IITA Research Highlights 1981

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Facts about IITA

The International Institute of Tropical Agriculture (IITA) – one of the major links in a world wide network of agricultural research and training centers – was established as an autonomous, non-profit corporation on July 27, 1967. The Federal Republic of Nigeria alloted 1,000 hectares of land for the IITA site, and the Ford Foundation provided initial capital for buildings and development.

IITA is governed by an International Board of Trustees, the membership of which includes representatives from developing countries in areas of the Institute's concern.

The principal financing of the Institute (and other centers) is arranged by the Consultative Group on International Agricultural Research (CGIAR) – an informal group of donor countries, development banks, foundations, and agencies. Support for IITA's research and training core program in 1981 was provided by the Canadian International Development Agency (CIDA), Overseas Development Ministry of the United Kingdom (ODM), U.S. Agency for International Development (USAID), World Bank, International Fund for Agricultural Development (IFAD), Ford Foundation, International Development Research Centre (IDRC), and the governments of Australia, Belgium, France, Italy, Japan, Netherlands, Nigeria, Norway, and Federal Republic of Germany. In addition, other donors provide funds to the Institute, particularly to support specific research or training programs.

The "geographic mandate" of IITA includes the humid and subhumid tropical zones, and the Institute concentrates its research and training in two major areas: farming systems and crop improvement of certain designated cereals (rice and maize), grain legumes (cowpeas and soybeans), and roots and tubers (yams, sweet potatoes, and cassava).

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Preface

The International Institute for Tropical Agriculture has spent a substantial portion of its first 10 years in the primary levels of food crop research for the humid and subhumid tropics. Fundamental work was required, because food crops had not received much research attention in the past.

Now the Institute is seeing its efforts come to fruition. Many of the results of IITA research are ready for widescale testing and adaptation. Others are already in the field. Among the achievements presented in this edition of Research Highlights are the adoption of IITA cowpea breeding lines in Tanzania, named with the Swahili words for "hope" and "pride;" the release of three natural enemies of the dangerous cassava mealybug, initiating biological control of that pest; and the manufacture, by small fabricators in Nigeria, of simple labor-saving farm tools developed by IITA agricultural engineers. Building on an evergrowing base of knowledge about tropical ecosystems and the hard realities of African farming, IITA research is beginning to make small but real contributions to food production.

IITA is at a crucial stage in its development. The Institute will need additional financial support to make a significant impact on a continent that is experiencing great difficulties in meeting its food needs. The time has come to put research results to work as rapidly as possible. We are expanding collaboration with national and international programs. They are the necessary channels to local adaptations and, finally, to the farmers' fields.

Through an interesting and challenging and rewarding first decade, our goals have not changed. We intend to be a real tool for the development of agriculture in Africa and throughout the humid and subhumid tropics. The 1981 Research Highlights chronicles some of the steps along the way, but it does not tell the whole story. If you wish more complete information, it can be found in the Institute's Annual Report, available to you upon request.

Director General

Contents

As a result of cooperation between scientists of SAFGRAD-IITA and CIMMYT, an early-maturing, high-yielding maize – SAFITA-2 – has been developed for the semi-arid tropics of Africa.

Tailoring Maize for Semi-Arid Ecology in Africa

By the end of 1981, three early-maturing, high-yielding maize varieties for semi-arid ecology were identified from existing lines and another three developed through full-sib family testing, evaluated, and found promising in 15 African countries.

IITA scientists started their efforts to breed maize varieties for the semi-arid tropics four years ago by planting a three-hectare observation nursery made up of thousands of lines, populations, and varieties in Upper Volta under the Semi-Arid Food Grains Research and Development (SAFGRAD) Project. This first round identified materials adaptable to that environment (700–900 mm rainfall zone). The following year, a full breeding program began at Kamboinse – a national research station in Upper Volta.

Since then, two major areas of work have been underway for both the 700–900 mm and the 900–1,100 mm rainfall zones: (1) systematic evaluation of available and promising early and medium-maturing varieties from national, regional, and international programs, and (2) population improvement through regional full-sib family testing trials to combine tolerance to common stresses frequently encountered in the semi-arid tropics.

The objective for the first program was short-range to mobilize the available promising materials, but the second one is long-range to develop maize populations with wider adaptability by slowly pyramiding the genes which give tolerance to stresses in a semi-arid environment.

Over the past three years (1979–81), more than 100 tests were conducted at experiment stations in 15 countries. As a result, BDS III, TZE-4, and POOL-16 were identified as the most promising early-maturing materials and IRAT-81,

TABLE 1.
Average grain yield of promising varieties of maize tested in regional uniform trials in 15 countries (1979–81).

	Yield (kg/ha)	Days to 50% flowering
POOL-16	2719	49
BDS III	2930	53
TZE-4	2494	50
IRAT 81	3578	62
TZPB	3533	61
Comp. C-4	3534	62

Composite C-4, and TZPB as the top medium-maturing populations (Table 1). BDS III, IRAT-81, and Composite C-4 were developed by national programs, TZE-4 and TZPB at IITA. POOL-16, originally put together by the International Maize and Wheat Improvement Center (CIMMYT), was identified as a promising material for the semi-arid ecology of Africa by the SAFGRAD-IITA Program. It was entered later in the regional uniform tests.

Tailoring maize for the semi-arid tropics (specifically for the 700–900 mm rainfall zone) essentially demands combining early maturity with high yield and introducing tolerance to unpredictable drought spells during the growing cycle of the maize plant. To accomplish this, the scientists are selecting for high yield and tolerance to drought in early-maturing populations and selecting and developing derivatives from Temperate × Tropical materials.

TZE-3 and TZE-4 were the early-maturing populations selected for the first approach using a full-sib family testing scheme. In cooperation with four national programs, the most promising families were selected on the basis of multi-location testing and these families re-combined to develop the experimental varieties.

TABLE 2.
Performance of selected families of POOL-16 to develop experimental maize variety SAFITA-2.

Families	Grain yield kg/ha (Kamboinse)	Days to 50% flowering
F.S. 3	5227	48
F.S. 36	4053	48
F.S. 109	4160	46
F.S. 116	3947	46
F.S. 45	4053	46
F.S. 70	3520	49
F.S. 86	3733	47
F.S. 93	2987	54
F.S. 145	3307	52
F.S. 69	4480	46
Mean:	3947	48
POOL-16 (check)	2453	50
J.F.S. (check)	2133	46

As soon as POOL-16 was identified as a very promising early-maturing population in 1980, it was included in the population improvement scheme, and in 1981 regional full-sib family trials were organized in collaboration with four national programs for multi-location testing. On the basis of the results obtained from this testing, an experimental variety called SAFITA-2 has been developed. The average yield of the selected families constituting SAFITA-2 was substantially higher than the POOL-16 population and the local variety commonly grown in Upper Volta (Table 2).

The plant breeders are increasing their use of Temperate × Tropical materials because of yield performance and desirable plant architecture. Several of these materials put together by CIMMYT, IITA, and others have been evaluated and used in thousands of crosses both at Ibadan, Nigeria, and Kamboinse, Upper Volta. The materials developed from the Temperate × Tropical crosses do have a good plant architecture, but many of them are susceptible to lowland leaf diseases when grown in the humid forest zone. In the semi-arid regions, the disease pressure is far less, making them attractive for use in the semi-arid ecology.

SAFITA-104 and TZUT have emerged as two promising materials in the regional uniform tests conducted in 15 countries in 1981. Both varieties yielded about 3 t/ha in these tests. In the meantime, efforts are being continued to develop better populations from the Temperate × Tropical materials.

A medium-maturing, white grain variety – SAFITA-102 – has been found to be promising for the 900–1,100 mm rainfall areas of the semi-arid tropics.

Role of Tied Ridges in Maize Production in Upper Volta

Field experiments from 1979–1981 with tied ridges in Upper Volta in the 700–900 mm rainfall belt show that they can reduce the risk of drought stress during the maize growing season and substantially increase yields. (Tied ridges are either earthed-up rows or ridges with laterals built to connect the rows on which the maize is grown; the result: a series of miniature catch basins to hold rainfall around the plants.) This practice has been tried successfully in other countries in the past.

In the 1981 experiments, three ridging systems were tested: simple ridges, tying the ridges every second furrow,

Maize production under three different ridging systems: left, simple ridges; center, tying all ridges; and right, tying the ridges every second furrow.

and tying all the ridges. The last, under both low and high management levels, gave the largest maize yields – at least double those of the control plots except for the hydromorphic soils (Table 3 and Figure 1). Preliminary evaluations indicate that the practice can be economically feasible even when the ridges and the tying operation are done with a hand hoe. The farmer has the choice of either planting on the flat and earthing-up later or planting directly on tied ridges.

In some soils, the ridges last more than one season, thereby sharply reducing the amount of labor required after the first year. As shown in Table 3, the tied ridges built in August 1980 were still effective in increasing the yield of the second maize crop planted 10 months later in 1981.

The yield increases obtainable with tied ridges depend on three principal factors regardless of soil preparation methods:

(1) Rainfall distribution pattern during the rainy season; the longer the duration and frequency of the dry periods during the season, the higher the response to tied ridges.

(2) Position along the toposequence (Figure 1); the response to tied ridges is generally maximum in the plateau and upper slope soils and decreases towards

Earthing-up system		Low*	High**	Mean
		Management level		
1. No earthing-up		1040	1480	1260
2. Earthing-up at 30 days after planting (DAP)		990	1470	1230
3. Earthing-up at 30 DAP and tying the ridges every other furrow since 1980		1840	2540	2190
4. Earthing-up at 30 DAP and tying all the ridges since 1980		2040	3280	2660
	Mean	1480	2190	1840
	L.S.D. (5%) for management			701
	L.S.D. (5%) for system			416

Low fertilizer and low plant density.
**High fertilizer and high plant density.*

TABLE 3.
Maize grain yields (kg/ha) under two management levels and four ridging (earthing-up) systems in Upper Volta (1981).

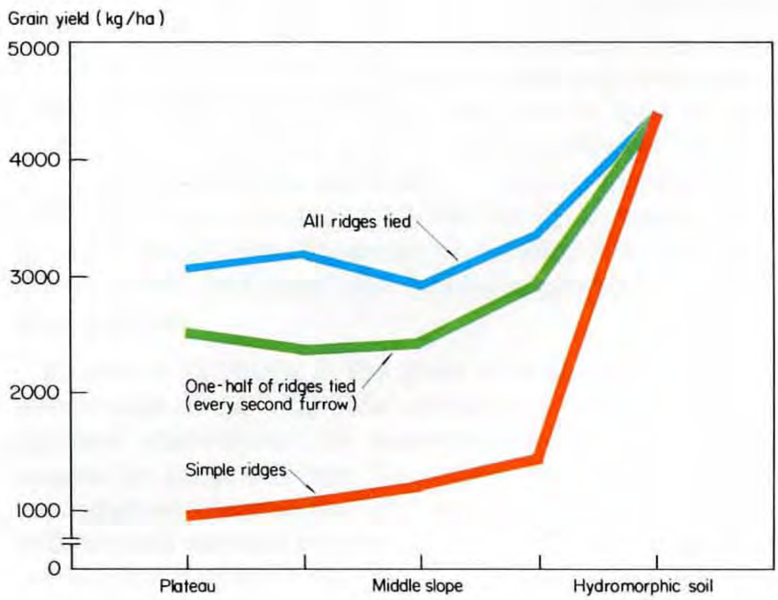


FIGURE 1.
Effect of crop position along the toposequence and tied ridges on maize grain yields, Kamboinse, Upper Volta (1981).

Tied ridges – a moisture-conserving practice tested in Upper Volta during the past three years.

the lower slope, deeper, hydromorphic soils. (Although no decrease in maize yield was observed in 1981 when the ridges were tied on hydromorphic soils, this practice can be detrimental on these soils in wet years.)

(3) Soil characteristics such as texture, structure, surface crusting, compaction, and residue mulch; soils with low water infiltration rates respond more to tied ridges even in the lower slope, hydromorphic soils.

Rice Yield Potential in West Africa

Irrigated lowland rice experimental plots at IITA (above) and variety ITA 212 (below) – one of two cultivars that produced high yields comparable to those in other countries.

Low yield levels of most rice cultivation in West Africa are often said to be due to climatic conditions. But is this true, partly true, or not true at all? To clarify the effect of climate on the growth and yield of rice plants, IITA scientists began a series of experiments in 1980/81 with special attention given to solar radiation. Their preliminary results show that high yields comparable to those in other parts of the world are obtainable under the climatic conditions in West Africa. To accomplish this, however, medium-maturing cultivars (about 130 days) with high yield potential must be selected, appropriate fertilizer applied, pest-free growing conditions provided, and correct timing of planting followed so that ripening periods correspond with favorable solar radiation.

Two rice cultivars – TOs 103 (105–120 days) and ITA 212 (120–135 days) – were grown in irrigated lowland at IITA (Ibadan, Nigeria) with periodical plantings every four weeks beginning in December 1980 and continuing throughout 1981. The highest yields in the trials (10–11 t/ha for one crop) are comparable to those in other countries. This level was obtained without particularly intensive management. The fertilizer amounted to 90 kg/ha of N, P_2O_5, and K_2O and the plant density was 22 plants/m^2. Furthermore, the paddy was not ideal, and some iron toxicity appeared because of poor drainage.

As shown in Figure 2, the grain yield is high when rice plants ripen under high solar radiation and low under low radiation conditions. For example, when ITA 212 was planted in June/July and December, the ripening period coincided with September/October and March, respectively, and the yield reached 10 t/ha because of favorable radiation (about 450 gcal cm^{-2} day-1). In contrast, when the same

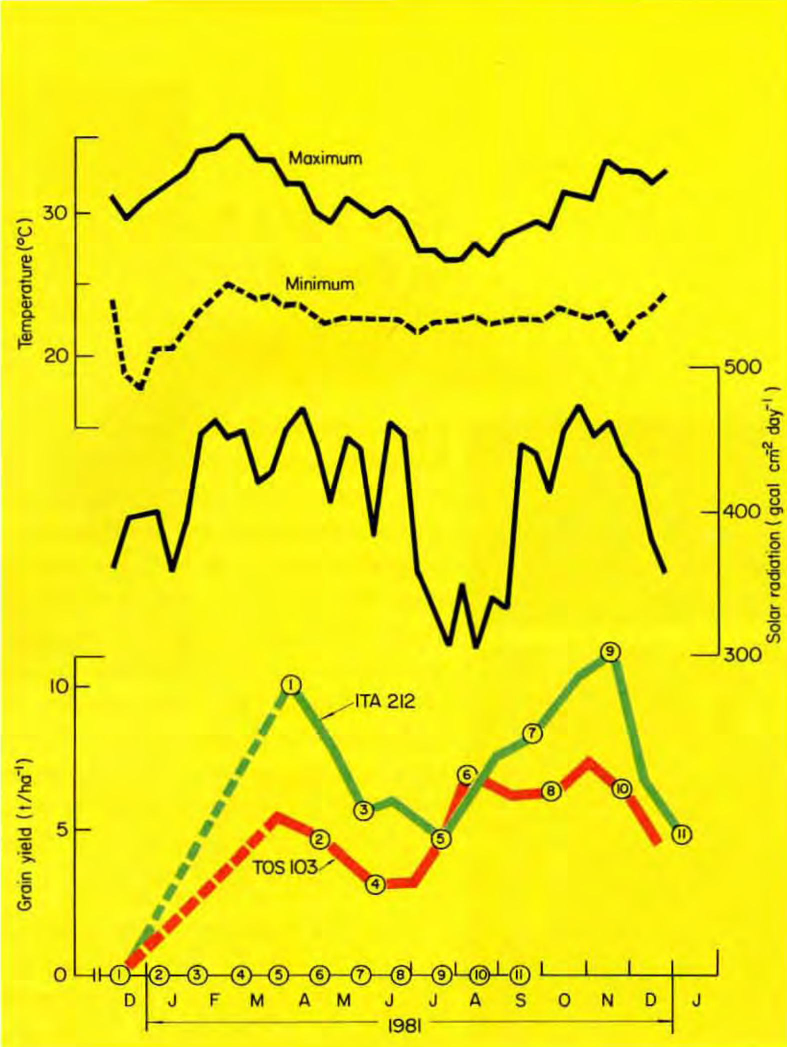


FIGURE 2.
Climatic effect on the grain yield of rice plants. (The numbers in the circles indicate the date of transplanting and the corresponding date of full maturity.)

cultivar was planted in March and September, the ripening period coincided with June/July and December, respectively, and the yield hardly reached 5 t/ha – less than one-half the previous yield. This was due to unfavorable radiation (300–350 gcal cm-^{2} day-1). Temperature (either maximum or minimum) did not seem to be critical to the plant growth.

Grain ripening during the ascending periods of solar radiation (such as from January to March and from August to September) had higher yields than the grain ripening during descending periods of solar radiation from June to July and from November to January. This can be explained by the fact that when rice plants at early growth stages are grown under favorable light conditions, their growth becomes very vigorous with active tillering and leaf development. They produce fewer photosynthates due to mutual shading and consume more energy to maintain themselves. The plants fail to allocate a larger proportion of photosynthates to grains during the ripening period. But when the ripening period meets with favorable light conditions, plants produce a large amount of photosynthates, thereby producing high grain yields.

Impact of IITA Cowpea Varieties in Different Countries

The cowpea breeding line – TK-1 – has been renamed "Tumaini" (meaning "Hope" in Swahili) by the Ministry of Agriculture in Tanzania.

Cowpea varieties originating from IITA breeding lines have been released by several national governments and the seed multiplied for planting by farmers on thousands of hectares. The following are a few examples out of many.

On July 30, 1981, the cowpea variety "Manaus" – a cultivar originating from the IITA breeding line 4R-0267-01F – was released in Brazil by the National Research Center for Rice and Beans (CNPAF) and the Empresa Brasileira de Pesquisa Agropecuaria (EMBRAPA). This variety – named after the capital city of the State of Amazonas – is high-yielding, early-maturing, and resistant to cercospora and leaf smut (*Entiloma vignae*). Seed was received in Brazil in 1978 and planted in an isolated plant quarantine area and multiplied for use in national and international trials. It outyielded the local material by 17 percent during the rainy

KN-1 (left), originally a cowpea double cross made at IITA, was released by the government in Upper Volta and the first multiplication started in 1981. Right, a close-up of pods, leaf, and seeds of the variety.

season with upland plantings on soils low in phosphorus and by 71 percent during the "dry" season planting on the rich flood plain of the Amazon River.

Brazilian officials report that this variety has great possibilities in new, large areas where mechanization is being tried. Six tons of seed were produced in 1981, and it is expected that the impact of this cultivar in the Amazon Valley will be significant, amounting to perhaps 22 million cruzeiros (200,000 U.S. dollars) in added profits for farmers in 1982 alone. This would exceed the Amazonas State agricultural research costs for the year.

In addition to "Manaus," two more varieties are planned for release during 1982 in northeast Brazil. The state government of Ceara has started to multiply seed of IITA's VITA-7 and TVx 1836-013J varieties for commercial distribution under its own names of IPACE-1 and IPACE-2 (IPACE = Institute do Pesquisas Agropequarias do Ceara). VITA-3 was released in 1981 in the State of Maranhao and the seed multiplication area included 10 hectares. This variety was also released in Venezuela in 1979.

Late in 1980, Tanzania released two breeding lines – TK-1 and TK-5 – and, because of their popularity with farmers, the Ministry of Agriculture in 1981 renamed the former "Tumaini," meaning "Hope" in Swahili, and the latter "Fahari" meaning "Pride." The Ministry and IITA have

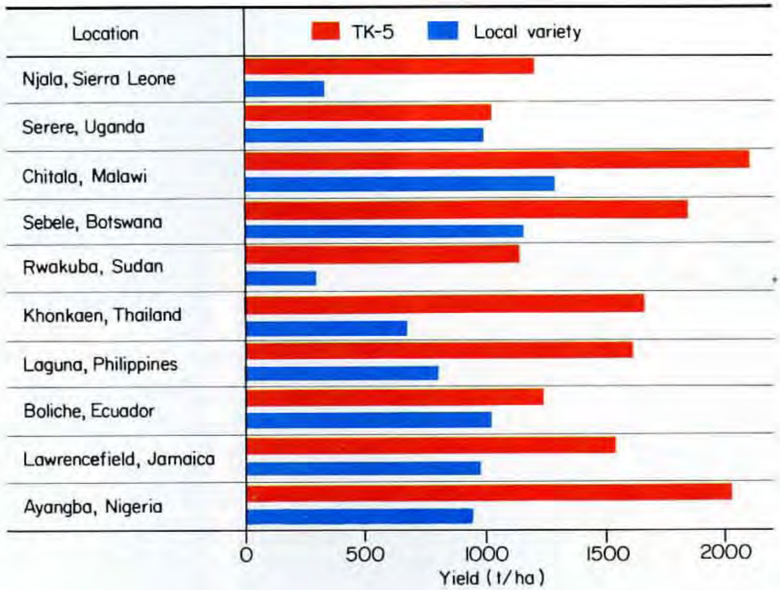


***FIGURE 3.* Performance of cowpea variety TK-5 at various locations in the tropics during the 1980/81 season.**

been collaborating since 1975 on the development and identification of several breeding lines and varieties. The two mentioned here were released after three years of yield evaluations at 10 locations in different regions of Tanzania.

Both varieties have multiple disease resistance and high-yield potential with acceptable leaf and grain qualities. In addition to the main season crop, they can also be successfully grown in the short rainy season of bimodal rainfall areas. In the varietal demonstrations conducted in farmers' plots in the short rains of 1980–81 at Ilonga, Tanzania, both TK-1 ("Tumaini") and TK-5 ("Fahari") yielded up to 1.5 t/ha when the adjacent plots of maize dried prematurely. TK-5 also holds promise for a number of other countries where it significantly exceeded the yield performance of the local varieties at each location (Figure 3).

Thousands of early-segregating progenies, as well as fixed lines originating from IITA, have been evaluated under the National Cowpea Improvement Program in various trials covering different ecological conditions in Upper Volta. As a result of this effort over the past three years, KN-1, which

TABLE 4.
Yield (kg/ha) of KN-1 cowpea variety compared with a local check variety in trials in four African countries (1981).

Variety	Locations				
	Farako-Ba Upper Volta	Samaru Nigeria	Guiring Cameroon	Nyankpala Ghana	Overall mean
KN-1	1468	2102	2081	1033	1671
Local check	1227	1100	261	522	778

yielded significantly better than the local material, was identified. KN-1, originally a double cross made at IITA, has been released by the government in Upper Volta for areas with a rainfall of 700 mm or more. Under good management conditions (particularly with insecticide application), this variety produced yields as high as 2,000 kg/ha on experimental plots and close to 1,500 kg/ha in controlled trials on farmers' fields. Also, 1981 trials in Nigeria, Cameroon, and Ghana showed KN-1 to be a high-yielding variety (Table 4).

The first multiplication of KN-1 in Upper Volta started in 1981, and seeds were then distributed to farmers for large-scale cultivation. Although only 1.5 tons of seed of this variety were distributed in 1981 through Upper Volta's National Extension organization, 10 tons (enough to plant 400 hectares) were scheduled for distribution in 1982.

The Republic of South Yemen released VITA-5 – another high-yielding, disease-resistant variety developed by IITA – and in 1981 approximately 7,000 hectares were planted in the country. During the same year, about 5,000 hectares of this variety were planted on farms in Togo.

Cross 1-6E-2 – a new high-yielding, extra-early maturity cowpea (61 days) – being multiplied in this Tanzanian field.

(Upper right) Two cowpea crops planted at the same time in Tanzania. The new line (right) matured three to four weeks earlier than the local late variety (left).

Extra-Early-Maturing Cowpeas for African and Asian Countries

Because of the need for extra-early-maturing cowpea varieties (60–65 days) in many African and Asian countries, IITA scientists have initiated a systematic breeding program to accomplish this. They knew that such varieties would not only permit double and/or relay cropping but make effective use of very short rainy seasons in many tropical areas.

Initial work was started in 1979 by the Institute's scientists located in Tanzania. In some areas, the short rains begin in October–November and end in late December or January, depending on the region. A dry period for about a month follows after which the main rains start and continue for about 75 to 90 days. Farmers plant maize with the onset

TABLE 5. Performance of extra-early-maturing cowpea varieties in Tanzania (1980–81).

Variety	Days to maturity	Yield (kg/ha)	
		Short rains (Dec.–Jan.)	Main season (March–April)
ER-1	75	1482	940
TKx 133-16D-2	65	1547	1278
Cross 1-6E-1	61	1803	1585
Cross1-6E-2	61	1886	1613
LSD 5%		329	100

of the short rains in October–November, and frequently the maize crop dries prematurely during the dry weeks of January and farmers lose their crop. Only in occasional years when the rains extend until February does a farmer get a successful maize crop. In spite of this uncertainty, farmers plant maize because it is the principal food crop in Tanzania, and there has been no alternative crop early enough to mature within two months.

Since 1979, the scientists have developed extra-early-maturing cowpea lines that will fit in this season in Tanzania and also serve as a mix crop/relay crop in monomodal rainfall areas. Two new lines – Cross 1-6E-2 and TKx 133-16D-2 – mature within 65 days and yield between 1.5 to 1.9 t/ha (Table 5) – the same range as full-season varieties. However, being erect and early, the early-maturing varieties were planted in narrow rows with approximately 130,000 plants per hectare vs. 66,000 for the full-season varieties.

The early-maturing varieties are resistant to most major cowpea diseases and have acceptable seed quality. Flowers on the cowpea plants are all produced within a short period, cutting down the need for multiple insecticide sprays. Also, pods mature synchronously which permits a single harvest and reduces labor costs. These lines are now being widely tested in farmers' fields.

A number of other early-maturing selections made at IITA appear promising for certain areas in Africa and Asia. They become ready for harvest within 60 days after planting, have large white seeds, combine resistance to major diseases, and have synchronous flowering and maturity. Seeds of these lines will be ready for wide-scale yield testing in late 1982.

High Temperature-Tolerant Rhizobia for Tropical Inoculants

Tolerance to high temperatures is a desirable property for inoculants intended for use in the tropics where temperatures during transportation, storage, and planting may be high. As long as the rhizobia used as inoculants are intolerant of high temperatures, farmers in many tropical countries will continue to be denied access to the cheap form of nitrogen from biological nitrogen fixation. Recent findings on high temperature-tolerant rhizobia by IITA scientists, in collaboration with scientists at Cornell University and Boyce Thompson Institute (USA), appear to hold much promise toward the solution of this problem.

When a germplasm bank of 750 cowpea rhizobial isolates was obtained from three environments in West Africa (the IITA main site and its substation at Onne, Nigeria, and Maradi in the Republic of Niger), it was soon observed that many of the rhizobia from the hot, dry environment of Maradi grew as well at 37°C as at the usual temperature of 30°C employed by microbiologists to culture rhizobia in the

Origin	Strain (IRc)	Tolerance of 37°C	Colony form
Onne	252	–*	Wet
	256	+	Dry
	283	nd	nd
	299	++	Dry
	344A	nd	Dry
Maradi	383C	+++	Dry
	400A	+++	Dry
	409C	++	Wet
	430A	++	Dry
IITA	462D	nd	Dry
	489B	+	Wet
	500A	++	Wet
	506C	++	Wet

Growth relative to 30°C: –, none; +, poorer; ++, equal; +++, better.

TABLE 6. Information on the 13 cowpea strains used in the field inoculation trials in three countries.

laboratory. Some of these even grew at 44°C, which is higher than any temperature ever reported for growth of tropical rhizobia. By contrast, few of the rhizobia from the cooler sites at Onne and IITA tolerated 37°C. Many of the rhizobia from Maradi were predominantly of a "dry" colony type. Preliminary data showed that the extracellular gum produced by some of the rhizobia might be important in temperature tolerance.

Those were exceptional and unprecedented findings. Therefore, IITA scientists decided to evaluate under field conditions rhizobial strains that combine effectiveness in nitrogen fixation with high temperature tolerance. In addition to this, a third criterion of inoculant quality is the competitive ability in terms of nodule formation. Effective strains are useless in the field unless they can compete successfully with natural field rhizobia and can form the majority of nodules on the host plant. Cowpeas tend to show little or no response to rhizobial inoculation in terms of grain yield, but in the past there has been no way to determine whether this was caused by inoculant failure, nutritional problems, or other factors. With the new methods that now allow microbiologists to follow the course of nodule formation by rhizobia, a new dimension has been added to inoculant studies. One of these methods is the

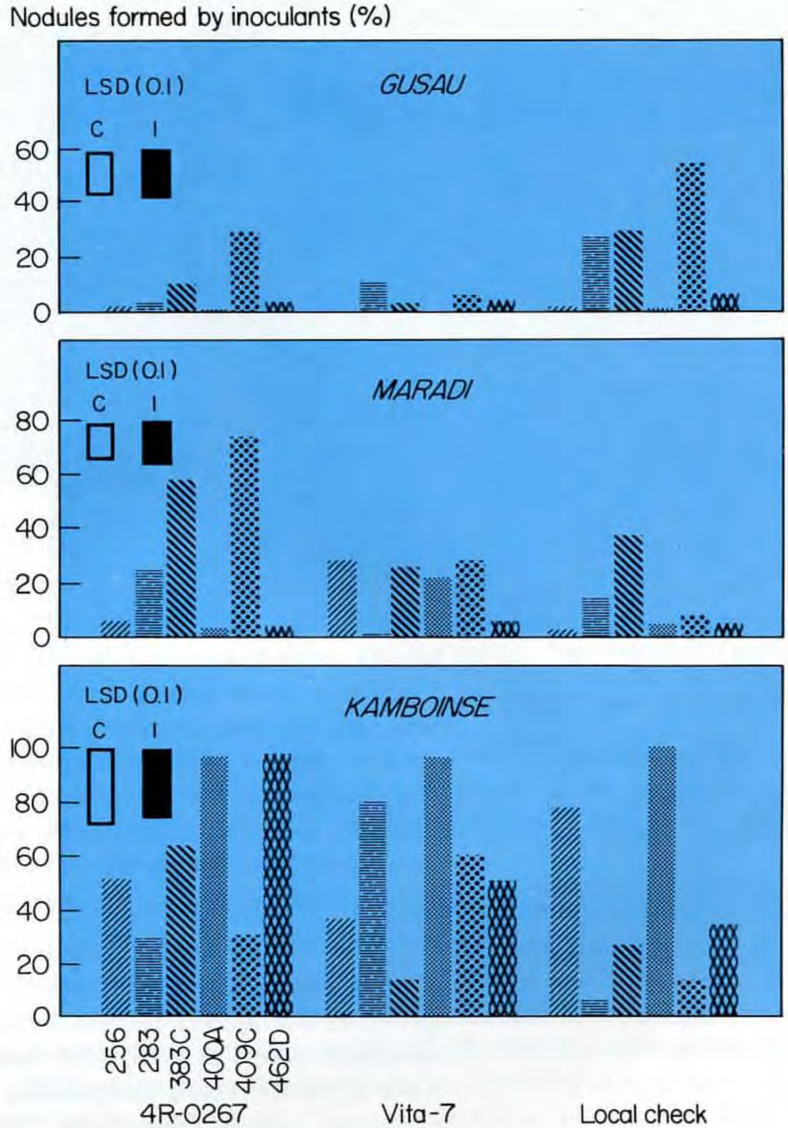
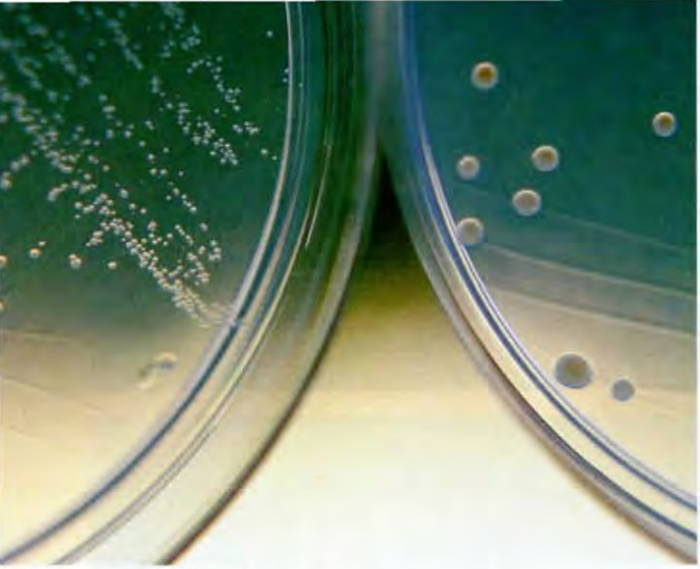
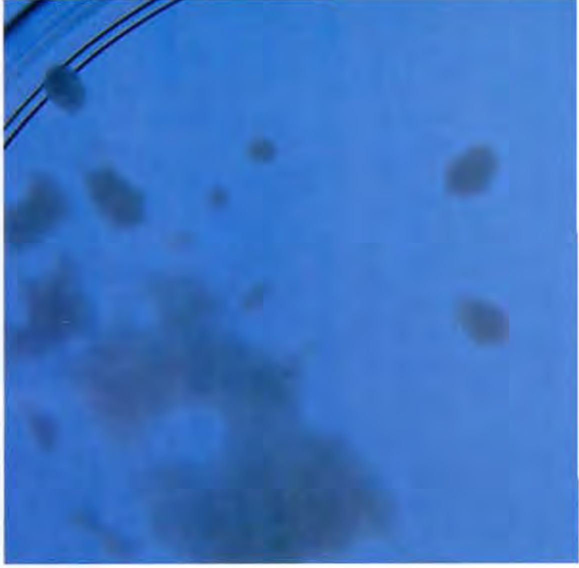


FIGURE 4. Competition of six inoculant rhizobia with indigenous rhizobia for nodulation of three cowpea cultivars at three locations in West Africa.

serological test, enzyme-linked immunosorbent assay (ELISA) described in *Research Highlights* 1980.

To evaluate the effectiveness and competitive ability of temperature tolerant rhizobia, a selection of 13 *Rhizobium* strains was employed in field trials at Gusau in Nigeria, Maradi in the Republic of Niger, and Kamboinse in Upper Volta. The rhizobia were selected on the basis of high temperature tolerance, colony morphology, and origin





Rhizobia from the hot, dry environment of Maradi, Republic of Niger, were almost exclusively of the "dry" type (left); those from IITA/Ibadan and Onne, Nigeria, predominantly "wet" (right).

(Table 6). Five of them originated from Onne and four each from Maradi and IITA. Strains IRc 383C and 400A from Maradi were the most tolerant of 37°C and IRc 252 from Onne the least tolerant. All were highly effective on cowpeas in greenhouse tests. Uninoculated and +N controls were included for comparison. Two high-yielding and improved IITA cowpea cultivars (4R-0267-1F and VITA-7) and one local check were the hosts. Seed was inoculated with 1–10 million rhizobia/seed as single strains. Antisera were produced against each strain to permit nodule typing for competitive ability.

After six to seven weeks of growth, nodules were collected for typing by the ELISA method to determine competitiveness of six of the strains. Indigenous rhizobia were generally more competitive for nodulation than the inoculum strains (Figure 4). The mean proportions of nodules formed by inoculum strains were low at Gusau and Maradi, but high at Kamboinse (especially on cultivar 4R-0267-1F). Strains originating from Maradi were generally more competitive with indigenous strains at Maradi than were strains from Onne and IITA. This was probably due to their better tolerance of the high soil temperatures prevailing there.

The improved cultivars were generally more compatible with the inoculum strains than the local checks. (At Gusau,

TABLE 7.
Grain yield response to inoculation of three cowpea cultivars at two locations in West Africa.

Treatment	Gusau, Nigeria			Maradi, Rep. Niger		
	4R-0267-1F	VITA-7	IFE BROWN	4R-0267-1F	VITA-7	TN88-63
	Yield t/ha					
Uninoculated	1.46	1.43	1.99	0.29	0.27	1.01
N fertilizer, 100 kg/ha	2.05	2.05	1.81	0.48	0.43	0.90
Inoculated, (IRc) 252	1.14	2.43	1.01	0.38	0.31	1.97
256	1.49	2.17	1.34	0.25	0.24	1.37
283	1.71	1.87	1.24	0.27	0.21	1.32
299	1.75	2.22	1.33	0.29	0.19	0.45
344A	1.24	1.68	1.35	0.40	0.38	1.40
383C	1.60	2.31	1.31	0.18	0.32	0.51
400A	1.58	1.85	1.39	0.21	0.26	1.68
409C	1.37	2.19	1.11	0.24	0.24	0.60
430A	2.10	2.37	1.97	0.22	0.43	1.43
462D	1.37	2.14	0.91	0.28	0.30	0.98
489B	1.65	3.06	1.51	0.21	0.27	0.89
500A	1.48	2.25	1.46	0.25	0.47	0.92
506C	1.73	1.95	1.41	0.21	0.22	0.83
LSD 0.10		0.93			0.38	

Ife Brown – the check – is actually an improved, high-yielding cultivar.) These results point to the potential to improve nodulation of high yielding cultivars by inoculation with selected rhizobia.

Grain yield of VITA-7 cowpea inoculated with three of the 13 strains was significantly greater than that of uninoculated cowpea at Gusau (Table 7). In the hot, dry environment of Maradi, four of the inoculants produced more grain on the local cultivar, TN 88-63, than the uninoculated. Yield of the improved cultivars at Maradi was low because of poor adaptation. Nitrogen fertilizer did not produce any more grain than the uninoculated treatment at either location.

Based on these results, strains IRc 252 and IRc 430A are considered the most superior. Future experiments will examine their capability to survive the hot, dry environment at Maradi, in the absence of host plants.

Breeding Soybeans that Nodulate with Indigenous Rhizobia

During the past few years, scientists have observed that several soybean varieties nodulate consistently on African fields without a history of rhizobium inoculant application. They nodulated well with the indigenous rhizobia which provided adequate nitrogen for vigorous plant growth. Called "promiscuous nodulators" because of their indiscriminate characteristic of forming symbiotic relationships with various rhizobia strains, they could provide an opportunity for many farmers in Africa to grow soybeans without the use of commercial inoculants. This is an important consideration because most developing countries do not have inoculant industries.

IITA scientists initiated a crossing program in 1978 to incorporate the promiscuity character into genetic backgrounds adapted to different tropical environments. The following year, early generation segregants were screened on soils with low soil nitrogen without inoculants at

A non-promiscuous soybean variety (below, foreground) with a promiscuous nodulating line next to it in a breeding nursery at Mokwa, Nigeria (1980).

Evaluation of promiscuous nodulating lines in a nursery in eastern Nigeria, 1981 (below, right).

Mokwa, Nigeria. Breeding lines that grew vigorously were dug at physiological maturity and scored for the presence of nodules. Selections were multiplied under irrigation during the dry season at Ibadan, Nigeria, and sown at Gusau, Mokwa, Ikenne, and Onne during the 1980 main season.

Based on nodulation performance and seed storability characteristics, 788 breeding lines were planted during 1981 in two replications per site at six Nigerian locations. Some selections were also sent to 30 collaborators in other countries. Detailed results from the international collaborative trials had not been compiled at this writing, but the Ivory Coast reported that the IITA breeding lines nodulated very well.

Results of the trials in Nigeria also showed that the majority of the promiscuous lines nodulated well and grew vigorously at all the sites, but most of the non-promiscuous check varieties did not. Yield data was collected at four of the six locations (Table 8). The plant breeders are confident that they can genetically transfer this promiscuous characteristic into diverse areas where commercial rhizobial inoculants are unavailable.

During 1982, elite lines from the first cycle will be evaluated for performance in large plots, and the progenies of the second cycle of improvement will be evaluated in preliminary yield tests at six sites in Nigeria.

TABLE 8.

Yield (kg/ha) and nodulation scores* for five promising late-maturing soybean breeding lines at four locations in Nigeria sown without rhizobial inoculant (1981).

Varieties	Mokwa** ABU/IAR		Mokwa** N.G.P.C.		Yandev IAR		Ilorin IAR&T	
Breeding Lines	Yield	nod.	Yield	nod.	Yield	nod.	Yield	nod.
DSm 776	3880	3.00	1093	3.50	1177	3.75	2708	4.00
DSm 1449	2050	3.25	1603	3.50	1156	3.75	2604	2.00
TGx 306-036D	2743	3.25	1613	3.50	1230	2.75	1771	4.00
DSm 884	1903	2.50	1727	2.75	910	4.25	2500	3.50
TGx 330-0102D	1916	3.25	1543	4.50	1093	3.50	2552	3.25
Promiscuous Parents								
TGm 344	3083	3.50	1360	3.75	790	4.25	3021	3.50
TGm 119	1730	3.25	1680	3.50	777	3.75	2312	4.00
TGm 579	1673	3.50	1943	3.50	1120	4.00	2500	3.50
Malayan	1667	3.50	1363	3.75	673	3.75	2396	1.75
Nonpromiscuous Check								
Jupiter	1743	1.75	1473	2.25	670	2.50	1510	1.75
Trial Mean	1587	2.67	1320	3.26	797	3.48	1790	2.95
LSD 0.05	980	1.09	747	1.12	357	1.21	931	1.65
CV %	31	21	28	18	22	17	26	28
Entries	100	100	100	100	100	100	100	100
Reps.	2	2	2	2	2	2	2	2

**Nodulation scores: 1 = no nodules, 2 = few nodules, 3 = good nodulation, 4 = very good nodulation, 5 = excellent nodulation.*

** *Mokwa ABU/IAR = Ahmadu Bello University Experiment Station;*
Mokwa N.G.P.C. = National Grain Production Company Farm located north of Mokwa, Nigeria.

Maruca *larvae spin a web in these containers as they feed on the artificial diet and become pupae.*

Artificial Medium for Rearing Pod Borers Used in Cowpea Resistance Studies

During the past two years, IITA entomologists have been working on the development of an artificial rearing medium for some of the lepidopterous insect pests found in Nigeria. One of these – the legume pod borer, *Maruca testulalis* (Geyer) – is an important and ubiquitous pest of

Development Parameter	Diet (a)							
	1		2		3		4	
	♂	♀	♂	♀	♂	♀	♂	♀
Av. pupal weight (MG) (b)	47.3		41.4		47.5		45.4	
Av. pupation time (days)	12.0	11.8	13.4	13.8	16.6	16.8	15.9	14.3
Av. time to emergence (days)	6.5	6.5	7.3	6.8	7.0	6.6	7.6	7.0
Total development time (days)	18.5	18.3	20.7	20.6	23.6	22.7	23.5	21.3

(a) Diet 1 = soyflour wheat germ, 2 = cowpea flour casein; 3 = cowpea flour torula yeast; 4 = corn soy milk (CSM) human food supplement
(b) Male and female pupal weights averaged together since Maruca *exhibits no pupal dimorphism.*

TABLE 9.
Growth and development of* Maruca testulalis *on four artificial diets.

cowpeas and other legumes. It can cause between 30 and 60 percent crop loss if left uncontrolled.

One of the scientists' principal objectives is to breed cowpea varieties with adequate levels of resistance to the borer. To help reach this objective, an insect rearing facility has been established for the production of large numbers of insects to be used in artificial infestation of cowpea plants in resistance evaluation studies.

Several diets have been developed for rearing lepidopterous pests. A number of these were tried and some selected for closer evaluation. These included cowpea casein diet, soy wheatgerm diet, cowpea yeast diet, and corn soy milk (CSM) – a human food supplement. The best larval performance was obtained on the soyflour wheat germ diet (Table 9). Performance on this diet is comparable to that of a natural diet and has since been adopted as the rearing medium. (A list of ingredients used to prepare the diet is available from IITA.) A recent modification to this diet has been the replacement of soyflour with cowpea (Ife Brown) flour.

Evaluation of Different Spraying Techniques Against Cowpea Pests

Many farmers in the major cowpea production areas in the Sahel and Sub-Sahel regions of Africa often run short of water for their insecticide spraying operations. Because of this, ultra-low volume and electrostatic insecticide application methods which use no water have special value for them.

Field tests by IITA entomologists show that these two methods were as effective for insect control as high-volume knapsack sprayers that use from 250 to 500 liters of water per hectare. Furthermore, the initial purchase price and labor and operating costs per hectare were much lower (Figure 5). Another advantage for the farmer is that the two non-water sprayers weigh only 3 kg each, compared with 25 kg for the knapsack sprayer full of water.

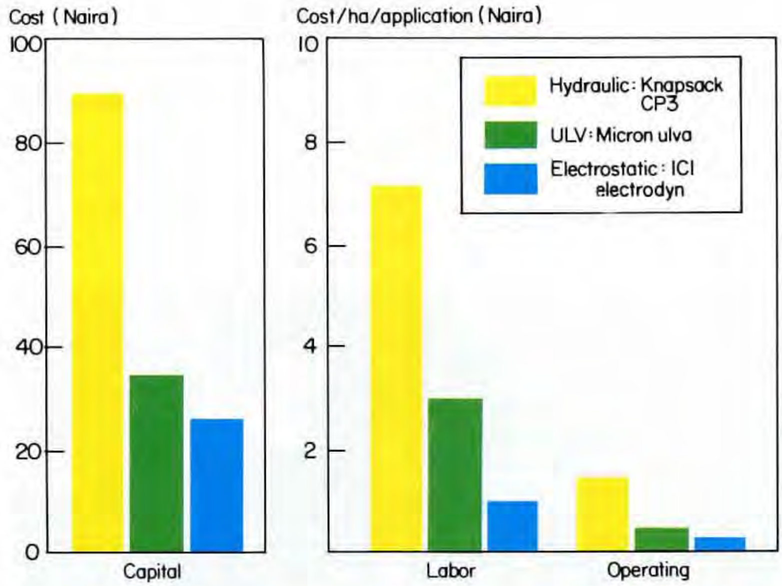


FIGURE 5. Comparative capital, labor, and operating costs of three different types of insecticide sprayers.

A new electrostatic-type insecticide sprayer (left) is more efficient and costs less to own and operate than the older-type knapsack sprayer (right).

For thrips control alone, insecticide applications of cypermethrin alone and cypermethrin plus dimethoate were equally effective (Table 10).

TABLE 10. Comparative performance of different insecticide formulations against cowpea flower thrips using an electrostatic sprayer (IITA 1981).

Insecticide	Dosage*	Thrips per** flower	Yield*** (kg/ha)
Cypermethrin (2-row application)	15	6.0	760
Cypermethrin + dimethoate (2-row application)	15 + 250	5.8	712
Cypermethrin + dimethoate (1-row application)	15 + 250	3.7	632
Dimethoate 50 (2-row application)	250	6.8	553
Control		18.9	453
LSD @ 5%		5.8	272
C.V.		45	28

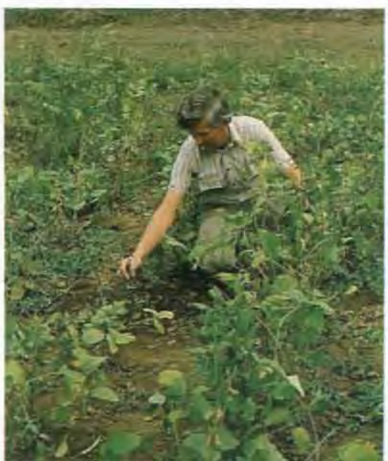
**Dosage = gr.a.i./ha/application applied at 30, 45 and 55 days after planting.*
***Data collected 50 days after planting.*
****VITA-5 cowpea variety.*

Increasing Danger of Virus Diseases in Rice and Soybeans

Under conditions of more intensified cropping, virus diseases in rice and soybeans – generally of low incidence in the past – are now being reported more often. In 1981, a yellow mottle disease was reported from two important rice growing areas in eastern and central Nigeria. IITA virologists tested samples from those areas and identified the rice yellow mottle virus (RYMV) as the causal agent of the disease. During a survey of the area in eastern Nigeria, they found that the disease had established itself at experimental sites of a large rice development scheme where many new and apparently highly-susceptible varieties were being tested for performance. The disease was obviously building up because the infection incidence in fields developed several years ago was significantly higher than at recently-developed sites.

The introduction of new and mostly highly-susceptible varieties apparently plays a significant role in the occurrence of this disease, believed to be indigenous to tropical Africa. IITA scientists have found most traditional African upland

Soybean plants badly stunted by soybean dwarf virus (SDV) compared with a healthy one.



(Far right) An IITA virologist inspects a plant in a row of soybean dwarf virus-infected plants surrounded by healthy ones.

rice varieties to be moderately to highly tolerant to RYMV. This probably explains why the disease has only recently become important in Nigeria and several other countries in West and East Africa.

A severe stunt disease almost completely destroyed a two-hectare planting of soybeans at Mopa in central Nigeria in 1980. (A similar or identical disease was observed in northern Nigeria as far back as 1975.) The disease at Mopa proved to be graft-transmissible but could not be transmitted by means of sap inoculation.

Such monitoring of season-to-season and year-to-year incidence and importance of various virus diseases identified or newly discovered in the various target crops of IITA continues to be one of the aspects of the work of the Institute's virologists. Dwarfed soybean plants have been found occasionally at IITA/Ibadan during the past five years but always at very low incidence. During the last few months of 1981, however, a very high incidence of severely stunted plants (> 50 percent) was observed at a site planted with one particular breeding line. This disease also proved to be graft-transmissible only. In serological tests with an antiserum to soybean dwarf virus (SDV) from Japan, virus specific positive reactions were obtained with samples from severely stunted plants from this field.

Because genetic resistance is the only effective means to control virus diseases, IITA scientists are giving high priority to a resistance breeding program. For RYMV, it involves the use of resistance levels found in traditional African upland rice varieties. For the severe dwarfing disease of soybeans, resistance sources still have to be identified among the more than 3,000 accessions of germplasm available at IITA.

Soybeans intercropped with sorghum in a farmer's field in Benue State, Nigeria.

Economists Survey Smallholders' Production of Soybeans

As part of a study of the potential for soybeans in Nigeria, IITA agricultural economists surveyed farmers in the two main production areas – Benue State and the Zonkwa region (Figure 6). They selected 36 farmers from several villages in the former and 30 in the latter in cooperation with local officers of the Ministry of Agriculture.

Smallholders produce most of the soybeans in Nigeria, and nearly all of their crop is sold in local markets for human consumption. Although the potential for greater production exists in view of the large and increasing amounts of imported soybean meal for poultry feeds, soybeans at present rate as a minor crop.

The average farmer grows two to three crops of soybeans in successive years, mainly on upland fields. The rotation

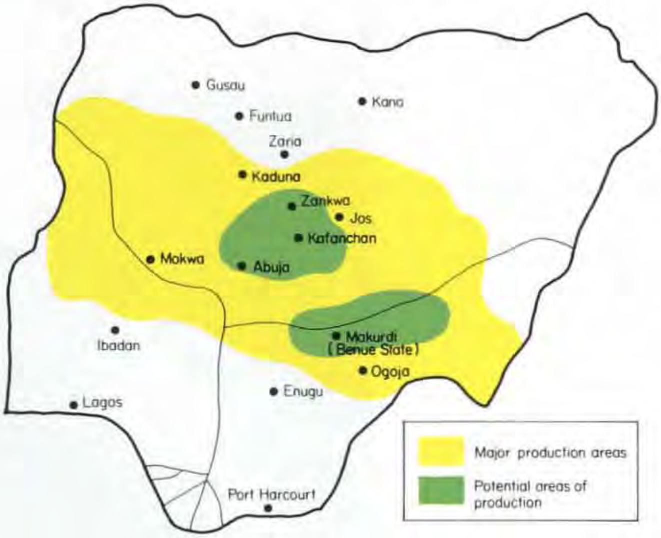


FIGURE 6.
Map of Nigeria showing major areas of present soybean production and potential areas.

after fallow nearly always starts with yam in Benue State and with sorghum in the Zonkwa area. In the second year, soybeans appear in the rotation often intercropped with sorghum and sometimes with maize. The picture is a sorghum-based cropping system in which sorghum/soybeans appear for two or three years during the end of a four-to-five year cultivation period. Plant spacing for soybeans varied greatly, and weed control was the main factor influencing it.

The majority of farmers used only hand-hoeing for land preparation. Those who used tractors (about one out of five in the sample) hired them mostly from the government.

Farmers were asked to compare labor use for soybeans with that for other more popular crops for which data are fairly well known. Soybeans required less labor for planting, weeding, and harvesting than groundnuts but more than sorghum. Slightly more than two-thirds of the labor input (78 man-days) was absorbed for planting, weeding, and harvesting the soybeans. The next largest labor use was for land preparation (Table 11).

TABLE 11. Combined labor utilization data for soybean cultivation in Benue State and the Zonkwa region.

Operation	Relative labor utilization %	Man-days
Planting, weeding, harvesting	65.3	78
Land preparation	25.3	30
Fertilizer application	6.0	7
Insecticide application	0.5	1
Bird scaring	2.9	3
Total labor	100.0	119

TABLE 12. Relative importance (%) of different labor sources by operation and by region.

	Family		Hired		Community		Total	
Region*	B	Z	B	Z	B	Z	B	Z
Operation:								
Land preparation	7.7	22.8	13.3	3.4	3.4	—	24.4	26.2
Planting	6.8	13.9	3.9	1.0	0.5	0.4	11.2	15.3
Fertilizer application	4.0	7.0	0.1	0.3	0.3	0.3	4.4	7.6
Weeding	15.4	14.3	3.1	6.0	1.3	1.8	19.8	22.1
Insecticide application	0.4	0.5	—	—	—	—	0.4	0.5
Bird scaring	2.4	3.4	0.1	—	—	—	2.5	3.4
Harvesting	16.7	15.3	19.4	2.8	1.2	6.8	37.3	24.9
Total	53.4	77.2	39.9	13.5	6.7	9.3	100.0	100.0

**B = Benue State; Z = Zonkwa Region.*

The survey also showed that the farmers in Benue State used about half their labor from sources outside the family, but the family was the main source for farmers in the Zonkwa region (Table 12). The timing of the land clearing ranged from April–June, planting from June–August, and harvesting from November–December (Figure 7).

Farmers in the survey mentioned pest control and economic inputs as their most important production problems. The majority of them (86 percent) store part of their crop before selling it and market the soybeans throughout the year (Figure 8). Two out of three farmers criticized the

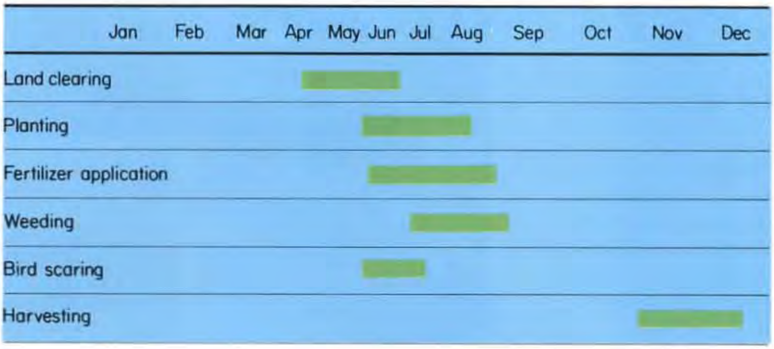


FIGURE 7.
Labor calendar for soybean production in Nigeria.

poor marketing facilities, but toward the end of 1981 marketing opportunities were looking brighter because of higher local prices and processing of soybeans by mills in Gusau and Funtua.

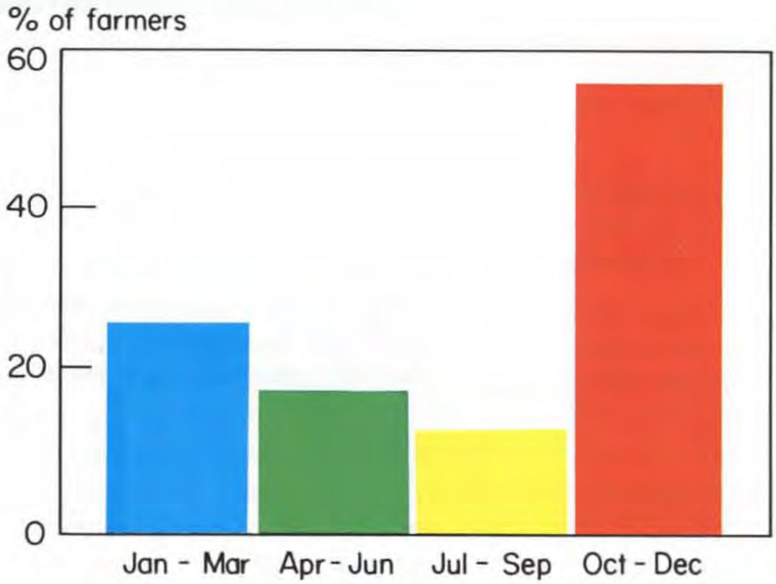


FIGURE 8.
Percent of farmers marketing soybeans in three-month sequences of the year.

A natural enemy,* Apoanagyrus lopezi, *(above) parasitizing a second instar cassava mealybug.

A predator –* Scymnus *sp. – feeding on mealybug eggs (above, right).

Parasites and Predators for Cassava Mealybug in Africa

Because millions of people depend upon cassava for their basic food source, the cassava mealybug, *Phenacoccus manihoti*, (MAT-FERR), may have gained the status of Africa's worst single agricultural pest. Since the mealybug was discovered first in Zaire in 1973, it has spread into almost all the cassava-growing areas of Africa. This pest insect causes heavy yield losses – an average of 60 percent reduction in yield for the roots and up to 100 percent for the leaves.

It attacks the cassava plants throughout the year with population numbers peaking in the dry season. Late plantings usually will be totally lost, while early plantings may escape heavy damage. *P. manihoti* has a parthenogenetic life cycle, completed in 24–26 days at 27°C. The average fecundity in the laboratory is 440 eggs per female. In the field, 9–10 generations a year have been recorded.

IITA has advocated biological control of the cassava mealybug for several reasons. In Africa, cassava is grown by small landholders in widely dispersed plots usually with

Cassava plants in the field on the left are recovering quickly during the dry season after the mealybug colonies have been destroyed by the released enemies Scymnus *sp. and* A. lopezi. *(Inset photo shows the new shoot growth free of mealybug.) In the control field on the right no new shoots are produced and the cassava mealybugs will eventually kill the terminal shoots.*

difficult access. As the cassava mealybug is exotic to Africa, having been accidentally introduced in this continent, there are no natural control agents (predators-parasitoids-entomopathogenes) ecologically adapted to this species. To solve the problem, the natural control elements of the original situation in the Americas where the mealybug is not a pest have to be re-established. This is done by introducing the natural control agents into Africa. They have then the potential to bring the population of the pest insect below the economic damage threshold and keep it in an equilibrium state with its natural enemies.

The first step in effective biological control is to find the area of origin of the pest insect and collect the natural enemies species complex associated with it over its entire area of distribution. Selected natural enemies are then introduced into Africa after careful quarantine checks. After in-depth studies of their bionomics, the natural enemies are multiplied in mass and released into cassava fields infested with mealybugs. *P. manihoti* was described as a new species in 1977. Its morphological similarities with North American *Phenacoccus spp.* permitted the designation of the Neotropics as its probable area of origin.

IITA's intensive exploration work for the cassava mealybug and its natural enemies conducted in the Americas over the last two years in cooperation with the Commonwealth

Natural enemies of the cassava mealybug are multiplied in this culture room for IITA's biological control research.

Institute of Biological Control (CIBC) and the International Center for Tropical Agriculture (CIAT) has lead to the discovery of this pest on cassava in Paraguay by CIAT, and in Bolivia and Brazil by CIBC.

Four new species of natural enemies (three predators: *Exochomus* sp., *Hyperaspis notata*, and *Scymnus* sp. and one parasitoid, *Apoanagyrus lopezi*) have been collected in South America by CIBC. After quarantine in Trinidad and London, they were brought to Nigeria with the approval of Nigerian quarantine authorities and studied in detail. *Scymnus* sp. and *A. lopezi* have been mass multiplied, and releases in IITA's experimental fields have resulted in successful establishment of the two species.

In less than two months after release, cassava plants in the release field are exhibiting rapid recovery from the initial mealybug attack. The exotic natural enemies have destroyed the mealybug colonies in the release field and are spreading to neighboring fields. The multiplication potential observed in the laboratory for the two species has been fully maintained in the field, and they appear to be ecologically well-adapted to southern Nigerian dry-season conditions.

This early and very positive success supports the biological control approach. Because it is generally the natural enemy complex (rather than a single predator or parasitoid) that ensures control, further exploration for more natural enemy species is currently being undertaken. This will provide several species of natural enemies to fit all the different ecological conditions of the African cassava growing areas.

Hyperaspis sp. was collected on *P. herreni* (a close relative of *P. manihoti*) from Guyana and released in 1980 in western Nigeria. However, its impact on the cassava mealybug has been minimal because of its slow population build-up in response to increases in the host population.

An increased research effort is underway on the ecology of *P. manihoti*, as well as on the exotic natural enemies of potential use for biological control. More efficient mass-culture techniques will be required and then expanded as soon as possible to supply the quantities of natural enemies needed by any country. Also, IITA's scientists will assist African countries to build up their own biological control programs, supplying technical knowledge and stock cultures of natural enemies. So far, predators (*Hyperaspis* sp. and *Scymnus* sp.) and a parasitoid (*A. lopezi*) have been distributed to Zaire (PRONAM) and Republic of the Congo (ORSTOM-FAO) for further multiplication and release.

An important consideration of the cassava mealybug biological control is the peculiar secondary effects of the pest's feeding behavior. Early studies have shown that the mealybug's first two larval instars are strongly toxinoferus, inducing severe leaf and terminal shoot growth disturbances. The mealybug gets protection from adverse climatic conditions and natural enemies as the terminal leaves curl and surround the mealybug colonies. It is IITA's aim to develop plants resistant to the toxin, thereby allowing them to grow normally and leave the mealybug exposed to increased activity of the natural enemies and adverse climatic conditions.

The amount of hair density on the young cassava leaves at the tip of the plant as shown here may have an effect on resistance to both mealybug and green spider mite.

(Above, right) Preliminary research in Zaire shows that mealybugs find it more difficult to settle on the growing tips of the resistant cassava clone (left) compared with an improved local selection (right).

Two Cassava Plant Mechanisms: Their Effect on Mealybug Resistance

Genetic resistance to the destructive cassava mealybug (CMB) through improved plant varieties complements the system of biological control with predators and parasitoids described in the previous article. It is expected that the successful combination of these two control methods will greatly reduce mealybug problems in Africa in the future. As part of a continuing program to breed cassava for further resistance to this pest in Africa, IITA scientists worked on two different approaches during 1981. One involved the possibility of incorporating higher hair density on the surface of young cassava leaves and the other the development of glabrous clones that keep the mealybug population at a relatively low level.

For the pubescence or hair density study, 60 clones were selected from the IITA's germplasm sources based on their potentials and resistance to major diseases. Five months after planting (February, 1981), the cassava plants were evaluated not only for mealybug (CMB) resistance but also for green spider mite (CSM) resistance. The subjective ratings were based on six classes of infestation severity of young top leaves ranging from class 0 which meant no obvious damage symptoms to class 5 – the heaviest damage (90–100 percent of plants in the plot affected or plants defoliated).

Researchers counted the hairs per 1 cm^2 along the under-surface of the central lob and petiole of a young fully-expanded leaf and tip stem four months after the cassava was planted. In general, the largest number of hairs was observed on the leaf upper surface. The number of hairs on this surface was related to those on the leaf under surface, petiole, and tip stem. Several clones with high pubescence showed resistance to both CMB and CGM (Table 13). Figures 9 and 10 show the relation of CMB and CGM resistance ratings with hair density of the leaf upper surface.

These results suggest that if the hair density were increased further through breeding, CMB and CGM resistance might be improved accordingly. Also, the CMB scores were significantly associated with CGM scores ($r = 0.69$), indicating that improvement for resistance to CMB will lead to CGM resistance and vice versa.

In the other research project with clones of a different type (glabrous or without hairs on the leaves), IITA scientists in Zaire's Programme National Manioc started by screening a large cassava seedling nursery which had been artificially infested with mealybugs in the dry season. The first negative screening resulted in the identification of 120 clones with no apparent mealybug damage. These clones on further screening after artificial infestation in the field showed that the clone 70453 had no apparent damage to the plant although there were a few mealybugs still on it. In sharp contrast, the improved local selection – 02864 – showed considerable plant damage symptoms and harbored a large mealybug population.

Greenhouse studies were then conducted to further check the reaction of the two clones to mealybug infestation. Plants of both clones were infested with three adult

TABLE 13.
Cassava clones with high pubescence and resistance to both mealybug and green spider mite.

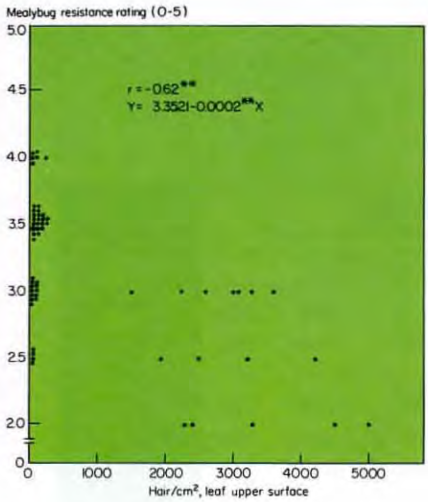
Clone	Hairs/cm²				Rating***	
	L(UP)*	L(UN)**	Petiole	Stem	CMB	CGM
TMS 61677	5013	2118	604	515	2.0	2.5
TMS 60142	4550	2792	464	713	2.0	2.0
TMS 5326 × TMS 5032	4237	962	158	201	2.0	3.0
TMS 61324	3388	1310	373	233	2.0	2.0
TMS 42025	2480	1195	238	210	2.0	(3.5)
TMS 4(2)1425	2188	347	79	91	2.0	2.0

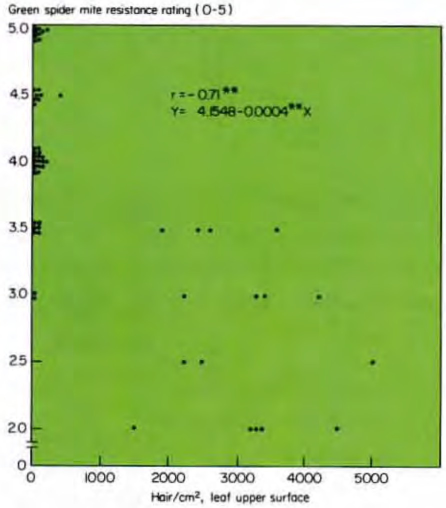
**Leaf upper surface.*
***Leaf under surface.*
****Range: 0 = no obvious change; 5 = heaviest damage.*

mealybugs at the growing tip of the cassava plant. Four to six days after infestation, the number of mealybugs and their position on the plants showed contrasting differences in mealybug establishment.

More than half of the adult mealybugs initially placed on the clone 70453 were lost within four to six days after infestation, indicating that an antibosis mechanism may be at work here. The mealybug loss was less than 8 percent in the case of variety 02864. Furthermore, the position of the few remaining mealybugs on clone 70453 showed that less than 27 percent of them were near the growing tip, but the figure for variety 02864 was a high 60 percent. (The growing tip is the most preferred place for establishment, multiplication and dispersal of mealybugs.) These observations indicate that adult mealybugs find it more difficult to settle on the growing tip of the resistant clone.

For a better comparison of the multiplication rate of mealybugs on clone 70453 and variety 02864, the numbers lost on each shoot were replenished. One month after the initial infestation, the total number of mealybugs, immature (1st, 2nd and 3rd instars), preovipositing, and ovipositing





FIGURES 9 and 10. Relation of cassava mealybug (left) and cassava green spider mite (right) resistance ratings with hair density of the leaf upper surface.

adults were counted and the results showed significant differences in the mealybug population and its composition on the two clones. The rate of multiplication of mealybugs on clone 70453 was much lower than on 02864. Also, a significantly lower number of adults (9.2 percent) on the resistant clone suggests a slower rate of development of mealybugs on it compared with the susceptible variety (Table 14).

TABLE 14. Average mealybug count per shoot on a resistant cassava clone 70453 and the check variety 02864. (Three replicates of two and three plants per clone/variety; greenhouse conditions.)

Clone/Variety	Immature mealybug	Preovipositing adults	Ovipositing adults	Total
70453	16.3**	0.5**	1.0**	17.8**
02864	195.1	29.8	17.0	241.9

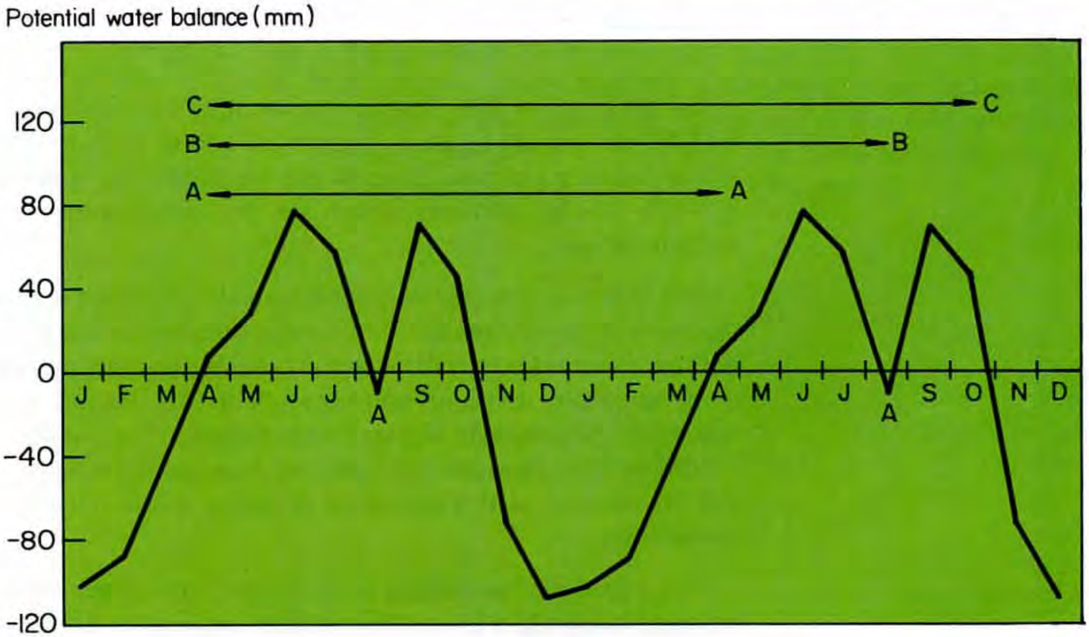
***Significant at 1 percent level.*

Agro-climatic Considerations for Cassava Cropping

Farmers in many areas of the humid and subhumid tropics, particularly in West Africa, commonly leave cassava in the field for up to 18 months because of various constraints in their farming systems as a means of safe storage of the roots. The prolonged dry seasons that may occur within any 12–18 month cassava production cycle affect yields quantitatively in view of the well-established relationships between dry matter production and yield on the one hand and evapotranspiration and transpiration on the other. Typical cassava production cycles in relation to moisture cycles for the humid/subhumid transition zone as represented by Ibadan, Nigeria, are shown in Figure 11.

Cassava reduces leaf area during the dry season as an adaptive mechanism to reduce transpiration, but the

FIGURE 11. Mean monthly potential water balance (rainfall-potential evapotranspiration) for Ibadan, Nigeria, in relation to three typical cassava growing cycles (A = 12 months, B = 16 months, C = 18 months).



Planting and harvesting of cassava varieties compatible with the yearly moisture cycles in certain West Africa areas may result in higher yields and better land use.

remaining leaves usually show no visual sign of wilting. Although this has been attributed to morphological and physiological modification of the stomatal system, evidence of a decrease in the whole plant and in starch weights during the dry period suggests a possible partial mobilization of accumulated dry matter over the period to sustain the crop or maintain necessary plant processes. (To support the remaining leaves, the plant draws energy from the roots.) In this context, it is to be expected that yields would decrease in association with this phenomenon and should bear a relationship to the duration/intensity of the dry season.

To test this hypothesis, yields of 10 cassava clones grown at IITA over a five-year period were analyzed in relation to an index of the severity of the respective seasonal droughts preceding the harvests of the crops. This index, I, is defined as the cumulative Class A pan evaporation over the period December 1 through February 28/29. The result of the analysis shows a negative and highly significant relationship between the fresh root yield of cassava, Y, and the drought severity index, I, (Figure 12) This is expressed by the equation:

$$Y = 176.69 - 0.342I; \ (r = -0.98^{**})$$

On the basis of this equation, a drought severity index of 516.64 mm constitutes a theoretical upper limit to areas where leaving the crop through the dry season for a second growth cycle appears possible for additional yield accumulation.

The index is strongly dependent on the duration and the intensity of the dry season. The longer duration of the period in the subhumid areas of the tropics and the parallel increase in evaporative demand compared with the humid areas results in increasingly higher index values. This implies an increased limitation on yield with an increase in the length of the dry season or the period of negative water balance in these areas.

Since cassava basically is no different from other crops in its requirement of a favorable moisture regime for dry matter

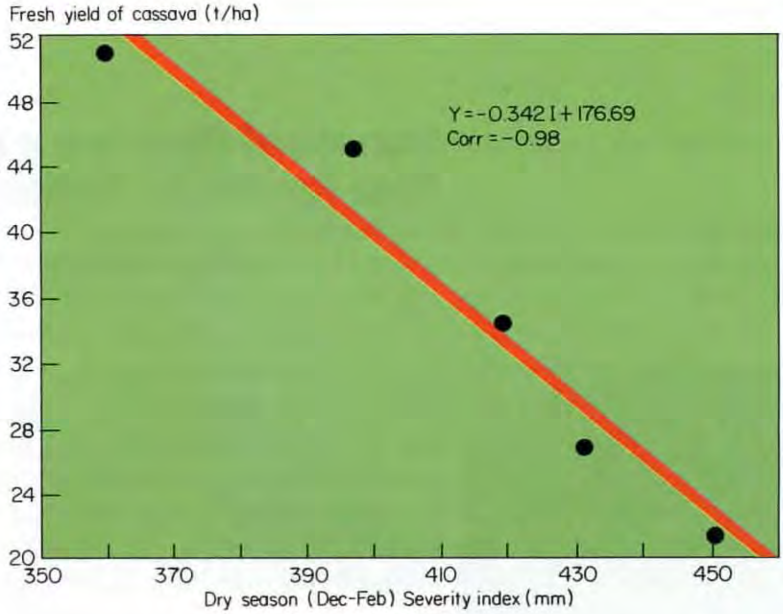


FIGURE 12. Relationship between the fresh yield of cassava and the dry season severity index at IITA over a five-year period.

accumulation and yield, a cropping system involving the planting and harvesting of varieties compatible with the yearly moisture cycles in given areas may be desirable on the basis of higher yields (at least per cycle) and better land use. It would offer farmers a choice for land use in the subsequent favorable moisture/cropping period. (See Figure 11.) This choice could become even more meaningful in a situation where cassava is harvested at the beginning or midway during the second moisture cycle with no possibility to use the land for the rest of the period.

Sources of Resistance to Cocoyam Root Rot Blight Complex

A cocoyam line resistant to root rot blight complex stands in a Cameroon field in the midst of non-resistant plants wiped out by the disease.

Appraisals of the constraints on the production of cocoyam (*Xanthosoma sagittifolium*) in many countries of humid Africa and the Caribbean indicate that field diseases rank high on the list and the cocoyam root rot blight complex (CRRBC) has now become number one among them. In West Africa it is referred to as the "Apollo" disease, in Puerto Rico as "Mal Seco" and it can cause severe losses to a root crop which is a staple food for many people.

Cocoyam plants naturally infected with cocoyam root rot blight complex show chlorotic leaves with brown blight developing from the periphery and later extending toward the petiole. The petioles droop and the leaves dry up and shed prematurely. Infected plants remain stunted and the root system becomes greatly reduced due to decay. Fungi associated with this disease are *Pythium myriotylum*, *Rhizoctonia solani*, and *Fusarium* spp., but research results showed that *Pythium myriotylum* appears to be the principal causal agent. The effectiveness of fungicides to control the disease has been variable. They are probably not a feasible method of control.

The disease is more prevalent in heavy soils, especially if they are poorly drained, and during wet years can be very damaging even on steep, well-drained soils. Growing cocoyam plants under different levels of soil moisture at IITA had a marked influence on their reaction to CRRBC. Plants growing under high soil moisture (hydromorphic) conditions were severely affected by the disease compared with those at higher elevation under low soil moisture conditions. The disease incidence was significantly higher under waterlogged conditions than in those with normal drainage. The low-lying or poorly-drained fields were definitely conducive for high disease incidence and predisposed the plants to infection.

In Cameroon, cultural practices (such as wide spacing along with high mounds) have shown promise in reducing the incidence of CRRBC. Wider spacings (1.5×1.5 m to 2.0×2.0 m) and earlier planting by 20 to 30 days have also shown less disease incidence and given higher yields than the closer spacings and later planting. In addition, planting in well-drained sandy or light soil reduces incidence of the disease. Use of cormels for planting gave less disease incidence and higher yields. Because cocoyams are a vegetatively propagated crop, clean material should be planted to minimize primary infection.

Recent research in Nigeria and in Cameroon has revealed potential sources of resistance among cocoyam hybrid seedlings from crosses between the local × Caribbean accessions. This implies that resistance may be present within the crop gene pool. Also, another related source – a local land cultivar of yellow type found in Cameroon and Nigeria – has shown some resistance to CRRBC.

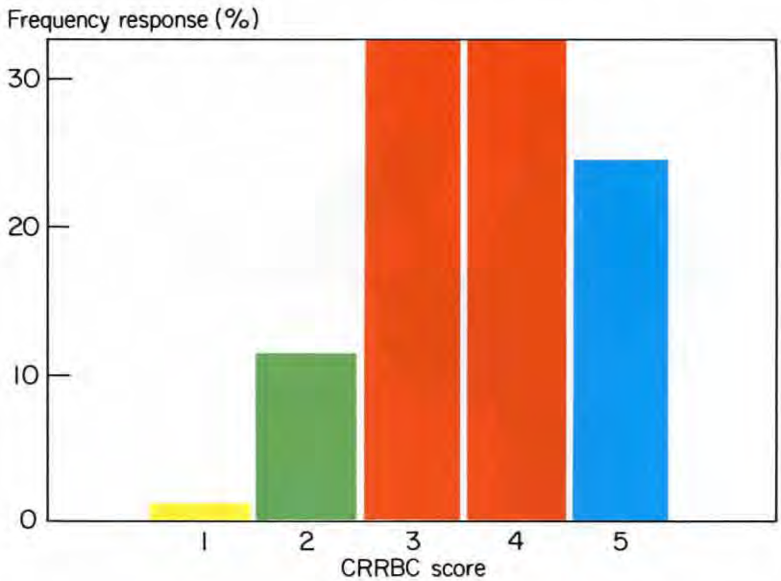


FIGURE 13. Frequency distribution of plants showing varying degrees of symptoms to cocoyam root rot blight complex (CRRBC) in a population of seedlings grown in hydromorphic soil at IITA.

Scientists at IITA and the Cameroon National Root Crops Improvement Program (CNRCIP) have been able to reliably induce the onset of the disease by growing the plants in heavy soils and under natural hydromorphic field conditions. This proved to be a good screening environment to discriminate between resistant or tolerant types and susceptible genotypes. Figure 13 shows the frequency distribution of plants showing varying degrees of symptoms in a population of seedlings grown in hydromorphic soil at IITA. Also, resistant types from a similar seedling population have been identified in Cameroon. The scientists selected 28 percent of these plants for further evaluation. These clones will be induced to flower and will be intercrossed. Efforts also are underway to transfer resistance from the yellow type to the cultivated types.

The potential for improving cocoyam production by combining genetic resistance with other desirable agronomic characteristics now seems feasible.

International Distribution of Tissue Culture Material

For the first time, IITA's Tissue Culture Laboratory distributed disease-free sweet potato and cassava clonal material in 1981 to 17 countries in Africa (Figure 14). In addition, sweet potato material was sent to countries in Asia, South America, and the Pacific area. During the previous year, most of the improved lines were determined to be virus-free through meristem-tip culture and virus indexing. After inspection by a quarantine officer, a phytosanitary certificate was issued for the material, and it was then multiplied and distributed in tissue culture form to requesting countries.

Improvements have been made in the virus indexing procedure for sweet potatoes which is necessary to prove that the plantlets from meristem are indeed virus-free. A new technique, Serological Specific Electron Microscopy

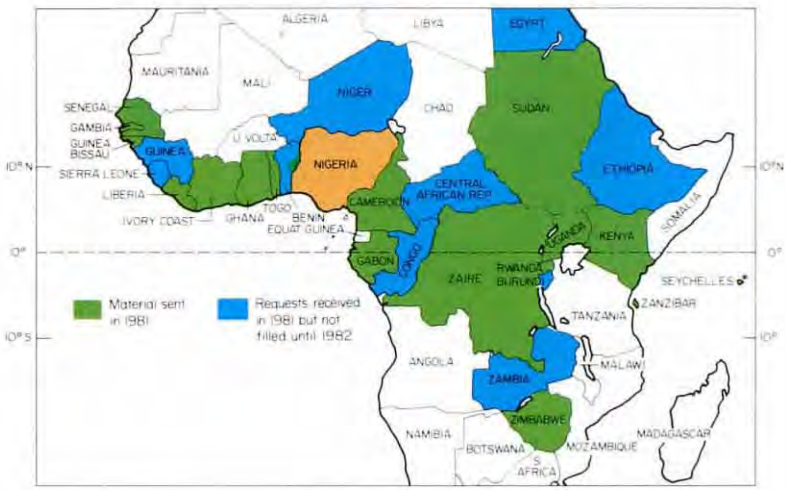


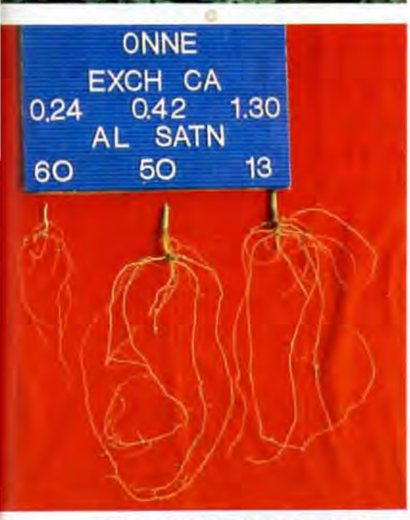
FIGURE 14.
Countries receiving tissue culture material in 1981 and others placing orders during the year that will receive it in 1982.

A new, rapid technique – Serological Specific Electron Microscopy – can detect an extremely low concentration of virus.

(SSEM) has been utilized. (Also sometimes called Imuno Sorbent Electron Microscopy.) It is very rapid and can detect an extremely low concentration of virus. This reduces considerably the time required to produce virus-free material, as well as providing added confidence of its disease-free status.

The *in vitro* germplasm collection of sweet potatoes now totals about 400 clones. Normal growth was obtained with some clones when transferred to a fresh medium after 28 months of culture in the same medium.

Forms completed upon arrival of the clonal material in a country and after the plantlets are ready for transplanting from pot to field give IITA valuable feedback information. This system also allows the Institute to rapidly airmail a new consignment in case the first one failed to reach its destination in good condition.



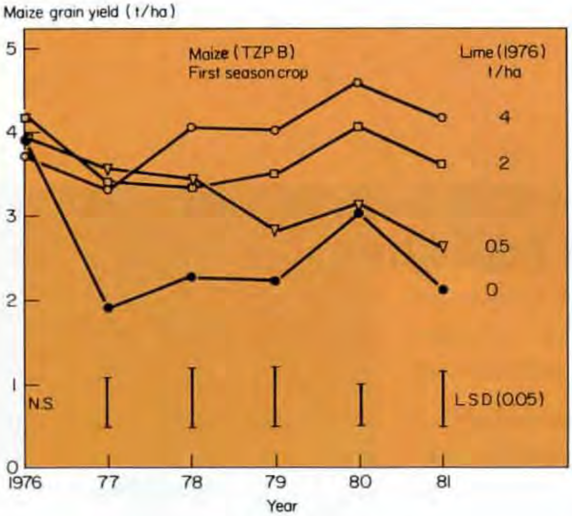
A second season crop of cowpeas in a high rainfall area shows tolerance to high soil acidity with minimum lime and no fertilizer (top).

Root growth and nodulation of IITA cowpea variety VITA-4 as a function of soil exchangeable aluminum and calcium levels (bottom).

Management of Acid Soils for Sustained Maize/Cowpea Production

Vast areas of arable land in the humid tropics are comprised of strongly leached soils – Ultisols and Oxisols. These soils are characterized by a low inherent nutrient status and a high degree of exchangeable aluminum (Al) saturation which often reaches levels toxic to the growth of many crops. The traditional "slash and burn" agriculture sustains economic yields for only one or two years after seven to 15 years of bush fallow. If smallholder farmers on such soils are to develop a more intensive food cropping system, purchased inputs such as lime, fertilizers, and pesticides will be necessary. But scarcity of lime sources and substantial leaching losses in the high rainfall region render the practice of using relatively high rates of lime financially prohibitive. Consequently, it is necessary to know the minimum rates of lime required for optimum crop production as well as the residual value that may be expected.

Results from a six-year liming and crop rotation experiment, conducted at IITA's high-rainfall station at Onne near Port Harcourt in southeastern Nigeria, showed that relatively low rates of lime would be adequate to sustain crop yields under a continuous maize/cowpea rotation system. (Mean annual precipitation in the area is 2,450 mm, monomodal; rainy season starts in March and ends in late November.) With an adequate supply of N, P, K, and Mg, liming at a rate of 0.5 t/ha maintained maize yields at a high level (4.0–4.6 t/ha) three years after liming (Figure 15.) Sustained maize yields for six years or more were possible with a lime rate of 2 t/ha. The critical level of exchangeable Al saturation for maize (IITA Cv. TZPB) required for 90 percent maximum yield was about 35 percent (or pH 4.8) for the coarse-textured, kaolinitic Ultisol (Typic Paleudult).



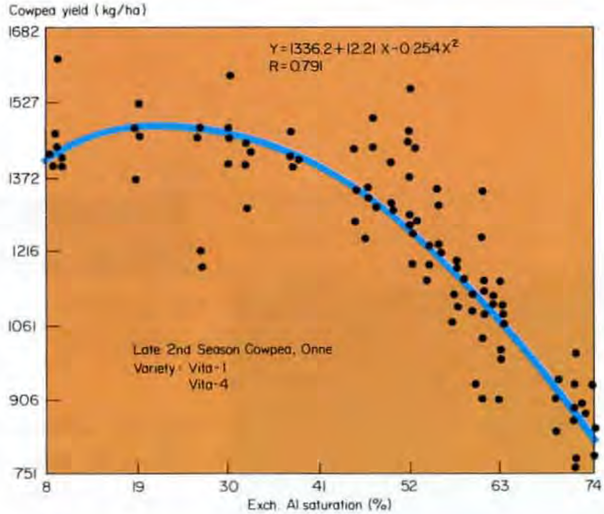


FIGURE 15. (Above) Residential effect of lime on maize yield grown in a coarse-textured Ultisol (Typic Paleudult) under high rainfall conditions (2450 mm p.a.).

FIGURE 16. (Right) Relationship between exchangeable aluminium (Al) saturation in soil and cowpea yield.

Cowpeas performed well at Onne when planted in late September or early October as a late rainy-season crop without additional fertilizer application. Many cowpea varieties (including VITA-1 and VITA-4) showed tolerance to high soil acidity and maintained a yield of 1.3 t/ha at about 50 percent exchangeable Al saturation in the surface soil (Figure 16). Earlier sowing of cowpeas immediately after maize harvest in July–August is not recommended because of severe insect and disease infestation, as well as temporary water-logging during the peak rainy season.

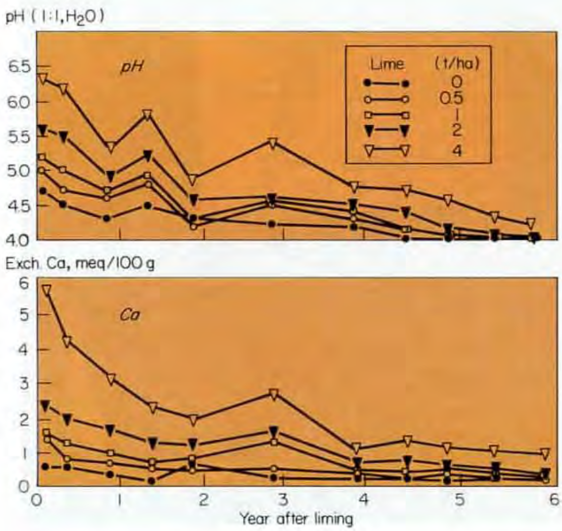
Applied lime leached readily from the surface soil, particularly at high rates of application and a rapid decline of soil pH followed (Figure 17). In fields that received 4 tons of lime per hectare, 2.7 t/ha of applied lime was leached from the surface layer in three years. The lime was leached as neutral calcium salts and had little effect on the subsoil acidity (Figure 18). Recycling of the leached Ca in the subsoil horizons would require deep-rooting species tolerant to high subsoil acidity.

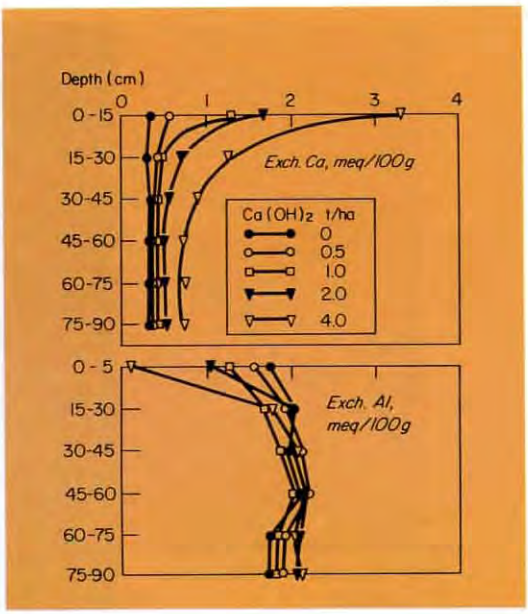
On the other hand, because relatively low rates of lime sustained yields for three years or more, IITA's soil scientists have concluded that for the coarse-textured kaolinitic soils in the high rainfall tropics an annual dressing of 200–400 kg/ha of lime should be sufficient to maintain maize and cowpea yields. At this rate, lime could be regarded as a fertilizer rather than a major soil amendment.

The introduction of cowpeas as a dry season crop in the high rainfall tropics deserves special attention. The tolerance of cowpeas to high exchangeable Al levels in the soil and the abundance of cowpea rhizobia in acid soils should make this crop more attractive to smallholder farmers than other food legumes which are susceptible to Al toxicity. Moreover, in the high rainfall regions where cassava and yams are the major food crops, a productive maize (usually harvested and consumed as green maize) and cowpea rotation system could substantially improve the present low protein diet of many families.

FIGURE 17. (Below) Decline of soil pH and loss of calcium in the surface soil from the limed field as a function of time.

FIGURE 18. (Right) Distribution of exchangeable calcium (Ca) and aluminium (Al) as a function of soil depth three years after lime application.





Live Mulch for Intensive Cropping

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

Results of the three years of research show that maize yields averaged over five seasons of continuous cropping without nitrogen fertilizer were superior in a live mulch system (2.0 t/ha) to yields in either the no-tillage (0.8 t/ha) or conventional tillage systems (1.0 t/ha). Maize in the live mulch showed little or no response to nitrogen fertilizer.

*Live mulch (*Psophocarpus palustris*) with maize crop – no nitrogen fertilizer and no weeding.*

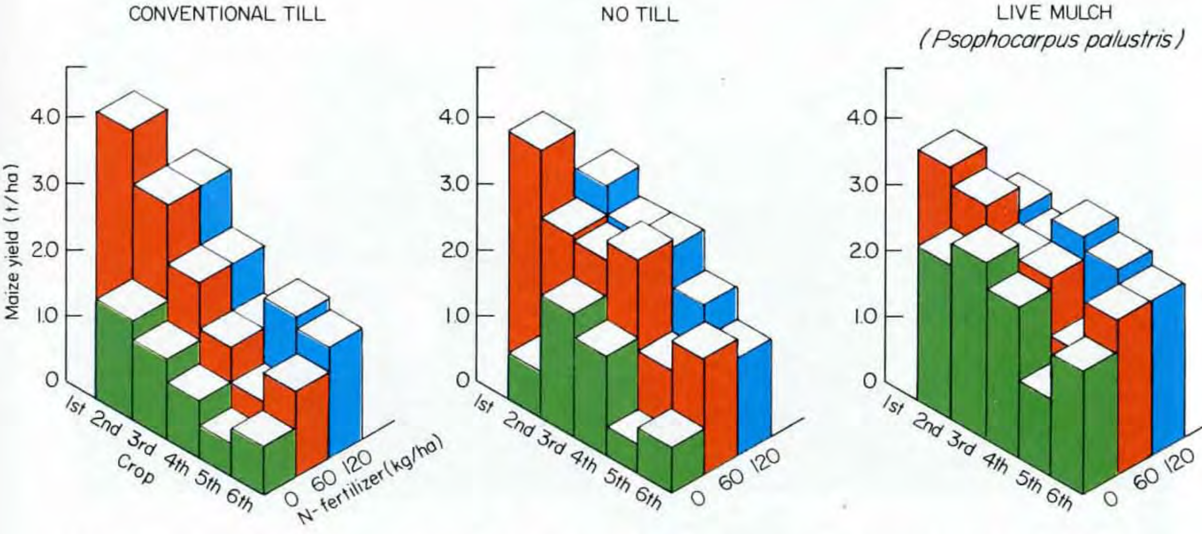


FIGURE 19.
Effect of land management, nitrogen fertilizer, and crop intensity on maize yield (IITA, 1979–81).

Good maize yields on a sustained basis and at low input levels could be observed only where the land management system involved the use of the legume cover crops (*Centrosema pubescens* and *Psophocarpus palustris*) as a live mulch.

Maize yields in the conventional tillage system declined steadily with subsequent cropping, and this decline was not

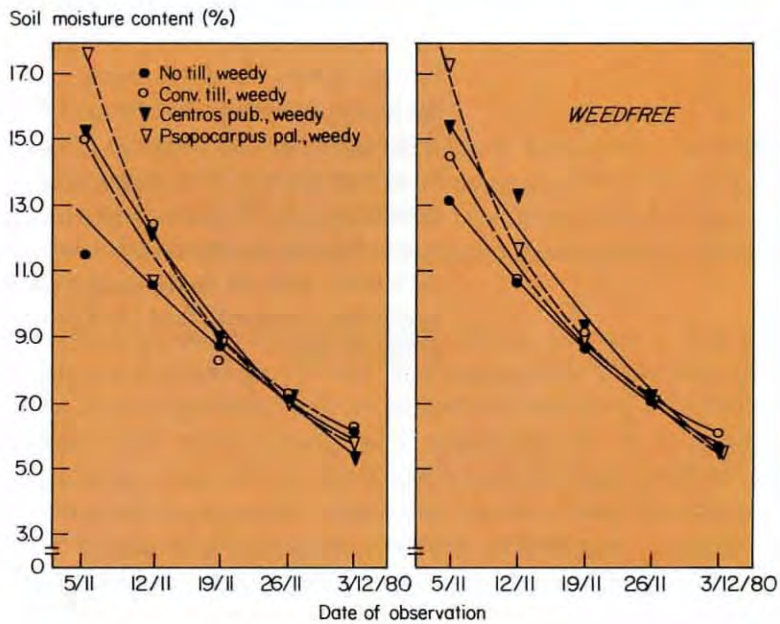


FIGURE 20.
Trend in soil moisture content under different mulch-crop combinations (1980).

Left, maize crop in live mulch without nitrogen and no weeding. Right, maize smothered in weeds – conventional tillage without live mulch and no nitrogen or weeding.

overcome by the application of nitrogen (Figure 19). In the no-tillage system, low maize yields were observed when no nitrogen fertilizer was applied. High maize yields were possible in the no-tillage systems with the application of 60 kg/ha or more of nitrogen. Response of maize to nitrogen was conspicuous in this land management.

The pattern of moisture depletion in the soil surface layers (0–30 cm) in the land management systems showed that the depletion rate was generally faster in the presence of the live mulches but that these mulches contributed to higher moisture retention in the soil following rainfall than either conventional or no-tillage (Figure 20). This is evidently due to protection of the soil surface against raindrop impact, maintenance of better soil structure, and better infiltration rate. Moisture retained was highest in *Psophocarpus palustris*, and, in general, a slightly higher moisture regime prevailed in weed-free compared with the unweeded plots (Figure 20).

Sustained maize yield (right portion of photo) can be attained under continuous cropping on Alfisols with judicious fertilizer use and appropriate crop rotation.

Continuous Food Crop Production on High Base-Status Soils

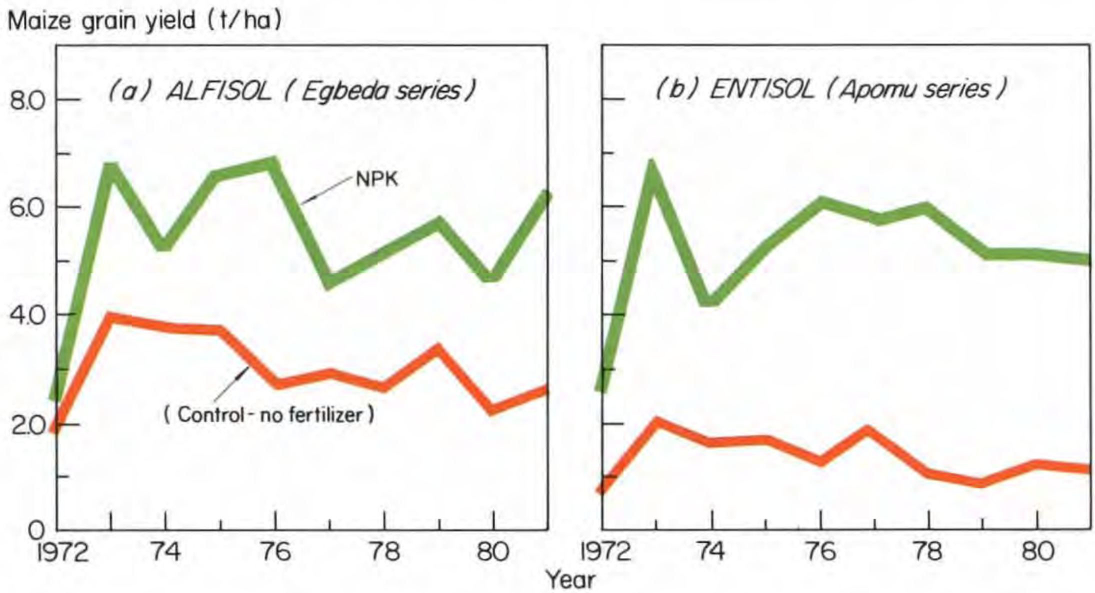
Alfisols and Entisols derived from basement complex rocks are abundant in the humid and subhumid regions of tropical Africa. These soils are highly susceptible to soil erosion, particularly under large-scale mechanized farming on sloping land.

Although the traditional bush-fallow system is not the most productive way to use land resources, it has provided subsistence farmers with an efficient, balanced, and stable system for maintaining soil productivity. But serious problems arise when land becomes limited because of increasing population pressures. Under these conditions, now happening in several countries, fallow periods become progressively shorter and soil restoration correspondingly less effective. In addition, already high and increasing costs of land clearing make it more difficult for farmers to bring fallow land into cultivation.

Long-term fertilizer trials (1972–81) were conducted at IITA as part of a research program to develop efficient land and soil management systems for continuous and sustained crop production in order to replace the bush-fallow system. These experiments were carried out on Alfisols and Entisols at IITA's main station at Ibadan, Nigeria. The scientists wanted to find out if it were possible to obtain sustained yields in continuous cropping with judicious fertilizer use on small plots where erosion is minimal as under traditional farmers' conditions. A sequential cropping of early-season maize followed by late-season sweet potatoes was used during the initial four years (1972–75), but the latter were replaced with cowpeas beginning in 1976. Plots were tilled once each year at the start of the first season.

Despite yield fluctuations from year to year due to climatic factors, sustained high yields of early-season maize were obtained on the Alfisol (Egbeda Series) with a fertilizer

FIGURE 21a and 21b. Long-term yield trend of maize grown on two major soil types at Ibadan, Nigeria, with judicious fertilizer use and without fertilizer.



application of 60 N, 30 P, and 80 K in kg/ha (Figure 21a). Yields obtained in 1981 with fertilizer application after 10 years of continuous cropping were comparable to those where maize was grown on a plot just cleared after more than 15 years of bush fallow and where plant residue was burned or applied as mulch.

On the sandy Entisol (Apomu Series), higher rates of fertilizer (150 N, 60 P, and 40 K in kg/ha) were needed to sustain the first-season maize yield (Figure 21 b). The 1981 maize yields from the fertilized plot were comparable to those from another plot after more than 15 years of fallow where the residue was burned but lower than that from the fallow and mulched plot. The yield difference was due mainly to the higher nitrogen status of the plants grown in the mulched plot, indicating that still higher nitrogen rates were needed in the fertilized plot.

These results show that on the medium-textured Alfisol, sustained high maize yield can be obtained with reasonable fertilizer rates in a continuous maize/cowpea sequential cropping. On the sandy Entisol, however, higher fertilizer rates are needed to sustain a high yield. Such rates are beyond the reach of the average farmer. Therefore, the inclusion of some type of fallow on sandy soil types during the cropping cycle is a possible alternative approach.

Rapid and dense bush regrowth after mechanized shear-blade clearing of land followed by no-till cultivation.

Soil Moisture Characteristics of an Alfisol After Mechanized Clearing

Previous research on large-scale land clearing for food crop cultivation (*Research Highlights* 1979) showed that shear-blade clearing with subsequent no-till farming was the most effective system of soil conservation. However, this system results in rapid bush regrowth and mechanical harvesting problems for some crops. Costly herbicides could be used to suppress the regrowth of bush, but it was felt that this regrowth would not compete with food crops for soil moisture and nutrients because of their deeper root system.

A series of experiments was conducted during 1981 to verify the effects of bush regrowth on soil moisture depletion and on the plant-water status of maize. Fluctuations in soil-water suction at different stages of maize growth, as well as changes in soil moisture potential at three different depths, were monitored. Results showed that moisture depletion was greater from the sub-surface layers (10–20 cm and 20–30 cm) of the bush regrowth plots than from the surface layer of the bare plots, indicating that the bush extracted more water from the sub-surface layer (Figure 22). The shading effect of the bush also decreased evaporation from the surface layer.

A comparison of soil moisture potential in maize alone and maize with bush regrowth showed that maize with bush regrowth extracted soil moisture at least up to a depth of 30 cm (Figure 22). The effect of bush regrowth on soil moisture was evident by low soil water potential during dry spell periods (i.e. between 37 and 42 days after planting). During this time, the soil moisture potential in soil with maize plus bush regrowth was approximately 50 to 100 cm lower than in plots with maize alone. Furthermore, the

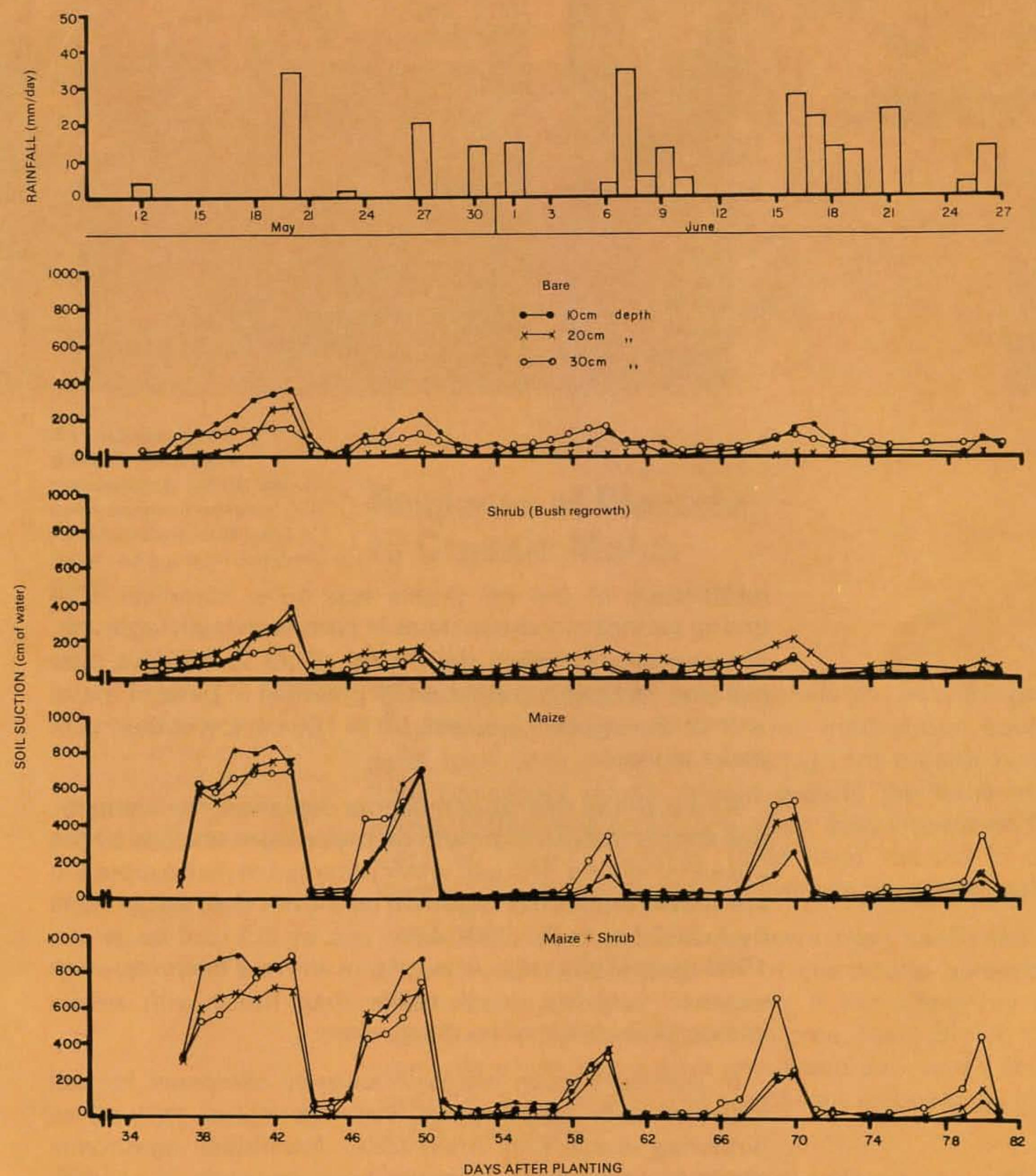


FIGURE 22.
Soil suction distribution in bare, shrub, maize alone, and maize with shrub plots under shear blade/no-tillage treatment.

TABLE 15.
Shrub regrowth and leaf water potential of maize.

Date	Hour of day	Maize alone	Maize plus bush regrowth
		(−Bar)*	
22/5/81	1500	16.3	20.2
23/5/81	0900	6.9	10.1
26/5/81	0900	11.5	12.4
26/5/81	1500	18.1	18.7
27/5/81	0900	11.2	13.8
27/5/81	1500	16.0	17.0

**Bar = approximately 1,000 cm of water suction.*

resaturation of the soil profile was never complete even during periods of frequent rains in plots with bush regrowth. For example, between the period of 50 to 58 days after planting, the mean soil moisture potential in plots of maize with bush regrowth was also 50 to 100 cm lower than with maize alone.

As a result of this rapid moisture depletion, the competitive effects of bush regrowth on maize were obvious by the observed wilting. The leaf water potential of maize grown in association with bush regrowth was lower than maize alone by 1 to 2 bar at the 0900 hour and by 0.5 to 4 bar at the 1500 hour (Table 15). Also, plants without bush regrowth regained turgidity much earlier than those with severe competitive effects of bush regrowth.

In summary, bush regrowth severely competed for soil moisture with arable crops such as maize, as well as hindering harvesting operations. Additional agronomic research on ways to suppress bush regrowth is needed. Appropriate herbicides, biological means of growing an aggressive cover crop, and mechanical methods of root cutting and ripping may be useful for some soils and agro-ecological environments.

A comparison of a medium false-horn plantain plot which has been mulched without fertilizer (left) with one fertilized but not mulched (right).

Response of Plantain to Organic Mulch

The high productivity and longevity of backyard-grown plantains, compared with their field-grown counterparts, have been attributed to the high soil organic content from household refuse thrown around the roots of the plants. Under field conditions, even when inorganic fertilizers are liberally applied, rapid yield decline is often observed from the first ratoon in tropical weathered soils.

IITA trials and observations have now confirmed that the productivity and longevity of compound gardens are obtainable under field conditions if the plants are adequately mulched with organic material. Tests on two false-horn type plantains – a giant and a medium – and a banana "paranta" have shown that significant response to mulch occurs (Table 16).

In observation plots in which the effects of mulch and inorganic fertilizers have been compared, the former showed a slight yield increase compared with a marked yield decline of unmulched fertilized plots (Table 17). The mulch plot received approximately 40 t/ha/yr (fresh weight) of leaves

Treatments	False-horn type plantain		Banana
	giant	medium	
No mulch, no fertilizer**	—	—	—
No mulch, fertilizer	18.0a*	16.7a	7.5a
Mulch, no fertilizer	17.2a	15.8a	9.5a
Mulch and fertilizer	31.3b	19.8a	13.3b

TABLE 16.
Yield of plantain mother plants with and without mulch and fertilizer (t/ha).

**Numbers in the same column followed by the same letter are not significantly different at 5 percent.*
***Most of the plants broke.*

	Mulch	Fertilizer
Yield (t/ha)	22.8	4.8
Bunch wt. (kg)	11.8	8.1
Plants harvested (% of planted)	116.0	36.0
Harvest duration (months)	10.0	6.0

TABLE 17.
Observations on response of plantain to mulch and fertilizer at the end of the fourth cycle (1981).

and stems of *Eupatorium odoratum*. Fertilizer applied to the unmulched plot was 300 kg N, 250 kg P_2O_5, and 550 kg K_2O per hectare per year. In the fourth year, the yield of the mulched plot was four times that of unmulched fertilized plots (Table 17). Since no suckers were manually eliminated, the number of plants producing fruits increased in mulched plots but decreased in unmulched ones, and the harvest duration lasted longer in the former. Work on developing cheap and efficient mulching techniques is in progress.

Designing, Testing, and Making Low-Cost Equipment for Farmers

Prototypes of several simplified, low-cost farm tools and equipment designed and tested by IITA's agricultural engineers over the past several years have been turned over for local production to small manufacturers and government development centers in Nigeria. They are also being sent to several other countries at their request for review, fabrication, and testing under their farming conditions.

The Nigerian Federal Ministry of Agriculture ordered 1,300 single-row rolling injection planters and 300 cassava levers from local fabricators during 1981 for distribution to small farmers. Also, at the request of the Chancellor of the University of Philippines at Los Banos and officials of the International Rice Research Institute (IRRI), prototypes of five tools and machines were taken to that country (rolling injection planter, auto-feed "jab" planter, fertilizer band applicator, maize sheller, and a modified "Hampasan" or rice thresher). Both engineers and students assisted in the

Left, an inexpensive hand tool for shelling maize.

Center, a single-row injection planter designed by IITA being used in the field. Right, the planter being fabricated in a small shop in Ibadan, Nigeria, which has made several hundred for later distribution to farmers.

This newly-designed and low-cost lever makes the job of lifting cassava out of the ground much easier.

fabrication of several of these in the shops there. In turn, IRRI agreed to send some of its small equipment to IITA for testing under African conditions.

Simplicity in design was essential so that small local shops could copy the prototypes and make them at low cost. Other objectives were to ease the drudgery and back-breaking work of traditional farming and enable small-holders to make more efficient use of labor at critical stages in the crop cycle – land preparation, seeding, weeding, and harvesting.

The single-row rolling injection planter now being made by small fabricators has been modified to improve its performance in both conventional and no-tillage systems. It

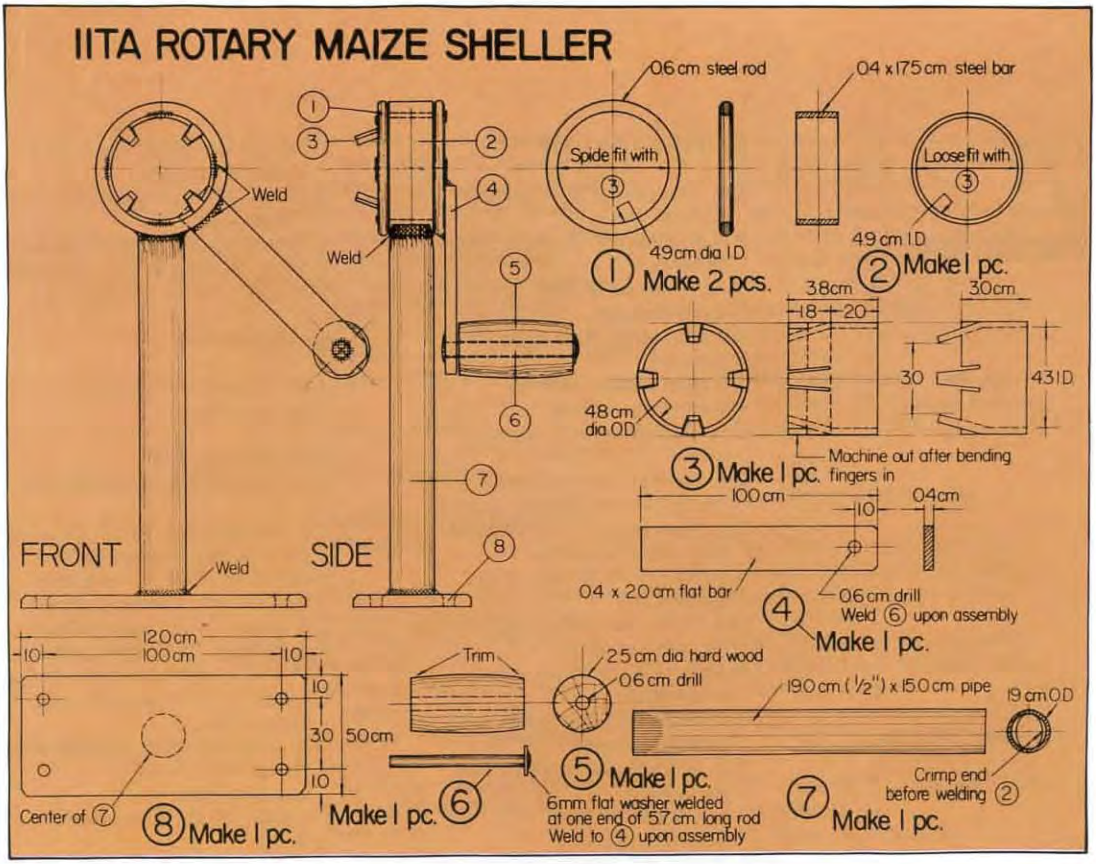


FIGURE 23.
Drawings for simplified small farm equipment and tools, such as this hand-operated maize sheller, are made available to small local shops for production.

has a series of jaws around the periphery of a wheel into which the metered seed is dropped from a central hopper. Fertilizer band applicators to be used in combination with this planter have also been designed and tested.

A simple, inexpensive maize sheller has been designed and fabricated to replace tedious hand or finger shelling (Figure 23). The demand for this tool during 1981 was far greater than the supply. In addition, a new cassava lever – simpler and less than half the cost of one previously designed – can be used not only for lifting cassava quickly and easily at the time of harvest but also for planting and digging yams. Several other types of small equipment are being improved and tested by IITA's agricultural engineers.

List of Personnel

ADMINISTRATION

E.H. Hartmans, Ph.D., director general.
B.N. Okigbo, Ph.D., deputy director general.
M.A. Akintomide, B.S., director for administration.
S.V.S. Shastry, Ph.D., director of research.
J.E. Haakansson, M.B.A., controller/treasurer.
O.O. Ogundipe, M.D., medical officer
C.A. Enahoro, administrative assistant to the director general.
K.A. Aderogba, D.P.A., principal administrative officer
S.J. Udoh, A.M.N.I.M., chief accountant.
M.E. Olusa, assistant to the director for administration.
R. Vick, M.S., manager, data processing.
D.J. Sewell, dormitory and food service manager.
R.O. Shoyinka, B.S., personnel manager.
E.A. Onifade, security superintendent.
A. Yusuf, B.S., controller of stores.

CEREAL IMPROVEMENT PROGRAM

Y. Efron, Ph.D., assistant director and program leader.
K. Alluri, Ph.D., agronomist/ physiologist.
S.K. Kim, Ph.D., maize breeder.
J. Yamaguchi, Ph.D., physiologist.
M. Bjarnason, Ph.D., CIMMYT maize breeder, IITA.
Kaung Zan, Ph.D., IRRI liaison scientist.
A.O. Abifarin, Ph.D., IITA liaison scientist, WARDA, Liberia.
J. Arrivets, Ph.D., IRAT liaison scientist, IITA.
V.L. Asnani, Ph.D., SAFGRAD project leader, Upper Volta.
M. Rodriguez, Ph.D., agronomist, SAFGRAD, Upper Volta.
Y.S. Rathore, Ph.D., entomologist, SAFGRAD, Upper Volta.
T.G. Hart, Ph.D., chief of party, NCRE, Cameroon.
D.C. Goodman, M.B.A., administrator, NCRE, Cameroon.
D. Janakiram, Ph.D., rice breeder, NCRE, Cameroon.
A.C. Roy, Ph.D., rice breeder, NCRE, Cameroon.
S. Sarkarung, Ph.D., rice breeder.
J. Singh, Ph.D., maize pathologist.
M.S. Alam, Ph.D., entomologist.

Visiting scientist

J.M. Fajemisin, Ph.D., maize pathologist.

GRAIN LEGUME IMPROVEMENT PROGRAM

P.R. Goldsworthy, Ph.D., assistant director and program leader.
Mazo Price, Ph.D., coordinator, IITA/USAID Tanzania project.
S.R. Singh, Ph.D., entomologist.
R.J. Redden, Ph.D., plant breeder.
M.J. Lukefahr, Ph.D., entomologist.
E.L. Pulver, Ph.D., physiologist/ agronomist.
A.A. Ayanaba, Ph.D., microbiologist.
V. Ranga Rao, Ph.D., microbiologist.*
E.E. Watt, Ph.D., plant breeder, Brazil.
V.C. Aggarwal, Ph.D., plant breeder, Upper Volta.
F. Brockman, Ph.D., agronomist, SAFGRAD, Upper Volta.
L.E. Jackai, Ph.D., entomologist.
H. Wosten, Ph.D., physiologist.
S. Asanuma, Ph.D., microbiologist.
E.A. Keuneman, Ph.D., plant breeder.
B.B. Singh, Ph.D., plant breeder.

ROOT AND TUBER IMPROVEMENT PROGRAM

S.K. Hahn, Ph.D., assistant director and program leader.
M.N. Alvarez, Ph.D., junior breeder.
F.E. Caveness, Ph.D., nematologist.
J.H. Chung, Ph.D., project leader and plant breeder, National Root Crop Improvement Program (CNRCIP), Cameroon.
W.W. Fiebig, M.S., extension agronomist, PRONAM, Zaire.
H.R. Herren, Ph.D., entomologist.
R.D. Hennessey, Ph.D., entomologist, PRONAM, Zaire.
K.M. Lema, Ph.D., junior entomologist.
K. Leuschner, Ph.D., entomologist.*

S. Pandey, Ph.D., extension agronomist, PRONAM, Zaire.
D. Perreaux, Ph.D., pathologist.
H.J. Pfeiffer, Ir., production agronomist, CNRCIP, Cameroon.
P. Rao, Ph.D., biochemist.*
T.P. Singh, Ph.D., acting program leader and plant breeder, PRONAM, Zaire.
M. Veloso, physical plant service officer, PRONAM, Zaire.

Associate Expert
E.A. Frison, Ir., FAO, tissue culture and virus indexing.

FARMING SYSTEMS PROGRAM

C.H.H. ter Kuile, Ph.D., assistant director and program leader.
B.T. Kang, Ph.D., soil fertility specialist.
I.O. Akobundu, Ph.D., weed scientist.
M. Ashraf, Ph.D., agricultural economist.
P. Ay, Ph.D., socio-economist.
D.S. Ngambeki, Ph.D., agricultural economist.
G. Cesarini, Ph.D., socio-economist.
C. Garman, M.S., agricultural engineer.
N.C. Navasero, B.S., associate agricultural engineer.
H.C. Ezumah, Ph.D., agronomist.
P.S.O. Okoli, Ph.D., agronomist.
G.F. Wilson, Ph.D., agronomist.
R. Swennen, Ir., FAO, agronomy.
T.L. Lawson, Ph.D., agro-climatologist.
R.D. Bowers, M.S., FAO project manager and agricultural engineer.
K.V.Vanek, Ph.D., FAO, agricultural engineer.*
W.N.O. Ezeilo, agronomist, BIDA project.
H.C. Knipscheer, agricultural economist.*
A.S.R.Juo, Ph.D., soil chemist.
Y. Arora, Ph.D., soil chemist.
R. Lal, Ph.D., soil physicist.
H.O. Maduakor, Ph.D., soil scientist.
B.S. Ghuman, Ph.D., soil scientist.
O.A. Opara-Nadi, Ph.D., soil scientist.
K. Mulongoy, Ph.D., microbiologist.
M.A. Gowman, weed scientist.
J. van der Heide, Ir., soil scientist.
Van der Kruijs, Ir., soil scientist.
R. Balasubramanian, Ph.D., soil fertility specialist, MIDAS, Ghana.
J.O. Braide, Ph.D., agronomist, MIDAS, Ghana.
E.A. Atayi, Ph.D., agricultural economist, NCRE, Cameroon.
N.V. Nguu, Ph.D., agronomist, Cameroon.
T. Kaufmann, Ph.D., ecologist.*
A. Getahun, Ph.D., agro-forester.*
P. Rosseau, Ir., FAO, soil physics.*

TRAINING PROGRAM

W.H. Reeves, Ph.D., assistant director and head of training.
G.A. Cambier, Lic., translator/interpreter.
D.W. Sirinayake, training officer.
A.P. Uriyo, Ph.D., training officer and agronomist.

INTERNATIONAL PROGRAMS

E.R. Terry, Ph.D., assistant director and head.
E.F. Deganus, B.S., CAR, administrator.
F.O. Ogunyemi, FCSA, accountant.

RESEARCH SUPPORT UNITS

ANALYTICAL SERVICES LABORATORY

J.L. Pleysier, Ph.D., head.

BIOMETRICS

J. McGuire, Ph.D., biometrician.

COMMUNICATIONS AND INFORMATION

J.E. Keyser, B.S., assistant director for public affairs and development.
J.O. Oyekan, B.S. head, communications and information.
J.C.G. Isoba, M.S., communications officer, publications.
R.E. Rathbone, M.S., editor.

FARM MANAGEMENT

D.C. Couper, B.S. farm manager.
S.L. Claassen, M.S., assistant farm manager.
P.V. Hartley, B.S., farm management engineer.
P.D. Austin, B.S. farm manager, Onne.
Chitti Babu, B.S., agricultural engineer, Tanzania.

GENETIC RESOURCES UNIT

W.M. Steele, Ph.D., head.*
N.Q. Ng, Ph.D., plant geneticist.
A.T. Perez, Ph.D., plant explorer.*

Associate expert
M. Davids, Ir., FAO.

LIBRARY AND DOCUMENTATION CENTER

S.M. Lawani, Ph.D., head.
G.O. Ibekwe, B.A., principal librarian.
E.F. Nwajei, B.A., acquisitions librarian.
M.O. Odubanjo, B.S., cataloger.
B.O. Adenaike, M.S., bibliographer.
S.B. Akande, assistant cataloger.

PHYSICAL PLANT SERVICES

J.G.H. Craig, assistant director for physical plant services.
E.O.A. Akintokum, research vehicles service officer.
A. Amrani, heavy equipment service officer.
A.C. Butler, buildings and site service officer.
O.O.A. Fawole, automotive service officer.
J.M. Ferguson, fabrication/water utility service officer.
G.D. Garrity, electrical service officer.*
N. Georgallis, scientific/electronics service officer.
J. Lukowski, electrical service officer.
T.V. Manohar, refrigeration/air conditioning service officer.
M.O. Yusuf, construction/site engineering service officer.

VIROLOGY UNIT

G. Thottappilly, Ph.D., virologist.
H.W. Rossel, Ir., virologist.
J.W.M. van Lent, Ir., virologist.

**Left during the year.*

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