizer alone. The final conclusion will depend on the performance of the crops in succeeding years.

In-Situ Mulch

In the management of plantain plantations, a major drawback to using mulch is the high labor requirement of cutting, transporting and applying the organic materials commonly used in the humid tropics. To overcome these problems research is being carried out on in-situ mulch production. The methods being tested are two spatial arrangements in which the mulch producing plants are grown close to the plantains (Figure 34). In one of these spatial arrangements, every four rows of plantains (spaced 2 m × 2 m) are separated by an equivalent area of mulch, with a 2-m border between the mulch source and plantains. In the other arrangement each pair of plantain rows is separated by an equivalent area of mulch, leaving a 1-m border between the plantains and mulch source. The species used for producing mulches were *Flemingia congesta*, *Eupatorium odoratum* and *Pennisetum purpureum*. The mulch was cut and applied to the adjacent plantains three times a year. The plantains also received inorganic fertilizers at rates of 300 kg N/ha and 550 kg K_2O/ha per annum applied in five equal applications over 10 months. The design was a split plot with three replications. The main plots were the mulch sources and the subplots were the spatial arrangements.

In bunch weight (Table 42) there were no significant differences between spatial arrangements, but there were significant differences between types of mulch. *P. purpureum* and the control were marginally better than *F. congesta*. *P. purpureum* was also better than *E. odoratum*.

Differences in yield between the two spatial

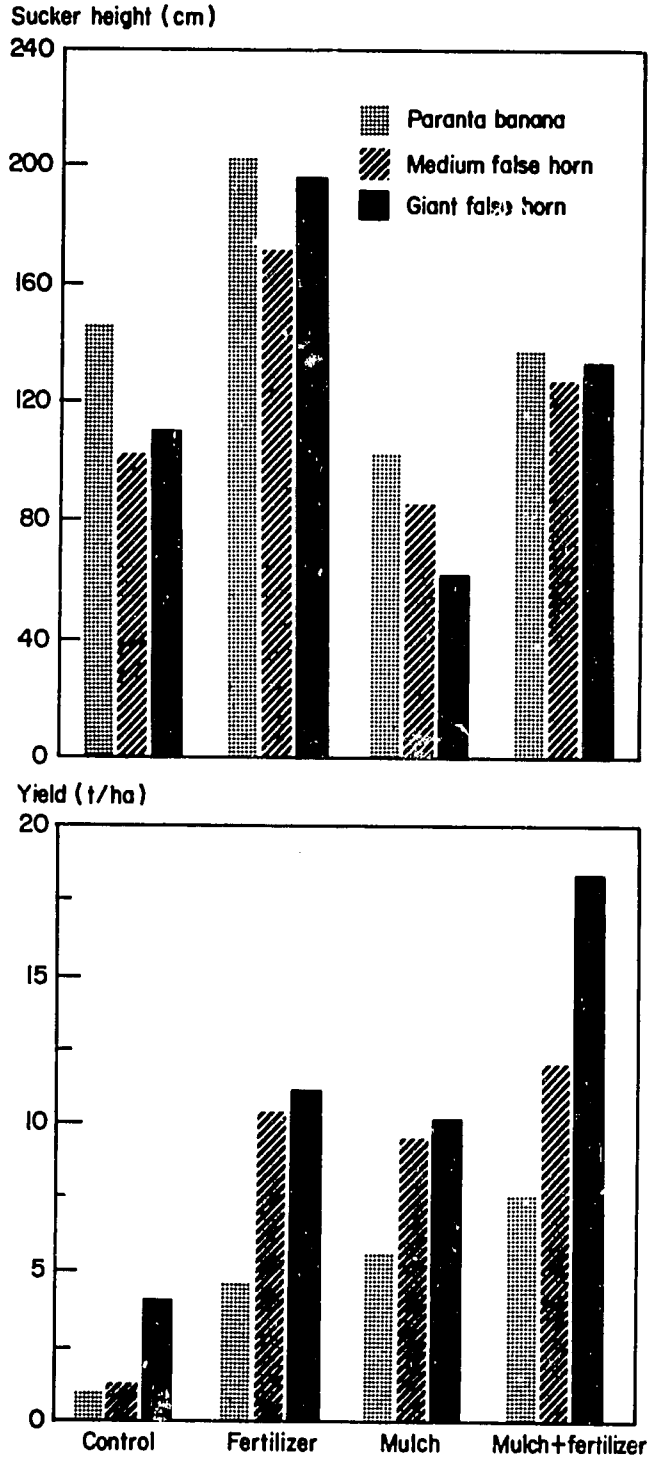


Figure 33. Effect of mulch and fertilizer treatments on yield and first sucker height of banana cultivars, Onne, Nigeria, 1982.

arrangements were due to differences in plant density. The lower yield in the first spatial arrangement is the result of its lower plant density and could be a disadvantage if the trend persists in the ratoons. The significantly lower yields of *E. odoratum* and *F. congesta* in the second spatial arrangement suggest that the mulch source and crop compete. There were also indications that shade from the plantains was affecting the mulch source

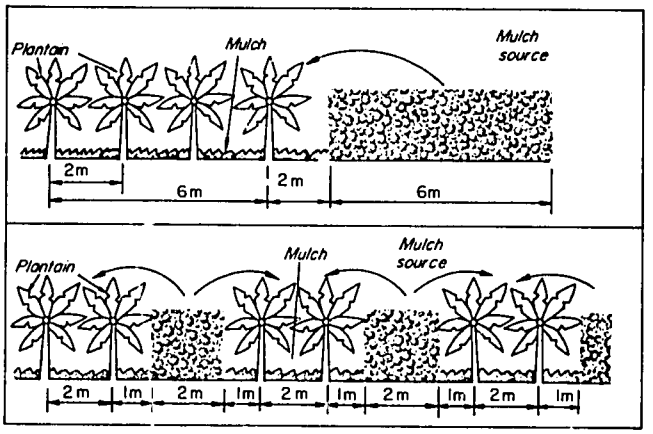


Figure 34. Arrangements of plantain and mulch source plants for in situ mulch production, Onne, Nigeria.

plants adversely in the close spacing.—*R. Swennen and G.F. Wilson*

Farm Inputs and Equipment

No-Tillage Planters and Sprayers for Small Farms

Establishing a good stand in a no-tillage system is usually more difficult than in a conventional tillage system. To determine what planter configuration will give the best establishment with different no-till planters, several tests were conducted this year.

Modifications in the Rolling Injection Planter

Certain modifications were made in the planter to increase its effectiveness in establishing a good stand. The length of the openers was increased from 50 to 70 mm to achieve deeper seed placement, and the configuration of the press wheel was changed to achieve better seed-soil contact.

Tests were made in both growing seasons of 1982 in maize. A total of 10 combinations of openers and press wheels were tested in an experiment that had a complete factorial design with eight replications. A depth of seed planting test was done simultaneously with each of those tests. Single seeds were planted at depths of 0, 10, 25, 50, 75 and 100 mm. Each treatment had 25 seeds. The planting procedure was as follows. A cylinder with a diameter of 50 mm was pressed into the ground to the desired depth of planting. The cylinder was pulled out with the soil core. One seed was dropped into the hole, and the soil core was pushed back in to cover the seed. Best establishment was achieved between the depths of 25 and 50 mm, and it was usually good up to 75 mm.

As for the planter modifications, the 70 mm opener gave consistently better establishment, but the different press wheels failed to improve overall establishment, compared to that with the original press wheel or with no press wheel at all. The failure apparently had two causes, the first of which was

Table 42. Performance of plantains in two different spatial arrangements with different mulch sources, Onne, Nigeria, 1982

Mulch source	Mean bunchweight, kg/plant			Yield, t/ha		
	Four rows	Two rows	Mean	Four rows	Two rows	Mean
Control	6.7	8.0	7.4	10.8	16.8	13.8
Eupatorium odorata	6.7	7.2	7.0	10.8	15.1	13.0
Flemingia congesta	6.3	6.7	6.5	10.0	14.1	12.1
Pennisetum purpureum	7.5	7.9	7.7	12.1	16.5	14.3
Mean	6.8	7.4		10.9	15.6	
LSD (5%) between:						
Spatial arrangements			2.6			3.9
Mulches			0.5			0.8
Mulches, same arrangement			0.7			1.2
Mulches, diff. arrangements			0.8			2.7

depth of planting. When the seeds were not planted at least 25 mm deep, establishment was poor, a finding that agrees with the results of the depth of planting test. The second cause is the inability of the different press wheels to make a real difference in soil compaction around the seed at a depth of more than 25 mm.

The increased opener length did not increase planting depth in proportion to its length probably because of the shape of the opener lever. The average depth of planting on friable soils was 29 mm for the 50-mm opener and 38 mm for the 70-mm opener. The force required to push the planter increased proportionally with increased depth. With 50-mm openers it averaged 2.8 kg and with 70-mm openers 3.6 kg. For hand-pushed planters, it may be necessary to use the shorter opener since it is easier to operate.

A number of other changes were made in the rolling injection planter during 1982. We added a new hopper that is easier to construct and a new seed cutoff and developed a six-row, fully mounted planter for small four-wheel tractors.

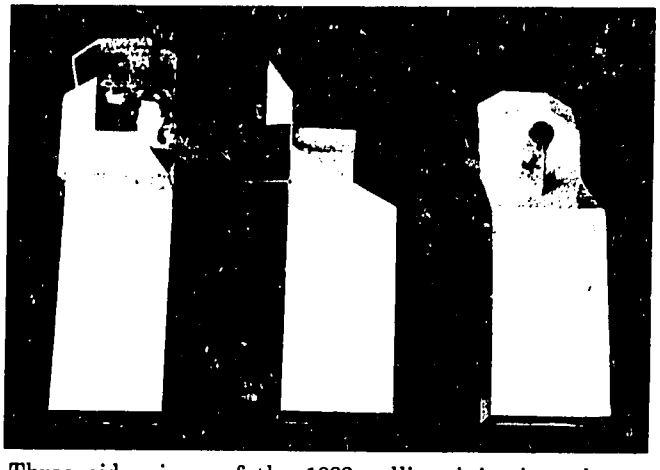
The old hopper had many curved and oblique surfaces that required cutting curves in the sheet metal before forming. Most local shops that could manufacture these planters would have to cut the curves by hand. The oblique angles made it difficult to fabricate the hopper true to shape. The new design has all straight cuts and all but two folds at right angles. Three views of the new hopper are shown in the accompanying photograph.

The seed cutoff separates the seed in the hopper from the seed held in the seed cup on the metering roller, allowing only the metered seeds to pass. A number of types of cutoffs have been used, but the best appears to be a small brush that handles the seed very gently. The disadvantage of the brush is that it has not proven to be very durable under field conditions.

Rubber is an excellent material for the cutoff because it is durable and in villages can be obtained from old tires. Although a number of rubber cutoffs have been made in the past, all of them have the same problem; they flick the seed as it moves out under the cutoff, causing it to drop into the wrong opener and resulting in uneven seed drop. The new rubber cutoff, which is cut from a motorcycle tire, has lessened this problem (see accompanying photograph). The natural curve of the tire allows the finger of the cutoff to fit the metering roller in such a way that the seeds are held in the cup of the metering roller until they are in a position where the cutoff does not exert much force on them. The seed then moves out from under the finger of the cutoff without being thrown. During 1981 a four-row, tractor-mounted planter proved very effective in a village cooperative near Ibadan that owned a 65-hp tractor. In 1982 a six-row tractor-mounted planter was constructed. The force required to pull one rolling injection planter is only 3 to 4 kg, and the maximum forward speed for the planter is 3.5 kph. Under local conditions a planter mounted on a tractor must be narrow enough that it can easily be maneuvered in fields that have trees, stumps, rock outcrops and other obstructions. The maximum possible width was thought to be 5 m. A 4.5-m tool bar was made and six planter units mounted on it at 0.75-m spacing.

The planting wheel and compaction wheel supports had to be strong enough to stand up to the bouncing that occurs while the tractor is travelling in the field. The planters had to have even better support during road transport. The accompanying photograph shows the planter built in 1982. The first two planting units are in operating position, and the other four are in transport position. The planter weighs 325 kg. The 15 kW tractor used with the planter was just capable of lifting it.

Other modifications have been made, which, though not yet tested fully, appear to be excellent. New hinge pins have been put on the moving opener to simplify manufacturing, and a fixed-opener reinforcement was made to go with the 70-mm opener to keep it from bending. This can also be used to reinforce the 50-mm opener where the steel available

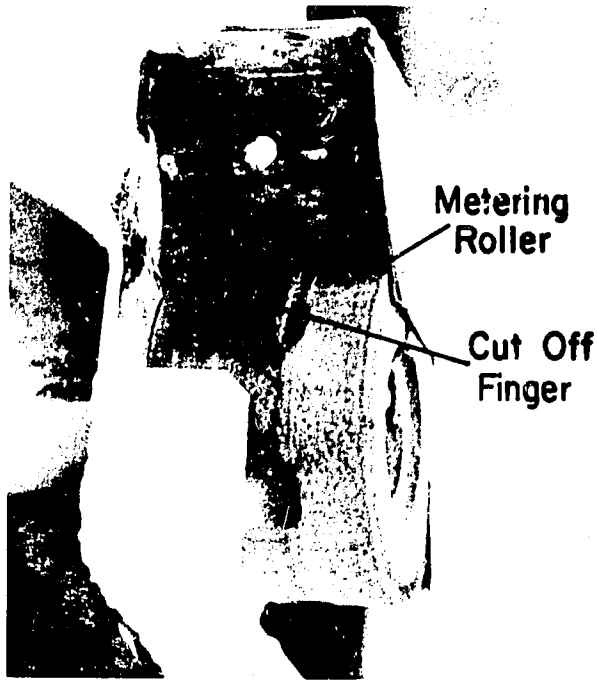


Three side views of the 1982 rolling injection planter hopper.

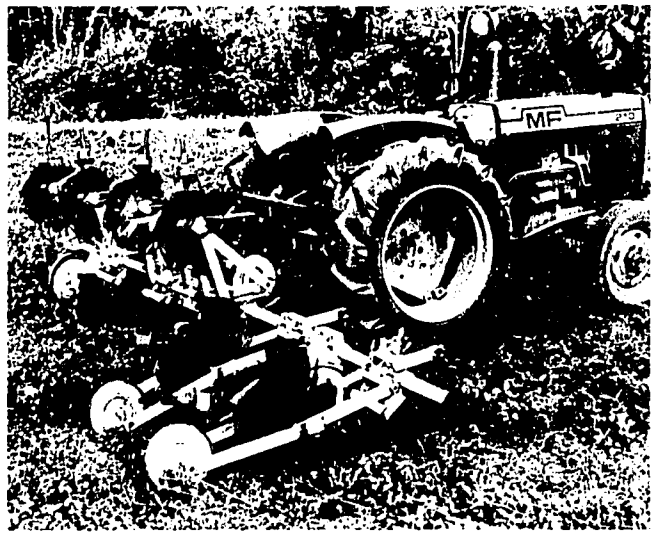
is not strong enough to prevent the fixed opener from bending.—*C. Garman and N.C. Navasero*

Comparison of the Rolling Injection Planter With a Conventional No-Till Planter

A six-row rolling injection planter mounted on a 15-kW tractor and a four-row John Deere 7000 no-till planter pulled by a 50-kW tractor were tested under difficult no-tillage field conditions (the soil was too hard to be penetrated easily). The two planters made alternating passes across the field, and for nine passes of each planter, stand establishment was measured. A similar comparison was made between the rolling injection planter (hand pushed) and a four-row Gaspardo no-till planter, except that in this test the no-till field conditions were good.



The 1982 design of the rubber cut off. The cut off finger keeps the seeds from being flicked out of the seed cup in the metering roller.



A six-row planter mounted on a 15-kW tractor. The individual planter units are rolling injection planters with 70-mm openers.

In each test the establishment rates were found to be equal at the 5% level of probability. Under good field conditions, the rolling injection planter had 82% establishment and the Gaspardo 81%. Under very difficult conditions the rolling injection planter had 16% establishment and the John Deere 12%.

These results show that the rolling injection planter is as effective in crop establishment as either of the conventional no-till planters. From the results of this experiment and the one on different press wheel configurations, it can be concluded that the rolling injection planter with the longer openers will give establishment rates comparable to those of the conventional no-till planters.

Seedbed Preparation Devices

A standard no-till planter (Gaspardo) was set up with seven different commercially available trash cutting and/or strip-tillage seedbed preparation devices. These planter setups were as follows: fluted coulter followed by a small fluted coulter, ripple coulter followed by a small fluted coulter, ripple coulter followed by another straight coulter offset 40 mm to one side, ripple coulter followed by a trash flinger, fluted coulter only, ripple coulter only, and ripple coulter followed by a chisel. All coulters were operated at a depth of 6 cm and the chisel at 20 cm. Each treatment was replicated eight times. Plant establishment for each setup was not significantly different, except for the ripple coulter followed by the small fluted coulter, with which establishment was significantly lower than with the others. These trials need to be repeated.

No-Tillage Planting in Wet Soil

Establishment of crops in no-tillage systems is a problem when the soil is very wet and soft and has a recent crop or weed residue, conditions that often exist during second season planting. Under these conditions the trash cutting coulters in front of the planter units press the crop residues into the soil, forming an envelope of mulch instead of cutting through the mulch. Since seeds are then dropped into this envelope, germination is reduced. A test was done to check the effectiveness of trash flingers under these conditions. (Trash flingers consist of two discs running at an angle to each other that plow away the surface trash, leaving a narrow strip of bare soil for the double disc opener to plant in).

A four-row John Deere 7000 planter was used, with two trash flingers in front of two of the planter units and fluted coulters in front of the other two. Both were standard attachments. The field was planted in the normal way, creating a pattern of four rows with trash flingers and four rows with fluted coulters.

Sixteen observations each of 10 m of row length were made for both setups. General field conditions during planting were very favorable and the difficult wet and soft conditions required for testing this configuration did not occur. The two setups were equally effective in plant establishment. The tests will be repeated under unfavorable conditions in 1983.—*C. Garman*

Hand-Pulled Boom Sprayer

Small farmers need more uniform and safer application equipment for herbicides. Hand application using a knapsack sprayer with a 1.5-m spray pattern width has several serious problems: spraying is not uniform because of the large overlap per hectare; the spray operator contaminates himself by walking through the area just sprayed; he must carry heavy loads of water; he may spill spray mixture on himself; and spraying with this equipment is very time consuming.

A hand-pulled wheeled sprayer with a 4-m boom was built that reduces the overlap problem by 67%. The spray operator walks in front of and pulls the sprayer and does not have to walk through the sprayed area at any time. Since the operator is farther away from the spray nozzle, there is less chance of the spray drift getting on him. The spray tank is carried on two bicycle wheels, reducing the load the operator carries and the possibility that he may spill spray mixture on himself.

The sprayer uses a 15-l pneumatic knapsack sprayer (which is pressurized before use) with a pressure regulator on the outlet.

The pressure regulator allows for constant pressure on the nozzles as long as the tank pressure is above the set pressure. Four low-volume flood jet nozzles were used that apply approximately 70 l/ha at a walking rate of 3.5 kph. The sprayer was used on areas where old row stubble could still be seen, so the operation could be done without markers.

The effective field capacity with water and chemicals at the side of the field was 1.67 h/ha. The theoretical field capacity is 0.7 h/ha at a walking rate of 3.5 kph. The time spent filling the sprayer and adding one chemical was 5 min per 15-l tank. It took 4.5 tanks/ha and a total of 25 min/ha to fill the tank.

The sprayer appears to have solved the problems mentioned above, although the volume of water is still very high for areas where water must be carried long distances. This sprayer does not reduce the difficulty of walking in straight lines or following the previous pass, and agitation of chemicals in the tank seems to be inadequate for suspended materials.

The sprayer was used in a number of fields where it could be compared to a large, tractor-mounted boom sprayer applying the same rate of chemicals. In general, it controlled weeds as well as the tractor-mounted sprayer, but further work needs to be done before any definite conclusions can be drawn.—*N.C. Navasero*

Comparison of Cowpea Harvesting Methods

Previous work has shown that determinate upright cowpeas (04-0267-IF) can be cut mechanically at 5 cm above the ground with field losses of 13%. Setting the cutter bar higher caused field losses of more than 35% of the potential yield. With a spreading type cowpea like VITA-5 losses were 45% when the cutter bar was at 5 cm (Table 43).

In 1982 comprehensive tests were made to compare four different methods of harvesting: (1) manual picking, which involves picking the pods and drying them before threshing; (2) plant harvesting and windrowing, in which the plants are cut or pulled, six rows are piled in one windrow, and plants are threshed after drying; (3) cutting with a one-row cutter bar conveyor, which cuts most of the pods and a small amount of straw, followed by drying and threshing; and (4) the one-row combine harvester, a simulated system using the same cutter bar conveyor used in treatment 3 and a standard rubber roller type thresher at the same time. (The same thresher was used to thresh the other harvests).

About one-fifth hectare of cowpeas ready to harvest was subdivided into four replications, on which the four harvesting methods were used. Treatment plots of 120 m^2 were randomized following the randomized complete block statistical design. The cowpea variety used in this experiment was IT-82E-9, an upright, early maturing variety. The cowpea crop was fully dried at harvest, with a seed moisture content of about 12%. Measurements were made of the harvesting rate, harvesting losses, threshing rate, threshing losses, impurities, seed damage caused by threshing, moisture content and total yield.

Because the test field had a very uneven surface, the cutter bar had to be set at 10 cm rather than 5 cm, which could have caused fewer losses in treatments 3 and 4. With cutting and windrowing, most losses can be avoided because the person harvesting picks up plants that have fallen over. With manual pod picking, the harvesting rate was very slow because

Table 43. Effects of cutting height on yield and harvest losses of upright and spreading cowpea varieties, IITA, 1981

Cutting height	Yield, kg/ha	Losses kg/ha	Losses Percent	Dry matter, kg/ha
VITA-5				
0 to 5 cm	862.88	388.00	44.97	769.79
6 to 10 cm	706.00	390.45	55.31	434.88
11 to 15 cm	817.79	566.67	69.29	308.67
04-0267-IF				
0 to 5 cm	794.21	104.88	13.31	1,167.12
6 to 10 cm	807.55	284.00	35.17	444.88
11 to 15 cm	959.55	499.12	52.02	325.33

Note: The combine was operated at low speed (0.50 m/sec or 4.93 to 7.41 hr/ha).

Table 44. Comparison of four cowpea harvesting methods, IITA, 1982

Harvesting method	Total yield,[a] kg/ha	Rate, man-hr/ha			Losses, kg/ha			Net yield,[b] kg/ha
		Harvesting	Threshing	Total	Harvesting	Threshing	Total	
Manual picking	2,021	451	12	463	47	32	79	1,942
Plant harvesting and windrowing	2,201	124	33	157	54	152	206	1,995
Cutting by one-row cutter bar	2,023	81	24	105	426	193	619	1,404
One-row combine harvester	1,983	37	43	43	512	229	741	1,242

Note: Grain moisture content at harvest was 12.0%.
[a]Total yield includes harvesting and threshing losses.
[b]Net yield is total yield minus total losses caused by harvesting and threshing.

the harvesters were trying to avoid leaving any pods in the field.

There are strong indications that mechanization increases losses and that manual cutting and windrowing are more efficient. Losses are inevitable when a cutter bar is used for harvesting. Table 44 shows that yields from all trials were uniform. The data on losses and labor show an inverse proportional relationship with mechanized harvesting. Manual treatments 1 and 2 had minimum losses of 0.57 kg (2.35% of the yield) and 0.65 kg (2.46%), while mechanized treatments 3 and 4 had losses of 5.12 kg (21.09%) and 6.15 kg (25.84%). Nevertheless, harvesting with the cutter bar is significantly faster than manual picking. Harvesting and threshing with the combine was fastest, followed by the one-row cutter bar, and plant harvesting and windrowing. Manual picking was the slowest of the harvesting methods evaluated. The net returns of the four harvesting methods was calculated based on the net yield in kilograms per hectare (Table 45). The market price of 1 kg of cowpeas was $1.50, and the labor cost was $0.75 at harvest. The returns of harvesting methods 3 and 4 were sharply reduced because of excessive harvesting losses.—*N.C. Navasero*

Evaluation of Low-Horsepower Equipment

On land cleared by hand according to traditional methods (which usually leave large stumps protruding from the ground), mechanical planting under a no-till system is extremely difficult. It is almost impossible to use four-wheel tractors with conventional planters because of the high stumps, uneven surfaces and clustered roots in these fields. When a tropical forest is cleared mechanically with a tree pusher and root rake, it is left with partially filled stump holes and is unprotected from erosion. Clearing with a shear blade (Rome KG Blade) leaves large stumps cut off at ground level, which can severely damage planting equipment.

Appropriate farm machinery for these systems should be narrow, light and maneuverable so that it can operate around or over stumps and holes. Planters must have the capacity to penetrate through thick mulch left on the soil surface after bush clearing and through very hard soils. The heavy regrowth of weeds and bush is often a problem at the beginning of a planting season long after the forest was cleared.

In 1982 a series of experiments was carried out in the West Bank area at IITA to evaluate a low-horsepower, four-wheel tractor for its usefulness in no-till farming under tropical field conditions and to improve the design of the IITA farmobile, test its performance on relatively large fields and evaluate its operational and economic efficiency. A four-wheel Massey Ferguson 210 tractor of 15 kW (20 hp) was mounted with a six-row rolling injection planter and a 3-m box fertilizer applicator pulled behind the planters. For spraying the tractor was equipped with a PTO-driven, 8-m boom sprayer using a 375-l tank. Spraying had to be done in separate preplant and preemergence operations. During these operations, the tractor driver was guided by marking poles.

The IITA farmobile consists of a 4.85-kW (6.5-hp), two-wheel tractor with a trailer and a tool bar carrying a four-row rolling injection planter attached to the hitchbar of the trailer. It also carries a 4-m boom sprayer powered by a pneumatic knapsack sprayer and a centrifugal fertilizer spreader powered by the tire of the trailer.

Both types of farm equipment were used on no-till fields of first season maize and second season cowpeas. The four-wheel tractor was used on about 15 ha and the farmobile on about 10 ha. Before planting of the second season crop, some of the plots were sprayed with desiccants and then mowed. The crops were harvested manually. The data in Table 46 show that the four-wheel, 15-kW tractor had an effective field capacity (amount of land covered

Table 45. Harvesting and threshing returns of four cowpea harvesting methods, IITA, 1982

Harvesting method	Net yield, kg/ha	Market value, $1.50/kg	Total labor, man-hr/ha	Labor cost $.75/ha	Net return after labor, $/ha
Manual pod picking	1,942	2,913.00	468	347.25	2,565.75
Plant harvesting and windrowing	1,995	2,992.50	157	117.75	2,874.75
Cutting by one-row cutter bar	1,404	2,106.00	105	78.75	2,027.25
One-row combine harvester	1,242	1,863.00	43	32.25	1,830.75

during the total field time) of 0.72, 1.72 and 0.7 h/ha for desiccant spraying, planting, fertilizing and preemergence spraying, respectively. The effective field capacity for herbicide application (desiccant or preemergence) ranged from 0.46 to 1.09 h/ha and for planting/fertilizing, 1.17 to 2.53 h/ha in maize. When planting cowpeas during the second season, the tractor's effective field capacity for herbicide application was 0.5 h/ha (with a range of 0.41 to 0.67 h/ha) and for planting cowpeas 1.5 h/ha (with a range of 1.13 to 2.07 h/ha). Its field efficiency ranged from 27 to 58% for planting and fertilizing maize, 33 to 60% for planting cowpeas and 20 to 53% for herbicide application. Field efficiency is the ratio of effective field capacity to theoretical field capacity expressed in percent. Theoretical capacity is the machine's rate of performance if it performs its function 100% of the time at the rated operating speed, using 100% of its nominal width.

Table 46. Comparison of a four-wheel, 15-kW tractor with the IITA farmobile in no-till planting of maize and cowpeas, IITA, 1982

	Effective field capacity, hr/ha		Field efficiency, %	
	First season maize	Second season cowpeas	First season maize	Second season cowpeas
Four-wheel tractor				
Desiccant spraying	0.72 ± 0.16	0.53 ± 0.12	31.47 ± 6.6	42.6
Planting/ fert.	1.72 ± 0.51	1.5 ± 0.35	43.2 ± 11.7	47.0
Preemerg. spraying	0.70 ± 0.21	0.52 ± 0.12	33.44 ± 8.8	42.6
Total mach. hr/ha	3.14	2.55		
Farmobile				
Desiccant spraying[a]....	2.20		25.0	
Plant./fert. spraying	5.98 ± 1.27	3.87 ± 0.57	20.0	27.0
Total mach. hr/ha	8.18			

[a]Desiccant spraying was done with different equipment during the second season.

Table 47. Economic indicators of an IITA farmobile and four-wheel, 15-kW tractor for no-till planting of maize and cowpeas, IITA, 1982

Economic indicator	Farmobile	Four-wheel, 15-kW tractor
Avg. effective field capacity, hr/ha		
For planting/fert. and spraying	4.9	1.62
For desiccant or preemerg. spraying...	2.22	0.71
Avg. field efficiency for:		
Planting, %	22.5	45.0
Spraying, %	25.0	30.3
Scale of operation, ha per season		
First season maize	15–20	32–35
Second season maize or cowpeas	10	22
Efficiency of input use, %		
Chemicals.....	70–90	87–95
Fertilizers.....	94	75
Maize seed	86	78
Cowpea seed	83	75
Initial cost of equipment and its attachments in dollars.....	10,200	28,050
Pay back period, years.....	2	3
West Bank net benefits in dollars	7,524	7,981.28
Enterprise net benefit per hectare per annum in dollars	855	554.25

With the farmobile, it took about 2.2 h/ha to apply the preplant desiccant spray using the 4-m boom sprayer. Planting, fertilizing and preemergence spraying were all done in the same pass over the field. During planting the spray boom was reduced to 3 m to match the width of the four-row planters, which were set at 0.75-m row spacing. A marking string was used to guide the farmobile during these operations.

The effective field capacity of the farmobile for planting, fertilizing and spraying in maize was 5.98 h/ha (with a range of 5.03 to 7.78 h/ha) and for planting and spraying in cowpeas, 3.87 h/ha (3.08 to 4.41 h/ha). The field efficiency of the farmobile in planting maize was 20%, in planting cowpeas 27% and in spraying 25%.

In tests over the last three years, the improved prototype of the farmobile has been found to have a number of advantages. The more expensive, two-wheel walking tractor with steering clutches, instead of a fixed axle, has removed the belt-clutch problem and greatly improved operational efficiency. The row string marking device has proven to be faster and more accurate than sighting poles. Putting larger wheels on the trailer has reduced the rolling resistance and improved the lateral stability of the farmobile. The centrifugal fertilizer spreader powered by the tire of the trailer has enabled the operator to plant, spray and fertilize simultaneously. The potential economic benefits of using either of these two small tractors in no-till planting of maize and cowpeas depends largely upon the tractor's effective field capacity and efficiency, the initial investment and operation and maintenance costs, and its reliability and economic life. Some of these economic indicators are presented in Table 47.

Considering the quantity of inputs used per field, the four-wheel tractor was more efficient than the farmobile probably because of its greater operating speed. The potential area of operations for the farmobile was estimated by the critical path method to be 15 to 20 ha during the first season and 10 ha during the second. For the four-wheel tractor, the area was estimated to be 32 to 35 ha during the first season and 22 ha during the second. The area of operation was smaller in the second season because the first season crop was harvested manually and the rainy period of the second season was short. During manual harvesting of maize and cowpeas, experienced farmers were employed on a daily task basis. Harvesting of maize took 9 man-days/ha, and cowpea

harvesting took 22 man-days/ha. Given the size of the area of operation, the farmobile operator needs 135 to 180 man-days (or 5 to 6 workers) to harvest maize and 220 man-days for cowpeas. The four-wheel tractor operator needs 288 to 315 man-days (or 9 to 11 workers) to harvest maize and 484 man-days for cowpeas.

The activities considered in the critical path analysis were procuring inputs, preparation of the tractor, procuring water for spraying, desiccant spraying, planting, fertilizing and preemergence spraying, employing of workers for manual harvesting and the harvesting itself, and transportation of produce from the field.

The initial costs of the equipment and its attachments are $10,200 for the farmobile and $28,050 for the four-wheel tractor. The maintenance and interest on capital costs over the farmobile's expected economic life of five years were estimated to be $7,941 and for the four-wheel tractor $21,838.50. From a budget analysis (with a farm size of 10 ha for the farmobile and 15 ha for the tractor), the payback period was estimated to be two years for the farmobile and three years for the four-wheel tractor. After one year's fixed and operational costs and labor, chemical, fertilizer, seed, transportation and bagging costs, the net benefit obtained from the farmobile per hectare per annum was $857 and from the four-wheel tractor $555 (Tables 48 and 49).

In assessing the suitability of these small tractors, it is important to examine the factors that affect their field efficiency. As shown in Table 50, the four-wheel tractor spent 45% of its field time actually working, while the farmobile spent only 22% of the time working. Interruptions during planting with the four-wheel tractor took 49.5% of field time and 73% with the farmobile.

The results of these experiments indicate that low horsepower tractors are mechanically and economically suitable for no-till farming in the tropical forest zone. Their initial investment costs of $10,200 to $25,050 may be within the reach of a large number of farmers in developing countries, especially if reasonable farm credit is available. The pay back period is only two to three years. With one of these tractors, a small farmer could increase the area cropped from 1 or 2 ha to over 15 ha for the first and second seasons of each year, provided that inputs and sufficient labor are available at harvesttime. This analysis also shows the importance of having more efficient harvesting procedures or equipment to reduce the likelihood of labor shortages at the end of each season.

The farmobile can be economical for small farmers since it enables them to operate a 10 ha farm very conveniently, obtain a net benefit of about $857 per hectare per annum and recover the initial investment capital in about two years. However, the low-

Table 48. Partial budget for an IITA farmobile

Costs	Dollars
Fixed costs	
Depreciation at 20% per annum	2,040
Interest on investment at 11% of $10,200	1,122
Operational costs	
Repairs and maintenance at 15% per annum	1,020
Fuel consumption for 117 hr at 0.6 l/hr	14
Operator's labor, two persons for 117 hrs at $3.54	414
Variable costs of farm inputs	
Preplant and preemergence herbicides	3,076
Insecticides for cowpeas	939
Fertilizers for maize	2,886
Labor for supplementary weeding in cowpeas	568
Mowing before second season crop	354
Labor for manual harvesting of maize, 79.2 man-days at $6.24	494
Labor for manual harvesting of cowpeas, 193.6 man-days at $6.24	1,299
Transportation, shelling and bagging	600
Maize seed, 196 kg at $0.375	73
Cowpea seed, 157.5 kg at $1.61	242
Total expenditure	15,141
Revenues	
Revenue from maize harvest (first season), 40.1 t at $375	15,037.50
Revenue from cowpea harvest (second season), 5.037 t at $1,500	7,555.50
Total revenue	22,593.00
Net benefit	7,452.00
Net benefit per hectare	857.00

Table 49. Partial budget for a low-horsepower tractor

Costs	Dollars
Fixed costs	
Depreciation at 20% per annum	5,610
Interest on investment at 11% of $28,050	3,085
Operational costs	
Repairs and maintenance at 15% per annum	4,208
Fuel consumption for 82.81 hr at 0.9 l/hr	14
Operator's labor, two persons for 82.81 hr at $3.54	293
Variable costs of farm inputs	
Preplant and preemergence herbicides	4,533
Insecticides for cowpeas	1,406
Fertilizers for maize	4,966
Labor for supplementary weeding in cowpeas	635
Mowing before second season crop	636
Labor for manual harvesting of maize, 129.6 man-days at $6.24	809
Labor for manual harvesting of cowpeas, 314.62 man-days at $624	1,963
Transportation, shelling and bagging	1,002
Maize seed, 417 kg at $0.375	156
Cowpea seed, 280 kg at $1.61	449
Total expenditure	29,765
Revenues	
Revenue from maize harvest (first season), 66.8 t at $375	25,050
Revenue from cowpea harvest (second season), 8.47 t at $1,500	12,705
Total revenue	37,755
Net benefit	7,990
Net benefit per hectare	555

Table 50. Activities affecting field efficiency of a four-wheel, 15-kW tractor and IITA Farmobile, IITA, 1982

Activity	Average time spent as a percentage of field time: Four-wheel 15-kW tractor	Farmobile
Turning		
Spraying	9.0	
With planters	15.0	10.0
Materials handling		
Seed	7.2	5.0
Fertilizers	8.6	6.0
Chemicals and water	16.0	13.0
Machine adjustments	6.0	10.0
Cleaning up clogged spray nozzles	6.3	9.06
String marker adjustment	8.9	4.75
Removing trash and cleaning clogged planters	3.8	1.2
Traveling around obstacles, ditches, etc.	—	2.0
Other field interruptions	—	12.0
Total no. of interruptions		
During spraying	46.2	—
During planting	49.5	73.0

horsepower tractor needs further improvement and must be tested on farmers' fields. The various mechanical components of each tractor, especially the farmobile, also require further development. At present handling of chemicals and the spray nozzle system unnecessarily reduce field efficiency.—*C. Garman, D.S. Ngambeki and N.C. Navasero*

Production Economics

Alley Cropping Leucaena/Maize/Cowpeas

Agronoeconomic studies on alley cropping of *Leucaena leucocephala* with maize followed by cowpeas were continued at IITA in 1982. The objectives of these studies were (1) to monitor labor and other inputs and determine the economics of the system, (2) to assess the effects of alley cropping with leucaena on maize and cowpea yields, and (3) to check the 1981 findings that there is a negative interaction between leucaena and nitrogen and that leucaena can increase farm profits by as much as 30%, even though leucaena stands occupy 20% of the land and the pruning increases labor costs by about 50%. This is double the profits from nitrogen and about 20% more than those from either leucaena-nitrogen or leucaena-herbicide.

First season maize and second season cowpeas were grown in a trial with four replications on a plot that had produced two successive crops of maize in 1981. Leucaena and herbicides were the main plot treatments, and in the first season maize, a subplot treatment of nitrogen at 80 kg/ha was superimposed on these. No nitrogen was applied to the cowpeas during the second season. During each of these seasons at planting, weeding and flowering, leucaena tops were pruned, weighed and returned as mulch to the crop.

The herbicide plots were sprayed with paraquat and atrazine for maize and paraquat and dual for cowpeas. The cowpea crop received four insecticide applications to control thrips, aphids, *Maruca* and pod bugs. The control plots were weeded each season with a hoe two weeks after planting. All plots were planted to maize or cowpeas without tillage and were top-dressed with P and K fertilizers during the first season only. To obtain realistic labor input data, casual workers with some farming experience were hired on a daily task work basis. This resulted in more efficient labor inputs than in the previous year.

During the first season, the cutting of leucaena regrowth and pruning of shoots took 16.46, 14.6 and 7.5 man-days/ha or a total of 38.56 man-days/ha. In the second season, these activities required 16.2, 7.5 and 6.9 or a total of 30.6 man-days/ha. It thus took an average of 16.3 man-days/ha for cutting and 9.1 man-days/ha per pruning, compared to 30 to 24 man-days/ha in the previous year for cutting and one pruning of leucaena stems after the plots had been under fallow for one year.

The leucaena treatments this year increased labor costs by only 32%, and leucaena-nitrogen increased them by 34%, about 20% less than the increase of the previous year (Table 51). But the herbicide component in the leucaena plots reduced labor inputs by 19.97%, so that leucaena-herbicide actually increased labor costs by only 12% and leucaena-nitrogen-herbicide by only 14%. As in the previous year, nitrogen increased labor costs by less than 10%, while herbicide-nitrogen and herbicide alone reduced labor costs by over 20%. The total nitrogen contribution from three prunings of leucaena was about 145 kg N per hectare per season. However, the purchase of chemicals such as nitrogen and herbicides at unsubsidized prices caused the leucaena-herbicide treatment to increase total production costs by 40.4% ha, leucaena-nitrogen-herbicide by 48.84% and leucaena-nitrogen by 44.87%, compared to leucaena alone, which increased total production costs by only 36.4%.

As shown in Table 51, leucaena increased maize yields by 45% (982 kg/ha), leucaena-nitrogen by 48% (1,047 kg/ha), leucaena-herbicide by 69% (1,501 kg/ha), and leucaena-nitrogen-herbicide by 118% (2,549 kg/ha), compared to the yield (2,159 kg/ha) of the control plots. The nitrogen treatment increased yield by 33% (713 kg/ha) and herbicide-nitrogen by 40% (862 kg/ha).

In cowpeas herbicide alone and leucaena-herbicide gave yields of 745 and 730 kg/ha, respectively, an increase of 19.58 and 17.17%, compared to the yield (623 kg/ha) of the control plots. But the leucaena treatment by itself appeared to depress cowpea yields drastically. The main effects of leucaena on maize yield were significant at the 1% level and greater than those of nitrogen and herbicide. The main effect

Table 51. Data on yields and labor costs in an alley cropping experiment, IITA, 1982

Treatment	First season maize: Grain yield, kg/ha	First season maize: Percent yield increase per hectare	Second season cowpeas: Grain yield, kg/ha	Second season cowpeas: Percent yield increase per hectare	Percent increase in labor costs per hectare, first and second season
Control	2,159	—	623		
Nitrogen	2,872	33			2.0
Herbicide	1,929	−10	745	19.58	−31.7
Herbicide-nitrogen	3,021	40			−29.7
Leucaena	3,141	45	576	−7.54	32.0
Leucaena-nitrogen	3,206	48			34.0
Leucaena-herbicide	3,660	69	730	17.17	12.0
Leucaena-nitrogen-herbicide	4,708	118			14.0

Table 52. The economic contributions of various treatments in an alley cropping experiment, IITA, 1982

Treatment	Net return per hectare from first and second season cowpeas	Marginal rate of return per hectare: From maize and cowpeas: Unsubsidized	Marginal rate of return per hectare: From maize and cowpeas: Subsidized	Marginal rate of return per hectare: From maize alone	Benefit:cost ratio for first and second season: Unsubsidized	Benefit:cost ratio for first and second season: Subsidized
Control	$ 491	—	—	—	1.39	1.50
Nitrogen	670	1.69	8.60	2.90	1.49	1.72
Herbicide	650	2.60	2.23	1.25	1.51	1.65
Herbicide-nitrogen	992	3.90	10.00	3.10	1.76	2.04
Leucaena	396	−0.21	−0.21	1.58	1.23	1.31
Leucaena-nitrogen	302	0.34	−0.23	1.16	1.17	1.29
Leucaena-herbicide	765	0.63	0.43	2.81	1.44	1.49
Leucaena-nitrogen-herbicide	1,108	1.01	1.30	2.80	1.59	1.76

of the nitrogen treatment on maize ear leaf nitrogen was greater than that of leucaena, indicating that the fertilizer nitrogen is more efficient. The herbicide treatment had a negative main effect on maize ear leaf nitrogen. Interaction of leucaena and nitrogen on maize ear leaf nitrogen and maize yield were both negative. In cowpeas herbicide was the only treatment that had significant main effects on yield. The main effects of leucaena were insignificant. These results suggest that a leucaena alley cropping system has no beneficial effect on cowpeas probably because of the shading effects of the leucaena shoots.

Three economic indicators—net return per hectare from maize and cowpeas, marginal rate of return per hectare and benefit:cost ratio—were calculated at unsubsidized prices (except for those in columns 4 and 7) to determine the economic value of each treatment (Table 52). In absolute terms the combination of leucaena-herbicide-nitrogen gave the highest net return ($1,108/ha), followed by herbicide-nitrogen ($992/ha). However, herbicide-nitrogen and herbicide gave the highest marginal rates of return (3.9 and 2.6, respectively) per additional unit cost over costs of the control plot. Herbicide-nitrogen also gave the highest benefit:cost ratio (1.76), followed by leucaena-nitrogen-herbicide (1.59) and herbicide (1.51). The leucaena treatment gave a negative marginal rate of return of 0.21 units for both crops, but for maize alone it yielded a relatively high rate of 1.58 per unit additional cost.

When costs of fertilizers are calculated at subsidized prices (Table 52, columns 4 and 7), the combination of herbicide-nitrogen gives the highest marginal rate of return (10) and benefit-cost ratio (2.04), followed by nitrogen, for which the marginal rate of return per additional unit cost was 8.6. Generally, the three economic indicators show that with maize/cowpeas, herbicide-nitrogen gives the best economic return, followed by leucaena-nitrogen-herbicide, nitrogen and leucaena-herbicide in that order. In all cases leucaena gives better economic returns than leucaena-nitrogen.

From the results of this experiment, four conclusions can be drawn. First, the highly significant increases in maize yields brought about by leucaena and the small negative interactions between leucaena and nitrogen suggest that the maize/leucaena alley cropping system is biologically balanced and that leucaena can sustain high maize yields without nitrogeneous fertilizers. The use of nitrogeneous fertilizers with leucaena (even at subsidized prices) is an economic waste, a finding which corroborates the 1981 findings as well as other research results at IITA.

Second, the highest level of technological input, leucaena-nitrogen-herbicide, gives the highest net return (1,108/ha), a high benefit:cost ratio (1.59) and a favorable marginal rate of return (1.01) per unit additional cost per hectare. But herbicide-nitrogen gives the best economic return, especially if there is a very high (75%) subsidy on fertilizers. Third, the highly significant main effects of leucaena and the negative interactions between leucaena and nitrogen on maize yields are similar to those observed in 1981. But this year leucaena depressed cowpea yields, in contrast to its effect on maize yield.

Finally, although leucaena increased labor costs, it greatly increased maize yields and gave relatively high marginal rates of return and benefit:cost ratios for maize, as it did in 1981. But for both maize and cowpeas, leucaena gave lower marginal rates of return and benefit:cost ratios than those of the previous year for maize/maize, suggesting that leucaena alley cropping has no beneficial effects on cowpeas. This finding needs to be investigated further.—*D.S. Ngambeki*

Minimum Pest Management in Cowpeas

Cowpeas make an important contribution to West African farming systems. They fix atmospheric nitrogen in the soil, supply protein in the rural diet and, because they are readily sold in local markets, provide an assured source of farm income. The crop also provides employment for African women, who prepare and sell snack foods from cowpeas.

Frequent crop losses from a broad spectrum of insect pests has been threatening the position of cowpeas in local farming systems. In many parts of Nigeria, these losses have led to a severe reduction in planting of cowpeas, either as a monocrop or intercrop. Research at IITA has included work on the development of a minimum pest management regime that will enable small farmers to protect their cowpeas without having to use much expensive insecticide.

To test the performance of new cultivars in one of the most severely affected areas in Nigeria, on-farm research trials were conducted in Niger and Kwara States. The performance of these improved cultivars was checked without insecticide and at three to four spray levels. In the Bida Agricultural Development Project area of Niger State, Decis insecticide was applied 34, 42 and 56 days after planting in the treated plots. In the Ilorin Agricultural Development Project area of Kwara State, a mixture of Cymbush and Roger insecticides was applied four times in one-half of the plot, while the remaining half received only one Cymbush application. All other conditions were typical for that area.

Table 53 gives the yields, net benefits and benefit/cost ratios of insect management for different monocropped cowpea varieties. The data show that three to four applications control pests sufficiently and that the resulting yield increases more than cover the pest management costs. Farmers can only reap this net economic gain, however, by adopting improved cowpea varieties. The combination of a new variety and minimum pest management may be the most realistic means of reviving commercial cowpea production in Nigeria. For subsistence farmers, however, the cost, some $120 to $200/ha, may well be too high since they do not have much cash and run a high risk of crop failure caused by poor weather.

Maize Production on Small Farms

A farm survey conducted in the high and medium rainfall forest zones of Nigeria has shown that almost all subsistence farmers grow some maize and that the majority of them plant two or more maize plots of varying sizes every year. Most of the maize was planted in mixtures with yams, cassava, cowpeas, etc. Only 25% of the farmers reported planting part of their maize as a monocrop. This was relatively more frequent in the medium than in the high rainfall region. About 40% of the 168 farmers interviewed in eight different states of Nigeria grew only early season maize. The remaining 60% grew both early and late season maize. Farmers planted maize both for home consumption and for marketing, the latter being a prime motive in the medium rainfall region and less so in the high rainfall region.

Most of the white maize entering local markets was for human consumption. More than 75% of the farmers reported growing only white maize, while 5% grew only yellow maize. The remaining farmers grew maize of both colors. Yellow maize was planted mostly in areas where cheap supplies of imported maize were not available for the local poultry industry and where the price of yellow maize equalled that of white maize. Normally, a 25% premium is paid for white maize over yellow.

In the southern states of Nigeria, maize is one of the major constituents of the rural diet. Harvesting of green maize cobs (not fully mature) during the months of May to July was a common practice among

Table 53. Net benefit of minimum pest management in cowpeas, 1982

Variety	Yield, kg/ha: No spray[a]	Yield, kg/ha: Three sprays	Yield, kg/ha: Yield increase	Value of yield increase, $/ha[b]	Increased spraying cost, $/ha	Net benefit, $/ha	Benefit: cost ratio
Niger State							
Local	0	113	113	127.50	120.00	7.50	1.1
TVx 3236	13	1,223	1,210	1,362.00	120.00	1,242.00	11.4
TVx 3516	40	920	880	990.00	120.00	870.00	8.3
TVx 4262	26	522	496	558.00	120.00	438.00	4.7
Kwara State							
Semi-improved	80	570	490	552.00	127.50	424.50	4.3
Ife Brown	77	740	663	745.50	127.50	618.00	5.8
TVx 3236	118	918	800	900.00	127.50	772.50	7.1

[a]The treatments in Kwara State were one spray and four sprays.
[b]Increased yield was valued at a net market price of $1.125/kg after deducting the harvesting and marketing cost of $0.375/kg.

all farmers. The importance of fresh maize is that it helps overcome food shortages early in the season and serves as a source of cash income through the market. Maize is consumed in different food preparations, the most common among them being boiled or roasted snacks, custard or porridge for breakfast. Maize flour is made into a variety of dishes for lunch and dinner. Rural families reported that in a year they consumed an average of more than 200 meal servings made from maize.

Storage of maize is a major problem in the humid zone. Because of high grain losses in storage, maize is consumed over only a few months as farmers attempt to dispose of their crop soon after harvesting. Most farmers store maize on cobs inside the kitchen by either placing them on racks or hanging them in baskets tied to the ceiling to keep them dry and free from weevil attack. Since only a limited quantity of maize can be stored locally, a further increase in maize production in the forest zone of Nigeria would be difficult to achieve without more reliable, cheap seed sources.

Cowpea Production on Small Farms

About 25% of the 168 farmers surveyed in the medium and high rainfall forest zones of southern Nigeria were growing cowpeas in mixtures with maize, yams, cassava and/or vegetables. The remaining 75% had given up growing cowpeas because of the high risk of crop failure resulting from insect pests. Those still growing cowpeas had, on the average, one plot in cowpeas of a local indeterminate variety, which was manually harvested by women and children three to six times a season.

Consumer preference for cowpea varieties varied according to location and was guided by traditional tribal preferences. In the 40 villages surveyed, two general cowpea types, off-white and light brown, were grown and eaten.

Among those who grew cowpeas, nearly 20% used the leaves and green pods as fresh food. From the dry beans, a variety of food dishes and snack foods were prepared, both for family consumption and for selling to neighboring families. A large majority of farm families consume cowpeas year-round, with an average of two cowpea meals per week. Many farmers, whether producers or not, purchase dry cowpeas for family consumption. Farmers report no difficulties in marketing their cowpeas.

Storage losses from weevil attack, however, pose serious problems, particularly in the high rainfall regions. Farmers store cowpeas both as unthreshed pods and as threshed beans in their kitchens, where smoke reduces weevil attacks. Still, farmers reported storage losses of up to 12 to 15% within a four- to five-month storage period.—*M. Ashraf*

Cooperatives and Group Farms

West African farming is based mainly on manual labor in small-holder systems in which rotational fallows and shifting cultivation still dominate. Land clearing and land preparation in these systems are usually the most labor demanding activities, for which several forms of communal labor organization and group action have been developed in traditional agricultural production systems. In group farming the production process on a common farm is under group organization and management. With the promotion of cooperatives, group farming has also attracted increasing attention as a means of overcoming the limitations of small-holder production. Statistics appear to indicate that the number of farmer organizations with group farms is increasing, but information on performance at the village level is still scarce.

A survey was made of 87 group farms and cooperatives in 10 states in Nigeria through 87 group interviews and 294 individual interviews of members of 10 farmers' groups. These farms, under cooperative or group management, were located in three agroecological zones of Nigeria. The survey was based on a general questionnaire on group performance and on individual interviews along preestablished guidelines. The study was done with the cooperation of officers of the Nigerian Federal Department of Agricultural Cooperatives and selected students of the Federal Cooperative College at Ibadan. The survey included farmers' groups in the following states: Anambra, Bendel, Borno, Cross River, Gongola, Imo, Kaduna, Kwara, Lagos, Ogun, Ondo, Oyo and Sokoto.

General Group Characteristics

The average size of the cooperatives and farmers' groups was 65 members with large variation. Only about 14% of the members were women, even though 85% of the associations reported female members. Surprisingly, 70% of the membership was under 45 years of age, which is contrary to the usual age structure in the rural areas of Nigeria. This would seem to indicate that cooperative and group farming are of special interest to younger farmers. Farmers' associations must reach a certain size to assure their long-term survival. About one-third of the groups reported a stable or slightly declining membership, whereas the rest reported a steady increase in size.

Availability of Land and Labor

Very few groups had problems gaining access to land. The average farm size was 109 ha, of which 69 ha was cultivated and the rest kept in fallow reserve. Cultivated land averaged 0.86 ha per member, not far from the average small holder's cultivated acreage in many parts of Nigeria.

Less than half (41%) of the organized farmers had access to tractor services. One group owned a tractor, 3 hired one from private sources, and 33 used the tractor services of public institutions.

Table 54 shows the major energy sources of the farms. The tractor appears to be the only one that

correlates clearly with farm size. The manual labor input from group or hired sources is very similar for all three size categories. This appears to indicate that organizational factors and qualitative criteria for group functioning should be considered. Fifty-three percent of the organization hired manual labor. Nearly all included bush clearing and land preparation in their regular schedules. One-quarter of the tractor users did their land clearing manually by hired labor. The 294 individual interviews showed that only half of the members worked regularly on their group's farm; the others either sent a hired laborer as a replacement or gave monetary compensation. Table 55 gives a breakdown of the motivations for joining as related to the members' labor inputs. The members were asked to give two reasons for having joined the association. Although their own initiative is generally listed as the most important reason, it is clear that other underlying factors have resulted in their joining. Of these family influence, cooperative officers and radio are the most important factors.

Table 54. Size distribution and labor sources of group farms in Nigeria, 1982

Labor sources	Amount of cultivated land per member: 0.5 ha or less	0.6 to 1.0 ha	More than 1 ha	Total sample
			percent	
Tractor and group members	19	19	39	25
Tractor, group and hired labor	16	19	22	19
Tractor and mainly hired labor	—	5	5	2
Manual work done by group only	24	19	22	22
Manual work done by group and hired labor	30	29	5	22
Manual work done mainly by hired labor	11	9	9	10
	100	100	100	100
All tractor users	35	43	65	46
Groups doing manual labor only	65	57	35	54
	n = 37	n = 21	n = 23	n = 81

Table 55. Members' reasons for joining group farms in Nigeria, 1982

Reason for joining group farm	Members working regularly: First reason	Members working regularly: Second reason	Members not working regularly or at all: First reason	Members not working regularly or at all: Second reason
		percent		
Own initiative	65	—	85	—
Family decision	5	7	8	34
Influence of chief	12	6	2	1
Religious group	—	2	—	—
Extension service	10	5	1	5
Cooperative officer	2	33	3	12
Radio	1	15	—	2
Other group	—	2	—	13
Other or no answer	5	30	1	33
	100	100	100	100

Cropping Systems

Eighty-five percent of the farmers grew two or more crops in any one season. Most frequently (46%) they grew two crops. Cassava and maize were the most common combination, being grown on about half of the farms, together with yams, rice, and various vegetables, whenever more than two crops were grown. Table 56 gives the frequencies with which group farms and individual members produce a wide range of crops for marketing and for subsistence.

Marketing and Income

Most of the production from the farms was sold, and only a small part was distributed to members. The average sales per group farm during 1981–82 were reported to be $11,842.50, or $174.50 per member. Surprisingly, this amount of sales income from group activities stands in stark contrast with the average sales by members from their own private production units. The 294 individual interviews indicated an average sale of about $1,800 from their own private lands in 1981–82 (excluding one group farm in Sokoto, where members sold an average of $42,000 from their own land). The individual sales included a much broader range of crops, and regional differences were rather marked. Figure 35 shows the distribution of sales income by crops for the three major regions of Nigeria, derived from the individual interviews, and for 69 group farms.

The reasons for the disparity between individual and cooperative farm sales are unclear. It is obvious that farmers join groups only as a sort of sideline to their own private agricultural activities and not as an attempt to improve their income by increasing their efficiency through associated forms of production.—*P. Ay, P. Manson and G. Cesarini*

Technology Transfer and Training

The Methodology of On-Farm Adaptive Research

On-Farm Adaptive Research (OFAR) is a relatively new way of approaching the adoption of new technology by small farmers in the tropics. The approach emphasizes the necessity of understanding more thoroughly farmers' needs, conditions, and problems as a precondition for successful development and introduction of innovations into smallholder agriculture. It also stresses the need for a high degree of farmer involvement in the on-farm research and the importance of farmers' views of proposed

Table 56. Percentage of group farms and of members who also have their own farms growing certain crops in Nigeria, 1982

Crop	Group farms	Individual farmers
Cereals		
Maize	72	80
Rice	27	27
Guinea corn	14	41
Millet	6	41
Tubers		
Cassava	59	77
Yams	35	44
Cocoyams	4	44
Sweet potatoes	1	35
Trees		
Oil palms	6	30
Plantains	6	29
Cocoa	1	16
Oranges	4[a]	54
Bananas		47
Mangos		45
Guava		34
Pawpaw		28
Cashews		16
Cola nuts		16
Shear butter		6
Bitter cola		5
African mangos		5
Coffee		4
Breadfruit		4
Others		2
Vegetables		
Melons	6	32
Okra	5	78
Leaf vegetables	5	36
Peppers	3[a]	26
Tomatoes	1[a]	45
Pumpkins		18
Onions		10
Legumes		
Cowpeas	2	18
Beans	1	
Soybeans	1	
Pigeon peas		9
Lima beans		4
Special crops		
Pineapples		14
Leaves for food wrapping		10
Leaves for cola packing		3
Tobacco		4
Others		2

Note: These data were gathered in 87 group and 294 individual interviews.
[a]Planned for 1983.

innovations. In order for this approach to be implemented effectively, the development of specific OFAR procedures is indispensable.

As reported last year, the Farming Systems Program has set out to develop effective OFAR methodologies for West Africa through a new pilot project in areas of Nigeria in cooperation with the agricultural development projects (ADPs) financed by the World Bank. IITA also received a grant from

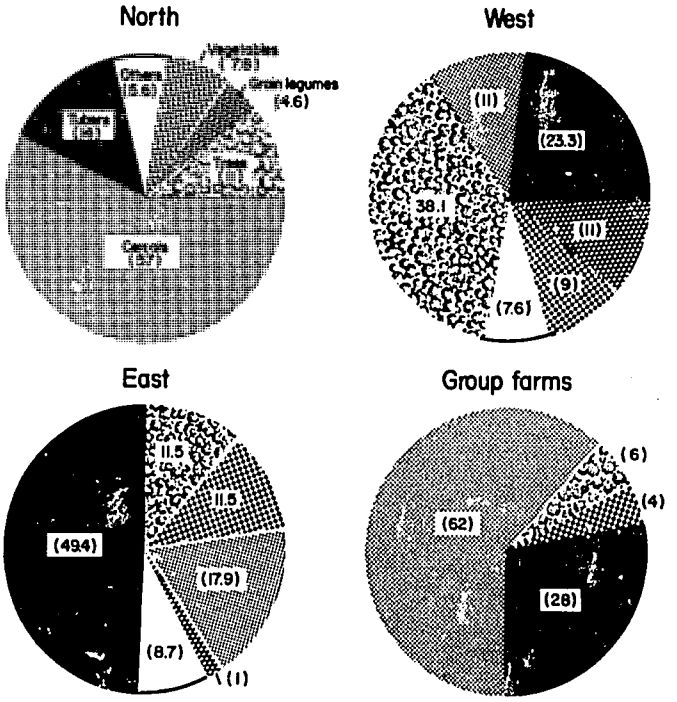


Figure 35. Proportion of crops contributing to the total product sales by individual farmers in three regions of Nigeria and by Nigerian group farms, 1981–82.

the Ford Foundation to broaden its research capability by creating a new project within its Farming Systems Program. The objectives of this project are to further develop on-farm adaptive research methodologies that are suitable to West African conditions, to assist national research institutions in West African countries in developing OFAR capabilities and applying the results of this research in their countries, and to set up courses in various West African countries and at IITA, for the staff of West African research institutions.

Because of the present lack of broad experience in OFAR in West Africa and at IITA, methodology development and training will initially go hand in hand. Scientists with an interest in on-farm adaptive research have been identified in national research institutes in Nigeria, Ivory Coast and Cameroon and will be participating in planning meetings and a training workshop at IITA, where a format for a West African methodology will be developed in detail.

In June IITA organized a workshop on on-farm experimentation that was attended by a large number of scientists with wide experience in OFAR. They reached a consensus on the basic elements needed in OFAR programs and produced the framework for IITA's own approach to on-farm adaptive research.

A second workshop was held at IITA in November 1982 with participants from national and international research and development institutions. It resulted in the creation of a West African farming systems research network. The objectives of this network are to "create links between individuals and institutions, interested in a common approach in

farming systems research, to establish a steady flow of information on methods and approaches, and to coordinate and facilitate training efforts." A steering committee and several working groups were set up to carry out specific short-term and long-term tasks, such as to survey on-going farming systems research and training facilities in the region, to make an inventory of terminology, definitions and taxonomy of farming systems research, to establish a documentation center and publish newsletters, to study the "zonification" of farming systems in West Africa, and to organize a technical workshop in 1983.—*H.J.W. Mutsaers*

An Approach to On-Farm Adaptive Research

The agricultural economics unit of the Farming Systems Program started an interdisciplinary on-farm research program this year for testing IITA technology. The work is being carried out in Nigeria with the Bida Agricultural Development Project, located in the Guinea savanna zone, and with the Ilorin ADP in the derived savanna zone.

The first step in the program was to review information on land types, topographical features, vegetation patterns and land use. In a socioeconomic and agronomic survey of project farmers, information was collected on the various agroecological regions of Nigeria and on the farmers' main production problems.

The Bida region has two agroecological regions, upland farmland dominated by dryland cereals and root crops and the lowland fadamas (small inland valleys), which are dominated by rice. Although the upland and lowland fields are quite far apart, the same farmers till the soil and raise crops in both. The upland crops are grown in various mixtures, while rice is always monocropped.

The survey also found that the lowland rice area is further divided into two topographic sequences that have different production problems. The slopes above the valley bottoms need short season drought tolerant rice varieties, while the wetter, flat parts of the fadama require midseason varieties with resistance to iron toxicity. The upland areas can be similarly divided according to cropping systems of maize, sorghum and yam and of sorghum/millets, cassava, and groundnuts.

In this first year our strategy was to produce the maximum amount of research information as quickly as possible for checking the suitability of available technology, which can then be used in developing recommendations for farmers. An assessment of the best production possibilities showed that the rice crop and the fadama areas should be the major research targets.

The agronomic survey showed also that a high demand for labor in the planting season was the principal cause for under-utilization of fadama land, despite the high potential productivity of these areas. With the start of the rains in May and June, farmers first plant their upland crops to ensure that they will mature before the rains stop in October.

Planting on fadama land is usually delayed and incomplete and requires a large labor input for ridging the land by hand. Easing this labor constraint in the months of July and August would increase the area of rice cultivated, increase the yield through more timely planting, and lessen the risk of failure. The means of doing so could be to change the land preparation method from ridged seedbeds to flat cultivation, which besides saving labor, would also be more appropriate for the newly expanded tractor hire services and for the proposed chemical weed control.

The change from ridged to flat cultivation would also tie in with the work of the ADP on contour bunds and permanent water control channels. This change would also make it possible to raise short season catch crops on residual moisture, provided that the rice is planted early enough. This analysis illustrates the use of a systems approach to matching production problems with potential improvements in the overall efficiency of a farming system. The next step is to choose experimental variables and treatment levels.

Other factors limiting rice yields in the Bida ADP area were low stand density and iron toxicity, both of which affect germination and seedling growth. The stand density was closely related to the ridged seedbeds; wider spacing between ridges results in a low stand. Stands could be increased either by reducing the spaces between ridges or by planting on the flat. Thus, in addition to seedbed preparation, stand density was included as a test variable.

Iron toxicity was a more difficult problem to deal with. One possible approach is to use varieties with tolerance to iron toxicity. Other problems, such as irregular water supplies and bird damage, were also encountered in the survey, but these are mostly outside the control of individual farmers.

A factorial design was chosen for agronomic rice trials, which included two treatment levels, one being the level used by farmers and the other being the level recommended by scientists. Only with the variety factor were three cultivars included. The three experimental variables, method of seedbed preparation, stand density and variety, were combined in four experimental designs requiring different levels of management.

The first design consisted of fully replicated factorial experiments. They were in central locations representing five agroecological niches within the project area and were under the direct management of the project research staff. The second design included two varieties rather than four. These experiments were planted on a farmer's field with his participation, especially in managing nontreatment factors. In the third set of tests, the stand density variable was eliminated, leaving variety (at three levels) and seedbed preparation (at two levels). These

tests were handled by farmers under the supervision of the project extension staff. The fourth design was the simplest of all, consisting of a single treatment plot composed of all three factors at the recommended level. These plots were managed exclusively by the farmer, and his adjoining crop field provided the basis for comparison.

Limited on-farm research was also carried out on cowpeas, maize and cassava, mainly to generate more information for a future research program in the upland areas. The objectives of the cowpea agroeconomic research were to evaluate minimum pest control and to explore the possibility of growing cowpeas on residual moisture after harvesting the rice crop at the beginning of the dry season. The maize and cassava trials assessed new cultivars for their ability to withstand attack by the most common insect pests and diseases. Unfortunately, the data from these on-farm trials are not yet available but will be reported next year. Some preliminary conclusions can be drawn, however, from the 1982 OFAR program on the selection of experimental sites, on farmers' participation, and on linkages between projects.

Unless they stand to gain something, farmers are reluctant to offer their fields for trials that require significant changes in crop management. Their reluctance probably stems from the high cost of land and seedbed preparation and from the risk involved in making changes. This problem often can be solved by choosing sites on community land, which have the major advantage of involving the entire village community in the implementation and demonstration of trials.

Farmer participation proved to be essential to the establishment and maintenance of research plots and to a correct assessment of farmers' reactions to changes in crop management. Farmers usually preferred to participate as a group so they could share the burden of inputs and labor. Unless farmers were paid, they tended to neglect the research plots. When trial plots offered tangible benefits (for example, when the researcher arranged and bore the costs of land preparation, fertilizers and pesticides), the farmers participated more readily. When assessing the results, the farmers proved to be very sharp observers of the research plots. In the rice experiments, the farmers were particularly aware of the tillering, crop growth, panicle size, grain color and grain size of the new varieties.

On-farm adaptive research evaluates technology that can be adapted to local biophysical, social and marketing conditions of farmers. To be relevant such research must set its priorities through a close association with commercial and extension people and farmers. It must take into consideration the inputs and services that can be provided as well as the farmers' real needs. An extension service can achieve its goal of transferring new technology only when it is fully informed and farm inputs and services can be provided.

In the Bida ADP, the on-farm adaptive research program quickly began to contribute to the development of close contact and cooperation between the project's commercial, extension and research divisions. The contact point was the farmer, whose progress is the best measure of success for all these divisions.—*M. Ashraf*

Cooperative Development

MIDAS Project in Ghana

The Managed Inputs and Delivery of Agricultural Services (MIDAS) Project, which ended this year and was sponsored by the U.S. Agency for International Development and the Government of Ghana, was designed to improve food crop production and increase the income of small farmers in the Brong-Ahafo region of Ghana. Small-farms systems research, one of six components of the MIDAS Project, was carried out by IITA. The primary aim of this research was to assist the government of Ghana in developing farming systems research capabilities in the Brong-Ahafo Region.

Owing to problems in building an access road and other facilities at the original research site, a new location adjacent to the Atebubu Training College was chosen in early 1982. Several field trials were laid out at this new site, and some trials started in 1981 were continued at the old site. Some on-farm trials were also conducted on farmers' fields during 1982.

Alley Cropping with Leucaena

Seeds of *Leucaena leucocephala* variety K-28 were drilled in continuous rows 4 m apart in April 1981 and were thinned to one plant every 40 to 50 cm in the row. A starter dose of 100 kg/ha of 15:15:15 fertilizer and 10 kg/ha of zinc sulphate was applied by banding. In 1981 yams, maize and cowpeas were planted in the alley space, and the leucaena was allowed to grow without pruning. After one year the height of the leucaena was 261.4 ± 32.9 cm; its circumference at a height of 1 m was 6.4 ± 1.7 cm; and its approximate dry leaf yield was 500 to 1,000 kg/ha per cutting. The labor requirement for pruning was 50 to 60 man-hour/ha per cutting.

This trial compared the performance of yam and maize/cowpeas with and without leucaena hedgerows 4 m apart. The main plots (20 m × 12 m) were divided into three subplots each with a different fertilizer level. The experiment had a split-plot design with four replications. The crops were to be rotated between plots in alternate years; that is, the plots that had yams in 1982 were to be planted with maize/cowpeas and vice versa in 1983. Maize (La Posta) was planted during the first season (April–August 1982), followed by cowpeas (VITA-5) in the second season (September–November) in the maize/cowpea plots; water yams (*Dioscorea alata*) were grown during both seasons.

The arrangement of the crops in four repre-

sentative main plots of one replication is shown in Figure 36. There were four rows of maize or cowpeas in leucaena plots and five in plots without leucaena. The spacing in cm was 80 × 25, 80 × 15 and 200 × 200 for maize, cowpeas and yams, respectively.

The fresh tuber yields of water yams (Akaba) in this trial were quite low because of poor rainfall. The overall effect of leucaena alley cropping was to reduce yield by an average of 43%. This reduction was due mainly to the shading effects of the leucaena stakes used to support the yam vines. This observation has also been made in experiments at IITA. The leucaena stakes must be ringed to prevent new leaf growth, which competes with the yam vines for sunlight. Fertilizer response of yams was also poor to irregular. The low rainfall was undoubtedly responsible for this failure; at harvest some of the fertilizer had not yet dissolved.

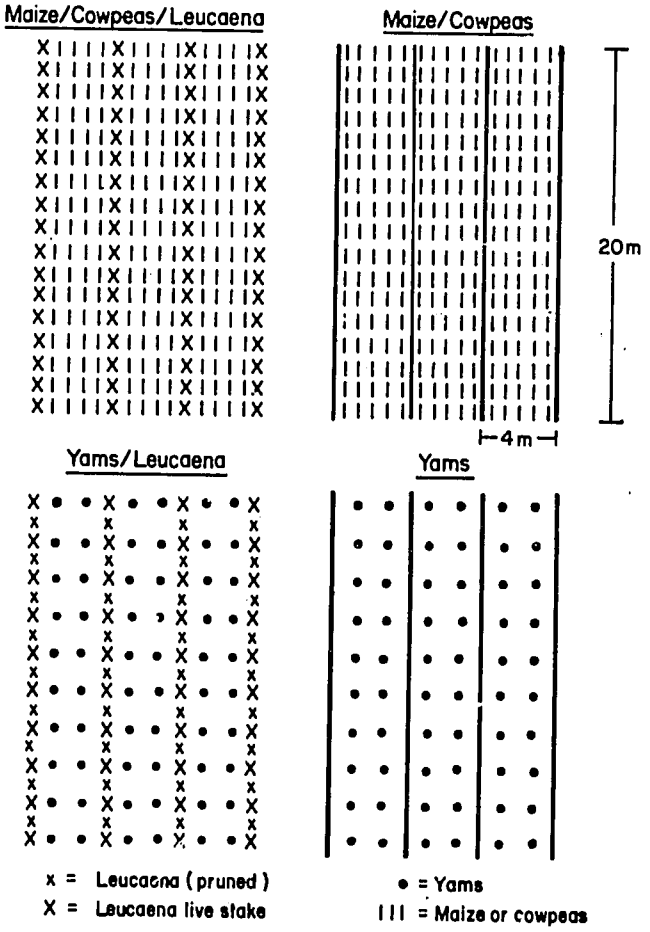


Figure 36. Arrangement of food crops and leucaena in an alley cropping trial, Atebubu, Ghana, 1982.

Table 57. Maize yield in an alley cropping trial with leucaena, Atebubu, Ghana, 1982

Fertilizer rate, kg/ha			Yield, kg/ha		
N	P_2O_5	K_2O	Without leucaena	With leucaena[a]	Mean
0	0	0	1,886	738	1,313
60	30	30	4,224	2,591	3,407
120	60	30	5,616	3,064	4,340
LSD (5%)			407		288
S.E.			—		887
Leucaena mean			3,908	2,131	—
S.E.			398		

[a]Maize yield in leucaena plots was calculated for the total area (80% maize and 20% leucaena) not for an equivalent area occupied by maize only.

Maize yields in the leucaena plots were only about half those in plots without leucaena (Table 57). This may have resulted from competition for moisture between the leucaena and maize during the many dry spells in 1982. Maize response to applied fertilizer was highly significant. The interaction between fertility levels and leucaena treatment was not significant.

Fertilizer Trials

Response of yams to fertilizer. Farmers usually cultivate yams on newly cleared land that has sufficient fertility for a good crop. However, fertilizer application may be needed on land that is cropped for an extended period with a rotation of yams and other crops. This practice reduces the need for clearing new bush every year.

In fertilizer trials conducted this year, the fertilizer responses of two varieties (Puna and Dendenpruka) of white yams (*D. rotundata*) and one variety (Akaba) of water yams (*D. alata*) were highly variable and in many cases negative. The erratic rainfall of 1982 was probably the cause of these poor results (Table 58). Differences between varieties were insignificant. Another experiment on nitrogen sources and yam varieties also produced poor results. Nor did fertilizer application increase tuber yield significantly on farmers' fields (Tables 59).

Response of maize to K, Mg and Zn. The soils in the Atebubu area are low in fertility, lacking, in addition to N and P, some secondary and trace elements. Deficiency of these elements commonly occurs in maize. Trials for testing the response of maize to K, Mg and Zn application included four levels each of K_2O (0, 30, 60 and 90 kg/ha) and Mg (0, 10, 20 and 30 kg/ha) and three levels of Zn (0, 5 and 10 kg/ha). A basal application of 60 kg each of N and P_2O_5/ha was made on all plots prior to sowing, followed by a topdressing of 60 kg N/ha four weeks after planting. Herbicides were used to control weeds. The plant spacing was 75 cm × 25 cm. There were four replications in each trial.

The results are given in Table 60. At Owowam maize responsed significantly only to K at rates up to 30 kg K_2O/ha. The crop did not respond consistently to Mg and Zn at this site. At Jatozongo grain yield was low because of dry spells at critical stages of crop growth. Even so, the crop responded consistently to Zn but not to K and Mg.

Nitrogen use efficiency of leucaena leaves and fertilizer. In a trial comparing the effect of dried leucaena leaves with that of chemical fertilizer on maize yield, leucaena leaves were applied at a rate of

Table 58. Response of yams to fertilizer, Atebubu, Ghana, 1982

Nutrient, kg/ha				Tuber yield, t/ha		
N	P_2O_5	K_2O	S	White yams (Puna)	White yams (Denden-pruka)	Water yams (Akaba)
0	0	0	0	4.76	6.66	9.34
0	60	60	24	3.73	3.74	5.17
30	60	60	24	4.06	4.69	5.93
60	60	60	24	2.22	3.07	5.23
60	0	60	24	2.77	5.02	5.09
60	30	60	24	4.37	3.66	7.65
60	60	0	24	4.04	3.93	4.32
60	60	30	24	2.88	4.44	6.04
60	60	90	24	3.02	3.14	5.89
60	60	60	0	3.02	4.44	9.15
LSD (5%)				1.31	—	—
C.V., %				22.6	36.2	34.7
S.E.				0.44	0.89	1.28

3,500 kg/ha, supplemented by 30 kg P_2O_5/ha, and fertilizer was applied at 90 kg N, 60 kg P_2O_5 and 60 kg K_2O/ha. Both leucaena leaves and fertilizer were applied by three methods, broadcasting, broadcasting and incorporating, and banding, two times (at planting and three weeks afterwards). In one additional treatment, a split application of leucaena leaves and fertilizer was banded at planting and four weeks afterward. All 14 treatments were arranged in a randomized complete block design with four replications.

The results, shown in Table 61, indicate that there was no significant difference in N use efficiency between the leucaena leaves and fertilizer, irrespective of the time and method of application. Incorporation after broadcasting and banding appeared to give better yields than broadcasting, both with leucaena leaves and fertilizer. Split application of both gave lower yields than full application.

Groundnut inoculation. The effect of rhizobial inoculation on groundnut (*Arachis hypogaca* L. cv. Konkoma) nodulation and yield was studied at two fertility levels, no fertilizer and 100 kg/ha each of P and K, 20 kg Mg/ha and 10 kg Zn/ha. The N treatments were no nitrogen (control), fertilizer N at 100 kg/ha and *Rhizobium* inoculation. All six treatments were arranged in a randomized complete block design with four replications. The trials were organized in collaboration with the University of Hawaii, which supplied the *Rhizobium* inoculum. During the major season, the trial was carried out in a field that had been cultivated for the past 15 years, and during the minor season on land just cleared from bush fallow.

In neither trial did the crop respond significantly to inoculation in the number of total and active nodules per plant at flowering or in seed yield (Table 62). On the new land, the high fertility level had a positive effect on nodulation and yield, but nitrogen application significantly depressed nodule for-

Table 59. Response of short season white yam varieties to fertilizer in farmers' fields, Atebubu, Ghana, 1982

Nutrient, kg/ha					Tuber yield, t/ha			
					Labacco			Puna seed yams[a]
N	P_2O_5	K_2O	S	Zn	Main tubers	Seed yams	Total	
0	0	0	0	0	4.59	5.18	9.77	3.46
30	30	0	0	0	5.88	8.70	14.58	4.02
30	30	30	0	0	7.88	8.20	16.08	3.66
30	30	60	0	0	6.41	8.18	14.59	5.32
60	30	0	0	0	7.81	11.18	19.00	4.79
60	30	30	0	0	7.16	6.45	13.61	4.48
60	30	60	0	0	8.56	4.78	13.34	6.01
60	30	90	0	0	7.68	3.23	10.91	4.32
60	30	30	24	0	6.66	8.13	14.79	5.19
60	30	30	24	5	9.34	5.28	14.62	5.10
C.V., %					22.50	30.40	20.60	39.10
S.E.					1.15	1.49	2.06	0.91

[a]The farmer harvested the main tubers of Puna without informing the researcher.

Table 60. Response of maize to fertilizer, Atebubu, Ghana, major season, 1982

Nutrient, kg/ha					Yield, kg/ha	
N	P_2O_5	K_2O	Mg	Zn	Owowam, Kumayili soil	Jatozongo, Ahmantin soil
120	60	0	0	0	5,137	1,154
120	60	0	10	5	4,179	1,213
120	60	30	10	5	5,284	1,286
120	60	60	10	5	5,462	1,439
120	60	90	10	5	4,907	1,306
120	60	60	0	5	5,609	1,218
120	60	60	20	5	5,337	1,413
120	60	60	30	5	4,950	1,388
120	60	60	10	0	5,776	1,152
120	60	60	10	10	6,077	1,480
LSD (5%)					880	118
C.V., %					11.5	6.3
S.E.					303	41

Table 61. Effect of leucaena leaves and fertilizer on maize yield, Atebubu, Ghana, minor season, 1982

Source	Maize yield, kg/ha	
	Leucaena	Fertilizer
At planting		
Broadcast	4,146	3,828
Broadcast and incorporated	4,790	3,997
Banded	4,710	5,584
Three weeks after planting		
Broadcast	4,546	4,911
Broadcast and incorporated	4,229	5,169
Banded	4,596	5,557
At planting and four weeks afterward		
Banded	3,897	4,025
Mean	4,416	4,716
C.V., %	28	
S.E.	426	

Table 62. Effect of fertility and inoculation on nodulation and yield of groundnuts, Atebubu, Ghana, 1982

Fertility level and nitrogen treatment	Major season: Total no. of nodules	Major season: No. of pink/red nodules	Minor season: Total no. of nodules	Minor season: No. of pink/red nodules
Without fertilizer				
Control	5.4	1.8	76.2	39.2
100 kg N/ha	9.7	3.5	23.8	5.2
Rhizobium	26.7	16.8	79.0	46.7
With fertilizer[a]				
Control	2.4	0.4	102.2	63.2
100 kg N/ha	7.3	2.8	92.5	17.2
Rhizobium	13.0	7.4	83.8	52.4
LSD (5%)	—	—	41.0	32.0
C.V., %	125.0	125.0	35.7	57.0
S.E.	6.7	4.2	13.6	10.6

[a]100 kg/ha each of P and K, 20 kg Mg/ha and 10 kg Zn/ha.

mation, especially the number of active nodules per plant. N fertilizer did not appear to reduce nodulation at the cultivated site. The groundnut variety used in these trials (Konkoma) can nodulate well in Atebubu soils without inoculation.

Response of cowpeas to Mg and trace elements. In this trial the response of cowpeas (VITA-5) to Mg, B, Mo and Zn application was evaluated. A basal application of 54 kg P_2O_5/ha was made in all plots. The total number of nodules per plant at flowering was not significantly affected by any of the treatments, although the percentage of active nodules was significantly higher in the presence of B than when it was absent (Table 63). The highest yield was obtained when all the elements were applied together, but yield did not respond significantly to any particular nutrient.—*V. Balasubramanian*

Crop Production

During the year several experiments were planned on different cropping systems, including rotation experiments, but when it was disclosed that this project would be terminated as early as June, all of the experiments were discarded. The experiments reported here, which had already begun before the disclosure of termination, were based on observations and discussions of farmer's practices.

Effects of mound size, staking and planting date. Yam farmers in Atebubu normally stake their yams, except in newly cleared fields where there are only a few trees that can be used as stakes. In this case farmers leave some of the yams unstaked. The farmers claim that not staking the yams has no effect on yield because they plant unstaked yams in larger mounds to compensate for the expected yield loss. A study was conducted to determine the effect of mound size and staking on the yield of white yams (*Dioscorea rotundata*, cv. dentempruka) and water yams (*D. alata*, cv. akaba).

The experimental design was a split plot in four replications with mound size, variety and fertilizer in the main plot and staking in the subplot. Mounds were spaced at 2 m, 1.4 m and 1 m to give approximately 2,500, 5,000 and 10,000 mounds per hectare for the large, medium and small mounds, respectively. The experiment was conducted on an old yam plot that received fertilizer and no fertilizer treatments. An additional treatment of 30 kg/ha each of N, P_2O_5 and K_2O was applied to all plots to determine crop response to one- and two-year fertilizer application. The results show that there was no difference in crop response to one- and two-year application.

Reducing mound size significantly decreased tuber size and tuber yield per mound, but total yield per hectare increased as the number of mounds increased (Table 64). For each mound size, *D. alata* was the higher yielding variety, although the percent increase in total yield of *D. alata* was significantly lower than that of *D. rotundata* in the small mounds and slightly higher in the medium sized mounds. Similarly, the percent loss in the average weight of a single tuber was much higher for *D. alata* in both the medium and small mounds. These observations indicate that there are varietal differences in response to yam mounds of different sizes.

Staking gave higher yields than not staking, especially with *D. rotundata*, the tuber yield of which

Table 63. Effect of manganese and trace elements on cowpea yield and nodulation, Atebubu, Ghana, 1982

Nutrient, kg/ha: P_2O_5	Mg	B	Mo	Zn	Nodules per plant: Major season total	Pct. of total active	Minor season total	Yield, kg/ha: Major season	Minor season
54	0	0	0	0	11.8	52.0	6.6	1,090	1,250
54	0	2	1	5	19.9	72.1	8.0	1,260	1,542
54	20	2	1	5	18.7	80.1	7.2	1,410	1,516
54	20	0	1	5	13.8	54.7	5.2	1,313	1,412
54	20	2	0	5	17.6	69.4	7.6	1,272	1,235
54	20	2	1	0	19.1	66.3	6.8	1,180	1,011
54	20	2	1	10	18.8	67.8	9.6	1,177	1,037
LSD (5%)					—	13.6	—	—	—
C.V., %					35.8	13.8	35.2	13.8	27.5
S.E.					3.1	4.6	1.3	86	177

Table 64. Effect of mound size on yam yield, Atebubu, Ghana, 1982

Mound size	*Dioscorea rotundata* t/ha	kg per mound	kg per tuber	*D. alata* t/ha	kg per mound	kg per tuber
Large	11.78	4.71	1.87	18.50	7.46	5.03
	(0)	(0)	(0)	(0)	(0)	(0)
Medium	15.79	3.14	1.50	25.15	5.00	3.45
	(+34.00)	(−33.30)	(−19.80)	(+38.00)	(−32.00)	(−31.40)
Small	24.28	2.43	1.30	30.92	3.09	2.38
	(−46.70)	(−48.40)	(−30.50)	(−67.10)	(−58.60)	(−52.70)
Mean	17.28	3.43	1.56	24.86	5.18	3.62
	(+46.70)	(−27.20)	(−16.60)	(+34.30)	(−30.50)	(−28.00)
LSD (5%)	5.06	1.28	0.78			

Note: The numbers in parentheses are percent increases or decreases from the yield of yams in large mounds.

was significantly reduced by not staking (Table 65). With *D. alata* tuber yield was in general not affected, although when planted in large mounds yield was depressed slightly without staking indicating, as shown in Table 66, that there is interaction between mound size and staking.

The percent yield loss caused by not staking was also reduced by decreasing mound size. This reduction can be attributed to the reduction in tuber size that occurs when the yam mounds are made smaller. This trend did not hold for the small mounds. Because their shallow depth inhibited further tuber development, they gave a higher percent yield loss than the medium size mounds. This suggests that there is a minimum depth in mound size below which the loss in yield caused by not staking cannot be reduced further by decreasing mound size.

In Atebubu yams are commonly grown in large mounds of approximately 2 m × 2 m. Some farmers, if they are planting late, use smaller mounds to permit deeper penetration of rain into the mound and to lower the soil temperature. This encourages quicker seedling emergence and compensates for the loss in growing time. An experiment was conducted in which mound size and variety were main plot treatments and planting date was the subplot; the experiment had a split-plot design and was replicated three times. Planting began with the first rains toward the end of February and continued at one-month intervals until the end of April. Spacing between mounds was 2 m (large), 1.41 (medium) and 1 m (small). Thirty kg/ha each of N, P_2O_5 and K_2O was applied by ring placement one month after each planting. All plants were staked, and all plots were harvested on the same day.

The results in Table 67 show that the longer the delay in planting the smaller the tuber yield or, that as the growing period gets shorter the yield loss becomes greater. The large mounds suffered the greatest yield loss, which increased from the 5% level of significance after one month to the 1% level at the end of two months. Yield loss in the medium size mounds was significant at the 5% level only after two months, while that of the small mounds was not significant even after two months. These results show that loss in tuber yield caused by late planting

Table 65. Effect of staking on yam tuber yield, Atebubu, Ghana, 1982

Variety	Staking	No staking	Mean
	kg per mound		
Dioscorea rotundata	3.78	3.07	3.42
	(0)	(−18.80)	(−9.40)
D. alata	5.30	5.08	5.19
	(0)	(−1.30)	(−0.70)
Mean	4.54	4.07	
	(0)	(−10.00)	
LSD (5%) for:			
Staking means	0.24		
Staking, same variety	0.34		
Variety means	0.24		
C.V., %	13.40		

Note: The numbers in parentheses are percent yield losses.

Table 66. Effect of mound size and staking on yam tuber yield, Atebubu, Ghana, 1982

Variety	Yield, kg per mound: Staking	No staking	Percent yield loss
Large mound			
D. rotundata	5.39	4.03	25.2
D. alata	7.88	7.04	10.7
Mean	6.63	5.53	17.9
Medium mound			
D. rotundata	3.32	2.95	11.1
D. alata	4.91	5.08	−3.4
Mean	4.12	4.02	−3.9
Small mound			
D. rotundata	2.63	2.23	15.2
D. alata	3.11	3.08	1.0
Mean	2.87	2.65	8.1
Mean	4.54	4.07	
LSD (5%) for:			
Staking means		0.24	
Staking, same var. and mound size		0.59	
Staking, same mound size		0.41	

can be minimized by reducing mound size. The reduction in mound size reduces tuber size and yield per mound, so that the magnitude in yield loss is also reduced.

D. rotundata suffered a significantly greater yield loss than *D. alata* when planting was delayed until April (Table 68). The latter yielded significantly less

in March because of drought. However, the non-significant yield loss in April seems to indicate that this variety may be less affected by late planting than *D. rotundata*, which is probably one of the reasons that some farmers plant it even as late as May.

Table 69 shows that yam seedling emergence was affected significantly by mound size as well as by planting date. The time of emergence was longest for the large mound and shortest for the small mound.

Table 67. Effect of mound size and planting date on tuber yield, Atebubu, Ghana, 1982

Mound size	Planting date 26 Feb.	29 March	30 April	Mean
		kg per mound		
Large	2.74	1.91	1.66	2.10
	(0)	(−30.30)	(−39.40)	(−23.20)
Medium	2.44	1.96	1.65	2.01
	(0)	(−19.70)	(−32.40)	(−17.40)
Small	1.63	1.60	1.06	1.43
	(0)	(−1.80)	(−34.90)	(−12.20)
Mean	2.27	1.82	1.46	
	(0)	(−17.30)	(−35.60)	

LSD (5%) for:
- Planting date means 0.37
- Planting date, same mound size ..... 0.64[a]
- Mound size means 0.37

C.V., % 28.9

Note: The numbers in parentheses are percent yield losses.
[a]LSD (1%) 0.87

Table 68. Effect of planting date on yam tuber yield, Atebubu, Ghana, 1982

Variety	Planting date 26 Feb.	29 March	30 April	Mean
		kg per mound		
D. rotundata	2.57	2.38	1.36	2.10
	(0)	(−7.40)	(−47.10)	(−18.20)
D. alata	1.98	1.27	1.56	1.60
	(0)	(−35.80)	(−21.20)	(−19.00)
Mean	2.27	1.82	1.46	

LSD (5%) for:
- Variety means 0.30
- Planting date means 0.37
- Planting date, same variety 0.52

C.V., % 28.9

Note: The numbers in parentheses are percent yield losses.

Table 69. Effect of mound size and planting date on average time of seedling yam emergence, Atebubu, Ghana, 1982

Mound size	Planting date 26 Feb.	29 March	30 April	Mean
		kg per mound		
Large	12.60	9.40	8.80	10.30
Medium	5.90	6.10	4.60	5.50
Small	2.90	2.70	2.40	2.70
Mean	7.10	6.10	5.30	
LSD (5%)		1.06		0.92
C.V., %	25.10			

Similarly, the later the planting date, the shorter the time of emergence.

Seedling emergence, as affected by mound size and planting date, was related to soil moisture and temperature. The quicker seedling emergence from the small mounds appears to be associated with their shallow depth, which permits moisture from the soil below to be transferred readily by capillary action to the developing seedling. With early planting emergence was slower because of high soil temperature and dry conditions, whereas with later planting in April, seedling emergence was quicker as a result of the cooler soil temperature and more favorable soil moisture conditions that prevail during that month. The quicker seedling emergence may explain why some farmers use smaller than normal mounds when planting late.

Effect of tillage and fertilizer on groundnut yield. In groundnut cultivation the method of seedbed preparation varies from ridging or plowing to little or no tillage after land clearing, depending on the cropping pattern used by the farmer. To find out if the different tillage practices have any significant effect on yield, the performance of groundnuts (Konkoma) was tested in seedbeds prepared by three methods and at three phosphorus levels (0, 36 and 72 kg P_2O_5/ha applied as single superphosphate).

The experimental design was a randomized complete block, with four replications and 60-cm spacing between rows and 15-cm spacing within rows. Potassium was applied to all plots at 30 kg K_2O/ha. The experiment was conducted at one location in the first season and at another location in the second season. In the no-tillage plots, except for the initial soil disturbance during land clearing, there was no further soil disturbance.

No-tillage significantly reduced groundnut yield, and there was no significant difference in yield response between plowing and ridging (Table 70). Yield was increased significantly by an application of 36 kg P_2O_5/ha of single superphosphate. Further phosphorus application did not have much effect on yield. The low yields caused by no-tillage can be attributed to the adverse effects of soil physical conditions on groundnut pod development. With groundnuts some form of tillage appears necessary for good yields.

ZAPI-Est Project in Eastern Cameroon

As part of Cameroon's Zones d'Actions Prioritaires Integrees de l'Est (ZAPI-Est) Project, field trials were carried out during 1982 at Bertoua in the savanna and at Doume in the forest zone. On-farm trials and multilocational trials on yield constraints and crop fertilization were carried out at Garoua Boulai in the savanna, at Abong Mbang in the forest zone and at various farmers' fields in four ZAPI Zones, Diang-Belabo, Nguelmendouka, Angossas and Doume. The

Table 70. Effect of tillage method and phosphorus application on groundnut yield, Atebubu, Ghana, 1982

Phosphorus rate	First season yield, kg/ha				Second season yield, kg/ha			
	No tillage	Plow	Ridge	Mean	No tillage	Plow	Ridge	Mean
0 kg P_2O_5/ha								
Pod	1,188	1,463	1,451	1,367	538	742	626	635
Kernel	847	1,021	991	953	371	516	436	441
36 kg P_2O_5/ha								
Pod	1,697	1,766	1,862	1,775	686	946	865	832
Kernel	1,196	1,257	1,313	1,255	469	644	610	574
72 kg P_2O_5/ha								
Pod	1,545	1,940	1,715	1,733	751	966	870	862
Kernel	1,051	1,388	1,224	1,221	508	664	611	594
Mean								
Pod	1,477	1,723	1,676		658	885	787	
Kernel	1,031	1,222	1,176		449	603	552	
LSD (5%) for:								
Pod, till. and P means		177				118		
Kernel, till. and P means		129				80		
C.V., %								
Pod		13.0				18.0		
Kernel		13.4				17.8		

crops used in the trials were maize, groundnuts, sweet potatoes, cassava, rice, cowpeas and pigeon peas. Only part of the data from the first season trials were available for this report.

Maize

On-farm and multilocational trials. These trials were carried out in cooperation with Young Farmers of ZAPI-Est, the Farmer Cooperative Fokpayono at Garoua Boulai, and the Agricultural Technic School at Abong Mbang. Three improved maize varieties, EMC, TZSR-W and TZB, were compared with local varieties at three levels of management and fertilization in 15 farmers' fields in four zones. The crops were planted and managed by the farmers with assistance from IRA-Est (Institut de la Recherche Agronomique) researchers and ZAPI-Est technical officers. At harvesttime, 8 out of 15 trials yielded good data for comparison.

The same three maize varieties used in the on-farm trials were also tested against local varieties at three research locations, Bertoua, Garoua Boulai and Abong Mbang. In these trials the variety EMC was also tested under eight different combinations of planting, weeding and fertilizer application. The trials were carried out by IRA-Est research staff.

The yields of the local variety, EMC, TZB and TZSR-W under farmers' management (Table 71) were considerably lower than at the research sites, where optimum agronomic practices tripled the yields of the improved varieties (Table 72).

On the farms, although improved varieties and fertilizers failed to increase yields, the use of a higher plant stand boosted production by about 32% (Table 73). Observations on crop characteristics of maize at harvest showed that the traditional method of seeding resulted in a lower plant population at harvest, a lower percentage of harvested ears and a higher percentage of big ears, unproductive ears and ears attacked by insects and diseases (Table 74). At the research site, however, the use of improved varieties and appropriate agronomic practices, such as weeding, plant density and fertilizer application, increased maize yields significantly. Yields of improved varieties were about twice those of local varieties. On the average 48% of the overall yield increase can be attributed to fertilizers, 34% to plant density and 18% to weeding.

Soil fertility management. Three field trials were conducted simultaneously at Abong Mbang, Bertoua, and Garoua Boulai to study the effect of fertilizer application on maize (EMC) planted under different environmental conditions in eastern Cameroon. On plateau soils at Abong Mbang, maize responded significantly to the application of 60 kg N/ha and 60 kg P_2O_5/ha. On soils in the upper part of a valley side slope at Garoua Boulai and on soils in the lower portion of a valley side slope at Bertoua maize responded to all nutrients, although only the response to nitrogen was significant (Table 75).

Planting date. Three maize varieties, EMC, TZB and TZSR-W, were planted on three dates, 30 March, 29 April and 1 June, in a split-plot design. Late

Table 71. Yield of maize varieties planted by farmers, Cameroon, first season, 1982

Trial	Yield, kg/ha			
	Local	EMC	TZB	TZSR-W
KANDA I	937	631	833	659
NKA I	981	928	779	817
KANDA II	1,430	1,729	1,652	2,312
NKA II	760	577	739	557
ANG. I	544	469	512	490
ANG. II	1,695	1,958	2,000	1,854
ANG. III	1,093	1,104	895	1,145
ANG. IV	1,097	807	1,287	1,343
Means	1,067	1,028	1,087	1,147

planting significantly decreased yields regardless of the varieties used (Table 76). Streak infestation in the susceptible varieties (EMC and TZB) was quite high in the 29 April planting but did not reduce yields. The 1 June planting was obviously too late and resulted in stunted plant growth.

Screening of herbicides. One of the major problems of maize production in eastern Cameroon is the shortage of labor for weeding during the early vegetative growth of the crops. A trial was conducted to screen locally available herbicides. Maize yields greatly increased when weeds were controlled. Of the herbicide treatments, Atrazine at 2.0 kg a.i./ha plus Stomp at 1.5 kg a.i./ha applied preemergence gave the highest yield (4,362 kg/ha), although it did not differ significantly from yields with the other herbicide treatments or with two weedings by hand (Table 77).

Groundnuts

On-farm trials. On-farm, demonstration trials on groundnuts were carried out at six locations in the first season of 1982. Groundnut variety 68–16 gave an average yield of about 1,233 kg/ha, 27.3 percent more than the yield of local varieties (Table 78).

Seeding date and fertilizer application. Groundnut variety 68-16 was planted on three dates, 3 April, 6 May and 2 June, and treated with six combinations of N, P and K fertilizer. Fruit yields of groundnuts decreased significantly from 1,862 kg/ha when it was seeded on 3 April to about 1,186 kg/ha when it was seeded on 2 June. The effects of fertilizer applications on groundnut yields were not clear, as was the case in 1981. This may be due to the high rate of Rosette virus infestation (30% average incidence).

Weed control. Groundnut variety 68-18 was subjected to seven weeding treatments. Dry fruit yield of groundnuts increased significantly from 1,116 kg/ha in the unweeded plot to about 1,950 kg/ha or more in plots where various weed control practices were used. Stomp applied preemergence at 1.2 kg a.i./ha gave good weed control and an excellent yield. A good single weeding by hand is apparently just as effective, though.

Control of leaf diseases. In addition to Rosette virus, groundnuts planted in eastern Cameroon are heavily attacked by a leaf disease caused by Cercosporiosis. The fungicide Peltas was applied at a rate of 3 kg of commercial product per hectare on five groundnut varieties, 65-7, Bertoua Blanche, 68-16, Ongnegne and Nkometou II, to control the cercosporiose. Depending upon the variety, Peltas application yield from 27 to 78% (Table 79).

Sweet Potatoes

Four promising sweet potato clones selected from last year's trials (TIB 1, TIB 2, TIS 23303 and TIS 527034) were tested at three locations from May to

Table 72. Yield of maize under different cultural practices, Cameroon, first season, 1982

Variety and treatment	Yield, kg/ha: Abong Mbang	Garoua Boulai	Bertoua
Local (traditional[a])			
No fert., no weeding.	386 a	1,152 a	196 a
Local (research[b])			
Fert., weeding[d]	2,261 ef	2,892 abcd	478 ab
EMC (traditional)			
No fert., no weeding.	569 ab	1,446 ab	1,139 bc
Fert., no weeding	1,426 abc	2,892 abcd	2,085 def
No fert., weeding	790 bcd	2,083 abc	1,629 cd
Fert., weeding	1,930 de	3,847 cdef	2,389 efg
EMC (research)			
No fert., no weeding.	1,275 cd	2,340 abcd	1,629 cd
Fert., no weeding	2,445 e	4,485 def	2,426 fg
No fert., weeding	2,316 e	3,223 bcde	1,691 cde
Fert., weeding	2,650 ef	5,171 ef	2,671 fg
TZB (research)			
Fert., weeding	3,125 f	5,551 f	2,855 g
TZSR-W (research)			
Fert., weeding	2,463 ef	5,312 ef	3,075 g

Note: Any two means in the same column followed by the same letter are not significantly different at the 5% level of probability.
[a]Maize was seeded according to the traditional method.
[b]Maize was seeded at 50,000 plants/ha with spacing of 80 cm × 50 cm.
[c]Fertilizer was applied at 80 kg N, 40 kg P_2O_5 and 40 kg K_2O/ha.
[d]One hand weeding was done four weeks after seeding.

Table 73. Yield of maize varieties planted by farmers under different cultural practices, Cameroon, first season, 1982

Variety	Yield, kg/ha: A[a]	B[b]	C[c]	Percent increase: Of B over A	Of C over A
Local	968	1,356	964	40.1	−0.4
EMC	962	1,215	908	26.3	−5.6
TZB	1,136	1,327	625	16.8	−45.0
TZSR-W	972	1,455	1,062	49.7	9.3
Mean	1,009	1,338	890	33.2	−10.4

[a]Maize was seeded according to the traditional method and without fertilizer.
[b]Maize was weeded at 50,000 plants/ha at 80 cm × 50 cm spacing and without fertilizer.
[c]Maize was seeded according to the traditional method with fertilizer at 80 kg N plus 40 kg P_2O_5 plus 40 kg K_2O/ha.

Table 74. Crop characteristics of maize planted by farmers, Cameroon, first season, 1982.

Characteristics	Method of seeding: Traditional	Research
Plant population at harvest, plants/ha	20,460	28,050
Percentage of harvested ears (total harvested over plant pop.)	86	93
Percentage of big ears	32	29
Percentage of ears attacked by insects and diseases	23	21
Percentage of unproductive ears	13	11

Table 75. Yield of maize at three locations under different fertilizer treatments, Cameroon, first season, 1982

Fertilizer rate, kg/ha			Yield, kg/ha		
N	P_2O_5	K_2O	Abong Mbang	Bertoua	Garoua Boulai
0	0	0	2,053 a	3,753 a	2,570 a
60	60	0	3,750 bc	5,263 bcd	4,222 b
0	60	60	2,738 ab	4,600 b	3,074 a
60	0	60	3,035 b	4,980 bc	4,160 b
60	60	60	3,779 c	5,539 cd	4,921 bc
120	60	60	4,181 c	6,069 d	5,434 c
60	120	60	4,196 c	5,590 cd	4,849 bc
60	60	120	3,750 bc	5,446 bcd	4,887 bc

Note: Means in the same column followed by the same letter are not significantly different at the 5% level of probability.

Table 76. Performance of maize sown at different dates, Bertoua, Cameroon, first season, 1982

Planting date	Yield, kg/ha	Streak, %	Plant height, cm
EMC			
30 March	5,097 b	7.8 c	270 a
29 April	3,875 c	23.3 a	260 a
1 June	2,467 d	7.1 c	205 b
TZB			
30 March	6,013 a	8.6 c	255 a
29 April	3,947 c	16.3 b	263 a
1 June	739 d	5.2 c	201 b
TZSR-W			
30 March	4,805 b	3.0 c	263 a
29 April	3,989 c	4.9 c	267 a
1 June	3,078	4.0 c	213 b

Note: Means in the same column followed by the same letter are not significantly different at the 5% level of probability.

October 1982. The highest yielder, as last year, was TIB 1, which gave average marketable tuber yields of about 17.8 t/ha (Table 80).

Intercropping

A trial was carried out to confirm previous findings on crop arrangements for maize/groundnut intercropping. The results of the trial confirmed last year's finding that maize in double rows gave the highest land productivity value. The land equivalent ratio of this system was 1.28 (Table 81). Yields of maize planted in association with groundnuts in two systems did not decrease appreciably, yields of maize planted according to a third system, the farmers', were significantly lower. The dry fruit yield of groundnuts was reduced significantly in association with maize, regardless of the crop arrangement used.

Trials on maize/cassava intercropping were also carried out, but not all the results were available for this report.

Table 77. Yield of maize with different weed control practices, Bertoua, Cameroon, first season, 1982

Weed control treatment	Yield kg/ha
No weeding	2,884 a
One hand weeding four weeks after germination	3,147 ab
Two hand weedings four and seven weeks after germination	4,101 bc
Atrazine, 1.5 kg a.i./ha (preemergence)	4,134 bc
Atrazine, 2.5 kg a.i./ha (preemergence)	4,265
Atrazine, 2.0 kg a.i./ha, and Stomp, 1.5 kg a.i./ha (preemergence)	4,362 c
Simazine, 2.5 kg a.i./ha (preemergence)	3,769 bc
Atrazine, 1.5 kg a.i./ha (preemergence) + 2,4-D, 0.5 kg a.i./ha, four weeks after germination	4,055 bc
Atrazine, 1.5 kg a.i./ha preemergence) + one hand weeding seven weeks after germination.	4,088 bc

Note: Means followed by the same letter are not significantly different at the 5% level of probability.

Table 78. Yield of groundnut varieties planted by farmers, Cameroon, first season, 1982

	A16			Local		
Trial	Traditional	Research[a]	Mean	Traditional	Research	Mean
DIANG	1,980	1,087	—	870	744	—
NKA I	521	770	—	289	925	—
NKA II	860	904	—	512	588	—
ANG. I	1,120	1,000	—	1,240	1,640	—
ANG. II	816	252	—	424	472	—
DOUME I	2,800	1,740	—	780	2,100	—
DOUME II	1,800	1,600	—	1,400	1,600	—
Mean	1,414	1,050	1,231	787	1,152	969

Note: Plant population was 200,000 plants/ha with spacing of 40 cm × 25 cm.

Table 79. Yield of groundnut varieties treated against leaf spot disease, Bertoua, Cameroon, second season, 1982

Variety	Yield, kg/ha Control	Yield, kg/ha Treated[a]	Percentage increase
65-7	1,579	2,005	27
Bertoua Blanche	995	1,685	68
68-16	1,458	1,995	37
Ongnegne	1,806	2,380	32
Nkometou II	1,361	1,875	38

[a]Groundnuts were treated with 3 kg of Peltas per hectare, beginning when spots were first observed and continuing until harvest at 15-day intervals.

Table 80. Yield of sweet potato clones at different locations in Eastern Cameroon, 1982

	Marketable yield, t/ha			
Variety	Bertoua	Doume A	Doume B	Mean
TIB 1	20.3	17.4	15.7	11
TIB 2	18.5	13.4	6.5	12
TIS 23303	10.8	18.1	11.4	13
TIS 527034	16.7	11.0	12.2	13
Local	10.9	—	—	—

Table 81. Performance of intercropped maize and groundnuts, Bertoua, Cameroon, 1982

Treatment	Maize yield, kg/ha	Groundnut yield, kg/ha	Land equivalent ratio
Maize alone	5,156 a	—	1.00
Groundnuts alone	—	1,749 a	1.00
Maize/groundnuts			
System A	4,791 a	552 c	1.24
System B	4,352 a	760 bc	1.28
System C	2,541 b	987 bc	1.06

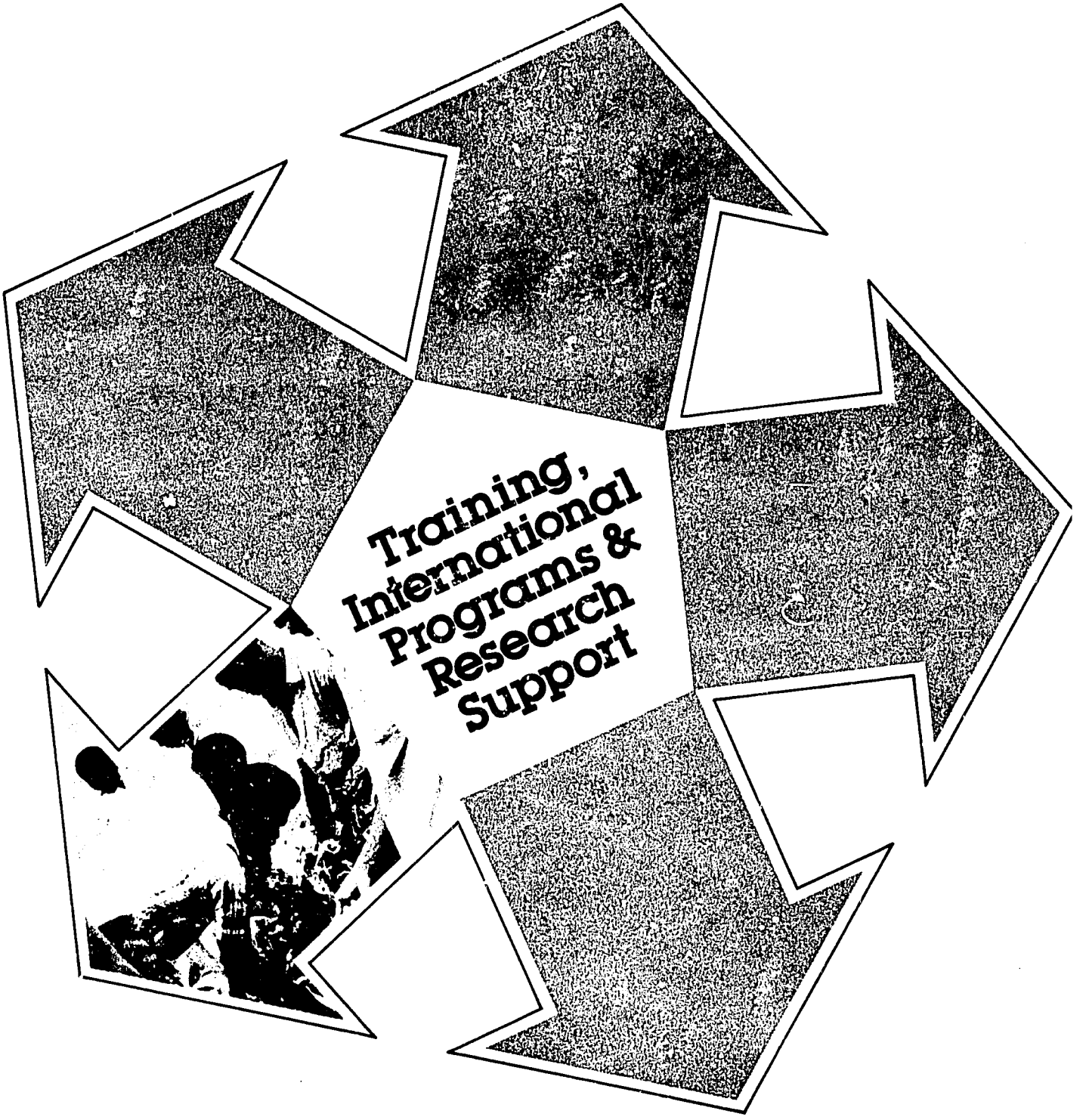
Note: Two means followed by the same letter are not significantly different at the 5% level of probability.

Farming Systems Research Network in East Africa

For the past six years, CIMMYT has operated an economics program in eastern Africa. A senior economist gathered and analyzed baseline data on the physical, biological, socioeconomic and sociocultural environments of groups of farmers in selected areas. Survey methods for gathering such information are being developed and communicated through training programs to some national institutions in East Africa.

An agronomist from IITA's Farming Systems Program has now been posted with CIMMYT's program in East Africa. In addition to helping develop farming systems research methods, he will conduct research on technology developed at IITA. This technology is intended to aid soil conservation (through reduced tillage systems, mulching, alley cropping, and mixed and relay intercropping); reduce inputs and increase yields (by means of mixed and relay intercropping, mulching systems, rhizobial nitrogen fixation and mycorrhizal phosphate nutrition); reduce drudgery (through weed control and low cost tools such as the rolling injection planter); and employ genetically improved varieties of various crops (grain legumes, cereals, and root and tuber crops). Technology from other sources (for example, high-to-mid-altitude maize and rice, drought tolerant pulses, and pigeon peas) could also be adapted to the region.

Full participation in the East Africa project by IITA has been hindered by unforeseen administrative delays. Preliminary contacts suggest that there is a great need in the essentially maize-based farming systems of eastern Africa for IITA technology in rice, cassava and the pulses. In this region, as in West Africa, crop production is usually increased by bringing more land under cultivation (though the increase in productivity lags behind population growth). Low-cost technology, such as improved varieties with resistance to stresses, mixed and relay intercropping and biological processes, would enable farmers to intensify production per unit area. Fertilizer and other soil ammendments, though costly, will have to be used.—*H.C. Ezumah*



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Training Program

IITA was established to serve as a center for agricultural research and training. Through its training program, the Institute helps prepare agricultural scientists to solve food production problems in the world's humid and subhumid tropics. The Institute also trains research workers to assist agricultural scientists and extension supervisors to transfer new technology to agricultural producers.

A total of 655 people received training through IITA in 1982, including, for the first time, participants from Belize, Cuba, Haiti, Mozambique, Switzerland and Vietnam. The numbers and countries of people that have received training through IITA since it opened in 1970 are listed in Table 1. The types of training programs offered by the Institute are described in the following sections.

Degree-Related Training

In the degree-related training program, postgraduate students from universities throughout the world conduct the field work portion of their degrees at IITA under the supervision of scientists. The program is designed primarily to give students from the humid and subhumid tropics the opportunity to conduct their field work in the tropics with the crops, soils and farming systems to which they will return upon completion of their degree programs.

During 1982, 34 Master's degree students (research scholars) from 10 countries and 30 doctoral students (research fellows) from 12 countries were engaged in research under the supervision of IITA scientists. In all, 17 countries were represented, of which 12 are in Africa, and 21 universities, of which 7 are in Africa. By the end of 1982, a total of 143 research scholars and 87 research fellows had conducted the field work portion of their degrees at IITA. The students' names and the topics of their studies are listed in Table 2.

Vacation Student Research Scholarships

The vacation student scholarship program was created to initiate and maintain cooperative relationships with agriculture faculties in Africa, some of which have no postgraduate programs, and to identify promising young students and motivate them to pursue careers as agricultural scientists. Scholarships are awarded to students in the next to last year of their first degree programs. During their last long vacation as undergraduates, the students carry out field and laboratory studies under the supervision of IITA scientists.

The program has attracted nominations from faculties in French- and English-speaking Africa. From 1971 through 1982, vacation scholarships were awarded to 180 students, representing 10 countries and 12 universities of Africa. The Institute remains in touch with these former scholars, many of whom now have positions in research institutions, universities and international organizations, including IITA.

Non-Degree-Related Training

Training of research workers and extension personnel is carried out in the non-degree-related training program and group courses. Through the former the Institute responds to requests for training in agricultural technology for employees of departments and ministries of agriculture, universities, agricultural experiment stations, international organizations, and private agencies in the humid and subhumid tropics. Training is organized on an individual basis to meet the specific needs of each research training associate. Because their individual needs vary widely, so does the length of the programs, from two weeks to nine months.

In 1982 the Institute received into this program 26 persons, representing 12 nations. The participants acquired research and technical skills, working under the supervision of IITA scientists and technicians (Table 3).

Group Courses

Group courses on various areas of agricultural production in the humid and subhumid tropics are organized as the need for training larger numbers of research workers and extension supervisors in a particular area becomes apparent. The demand is currently so great that the number of applications received for courses typically exceeds by two or three times the number of places available.

The group courses program expanded significantly in 1982, offering 21 courses, two of which were conducted in Cameroon and one in Upper Volta. The total number of participants was 554, more than double the number received in the previous year, during which 11 courses were offered, with 253 participants.

One of the highlights of the group courses program in 1982 was the development of training manuals for maize, cowpeas and soybeans, root and tuber crops, and soil and plant analysis. The maize and root and tuber crops manuals have been translated into French, and eventually all of them will be produced in both French and English. Another highlight was a 64-hour, intensive course in agricultural research management, which was conducted at IITA by the International Service for National Agricultural Research (ISNAR). Fifty-eight IITA scientists and research scholars and fellows completed the course, which consisted of a tightly integrated program of lectures, case studies, exercises, games and projects

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designed to improve the managerial skills of the participants. The course was received with much enthusiasm by the present and future agricultural scientists who took part.

The 21 group courses offered at IITA and off site this year are described in more detail in the following paragraphs. Information about courses conducted off site from 1974 to 1982 in cooperation with national agencies is listed in Table 4.

Communication planning and strategy in Africa (10 to 22 January). This course/workshop was conducted jointly by Cornell University (United States) and IITA. It sought to respond to the need of ministries and other agencies to communicate more effectively with the potential beneficiaries of rural development programs, with other groups that are vital to the success of those programs, and with the general public. There were seven participants from three countries.

Soil and plant analysis (18 January to 26 February). This course was conducted jointly by the Centre for International Programs of the University of Guelph, Canada, and IITA. It was funded primarily by a grant from the Canadian International Development Agency (CIDA). The principal objective of the course was to train senior laboratory technicians and technologists in the management, methodology, instrumentation and techniques of soil and plant analysis, with special emphasis on soils and crops of tropical regions. There were 21 participants from 16 countries.

Maize production (8 February to 30 April). The objective of this course was to train research workers and extension supervisors in improved methods of maize cultivation and experimentation and to acquaint them with maize research and production technology. The course focused on the different environments of maize production in tropical Africa, on identification of various field problems, and on practical solutions to problems common in Africa. The course was designed to teach participants how to perform simple applied research trials at experiment stations and on farmers' fields and to demonstrate new cultural practices. There were 30 participants from 16 countries.

Weed control (1 to 12 March and 7 to 18 June). Two courses in weed control were conducted in 1982 for IITA field technicians and representatives of the Nigerian Federal Department of Agriculture. The courses covered use and application of herbicides, including sprayer calibration. There were 63 participants.

Root crops multiplication (1 to 10 March). This course was conducted at the request of the Nigerian National Seed Service and was sponsored by that organization. The primary objective of the course was to train National Seed Service personnel in improved methods of tropical root and tuber crop multiplication and production. Nine persons participated.

Soil and water conservation research (15 March to 2 April). The principal objective of this training course/workshop was to acquaint researchers from agricultural research stations of the humid and subhumid tropics of Africa, Asia and Latin America with the current state of knowledge about erosion problems, principles of erosion control and techniques for conducting experiments in erosion. There were 24 participants from 16 countries.

Seed yam production (22 to 26 March). This course was requested and sponsored by the Ayangba Agricultural Development Project, Nigeria. Its objective was to provide practical training in seed yam production to field technicians who are responsible for accelerating yam production in the project. Nine persons participated.

Field surveying and data collection (29 March to 8 April and 23 August to 4 September). Two courses were conducted in Bambui, Cameroon, in cooperation with the Cameroon Institute of Agronomic Research. The primary objectives of the courses were to familiarize extension field demonstrators with field surveying, data collection, and interpretation techniques and to instruct them on group farm organization. The courses were designed to prepare field demonstrators to assist scientists of the Cameroon National Research and Extension Project, who are working with IITA scientists to build up Cameroon's on-farm research capability and improve technology transfer to its small farmers. Seventy-five people participated.

Intensive maize production (21 to 25 April). This course was planned, organized and conducted for extension personnel of three Nigerian state ministries of agriculture and natural resources by participants in the 12-week maize production training course offered by IITA in 1982 (see the description above). For the participants in the maize course, this course served as an exercise in planning and conducting training. Their primary objective in offering the course was to bring state extension personnel up to date on maize research, production and extension. Thirty-two people participated.

Maize and cowpea production (15 March to 9 April). This course was conducted in Upper Volta by the IITA/SAFGRAD team at the request and under the sponsorship of the government of Upper Volta and the U.S. Agency for International Development (USAID) foundation seed production project. It was designed for field extension personnel responsible for accelerating maize and cowpea production in Upper Volta. These people were joined by five of their colleagues from the Benin Ministry of Agriculture who have similar responsibilities. The latter were sponsored by the Food and Agriculture

Organization (FAO) of the United Nations. The primary objectives of the course were to train field extension personnel and research workers in improved methods of maize and cowpea cultivation and experimentation and to acquaint them with applied research and production technology for the two crops. There were 20 participants from two countries.

Tropical root and tuber crop production (10 May to 9 July). The primary objective of the course was to train research workers and extension supervisors in improved methods of tropical root and tuber crop production and acquaint them with applied research and technology. The course focused on the different environments in which root and tuber crops are grown in the tropics, on identification of problems, and on practical solutions to those problems. The participants worked alone and in teams in the field, greenhouse, laboratory and classroom. They were able to perform and demonstrate procedures for releasing new clones of these crops, plan and conduct applied research projects, interpret data, and write reports. The course was funded primarily by the United Nations Development Programme (UNDP) under its joint grant, entitled Technology Transfer on Root and Tuber Crops, to Centro Internacional de Agricultura Tropical (CIAT), the International Potato Center (CIP) and IITA. There were 33 participants from 25 countries.

Cowpea production (20 to 22 June). This course was requested and sponsored by the Kano State Agricultural Development Authority, Nigeria. The primary objective of the course was to train extension supervisors and other extension personnel in improved methods of cowpea production that are now becoming available. Thirty-six people participated.

Intensive course in tropical root and tuber crop production (5 to 9 July). The participants in IITA's 10-week course in tropical roots and tubers (discussed above) planned, organized and conducted this week-long course for extension personnel of Nigeria's Ogun-Oshun Basin Development Authority. Their primary objective was to bring the participants up to date on tropical root crops research, production and extension. Sixteen persons participated.

Orientation to tropical food crops and farming systems research (20 to 30 September). This course was requested and sponsored by the National University of Benin for agricultural students in their final year of academic training. The main objective of the course was to acquaint the students with research conducted at IITA and in the humid tropics on food crops and farming systems and to assist them in identifying projects for the research portion of their degrees. There were 36 participants from two countries.

Rice production (11 October to 19 November). The principal objective of this course was to train research workers and extension supervisors in rice production methods and varietal evaluation under irrigated, hydromorphic and upland conditions. There were 23 participants representing 13 countries.

Tissue culture of tropical roots and tubers (25 October to 12 November). The objective of this course was to familiarize research workers with simple tissue culture techniques and in particular to train them in safe handling and testing of tissue culture material upon its arrival in the recipient country. The course was sponsored by the UNDP grant, Technology Transfer on Root and Tuber Crops. There were 10 participants from 8 countries.

Management tools and perspectives for agricultural research (8 to 20 November). This 64-hour course for IITA research scholars and fellows and scientific staff was conducted largely in the evenings and on Saturdays. It was offered by ISNAR as a joint undertaking with IITA. The principal objectives of the course were: (1) to introduce scientists and future scientists to management tools such as budgeting, scheduling and manpower planning, (2) to improve the decision-making capability and communication skills of the participants, and (3) to improve their ability to plan, implement and evaluate research programs. There were 58 participants from 20 countries.

Genetic resources conservation (15 November to 3 December). This course was conducted jointly by IITA and the International Board for Plant Genetic Resources (IBPGR) and was funded by a grant from the latter. The overall objective of the course was to train participants in the collection and conservation of crop genetic resources. The course covered all major practical aspects of germplasm collection and conservation, including field techniques and gene bank activities. There were 19 participants representing 15 countries.

Cowpea and soybean production (22 November to 17 December). The primary objective of this course was to provide research workers with the practical knowledge and skill they need to establish and manage field trials and to take advantage of improved lines of cowpeas and soybeans distributed through international cooperative trials and nurseries. There were 33 participants from 22 countries.

Table 1. Numbers and countries of participants in IITA's training program from October 1970 through December 1982

Countries	Total	Research scholars[a]	Research fellows[b]	Vacation student research scholars	Research training associates	Courses
Africa						
Angola	7				1	6
Benin	137	25		12	7	93
Botswana	5				1	4
Burundi	6					6
Cameroon	88	9	5		17	57
Central African Republic	13				1	12
Chad	6				1	5
Congo	22				3	19
Egypt	5				1	4
Ethiopia	20	1		2		17
Gabon	4					4
Gambia	18					18
Ghana	119	7	4	16	17	75
Guinea	29				5	24
Guinea-Bissau	9					9
Ivory Coast	18	3				15
Kenya	45		2		3	40
Liberia	48		3		12	33
Libya	1					1
Malagasy Republic	4					4
Malawi	18				1	17
Mali	48				9	39
Mauritania	9					9
Mauritius	4		1	1		2
Mozambique	1				1	
Niger	13				1	12
Nigeria	780	15	32	116	42	575
Rwanda	11	1		1	1	8
São Tomé	7				5	2
Senegal	31				2	29
Sierra Leone	84		2	13	22	47
Somalia	9				1	8
Sudan	16				1	15
Swaziland	2					2
Tanzania	109	2	2		24	81
Togo	44	2	1	5	1	35
Uganda	38	3	1	4	4	26
Upper Volta	46	1	1	1	2	41
Zaire	108	16	10		15	67
Zambia	20				2	18
Zimbabwe	13			9		4
Total for 41 countries	2,015	85	64	180	203	1,483
Asia						
Bangladesh	3				1	2
Japan	2				1	1
India	16	2	2		2	10
Indonesia	11	1				10
Malaysia	6					6
Pakistan	2				1	1
Philippines	12	2			1	9
South Korea	2				1	1
Sri Lanka	14			1	2	11
Thailand	3				1	2
Vietnam	2					2
Total for 11 countries	73	5	2	1	10	55
Australasia						
Australia	3	1	2			
Papua New Guinea	5				1	4
Total for 2 countries	8	1	2		1	4

Table 1. Participants in training, continued

Countries	Total	Research scholars[a]	Research fellows[b]	Vacation student research scholars	Research training associates	Courses
Europe						
Belgium	32	29	2			1
England	10	6	1	2		1
West Germany	17	6	9			2
Netherlands	10	5	1		3	1
Switzerland	1	1				
Total for 5 countries	70	47	13	2	3	5
North America						
Canada	3	1	1			1
United States	50	4	4		13	29
Total for 2 countries	53	5	5		13	30
South and Central America						
Belize	1					1
Brazil	17				3	14
Colombia	2		1			1
Costa Rica	1					1
Cuba	1					1
Dominica	1	1				
Dominican Republic	1				1	
Guyana	3					3
Haiti	1					1
Jamaica	3			1	1	1
Nicaragua	3					3
Peru	4				1	3
Trinidad	4					4
Venezuela	2					2
Total for 14 countries	44	1	1	1	6	35
Pacific Region						
Fiji	2					2
Solomon Islands	1					1
Tonga	1					1
Western Samoa	1					1
Total for 4 countries	5					5
Total for 79 countries	2,268	144	87	184	236	1,617

[a]Candidates for Master's degree or equivalent.
[b]Doctoral candidates.

Table 2. Research fellows and scholars in residence at IITA during 1982

Name	Country	University	IITA supervisor	Degree pursued	Field of Study
Research fellows					
1. M. Ta'Ama	Togo	University of Ibadan, Nigeria	S.R. Singh	PhD	Evaluation of ultra low and high volume insecticide application on cowpeas.
2. M.N. Mahungu	Zaire	University of Ibadan, Nigeria	S.K. Hahn	PhD	Association among important agronomic characters and their effect on tuberous yield of cassava.
3. D. Akibo-Betts	Sierra Leone	University of Ibadan, Nigeria	I.W. Buddenhagen	PhD	Susceptibility of rice varieties stored under different conditions to the rice weevil (*S. oryzae*).
4. B.R. Ntare	Uganda	University of Ibadan, Nigeria	B.B. Singh	PhD	Comparison of early generation selection procedures in cowpeas.

Table 2. Research fellows and scholars, continued

Name	Country	University	IITA supervisor	Degree pursued	Field of Study
5. J.A. Otoo	Ghana	University of Ghana	S.K. Hahn	PhD	Effects of photoperiod, temperature and growth regulators on flowering, fruiting and seed setting and germination of cassava.
6. S.B.C. Wanki	Cameroon	University of Ibadan, Nigeria	Kaung Zan	PhD	Mineral nutrition and soil fertility of upland and lowland rice on the Plain of Ndop, Cameroon.
7. D.A. Shannon	United States	Cornell University, United States	E.A. Kueneman	PhD	Adaptation of soybeans of differential maturity to semiarid environments in Nigeria and soybean response to fertility.
8. F.N. Anno-Nyako	Ghana	University of Science and Technology, Kumasi, Ghana	G. Thottappilly	PhD	Characterization of viruses.
9. S.K. Asiedu	Ghana	McGill University, Canada	E.R. Terry	PhD	Resistance to bacterial blight in cassava.
10. K. Atta Krah	Ghana	University of Ibadan, Nigeria	G.F. Wilson	PhD	Management of *Leucaena* for production of stakes, fuel, wood and leaf nitrogen and its potential in food crop production.
11. J.L. Kiazolu	Liberia	University of Arkansas, United States	B.T. Kang	PhD	Phosphorus and varietal interactions in pluvial and hydromorphic rice.
12. J.A. Ayuk-Takem	Cameroon	University of Ibadan, Nigeria	V.L. Asnani, Y. Efron	PhD	Relationship of maize genotype and altitude in Cameroon.
13. C.F. Yamoah	Ghana	University of Ibadan, Nigeria	M. Ashraf	PhD	Field studies of *Gliricidia sepium*.
14. M. Armon	Nigeria	University of Ibadan, Nigeria	R. Lal	PhD	Soil erosion hazard in eastern Nigeria in relation to soil properties and land use.
15. L.T. Ogunremi	Nigeria	University of Ibadan, Nigeria	R. Lal	PhD	Soil moisture extraction patterns.
16. Mbe-Mpie Mafuka	Zaire	Catholic University of Louvain, Belgium	A.A. Ayanaba, K. Mulongoy	Doctorat	Survival and competitiveness of cowpea rhizobia.
17. M.E. Ogula	Zaire	Faculty Institute of Agricultural Sciences, Yangambi, Zaire	R. Lal, K. Alluri	Doctorat	Soil-water extraction and root system development of rice in relation to cultural practices.
18. C.A. Mba	Nigeria	Technical University of Berlin, West Germany	H.E. Ezumah, B.T. Kang	PhD	Intercropping of cassava and cowpeas.
19. N.O. Iwuafor	Nigeria	Ahmadu Bello University, Nigeria	B.T. Kang, A.S.R. Juo	PhD	Crop residue management.
20. N. Sanginga	Zaire	Faculty Institute of Agricultural Sciences, Yangambi, Zaire	A.A. Ayanaba, K. Mulongoy	Doctorat	Nodulation of *Leucaena* and its contribution to the nitrogen status of the soil.
21. E.T. Eshett	Nigeria	University of Ibadan, Nigeria	P. Ay, A.S.R. Juo	PhD	Production potential and fertility of soils from northern Cross River State, Nigeria.
22. M.B. Niyungeko	Zaire	Faculty Institute of Agricultural Sciences, Yangambi, Zaire	A.S.R. Juo	Doctorat	Micronutrient chemistry in tropical soils.
23. B. Kayombo	Tanzania	University of Dar-es-Salaam, Morogoro, Tanzania	R. Lal	PhD	Effects of soil compaction and crop response under reduced tillage systems.

Table 2. Research fellows and scholars, continued

Name	Country	University	IITA supervisor	Degree pursued	Field of Study
24. N.B. Lutaladio	Zaire	University of Ibadan, Nigeria	S.K. Hahn	PhD	Effect of different planting periods and associated agronomic practices on cassava performance in Zaire.
25. Wong Ting Fook	Mauritius	University of Reading, England	A.S.R. Juo	PhD	Nitrogen and water balance of maize and upland rice in the high rainfall tropics.
26. H.R.K. Franzen	West Germany	University of Göttingen, West Germany	R. Lal	PhD	Influence of tillage and traffic on rooting pattern and yield in an Alfisol in Nigeria.
27. U. Sabel-Koschella	West Germany	Technical University of Munich, West Germany	R. Lal	PhD	Soil erosion.
28. R.P.A. Unamma	Nigeria	University of Ibadan, Nigeria	I.O. Akobundu	PhD	Weed competition in yams (*Dioscorea* spp.).
29. S.N. Utulu	Nigeria	University of Ibadan, Nigeria	I.O. Akobundu	PhD	Persistence and movement of herbicides in the soil.
30. J.E.G. Ikeorgu	Nigeria	University of Ibadan, Nigeria	H.C. Ezumah	PhD	Use of two common Nigerian vegetables (okra and melon) to maximize benefits from intercropped cassava and maize.
Research scholars					
1 Muimba Kankolongo Ambayeba	Zaire	University of Ibadan, Nigeria	S.K. Hahn	MPhil	Latent infection of *Colletotrichum manihotis* in cassava.
2. Idumbo Kasele Nsongi	Zaire	University of Ibadan, Nigeria	S.K. Hahn	MPhil	Effect of some environmental factors on cassava tuberization.
3. Kiala Kilusi	Zaire	University of Ibadan, Nigeria	S.K. Hahn	MPhil	Screening cassava for resistance to cassava green spider mite.
4. Tomu Anota	Zaire	University of Ibadan, Nigeria	K. Leuschner	MPhil	Clonal effect of some sweet potato varieties on reproductive performance of *Cylas punticolis*.
5. H.O. Nsaiama She	Zaire	University of Ibadan, Nigeria	H.R. Herren	MPhil	Biological control of cassava mealybug.
6. Muyolo Gilumbu	Zaire	University of Ibadan, Nigeria	E.R. Terry	MPhil	Synergistic effect of *Xanthomonas campestris* pv. manihotis and *Colletotrichum manihotis* on cassava and assessment of potential yield loss.
7. S. Kundaiker	United Kingdom	University of Reading, England	E.A. Kueneman	MSc	Soybean yield trials and soybean trap cropping experiments.
8. W.N.O. Hammond	Ghana	University of Ghana	L.E. Jackai	MSc	Cowpea pests *C. shadebi* and *C. tomentosicollis*.
9 A.S. Ahissou	Benin	National University of Benin	I.O. Akobundu	Ing. Agr.	Weed interference and control in hydromorphic rice.
10. A.B. Salifu	Ghana	University of Ghana	S.R. Singh	MSc	Mechanism of flower thrips resistance in resistant cowpea cultivars.
11. G.B. Kouakanou	Benin	National University of Benin	J.M. Fajemisin	Ing. Agr.	Fusarium ear rot of maize in the field and its postharvest predisposition of kernels to deterioration.
12. S. Dassou	Benin	National University of Benin	E.A. Kueneman	Ing. Agr.	Varietal differences in pod pubescence of soybeans and its relation to population suppression of pod sucking bugs.
13. D. Koudoro	Benin	National University of Benin	B.T. Kang, C.H. ter Kuile	Ing. Agr.	Evaluation of four woody fallow species for alley cropping in a maize/cowpea annual rotation.
14. O. Adjadi	Benin	National University of Benin	B.B. Singh	Ing. Agr.	Inheritance of bruchid resistance in cowpeas.

Table 2. Research fellows and scholars, continued

Name	Country	University	IITA supervisor	Degree pursued	Field of Study
15. A. Alavo	Benin	National University of Benin	M.S. Bjarnason	Ing. Agr.	Maize breeding.
16. M.C. Van der Meersch	Belgium	Catholic University of Leuven, Belgium	A.S.R. Juo	Ing. Agr.	Dynamics of soil organic matter under different cropping and fallow systems.
17. G. Moens	Belgium	Catholic University of Leuven, Belgium	M.N. Alvarez	Ing. Agr.	Sink repartitions in sweet potatoes.
18. J. Janssen	Belgium	Catholic University of Leuven, Belgium	G.F. Wilson, A.N. Atta Krah	Ing. Agr.	Effect of mulch on the root system of plantains.
19. C. Laloux	Belgium	State Faculty of Agricultural Sciences, Gembloux, Belgium	G.F. Wilson, A.N. Atta Krah	Ing. Agr.	Growth of *Desmodium ovalifolium* in a pure stand and intercropped with maize.
20. X. Cornet	Belgium	State Faculty of Agricultural Sciences, Gembloux, Belgium	K. Alluri	Ing. Agr.	Glume discoloration in rice.
21. M. Lobuscher	West Germany	University of Bielefeld, West Germany	P. Ay	M.A.	Impact of agricultural development projects on rural development and effects of socioeconomic changes on farming systems.
22. V.W.M. Moenikes	West Germany	University of Bielefeld, West Germany	P. Ay	M.A.	Impact of agricultural development projects on rural development and effects of socioeconomic changes on farming systems.
23. W. Niemeyer	West Germany	University of Bielefeld, West Germany	P. Ay	M.A.	Impact of agricultural development projects on rural development and effects of socioeconomic changes on farming systems.
24. K. Wuerdermann	West Germany	University of Bielefeld, West Germany	P. Ay	M.A.	Impact of agricultural development projects on rural development and effects of socioeconomic changes on farming systems.
25. K. Zillikens	West Germany	University of Bielefeld, West Germany	P. Ay	M.A.	Impact of agricultural development projects on rural development and effects of socioeconomic changes on farming systems.
26. J.P. Goffart	Belgium	Catholic University of Louvain, Belgium	D. Perreaux	Ing. Agr.	Viability of *Colletotrichum gleosporoides* P. sp. *manihotis*.
27. S. Huke	United States	Yale University, United States	R. Lal	MSc	Soil erosion.
28. B. Duguma	Ethiopia	University of Ibadan, Nigeria	B.T. Kang	MSc	Comparative study of root systems of agroforestry species, seed collection and processing.
29. G.N. Ngala	Cameroon	University of Ibadan, Nigeria	Kaung Zan	MPhil	Studies of spikelet and panicle fungal diseases of rice.
30. D. Birmingham	United States	University of Illinois, United States	B.T. Kang	MSc	Determination of phosphate requirements of early maturing maize cultivars and early and intermediate maturing cowpeas.
31. B. Lame	Benin	National University of Benin	D. Perreaux	Ing. Agr.	Cassava anthracnose disease.
32. T. Haug	Switzerland	Federal Technical High School, Switzerland	H.R. Herren	Ing. Agr.	Biological control of CM.
33. Mbulu Ntoto	Zaire	University of Ibadan, Nigeria	H.C. Ezumah	MSc	Effects of mulching on cassava.
34. B. Landu-Kalemba	Zaire	University of Ibadan, Nigeria	H.C. Ezumah	MSc	Timing of fertilizer application in cassava.

Table 3. Numbers and countries of participants in IITA's non-degree-related training programs during 1982

Country	Number of participants	Country	Number of participants
Cameroon	5	Mozambique	1
Congo	1	Nigeria	4
Ghana	2	Sierra Leone	2
India	1	Tanzania	1
Jamaica	1	United States	4
Kenya	2	Zaire	2

International Programs

IITA provided much valuable assistance to national agricultural institutes during 1982 through its Office of International Programs. This office is responsible for planning, conducting and evaluating special research projects that are directly linked to the Institute's core program (consisting of the crop improvement, farming systems and training programs) but funded through special contributions from the Institute's donors. In carrying out this task, the Office works very closely in all technical matters with the core programs.

Its overall objectives are to cooperate with national programs in the development of their research capabilities, to extend technology developed at IITA to national and regional research centers (which then evaluate this technology and adapt it to fit their conditions), and to obtain feedback that aids IITA researchers in planning future research.

The main objectives and activities of the 22 special projects maintained by International Programs during 1982 are described below under two categories: mandated research projects and cooperative special projects. You will find the results of research carried out under these projects reported in the sections on the various core programs.

Mandated Research

The mandated research projects, of which there were 15 during 1982, used to be termed core-supplementing projects because they extend the research of the Institute's core programs. Their new title underscores the fact that these projects enable IITA to carry out its mandated research more effectively.

Semi-Arid Food Grains Research and Development (SAFGRAD) Project. In the CGIAR system, IITA is responsible for maize improvement in Africa and has a worldwide mandate for improvement of cowpeas. The SAFGRAD project is an important part of IITA's effort to fulfill those responsibilities. The Institute has a plant breeder, two agronomists and an entomologist at Ouagadougou, Upper Volta, working with the national, regional and other international agencies involved in SAFGRAD to develop improved maize and cowpea varieties and better cultural practices that are compatible with the farming systems of the semiarid region. The SAFGRAD project has become the focal point for maize research in the semiarid regions of West Africa primarily because of its program for multilocational testing of maize germplasm. The project also has done much to strengthen national programs through in-service and degree-level training.

High yielding varieties technology project. This is a multilocational crop improvement program for maize, rice, cowpeas and soybeans. In the project's first phase, which began in October 1981, IITA researchers (including four agronomist/breeders, one for each of the four crops involved) carried out international testing and demonstration of high yielding varieties. During the second phase,

Table 4. IITA Training courses conducted off site in cooperation with national agencies from 1974 through 1982

Course title	Year	Location	Clientele	Number	Country of clientele
Rice production	1974	Shendam, Nigeria	Extension personnel	23	Nigeria
Conducting coordinated agronomic trials	1976	Makeni, Sierra Leone	Field assistants	47	Sierra Leone
Rice production and conducting agronomic trials	1976	Kenema, Sierra Leone	Agricultural officers and superintendents of eastern and southern regions	23	Sierra Leone
Rice production and conducting agronomic trials	1976	Port Loko, Sierra Leone	Agricultural officers and superintendents of northeastern and northwestern regions and the western area	18	Sierra Leone
Rice production	1976	Makali, Sierra Leone	Peace Corps volunteers	26	United States
			Extension officers	10	Sierra Leone
Field surveying and data collection (two courses)	1982	Bambui, Cameroon	Extension field demonstrators	75	Cameroon
Maize and cowpea production	1982	Kamboinsé, Upper Volta	Field extension personnel of the foundation seed production project	15	Upper Volta
			Seed multiplication personnel	5	Benin

24 national programs will participate in multilocational testing to identify varieties that are suitable for the various ecologies of tropical Africa. Many technicians from these programs will receive in-service training, and others will work toward degrees in various agricultural disciplines. This project should markedly increase the pace at which new technology is developed for increasing rice, maize, cowpea and soybean production in tropical Africa.

Research on plantain production in Africa. The purpose of this project is to increase both the productivity and longevity of plantains, which are an important food in the humid forest zone and a key component in many of the region's cropping systems. The project is staffed by a plantain agronomist and a diversified crops agronomist. Drawing on research done by IITA's Farming Systems Program, these researchers are studying the physiology of suckering, determining the effects of mulch and soil organic matter on growth and yield, and establishing the multiannual yield potential of various cultivars. Much of this work is taking place at IITA's high rainfall substation at Onne, Nigeria.

In a closely related project, scientists are concentrating on the interaction between nutritional, ecological and hormonal factors in the regulation of sword sucker development and on in-vitro culture techniques for rapid multiplication of disease free propagating material. This work is taking place at the Laboratorium voor Tropische Plantenteelt, Katholieke Universiteit, Leuven, Belgium.

Accelerated research on biological control of the cassava mealybug and green spider mite. These two pests have become a serious threat in all the cassava producing areas of Africa. This project was created so that IITA could work more quickly on biological control of them. Institute scientists have carried out an extensive survey in Latin America for natural enemies of the mealybug and spider mite, tested the effectiveness of those enemies, and developed techniques for mass rearing and release of them. In the search for predators IITA has worked closely with CIAT, the Commonwealth Institute of Biological Control (CIBC), and Empresa Brasileira de Pesquisa Agropecuária (EMBRAPA).

On-farm, leucaena/maize/yam alley cropping trials. This project was completed during 1982, and a final report of its results is now available. The project involved an IITA agricultural economist, farming systems agronomist and soil scientist. Their objectives included: identifying problems in establishing and growing *Leucaena leucocephala* under farmers' conditions; testing the suitability of this species as a planted fallow; utilizing it as a source of yam staking material in the yam producing middle zone of Nigeria; determining the performance of yam and maize alley cropped with leucaena; and finding farmers willing to help adapt this technology to their conditions.

Research on nitrogen and phosphate fertilizers in humid tropical Africa. This project is an extension of research done by IITA's Farming Systems Program on soil management and cropping systems. The three soil scientists assigned to the project are studying what happens to native and chemically or biologically fixed nitrogen in the cropping systems of the humid tropics and determining the amount of native phosphorus and the requirements of external phosphorus in the soil of the region. Their ultimate aim is to develop fertilizer management practices that will permit continuous cropping by small farmers. They are also searching for local substitutes for expensive imported phosphorus fertilizers.

Maximizing nitrogen fixation by cowpeas and soybeans in farming systems in the humid tropics. To boost production of the protein rich legumes in the humid tropics, it is first necessary to increase the efficiency of nodulation and nitrogen fixation in these crops. IITA is working toward that end in this project with the Boyce Thompson Institute (BTI) and Department of Soil Microbiology at Cornell University (United States) and with the University of Western Australia. The project is being carried out by 11 scientists from these organizations.

The scientists' principal activities are to investigate the population size and diversity of types of legume bacteria in the soils, to screen cowpeas and soybeans in the field for high nitrogen-fixing ability, to determine the potential for improving nodulation and nitrogen fixation through the use of inoculants, and to identify superior cowpea and soybean lines and rhizobia strains with high symbiotic potential as well as soybean lines that can nodulate with indigenous strains of rhizobia. These soybean lines are being used in a breeding program to combine the nodulating character with other desirable characteristics. The project also includes a training program that has attracted graduate students and postdoctoral fellows from Latin America, Asia and Africa.

Improved agricultural research systems for West Africa. This project, which is staffed by an IITA agronomist and agricultural economist, will eventually consist of four parallel projects, three based at national research institutes in Nigeria, Cameroon and Ivory Coast and a fourth, based at IITA, that will coordinate the other three. The project was created to bridge the gap between research institutes and the agencies that transfer new technology to farmers. Its principal objectives are to develop socioeconomic survey methods for pinpointing problems in farming systems or features of them that can be improved, to establish an adaptive research program at the farm level for translating research results into better production practices that can be used by agricultural development projects, and to set up a system for getting feedback from farmers to the national research institutes to help researchers plan future research.

The project will also provide training for African researchers and technicians in farm level adaptive research.

Grain legume information center. The purpose of this project is to collect and distribute information about cowpeas and other food legumes on which IITA does research. The principal activities of the documentalist staffing the project are to locate literature on these crops, write abstracts of it in English, index the literature, set up a document storage and retrieval system, provide a literature search and duplication service to grain legume workers, publish bibliographies, and encourage communication among grain legume workers by means of newsletters, meetings and workshops.

Development of high yielding hybrid maize varieties for Nigeria. Two maize populations developed at IITA—TZB and TZPB—have sparked a major transformation of Nigerian agriculture, particularly through the work of the integrated agricultural development projects funded by the World Bank. Technology promoted by these projects is being put into practice all across the maize belt of Nigeria. What is needed now are high yielding maize hybrids so that the technology can be more fully exploited and growth in maize production sustained. That is essentially the objective of this project, which will develop inbred lines that are adapted to tropical conditions and from these produce high yielding hybrids for the major maize production areas of Nigeria. The project is staffed by two breeders and a pathologist/breeder.

Soil erodibility in relation to soil properties and management practices. The purpose of this project is to promote a better understanding of the soil fertility maintenance problems of the major soils in West Africa. The two scientists involved in the project are investigating the erodibility of a wide range of soils in Nigeria and the relation of erosion susceptibility to basic soil properties. An important aim of this work is to develop a means by which the risk of erosion can be evaluated through routine laboratory analysis. Part of the work is being carried out at IITA and part of the State University of Ghent in Belgium.

Root crops phytopathology research. This project complements IITA's breeding program in cassava, yams, sweet potatoes and cocoyams by providing information through basic phytopathological research on the major diseases of these root crops. Among the main activities of the project, which is staffed by an IITA pathologist/breeder and a pathologist at Universite Catholique de Louvain, are to find mechanisms of disease resistance and develop rapid resistance screening methods.

Efficiency of nitrogen utilization in farming systems of the West African humid tropics. The scientist involved in this project is attempting to determine the amount of leaching and the nitrogen balance under various cropping systems of the high rainfall tropics. Located at IITA's substation in Onne, Nigeria, the project complements the Institute's core research on soil fertility and chemistry and contributes to its goal of developing more effective fertilization programs and more efficient use of nitrogen fertilizers.

Adaptive rice agronomic research. This project is providing IITA's Farming Systems Program with an important opportunity for on-farm testing of its technology. In cooperation with the Bida Agricultural Development Project (BADP), Nigeria, the project's IITA agronomist is identifying agronomic problems through on-farm trials in the major rice production zones with which BADP is concerned and is assisting Nigerian extension workers in developing recommendations for farmers.

Cooperative Special Projects

Like its 15 mandated projects, International Program's 7 cooperative projects fall well within the scope of IITA's mandate and support the research of its core programs. The difference between these two categories of projects is that IITA does not seek involvement in the cooperative projects but rather undertakes them at the request of particular governments or regional organizations. IITA helps establish goals and provides the trained personnel needed to start the projects, and then trains national scientists and technicians to assume responsibility for the projects as soon as possible.

Food crops research within the ZAPI-EST rural development program of Cameroon. IITA's contribution in this endeavor (the acronym stands for Zones d'Actions Prioritaires Integrées de l'Est or Priority Action Areas of the East for Integrated Development) is a five-year, three-phase research and training program. The aims of this program are to identify problems preventing increased food production in eastern Cameroon, devise improved methods that local farmers can use with the resources available to them, develop a plan for establishing crops research capability in this region, and to provide Cameroonians with research training at IITA. Staffed by a farming systems agronomist, this project will give IITA a good opportunity to test its improved rice, cassava and maize lines for adaptation to the humid forest environment.

Food crops field trials and training program in São Tomé and Príncipe. Through this project IITA is providing training and technical guidance to the Ministry of Agriculture of the government of São Tomé and Príncipe in testing and evaluating food crop varieties and cultural practices. The project has given IITA an important link with Portuguese-speaking Africa and an excellent opportunity to test the performance of improved rice, maize, legume and root crops material in a tropical island environment. Of particular value was the chance afforded by this

project for IITA researchers to evaluate maize streak resistant varieties under epiphytotic conditions.

Small farms farming systems research in Ghana. This project, which is located at Atebubu, Ghana, consists of two main phases: soil fertility management and improved crop production management. The former is concerned primarily with soil series characterization; fertilizer use efficiency; the interaction of fertilizer, plant density and weeds and its influence upon rice yield; and alley cropping and relay/rotation cropping trials. The crop production phase involves variety testing for yield, date of planting and weed control trials, and cropping systems developed for yam, maize and rice based systems. The project has permitted useful field testing of land management practices developed by IITA's core program. This testing has been particularly worthwhile since the agroclimate of the project's location is very similar to that of Ibadan.

Zaire national cassava research program. IITA was originally invited to participate in this project to assist in developing cassava varieties for Zaire with resistance to bacterial blight and mosaic disease. Because of the enormity of the threat from the cassava mealybug and green spider mite, however, the program's emphasis has been shifted to control of those pests. The core program's work on mechanisms of resistance is strongly reenforced by the research carried out under this project. The ultimate aims of the project, which has a staff of seven persons, are to help researchers in Zaire s National Cassava Research Program increase the yield, resistance to diseases and insect pests, and nutritional level of cassava; to assist the national program in making new varieties and research results available to farmers; and to provide Zairian agricultural workers with in-service and degree-level training.

Food legumes in Upper Volta. With funding from IDRC, the IITA cowpea breeder responsible for this project is working to develop a breeding program for the development of improved cowpea varieties. These varieties must, among other things, be suited to mixed and monoculture as well as relay cropping patterns in the Sudanean and Sahelian areas of Upper Volta and other African countries. The project has enabled IITA to expand its cowpea improvement program to include the Sahelian region and has provided an important opportunity for IITA researchers to carry out genetic improvement of cowpeas in harsh, drought prone environments such as do not exist in Nigeria.

Cameroon national cereals research and extension. This project contributes to work being done in IITA's Cereal Improvement and Farming Systems programs. It was designed to assist Cameroon's National Cereals Research and Extension Project in the development of improved agronomic practices and high yielding varieties of cereal crops that are suited to mixed and monocropping systems in the country's various ecological zones. The project also includes a program for testing improved varieties and cultural practices in farmers' fields and a strong training program that will provide Cameroonian technicians with on-the-job, technical and degree-related training. The project staff consists of nine IITA scientists and one administrator.

Root crops improvement program in Cameroon. Small scale farmers are the ultimate beneficiaries of this project, the purpose of which is to develop improved varieties and production systems that will increase yields of cassava, yams, cocoyams and sweet potatoes in Cameroon. Cameroonians will also receive in-service and academic training so that eventually they can take over all aspects of the program. One of the project's main concerns is the cocoyam blight/root rot complex, a major disease of *Xanthosoma* sp. (one of IITA's mandate crops) in eastern Nigeria and in Cameroon. Through screening in Cameroon, researchers hope to identify resistant materials. They have also been testing and evaluating breeding material of the four crops on which IITA's Root and Tuber Improvement Program is conducting research. The project is staffed by a root crops breeder and an agronomist.

Research Support Units

The research and training programs at IITA receive essential services from a number of support units, including Farm Management, the Genetic Resources Unit, Virology Unit, Analytical Service, Laboratory, Library and Documentation Center, and the Office of Public Affairs and Development, which includes the Communications and Information Office and Conference Center. Other units not reported on here are the Biometrics Unit and Physical Plant Services.

Farm Management

The farm staff manages IITA's 1,000-ha main research facility at Ibadan, its 80-ha high rainfall station at Onne, and its 24-ha midrainfall station at Ikenne. Cooperating with national research stations, the staff also provides support at different locations in northern Nigeria to enable IITA scientists to grow trials under various climatic conditions and soil types. An additional task carried out by Farm Management in 1982 was to assist IITA cooperative projects in Upper Volta and Zaire in developing and improving their research facilities.

Farm Management provides research land, irrigates and applies fertilizers and pesticides. Scientists are encouraged to mechanize whenever possible; mechanical planters are available, along with mechanized spraying and harvesting equipment.

Farm Management gave support and technical assistance to research being carried out within

Nigeria at Mokwa, Ilorin, Ikenne, Onne and Zaria. A mobile unit consisting of a pickup truck and 26-ft gooseneck trailer enabled the staff to transport farm machinery to various locations, prepare the land, apply fertilizers and plant IITA trials mechanically. At Ikenne, a research substation south of Ibadan that is managed directly by the Farm Office, a program of upgrading and improvement was undertaken. Early in the year, all roadways were realigned, and field surface drainage was improved. A farm office, workshop, and equipment storage facilities were built with a grant from the European Economic Community (EEC). Further land development and a bore hole for irrigation are planned for 1983.

The staff at Onne continued research on crop improvement and farming systems and made a number of improvements in its facilities. Upland rice research was begun with the planning of an early and medium maturing varieties trial, and construction commenced on an underground lysimeter building for collecting information about the soil's chemical properties. The staff was joined by a soil scientist, who took charge of the nitrogen project being carried out jointly by IITA and the government of the Netherlands.

The substation is located in the humid zone of coastal Nigeria and was donated to IITA by Rivers State in 1974. The facilities include five houses, six offices, two laboratories, a maintenance workshop and machine shed, crop dryer and guest house. The work done there on soil fertility and chemistry, agroforestry, plaintains, cassava, sweet potatoes, maize, rice and cowpeas supplements that of IITA's four major research programs. The results of research at Onne are reported in the appropriate sections of this report.

A major accomplishment this year was the adoption of minimum and no-tillage systems by the cereals, grain legume and cassava programs of IITA. In these systems weeds are controlled by the use of knock-down and preemergence herbicides, and planting can be done with mechanical cone seeders specially designed to plant directly through a dead mulch cover. For hand-planted trials, small strips are rotovated through the dead mulch, leaving the soil between the rows undisturbed. Minimum tillage reduces erosion, maintains a mulch cover, eliminates crusting and enables the soil to retain moisture better.

Among the other projects completed this year at the Institute's main station was a grain handling and processing building with dryers and cold rooms (funded by an EEC grant). The drying rooms were used to dry improved IITA maize seed, and the cold rooms were used for seed storage. Equipment for threshing, bagging, weighing, cleaning, treating and handling improved varieties of seed has been ordered and will be installed in 1983.

A new workshop for repair and servicing of farm equipment has been completed and is being equipped Construction of a new irrigation pump house and installation of new irrigation pumps is underway. This facility will improve irrigation of IITA's 40 ha of dry season land. An ablution facility for farm staff and an equipment wash slab are being built.

New equipment was donated to the rice program by the government of Japan and to the grain legume program by the EEC. Additional equipment was purchased by the Institute for field operations. The machinery includes additional no-till planters, crop harvesting, threshing, mulching and cultivation equipment, prime movers and irrigation pumps for dry season cropping.

Farm Management maintains all farm roads and soil conservation measures on the research farms through its heavy equipment section. It also manages three lakes at Ibadan, which provide both drinking and irrigation water to the site. Aquatic weeds are removed from the lakes with a waterweed harvester: this material is then spread on the research plots to increase organic matter and improve soil conditions.

The farm's vegetable and fruit production unit provides fresh, high quality vegetables and fruit to IITA staff as well as to the Institute's cafeteria and the staff canteen. The lakes are stocked with different species of fish, which are caught by gill nets and also provide excellent sport fishing. The vegetable garden and fishing units are self-maintaining; sales of produce cover all inputs.

A land clearing and development conference was held at IITA during which primary forest was cleared using bulldozers with shear blade and tree pusher attachments. Additional land was cleared using manual labor and chain saws.

Farm Management staff contributed to all major training courses and trained students in farm management and mechanization. The staff also conducted many field tours and received numerous visitors who showed interest in land clearing techniques and minimum tillage farming.

Genetic Resources Unit

Conservation and Distribution

A major event for the genetic resources unit in 1982 was the commission of a seed store operated at −18°C for long-term seed conservation. The store is 7.3 m wide, 4.6 m long, and 2.4 m high and has a capacity of 48,000 aluminium cans 99 mm high and 46 mm in diameter. Each can holds around 95 g of cowpea seed or 69 g of rice seed. IITA will store three to five cans of cowpea seed (depending on the seed size) and two cans of rice seed of each germplasm accession for long-term conservation. Seed for storage is dried to less than 7% moisture content and permanently sealed in the aluminium cans. Under these storage conditions, the seed is expected to remain viable for 50 years or more. In this way germplasm, which is the foundation for present and future plant breeding, can be properly maintained.

Seed must have a germination rate of 88% or above

before it is sealed in cans for long-term conservation. If the percentage germination of an accession is 85 or below, it is rejuvenated. During 1982, 630 accessions of rice and 500 of cowpeas were sealed in cans and 1,049 accessions of soybeans in aluminium foil envelopes for long-term storage.

The Genetic Resources Unit continues to assemble new germplasm to enlarge the genetic variability of IITA's gene bank. During the year, 699 samples of cowpeas, 122 of Bambarra groundnuts and 545 of rice were received. These included a donation by Institut de Recherches Agronomiques Tropical (IRAT) and by a national program of the Malagasy Republic and samples provided by the International Board of Plant Genetic Resources. IITA's gene bank now holds 11,000 registered accessions of cowpeas, 1,504 of African rice, 4,558 of Asian rice, 1,300 of soybeans and over 2,000 of other crops. This germplasm is provided to national scientists free of charge on request.

In response to 235 requests from 32 countries, the Genetic Resources Unit distributed a total of 9,812 samples of germplasm from its gene bank for research. In addition, a total of 216 kg of seed of 16 elite cowpea varieties and advanced cowpea breeding lines multiplied by the unit were provided to IITA's cowpea improvement program for distribution to 34 countries for international field observational trials. Also, a total of 320 kg of seed of 30 varieties of cowpeas, rice and pigeon peas was provided to scientists for experiments or to national development projects for large-scale seed multiplication.

Multiplication and Rejuvenation

Newly received germplasm or old germplasm that has been depleted by use is grown for seed increase. Accessions that have a low percentage of germination (below 85%) are sown for rejuvenation. In 1982, 1,700 new accessions of rice germplasm were multiplied, and 350 rice accessions with a low percentage of germination were rejuvenated. The unit also multiplied 643 new accessions of cowpea germplasm and another 315 accessions depleted by use. In addition, a total of 2,937 accessions of cowpea germplasm, most of which had been multiplied in 1977, and 820 accessions of soybeans were rejuvenated.

Evaluation and Uses of Rice Germplasm

Rice yellow mottle virus resistance screening. Rice yellow mottle virus (RYMV) is now widespread in Africa and could become a serious threat to rice cultivation in this region. IITA's rice breeding program has begun breeding for varieties with tolerance to this disease. As part of that effort, the genetic resources unit screened rice germplasm for RYMV resistance and studied the variability of rice germplasm in its reaction to this disease.

Studies carried out by the unit last year on the reaction to RYMV of over 1,000 *O. sativa* accessions and 75 *O. glaberrima* accessions after artificial mechanical inoculation under normal field conditions indicated that whereas most of the *O. sativa* was highly susceptible, most of the *O. glaberrima* was highly tolerant to this virus. Tolerance here means that plants are either symptomless or show only trace symptoms and are fully fertile with no obvious reduction in plant height after mechanical inoculation, but that the virus can be detected by serological testing or the ELISA technique.

Rice accessions that appeared to be highly tolerant in last year's test were retested this year in the glasshouse and screenhouse. Sixty-five accessions of *O. sativa* and 30 of *O. glaberrima* were confirmed as being highly tolerant. Two accessions of *O. glaberrima* appeared to be immune; serological testing by a virologist showed no virus after mechanical inoculation. The studies also indicated that most of the tolerant accessions are upland varieties collected in Africa.

Blast resistance screening. In 1982 the Genetic Resources Unit carried out a field screening test that included 536 accessions of the African *O. sativa* land races, 287 of *O. glaberrima*, 20 varieties of *O. sativa* developed by the International Rice Research Institute (IRRI), 30 cold tolerant *O. sativa* varieties from Korea and 15 blast differential rice varieties. The test revealed that most of these Asian varieties are highly susceptible to the local blast disease at IITA: 17 IRRI varieties (85%), 21 Korean rice varieties (70%), 95 Accessions of *O. glaberrima* (33%), 69 accessions of the African *O. sativa* (13%) and 6 of the blast differential varieties were found to be susceptible to blast (Table 5). Those varieties and others with similar genotype are probably unsuitable for Ibadan or areas with a similar ecology.

It is not surprising that a low number of accessions of the African *O. sativa* germplasm were susceptible in this screening test because they were selected on the basis of no blast damage in field screening carried out during 1980 and 1981. The experiment was first begun in the main growing season of 1980 with a sample of 1,132 accessions of *O. sativa* germplasm. The susceptible ones were eliminated from the screening in subsequent years. The remaining 467 accessions of *O. sativa* were resistant to local blast diseases in three growing seasons over a period of three years. These materials are likely to be resistant to prevailing races of blast in Ibadan.

Stem borer resistance screening. The unit handed over 755 accessions of rice germplasm to an IITA rice entomologist for stem borer (*Diopsis thoracica*) resistance screening, and he selected 32 accessions with less than 10% infestation by this insect. The materials selected will be retested for confirmation of their resistance.

Agrobotanical characterization and evaluation. Fifteen hundred accessions of rice germplasm were evaluated for up to 41 agrobotanical characters, and the information gathered was updated by computer. Six *O. sativa* accessions that had good

agronomic characteristics and outyielded a local check were identified during 1982 field evaluations. These rice accessions were handed over to rice agronomists for further evaluation.

From its gene bank, the unit selected over 200 rice varieties, including many typical upland types from all over the world and varieties with superior agronomic traits (such as the largest and heaviest panicles or resistance to blast) for evaluation in Cameroon's National Cereals Research and Extension Project, which is being conducted by IITA and funded by USAID. Feedback information from the project indicates that some of the materials are performing very well, both in terms of agronomic aspects and disease resistance. Further testing of the materials will be carried out in 1983.

Characterization and Uses of Cowpea Germplasm

Agrobotanical characterization. The seed coat color of over 5,000 accessions of cowpea germplasm was evaluated and characterized this year. A wide range of variability in this character exists in the germplasm. Forty-two distinct seed coat colors and patterns were identified, and their characteristics will be described. The unit also evaluated 360 accessions of cowpea germplasm for 29 agrobotanical characters and another 1,500 accessions for four characters. In addition, studies on the stability and suitability of cowpea descriptors were begun in 1982 and will be continued in 1983.

Insect pest and disease resistance screening. The use of cowpea germplasm has increased as IITA scientists have continued the search for better sources of resistance to insect pests and diseases for use in plant breeding. A total of 7,184 samples of cowpea germplasm were distributed to scientists in the crop improvement program for insect pest and disease resistance screening during 1982. Of the 3,683 accessions that were screened for thrips resistance, six were identified as being resistant; their level of resistance is higher than that of accessions identified previously. Over 4,000 accessions were screened for bruchid resistance, and two new sources of resistance (TVu 11952 and TVu 11953) were identified. Of the 461 accessions that were screened for resistance to cowpea aphid-borne mosaic virus (CAMV) and cowpea yellow mosaic virus (CYMV), one (TVu 7941) was identified as being resistant to CAMV, and two (TVu 5971 and TVu 7483) were found to be resistant to CYMV. Over 200 selected accessions were screened for aphid resistance, and six sources of resistance (TVu 3272, 9836, 9914, 9929, 9930 and 9944) were identified. Of the approximately 1,000 accessions that were screened for resistance to pod borer (*Maruca testulalis*), 48 appeared to be resistant in a preliminary test. They will be further tested to confirm their level of resistance.—*N.Q. Ng*

Table 5. Blast disease reaction of rice varieties in a field screening test, IITA, 1982

Variety	Score[a]
Blast differential varieties	
Aichi Asahi	0
BL1	0
Fugisaka	7
Fukunishiki	1
Ginga	2
Hokkai 189	2
Kanto 51	7
Kusabal	2
K1	6
K3	6
K59	7
Pi No. 1	1
Shin 2	1
Toride 1	0
Yashiro	6
Control varieties	
BG90-2	8
OS-6	3
IRRI varieties	
IR 5	9
IR 8	9
IR 20	9
IR 22	9
IR 24	9
IR 26	9
IR 28	8
IR 30	9
IR 32	6
IR 36	6
IR 38	6
IR 40	6
IR 42	6
IR 43	8
IR 44	4
IR 46	7
IR 48	4
IR 50	9
IR 56	6
IR 52	2
Korean varieties	
Milyong 23	8
Kumkang Bae	9
Mansuk Bae	9
Milyang 30	9
Milyang 42	8
Tae Baik Bae	2
Saekweng Bae	0
Hengang Waxi	1
Baikwoon Waxi	1
Chung Chung	7
Surak Bae	4
Do Bong Bae	2
Chinjoo Bae	6
Nakdong Bae	7
Akibare	7

Table 5. Blast disease reaction, continued

Variety	Score[a]
Nong Baik	6
Pargun	7
Akihikari	6
Norimne	4
Parkwang	8
Samsesung	8
Choopong	3
Josaeng Tongi	9
Ysungnam Joseng	9
Honan Joseng	8
Milyang 21	8
Kwang Kum	9
Saesbi el	9
Minimikari	8
Parkoing	4

[a]Varieties with a score of 5 or above are considered susceptible. Based on IRRI, 1980, *Standard Evaluation System for Rice*, 2nd edition.

Virology Unit

Working with some eight crops and over 20 different viruses, the Virology Unit provides valuable research support to all of IITA's crop improvement programs. In general, the unit is responsible for identifying, characterizing and developing suitable resistance screening and/or indexing methods for all viruses that are or may become a serious problem in the crops for which IITA has a mandate. For that purpose the unit gathers detailed information on the epidemiology and ecology of the virus diseases identified in those crops.

All this information is considered in the context of changing cropping systems and agricultural practices in the tropics and of new varieties being developed for the region. Potentially important endemic virus diseases can thus be prevented from becoming serious threats to crop production, and breeding strategies can be adjusted to fit new information about the viruses. The results of virology research carried out this year are reported in the sections on IITA's crop improvement programs.

Analytical Service Laboratory

The Analytical Services Laboratory continued to perform routine analysis of soil, plant and water samples. During 1982 the laboratory analyzed 9,030 soil samples for chemical and physical properties. A total of 7,535 plant tissue samples were analyzed for nutrient elements, and 1,701 tuber samples were analyzed for total and free cyanide. The number of water samples analyzed for chemical composition amounted to 4,474. In addition, 514 animal tissue, blood and serum samples were analyzed for various elements. A total of 108,829 assays were carried out during 1982. Although the majority of samples came from the IITA research programs, an increasing number of requests from universities and research Institutes in Nigeria were also handled by the laboratory.

Library and Documentation Center

The Library added 3,600 monographs and 2,000 volumes of periodicals to its collection during 1982. In December the Library's holdings consisted of 25,000 volumes of periodicals, 23,000 books, 4,000 pamphlets, 3,500 microform items, 1,600 slides and 33 audio-cassettes. In addition, the Library has over 6,000 reprints on specialized subjects such as yams, plantains and cowpeas. Current acquisitions were announced every month through two media: *Selected List of Publications Received in the Library* and *Grain Legume Current Titles*.

With *Le Riz: Publications en Langue Française Disponibles à la Bibliothèque de l'IITA*, we initiated a series of bibliographical guides to our French language collection. Another guide in the series, *Répertoire des périodiques en langue française reçus à la bibliothèque*, was produced in 1982.

Sponsorship of the International Grain Legume Information Centre by the International Development Research Centre was extended by one year to July 1983. Two issues (Numbers 24 and 25) of the *Tropical Grain Legume Bulletin* were published and distributed. Two additional numbers were in press.

The third volume of abstracts of the world literature on cowpeas was published during 1982. It includes 1,050 abstracts, representing the literature published during the period 1974 to 1980. Substantial work was done on the fourth volume, which will be ready for publication in 1983.

Public Affairs and Development

Communications and Information

The office distributed about 25,000 copies of major IITA publications to 4,600 requestors in 132 countries last year. Most publications were distributed free.

Nineteen IITA publications were produced at the Institute and printed at the headquarter's printing plant or abroad. They were:

- Tissue Culture: Improved Cultivars for Africa's National Programs
- La culture de tissus: Des cultivars elites pour les programmes nationaux africains
- A profile of IITA International Programs
- Les programmes internationaux de l'IITA
- IITA Research Highlights 1982
- IITA Le point de la recherche 1981
- IITA Annual Report
- IITA Research Briefs, Vol. 3, Nos. 1 and 2
- Le Riz: Publications en langue française disponibles à la bibliothèque de l'IITA
- Cowpea (*Vigna unguiculata* L. Walp) Abstracts of World Literature Vol II 1974–1980

- Tropical Grain Legume Bulletin, Nos. 24 and 25
- An Appraisal of the Present Farming Systems of the Atebubu District of Ghana
- Automated and Semi-automated Methods for Soil and Plant Analysis
- Maize Production Manual
- Tuber and Root Crops Production Manual
- Soybean Production Manual
- Cowpea Production Manual
- Stage sur legumineuses à graines: Entomologie
- Stage sur legumineuses à graines: Pathologie

A total of 31 news releases were issued during the year. The office also wrote and placed more than 15 articles and feature stories about the Institute and its work in magazines and newspapers.

The Institute's publications mailing list was surveyed and a program to computerize the mailing system was initiated. The new program will allow the Institute to direct specific publications to users that most need the information.

New printing equipment, including a one-color offset press, was ordered and has arrived. It will be installed early in 1983.

Informal training in printing, photography and graphic design for agricultural information technicians and midlevel administrators from Nigerian agricultural research institutes continues.

Conference and Visitors' Center

The Institute held or hosted 13 conferences and workshops:

- Communications Strategy and Planning Workshop, 11–22 January 1982.
- CIAT/CIP/IITA Workshop on Germplasm Distribution and Quarantine Considerations, 28–30 April 1982.
- USAID Agricultural Development Officers Conference, 10–14 May 1982.
- Workshop on On-Farm Experimentation, 31 May–4 June 1982.
- Workshop on the Results of Agricultural Development Projects in Nigeria, 14–15 July 1982.
- OAU/CDA Workshop on the CDA Research Initiative to Promote Food Production, 16–18 July 1982.
- Planning and Evaluation Committee for Cowpeas, 2–4 August 1982.
- Workshop for African Rhizobiologists, 20–24 September 1982.
- Joint Meeting of Planning and Evaluation Committees for Maize, Rice, Cowpeas and Soybeans (CEC Project), 18–22 October 1982.
- FAO/IITA Expert Consultation on Durable Resistance Breeding, 25–29 October 1982.
- First Meeting of the IITA/IRAT/ICRISAT/GTZ Farming Systems Network for Africa, 15–19 November 1982.
- International Conference on Land Clearing and Development, 22–26 November 1982.
- Cassava Mealybug and Green Spider Mite Workshop, 6–10 December 1982.

Twenty-one research seminars were presented—nine as a series with the central theme, "IITA Research Advances for Food Production Increases."

The Institute received 120 visiting groups; ranging from primary school to final year university students. Government agencies, service organizations and other groups continue to visit the Institute regularly, seeking information on new varieties and improved technologies.

Appendix 1: The Weather at IITA

Recurrent periods of moisture deficit characterized the weather at IITA in 1982; the total rainfall of 907.6 mm (28% below normal) was one of the lowest on record. Insolation during the cropping season was generally below average, while mean temperatures were by and large above normal as a result of warmer nighttime conditions. A summary of the climatic data is given in Table A1.

Rainfall and Evaporation

January was characteristically dry, with only 1.6 mm of rain on the twentieth. An unusual succession of showers in the second half of February raised hopes of an early start to the rainy season, but instead the showers were followed by a prolonged dry period that lasted through the first two weeks of March. Since evaporative demand generally was above 5 mm/day, early plantings mostly dried out.

Total rainfall in March was below average (−10%) but was concentrated in the second half of the month, providing acceptable moisture conditions at the beginning of the first cropping season (Table A1 and Figure A1). Not until the second week of April, however, was a positive water balance established, and it was quickly followed by two weeks of moisture deficit (Figure A2).

This alternate pattern of brief intervals of favorable moisture followed by more sustained periods of drought characterized much of the first cropping season. The only exception was the four-week period from June until the first half of July, when weekly mean rainfall consistently exceeded moisture demand (Figure A2). Cumulative rainfall throughout the season stood at 730.4 mm (at the end of August) or 18% below normal, with individual monthly departures ranging from −6% in July to −32% in April and −33% in August.

The moisture regime in the second season was in some respects a repetition of that of the first season. A 50.8-mm rainfall on 28 August (out of a monthly total of 75.6 mm) contributed to favorable moisture conditions at the start of the season. There was again little rain in the last two weeks of September, which was marked by intermittent drizzles with a total water yield of 11.1 mm. Cumulative rainfall for the month as a whole fell 65% short of the mean (Figure A1). Conditions improved slightly in the first half of October (Figure A2), but crop growth remained severely impaired. A final persistant drought through the rest of the season led in many cases to near crop failure.

Sky Conditions and Solar Radiation

Higher than normal insolation prevailed from January through April, when departure in monthly mean values peaked at 18% above the long-term average. In spite of the low rainfall in May, increased cloudiness during this period slightly reduced incident radiation. Near-normal values (departure, +2%) prevailed in June, but cloudiness again reduced values by 9% in July and 6% in August below the corresponding multiannual means. A similar trend was observed in October, following a return to above average values (+8%) in September. Early arrival of the harmattan in December caused mists in the early morning hours and haze during the rest of the day.

Temperature and Relative Humidity

Daytime hours were cooler than normal except in January, April, September and December. Minimum

Table A1. Summary of climatic data, IITA, Ibadan central station, 1982

Month	Total rainfall, mm	Total evaporation	Solar radiation gm-cal/cm²/day	Temperature, °C Maximum	Temperature, °C Minimum	Relative humidity, % Minimum	Relative humidity, % Maximum	Mean temperature, °C	Mean relative humidity, %
January ...	1.6	153.8	393.5	33.3	21.2	34	92	27.2	63
February...	44.6	149.2	429.6	34.0	22.8	37	93	28.4	65
March.....	92.7	173.9[a]	508.2	33.4	23.3	45	95	28.4	70
April	87.9	153.5[a]	556.2	32.7	23.5	52	96	28.1	74
May.....	124.4	133.3[a]	428.1	30.7	21.6	64	98	26.2	81
June.....	166.7	119.1[a]	420.7	29.6	22.5	65	97	26.1	81
July.....	136.9	97.4[a]	324.7	27.2	21.6	71	98	24.4	85
August	75.6	88.9[a]	349.0	26.9	21.4	71	98	24.1	85
September..	36.1	97.1[a]	384.6	28.9	21.9	67	98	25.4	83
October....	102.2	125.4[a]	378.2	29.5	22.0	63	97	25.7	81
November..	8.9	137.1	425.2	31.8	21.9	44	97	26.9	71
December..	0.0	145.6	382.5	33.0	21.9	37	96	27.5	67

[a]Values adjusted for days for which no data were obtained

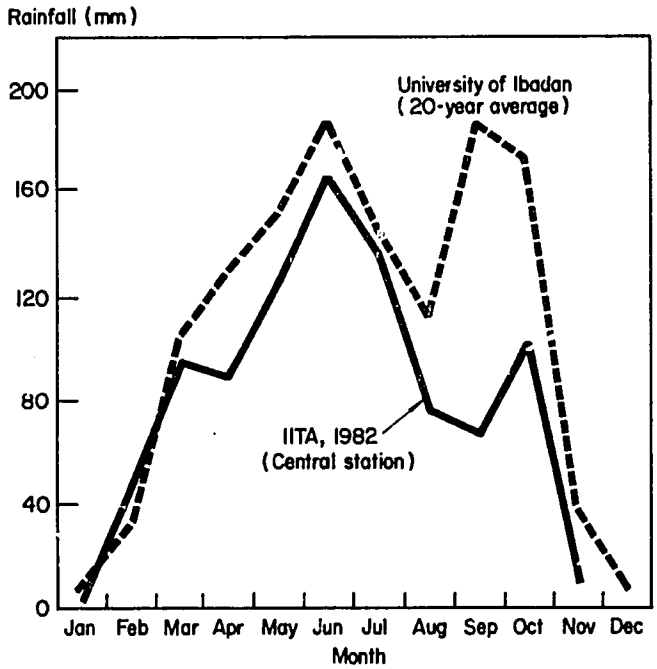

Figure A1. Mean monthly rainfall, IITA, 1982.

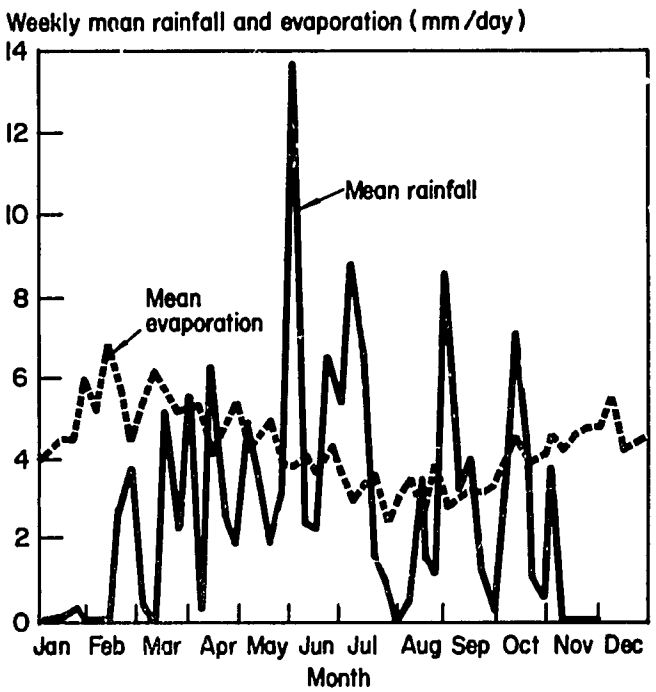

Figure A2. Weekly mean rainfall and evaporation, IITA, 1982.

temperatures were, in contrast, above normal, averaging more than 1°C above their corresponding long-term mean in January, February, April and December. Only in May were the nighttime hours cooler (departure, −0.2°C). The mean relative humidity remained above average in all months except November. This contributed to the slightly lower values of pan evaporation observed, particularly during the last two quarters of the year, in spite of the prevalent higher wind speeds.—*T.L. Lawson*

Appendix 2: List of Acronyms

ABU, Ahmadu Bello University, Nigeria.
ADPs, Agricultural Development Projects.
AICSIP, All-India Coordinated Sorghum Improvement Project.
APMEPU, Agricultural Projects Monitoring, Evaluation and Planning Unit, Nigeria.
BTI, Boyce Thompson Institute, United States.
CGIAR, Consultative Group on International Agricultural Research.
CIAT, Centro Internacional de Agricultura Tropical (International Center for Tropical Agriculture), Colombia.
CIBC, Commonwealth Institute of Biological Control.
CIDA, Canadian International Development Agency.
CIMMYT, Centro Internacional de Majoramiento de Maiz y Trigo (International Maize and Wheat Center), Mexico.
CIP, International Potato Center, Peru.
CNPAF, National Center for Research on Rice and Beans, Brazil.
CNRA, Centre National de la Recherche Agronomique (National Center for Agricultural Research), Cameroon.
CNRCIP, Cameroon National Root Crop Improvement Program.
EEC, European Economic Community.
EMBRAPA, Empressa Brasiliera de Pesquina Agropecuária (National Agricultural Research Organization of Brazil).
FAO, Food and Agriculture Organization.
GTZ, Deutsche Gesellschaft für Technische Zusammenarbeit (German Agency for Technical Cooperation).
IAR, Institute of Agricultural Research, Nigeria.
IAR&T, Institute of Agricultural Research and Training, Nigeria.
ICRISAT, International Crops Research Institute for the Semi-Arid Tropics, India.
IDRC, International Development Research Centre, Canada.
IFAD, International Fund for Agricultural Development.
IFDC, International Fertilizer Development Center, United States.
ILCA, International Livestock Center for Africa, Ethiopia.
INTSOY, International Soybean Program, United States.
IPO, Research Institute for Plant Protection, Netherlands.
IRA, Institut de la Recherche Agronomique (Institute for Agricultural Research), Cameroon.
IRAT, Institut de Recherches Agronomiques Tropical (Institute for Tropical Agricultural Research), France.
IRRI, International Rice Research Institute, Philippines.
IRTP, International Rice Testing Program.
ISNAR, International Service for National Agricultural Research, Netherlands.
MIDAS, Managed Inputs and Delivery of Agricultural Services Project, Ghana.
NAFPP, National Accelerated Food Production Project, Nigeria.
NCRE, National Cereals Research and Extension Project, Cameroon.
NCRI, National Cereals Research Institute, Nigeria.
NGPC, National Grains Production Company, Nigeria.
NIHORT, National Institute for Horticultural Research, Nigeria.
NRCRI, National Root Crops Research Institute, Nigeria.
ODM, Overseas Development Ministry of the United Kingdom.
ORSTROM, Office de la Recherche Scientifique et Technique Outre-Mer (Overseas Agency for Scientific and Technological Research).
PRONAM, Programme National du Manioc (National Manioc Program), Zaire.
SAFGRAD, Semi-Arid Food Grains Research and Development Project, Upper Volta.
SAREC, Swedish Agency for Research Cooperation with Developing Countries.
UI, University of Ibadan, Nigeria.
UNDP, United Nations Development Programme.
USAID, United States Agency for International Development.
WARDA, West African Rice Development Association, Liberia.
ZAPI-Est, Zones d'Actions Prioritaires Integrees de l'Est (Action Areas for Integrated Development in the East), Cameroon.

List of Personnel

Administration

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M.E. Olusa, assistant to director of administration
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A.C. Butler, building and site service officer
O.O.A. Fawole, automotive service officer
J.M. Ferguson, fabrication/water utility service officer
N. Georgallis, scientific/electronics service officer
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M.O. Yusuf, construction/site engineering service officer

*Left during the year

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