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IITA Research Highlights 1984

Facts about IITA

Established as an autonomous, non-profit corporation on July 27, 1967, the International Institute of Tropical Agriculture (IITA) is one of the major links in a worldwide network of agricultural research and training centers. The Federal Republic of Nigeria allotted 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.

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 1984 was provided by the Canadian International Development Agency (CIDA), Overseas Development Administration of the United Kingdom (ODA), U.S. Agency for International Development (USAID), World Bank, International Fund for Agricultural Development (IFAD), Ford Foundation, Rockefeller Foundation, and the governments of Australia, Belgium, France, India, 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, cassava, and cocoyams).

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Preface

A principal difference the reader may see in this edition of *Research Highlights* compared with previous ones is the larger number of reports originating in various African countries about on-farm adaptive research managed by scientists and on-farm trials managed by farmers. With the cooperation of national and regional programs, IITA's research results are gradually getting to farmers, and they are becoming active participants in research rather than passive recipients. A few examples from Cameroon, Zaire, Rwanda, and Nigeria are described in the following pages.

Furthermore, the Institute has moved closer to where the action is by letting research opportunities partially dictate the locale of our research. We are developing a coordinated and phased-in master plan to conduct more research and training activities outside of our main experimental station and headquarters at Ibadan, Nigeria and several sites in different ecological zones in Nigeria. It has taken more than a decade to develop a range of improved varieties and soil and crop management technologies that are ecologically and economically viable for both smallholders and large farmers in the humid and subhumid tropics. We now have many proven technologies "ready to go." It is against that background that we have stepped up our efforts to re-deploy more scientific and support staff to research locations outside of our headquarters. This move is not intended to erode our central research programs for we must keep a strong research base at IITA.

We have responded to calls from several countries and posted our scientists to work with regional and national teams to help speed up agricultural development and the capabilities for tackling food production problems. The largest of several such efforts is in Cameroon. During 1984, IITA also opened a new substation on a 50-hectare site donated by the Republic of Benin. Located on the campus of the National University of Benin near Cotonou, its main thrust involves farming systems and on-farm adaptive research.

Although most of IITA's research is concentrated in Africa, we have a global mandate for research on farming systems and on cowpeas, yams, and sweet potatoes. As part of this responsibility, we have put one grain legume scientist in Brazil to work in Latin America and another in the Philippines to work in Southeast Asia.

Along with research on improvement of crops and farming systems, an emphasis on socio-economics has moved forward because agricultural development involves more than farming *per se*. Marketing, food consumption, labor, post-harvest technologies, and household and gender factors require more attention as agricultural strategies and national food policies are developed. For the first time in this publication, we present the results of an exploratory field survey on the role of Nigerian women in food production and decision making. They may surprise many readers.

The problems IITA and others must help solve in Africa are among the most complex and crucial anywhere, and the calamity in Ethiopia and Sudan draws the world's attention even more forcefully to the food crisis on this continent. Without underestimating the severity of this crisis in the short term, we believe Africa can look to the future with a degree of optimism. There are realistic and practical solutions to many food production problems, only a few of which we briefly describe in this issue of *Research Highlights*. Additional details and other research results are available in IITA's annual report.

Ermond Hartmans
Director General

On-Farm Performance of a New Soybean and the Use of Soybeans in Treatment of Protein Malnutrition in Infants

To help meet the increasing demand for soybeans, farmers in the central and northern Guinea savannas of Nigeria that are outside the traditional soybean growing areas have needed not only higher yielding but earlier maturing varieties. They have depended largely on the old standby Malayan variety introduced to Nigeria in the early 1900s which matures in about 140 days. The rainy season in some of these areas is not long enough to insure a good yield.

But now a new line – TGx 536-02D with 105- to 110-day maturity – has been developed by IITA, tested in 1983 by its scientists in Mokwa and Zaria (1983 *Research Highlights*) and by farmers in Abet village in 1984. It is available also to national programs for testing. Nigerian soybean scientists have recommended this variety for release to farmers, plus two others – TGx 297-192C and TGx 306-036C.

In Abet village, IITA, in cooperation with staff members of the International Livestock Center for Africa (ILCA), established trials with farmers. Seed yields of TGx 536-02D

TABLE 1.
Results of on-farm trials of soybean line TGx 536-02D in Abet, Nigeria (1984).

Farmer	Plants/ha	Yield (kg/ha)
Mr. Katura	91,333	2200
Mr. Yashiyi	106,667	2150
Mr. Dauda	118,333	2100
Mrs. Bege	107,333	1750
Mrs. Charles	102,333	1650
Mr. Rago	84,667	1600
Mr. Charles	93,667	1500
Mrs. Sisi	77,667	1450
Mean	97,749	1800

(Left photo.) On-farm trial at Abet village in Nigeria of a new soybean line which Nigerian scientists have recommended for release to farmers. (Right photo.) Soybeans for sale in a village market in the Abet area.

A Nigerian farmer shows an IITA scientist the results of planting a new improved soybean variety.

ranged from 1450 to 2200 kg/ha with the only input being single super phosphate (200 kg/ha) and hand labor (Table 1). Malayan has been grown in the village, but yields seldom exceeded 500 kg/ha for this longer maturing variety because the growing season was too short.

An expanding market for soybean is due largely to the popularity of soybeans to prepare "dawadawa," a fermented paste used as a flavoring. There is also a growing interest in using soybean milk and flour as an important source of protein for feeding babies and young children. Nigeria now imports soybean oil for cooking and soybean meal to support an established poultry industry so there remains great scope for expanded soybean production in the country.

An outstanding example of the promotion and use of soybeans to combat infant protein malnutrition (kwashiorkor) in a Nigerian rural area was brought recently to the attention of IITA scientists. A children's home near Ogbomosho specializes in treating infants with severe symptoms of malnutrition swollen bellies and skeletal limbs. Protein malnutrition in infants is of growing concern in Africa, not only in countries suffering from drought and famine but in certain others on the continent.

The infants are admitted to the children's home with their mothers or guardians who prepare all the food for themselves and their babies under the supervision of the staff. Soybeans are

(Left photo.) Mothers prepare soybean milk for their babies at a children's home near Ogbomosho, Nigeria. (Center photo.) Bottle feeding soybean milk. (Right photo.) A mother has prepared a soybean/cereal pap for her infant.

prepared as a milk substitute by boiling, grinding, straining, and recooking the liquid. This "milk" contains about 35 g of protein per serving. It is especially important because about 40% of the infant "patients" are intolerant to cow's milk. Also, soybeans are prepared as a wet-milled full-fat flour added to a cereal pap. A normal ration for a one to two year-old child is the equivalent of about 200 g of whole soybeans per day at a cost of approximately 20 cents (U.S.).

Not only are staff members of the children's home concerned with the infants brought to them, but they visit villages near Ogbomosho to promote the cultivation and use of soybeans and teach women how to prepare them in local dishes. Several farmers — both men and women — in the area are now growing the crop and soybeans are being sold in local markets.

Women in other African countries, including Ghana, Cameroon, Uganda, Rwanda, and Zaire, are also using soybeans in local dishes. A village with small-scale equipment can provide soybean oil and meal for partially defatted soybean flour.

FIGURE 1.
Highland environments in Africa. Scientists are developing soybean lines adapted to the highlands. During 1984, the testing site was in the Jos Plateau area with an elevation of 1,300 meters.

Testing Soybean Lines Adapted to Highland Environments in Africa.

High yielding soybean lines have been developed for the West African lowlands, but they are not always adaptable to the highland environments which comprise most of Africa (Figure 1). Those developed in the lowlands tend to take longer to mature when moved to higher elevations and may mature after the end of the rainy season with consequent low yields.

In 1984, breeders at IITA began testing at Bukuru, Nigeria (near Jos) at 1300 m elevation and 9° 50′ N latitude. Soybean lines regarded as late maturing at Mokwa (150 m elevation, 9° 15′ N latitude) were inappropriately late at Bukuru, but many of medium maturity (110–120 days) at Mokwa were also appropriate at Bukuru and had reasonably good yields. Table 2

compares yields and days to maturity of three trials grown at both sites. Days to maturity averaged 10, 11, and 21 days later at Bukuru for the early, medium, and late trials, respectively.

Besides varietal testing, IITA scientists are using two other approaches to better serve cooperators in African highland environments. High yielding IITA soybean lines with good seed longevity and natural (promiscuous) nodulation are crossed with lines adapted to highlands. F_5 populations from some of these crosses were grown in 1984 at Bukuru, and superior plants were selected at 99, 106, and 120 days after sowing. The selections have been sown in progeny rows and will be tested for shattering resistance and promiscuity in the 1984/1985 dry season and tested for yield at Bukuru in 1985.

A second approach is that these same populations have been advanced by single pod descent without selection and will be sent to cooperators in Rwanda, Cameroon, Ethiopia, and other countries for selection at elevations where they will be grown. After testing at these sites, soybean seed of the best lines can be returned to IITA for a further round of crossing.

TABLE 2.
Yields and days to harvest of soybean lines grown in trials at Bukuru and Mokwa, Nigeria (1984).

	Bukuru		Mokwa	
Early	(kg/ha)	(days)	(kg/ha)	(days)
TGx 573-1E	1828	(116)	2484	(112)
TGx 299-7F	1826	(111)	1468	(109)
Trial mean	1626	(118)	2095	(108)
Medium				
TGx 536-02D	1948	(120)	2481	(114)
TGx 573-104C	1750	(117)	1941	(113)
Trial mean	1222	(128)	2169	(117)
Late				
TGx 304-059D	657	(154)	1052	(137)
TGx 713-011D	543	(164)	2050	(138)
Trial mean	605	(160)	1649	(139)

Progress of Tropically Adapted Soybean Lines in International Trials

Except in parts of Asia, soybeans are a relatively new crop for farmers in the tropics, and IITA scientists are working to develop high yielding, tropically adapted soybean lines and overcome the biological constraints to production. With a grant from the Commission of European Communities (CEC) beginning in 1981, they were charged with the task of developing lines for the different environments in the tropics and testing them in multilocational trials in 27 African countries and around the world.

Since 1982, there has been almost a nine-fold increase in the number of international trials sent to cooperators (Figure 2). In that year about 50 trials were sent in two groups, one with entries with promiscuous nodulation (not needing inoculant) and the

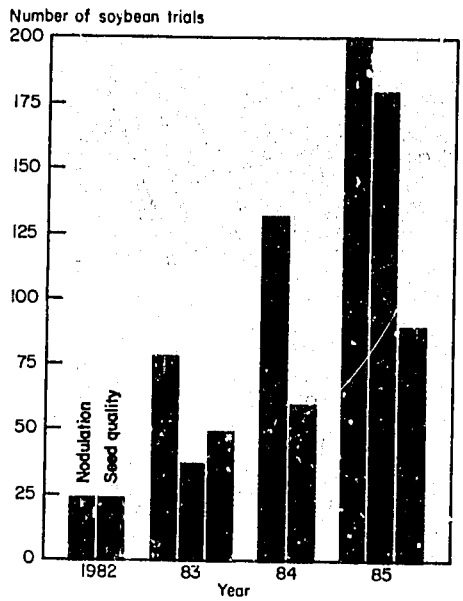
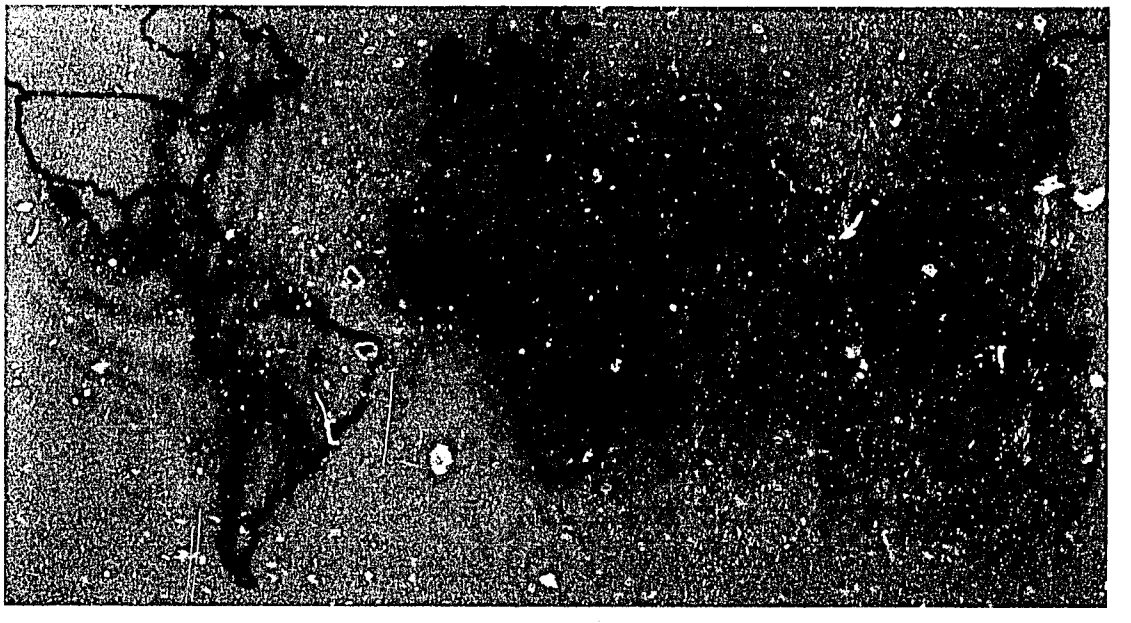


FIGURE 2.
Expansion of IITA international soybean trials from 1982 through 1984 and a projection for 1985.

FIGURE 3.
Sites of international trials of IITA soybean lines – a total of 42 countries.



other with improved seed longevity. By 1984, both traits had been combined in superior agronomic lines and trials were divided only by maturity. These trials were sent to cooperators in 42 countries (Figure 3).

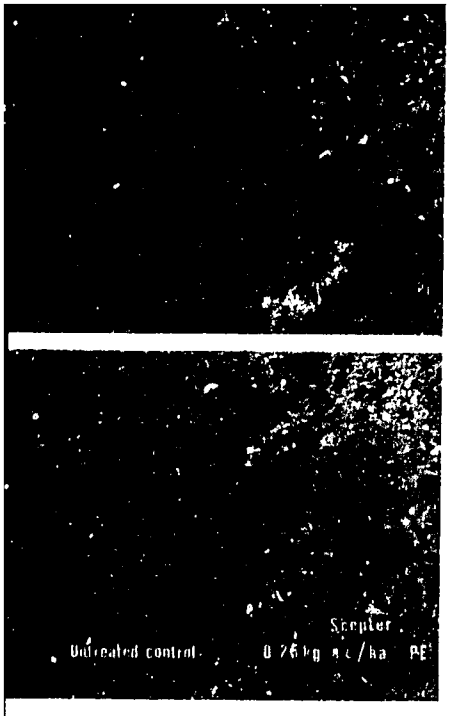
For 1985, IITA has prepared trials of lines combining promiscuity, good seed longevity, and resistance to bacterial pustule with earlier maturity (95–105 days), medium (105–120 days) and late (more than 120 days). About 440 trials have been requested for 1985.

Trial results from 1983, when most of Africa was dry, are encouraging. Table 3 includes results of trials grown at seven sites in Ivory Coast, Mali, Ghana, Togo, Nigeria, and Cameroon. The IITA lines shown in the table nodulated at all reporting sites without inoculum and maintained good seed viability after eight months of ambient storage. Although 1984 results were not available at this writing because some of the trials in the southern hemisphere would not be harvested until April 1985, preliminary data show that there has been good progress not only in the traits mentioned but also in resistance to lodging and shattering.

TABLE 3.
Performance of three IITA soybean lines in international trials in six countries in West Africa (1983).

	Range (kg/ha)	Mean yield (kg/ha)	Emergence* (%)
TGx 297-192C	994-3125	1803	81
TGx 342-375D	641-3263	1568	69
TGx 536-100C	803-2847	1484	77
Bossier (Check)	556-1917	1136	25

**After eight months of ambient storage.*



Two pre-emergence treatments of a new herbicide (Scepter) for control of wild poinsettia (Euphorbia heterophylla) on cowpeas compared with untreated plots.

Right,** Euphorbia heterophylla **from a herbicide (Scepter) treated plot at five weeks after application compared with the weed on the left from an untreated plot.

Promising New Herbicide for Control of Wild Poinsettia in Cowpeas and Soybeans

Wild poinsettia (*Euphorbia heterophylla*) - an annual broadleaf weed that can cause serious cowpea and soybean losses - has been resistant to most herbicides, but a new effective one named Scepter was recently selected through extensive screening in the field at IITA in 1984. The new product gave good control of the weed in both crops and is expected to be available in the African market in 1986.

The fast growing weed can completely shade cowpeas within six weeks after planting and make it difficult if not impossible to harvest a soybean crop. IITA research has shown that a density of 10 plants/m^2 of wild poinsettia reduces cowpea yields by 25 to 53% and 80 plants/m^2 by 68 to 75% compared with weed-free controls. If the crop is kept clean of weeds for 30 days after sowing, grain yields compared favorably with weed-free controls. This emphasizes the importance of keeping the crop weed-free in the early stages of growth.

When applied pre-emergence, the effective dose of Scepter was 100 to 250 g/ha with no phytotoxicity to either the cowpeas or the soybeans. Yields of both crops were equal to those of the weed-free controls and significantly higher than the yields of untreated control plots (Tables 4 and 5). Scepter was not available to IITA for testing in 1983, and none of the herbicides tested that year was effective on *Euphorbia heterophylla*.

Pre-emergence application of Scepter for the weed control in soybeans proved to be more effective than post-emergence in the IITA tests (Table 5), and the rate of 150 g/ha gave as good results as 250 g/ha. The lower rate, of course, would be less expensive for farmers.

Bioassay with soil samples taken from Scepter-treated plots at the time of the cowpea harvest showed no toxicity to maize and

rice used as test crops. This is of practical importance in cropping systems where maize or rice follows Scepter-treated cowpeas or soybeans.

TABLE 4.
Effect of a new herbicide (Scepter) on** Euphorbia heterophylla **control in cowpeas (IT 82 E-9) at IITA (1984).

Treatment*	Rate (kg a.e./ha)	Weed control rating (%) 3 WAP**	*E. heterophylla* dry weight (g/m²)	Grain yield (kg/ha)
Scepter	0.10	69	32	450
Scepter	**0.15**	**85**	**7**	**545**
Scepter	**0.25**	**84**	**4**	**658**
Scepter	0.30	79	10	443
Weed-free control		100	0	586
Untreated control		0	147	146
LSD (5%)			56	185

**All treatments were applied pre-emergence to the crop and weeds except Scepter at 0.30 kg/ha which was applied seven days before planting.*
***WAP = Weeks after planting; weed control rated on 0 to 100 scale where 0 = no control and 100 = complete control.*

TABLE 5.
Effect of a new herbicide (Scepter) on** E. heterophylla **control in soybeans at Mokwa, Nigeria (1984).

Treatment	Rate (kg a.e./ha)	Weed dry wt. (kg/ha) at 8 WAT*	Soybeans (TGx 576-02D) Height (cm) at 8 WAT*	Stand/m² at harvest	Grain yield (kg/ha)
Scepter**	**0.150**	**138**	**50**	**9**	**1987**
Scepter	0.150	1548	57	14	1332
Scepter	0.250	840	56	12	1770
Scepter	0.375	885	52	12	1644
Two hoe weedings (3 & 6 WAP***)		300	63	12	1858
Untreated control		1193	55	8	864
LSD (5%)		441	ns	ns	578

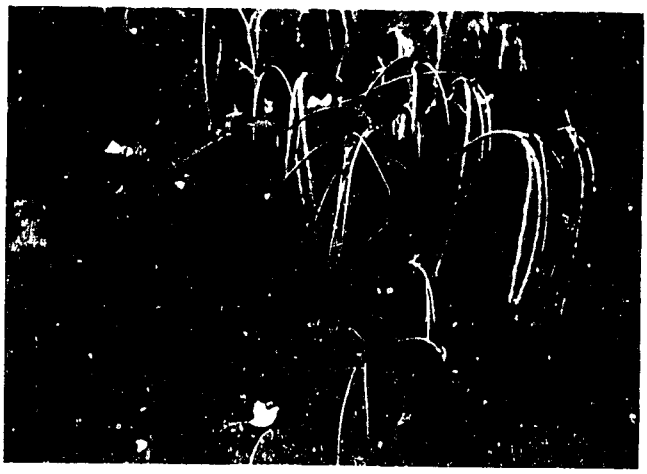
**WAT = Weeks after treatment.*
***Pre-emergence; other treatments post-emergence at four weeks after planting.*
****WAP = Weeks after planting.*

Three new IITA bush-type vegetable cowpea lines tested in African and Asian countries outyielded a climbing-type check variety. The former do not need costly staking or trellis support. The test shown here was conducted in the Philippines in cooperation with the International Rice Research Institute (IRRI).

Yield Results of Bush-Type Vegetable Cowpea Varieties in Africa and Asia

Vegetable cowpea varieties – grown for their long, tender, and fleshy pods harvested green and eaten as a vegetable – have become popular with many consumers in Asia and parts of Africa and Latin America. Traditional varieties have a climbing growth habit and require costly trellis support or staking to keep pods from touching the ground and becoming rotten. But IITA scientists have developed a number of bush-type varieties (1982 *Research Highlights*) which do not need staking and yield as much as or more than the climbing type.

Three of these new lines – IT 81D-1228-10, IT 81D-1228-13, and IT 81D-1228-14 – were distributed to countries in Africa and Asia, and the results reported back to IITA look encouraging. They gave the highest green pod yields at locations in six



Left, a close-up of a newly developed bush-type vegetable cowpea (IT 81D-1228-14); right, a traditional climbing-type in Sri Lanka.

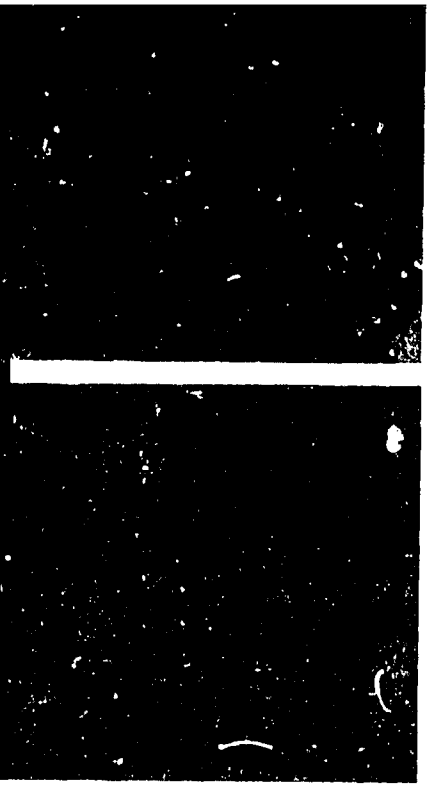
countries and were significantly better than the climbing-type check variety FARV-13, a bush-type check variety (Bush-Sitao), and a local check (Table 6).

Picking of green pods started at most of the locations between 45 and 55 days after planting. A total of five to eight pickings were made at three to four-day intervals. Within a period of 80 to 85 days, more than 10 tons of green pods were harvested from one hectare of land. With irrigation facilities, these varieties can be grown throughout the year in the tropics, provide a continuous supply of fresh vegetables, and improve the income of farmers.

TABLE 6. Performance of improved bush-type vegetable cowpea varieties at different locations in Africa and Asia.

Variety	Ibadan Nigeria	Mokwa Nigeria	Nyankpala Ghana	Abomey Rep. Benin	Parawanipur Nepal	Ganaruwa Sri Lanka	IRRI Philippines
				(t/ha)			
IT81D-1228-10	**14.3**	**10.7**	**9.4**	**12.1**	**7.7**	**6.8**	**16.0**
IT81D-1228-13	14.3	6.3	5.9	9.0	8.3	6.8	11.5
IT81D-1228-14	15.1	9.1	6.5	10.4	8.5	9.7	13.7
FARV-13	8.7	8.5	3.0	6.2	6.2	7.0	
Bush-Sitao	6.5	8.5	4.4	13.1	5.6	5.8	
Local check	*	*	2.0	7.9	3.4	4.5	12.3
LSD (5%)	4.1	2.8	2.3	2.3	3.9	2.5	4.7

**Local check in Nigeria was FARV-13.*



(Top photo.) Early stages of Striga in cowpeas. (Lower photo.) Cowpea plants killed by Striga.

Resistance to *Striga* on Cowpeas Developed in Burkina Faso

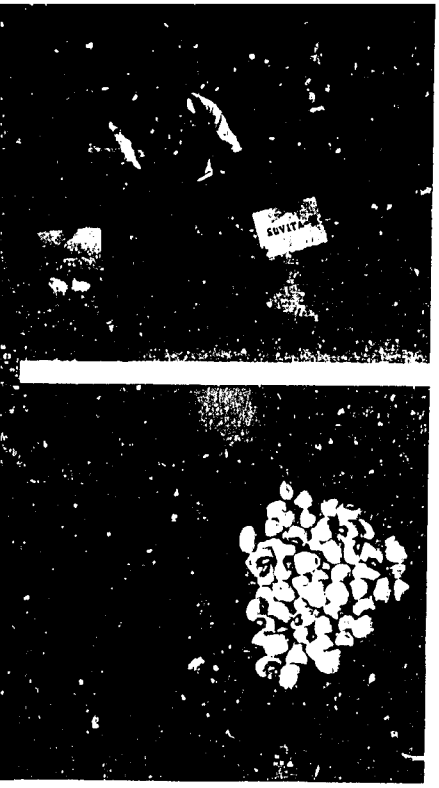
Susceptible cowpea plants can be completely killed by the parasitic weed *Striga gesnerioides*, and fields may become so infested with the seed that farmers cannot grow a cowpea crop. Moreover, *Striga* seeds may persist in the soil for as long as 20 years. They are stimulated to emerge by chemicals secreted from the cowpea roots, and germinating *Striga* plants attach to these roots and extract nutrients from the cowpea host.

IITA and national scientists working in Kamboinse in Burkina Faso (formerly Upper Volta) have identified sources of genetic resistance and progress has been made to incorporate this resistance into high yielding lines with acceptable seed quality. Also, lines resistant to *Striga* in Burkina Faso have been tested in Mali, Niger, and Nigeria (Table 7).

Resistance at sites in those three countries, though better than the susceptible check or the local variety, was not as complete as at Kamboinse. This observation was confirmed by the Weed Research Organization (WRO) in Oxford, England. *Striga* from seed collected from Nigeria and Niger emerged on the resistant line while *Striga* failed to do so from seed from Burkina Faso. This cooperation between IITA and WRO is especially important because researchers in Burkina Faso cannot bring in seed of exotic *Striga* due to the danger to the local crop. *S. gesnerioides* does not attack any crop in the U.K.

TABLE 7.
Percentage of cowpea plants with Striga emergence at sites in West Africa.

	Burkina Faso		Niger	Mali	Nigeria	
	Kamboinse	Quahigouya	Magaria	Seno	Kano	Bakura
KVx 30-166-3G	0	0	2	6	6	39
KVx 30-183-3G	0	0	3	3	9	19
SUVITA-2	0	0	5	3	8	19
Mougne (Local check)	87	16	46	28	20	45



(Top photo.) A cowpea variety with genetic resistance to Striga in Burkina Faso vs. a local one without it. (Lower photo.) Large cowpeas with rough white and brown coats preferred by consumers in Burkina Faso.

The emergence of *Striga* in Mali, Niger, and Nigeria on the lines found to be resistant in Burkina Faso suggests that there is more than one strain of the parasite. Work will continue at Kamboinse, in cooperation with WRO and national scientists, to identify other sources of resistance and to characterize the strains of the parasite.

The *Striga* resistance, which seems to be complete in Burkina Faso, has now been incorporated into lines with other important traits. The most important of these is resistance to bruchids (*Callosobruchus maculatus*), the major cowpea storage pest. This insect infests cowpea seed in the field and quickly multiplies in the stored grain, killing the seed and making the cowpeas undesirable for the market. Table 8 shows that lines have now been developed with good levels of resistance to both *Striga* and bruchids. Also, they have large seeds and are available with a rough white or brown coat preferred by consumers in Burkina Faso. These lines have been crossed with others with multiple disease and insect resistance to further improve and stabilize their yields.

TABLE 8. Performance of three IITA cowpea breeding lines with resistance to Striga and bruchids compared with SUVITA-2 and a local check.

	Yield (kg/ha)	Plants with *Striga* (%)	Stored seed with bruchid entry holes (%)	Seed color/ texture
KVx 30-G172-1-6K	812	0	10	White/rough
KVx 30-G183-3-5K	1027	2	20	Brown/rough
KVx 30-G200-1-3K	1255	2	15	Brown/rough
SUVITA-2	1059	0	100	Brown/rough
Local check	491	36	100	White/rough

One of the cowpea lines that performed the best under an unusually dry season at Niamey in Niger. It is a medium maturing line with resistance to thrips and bruchids.

Cowpea Lines for the Millet/Cowpea Cropping System in the Harsh Sahel Environment

In one of the harshest environments imaginable, small farmers in the Sahel zone struggle to produce a millet/cowpea mixed crop under drought, high temperatures, and marginal soil fertility. They need better plant types with medium maturity and resistance to diseases and insect pests.

Responding to this need, IITA, in cooperation with ICRISAT and national programs in the region, is working on ways to fit improved cowpea lines into a predominantly millet-based system. An IITA scientist was posted in 1984 at ICRISAT's Sahelian Center in Niger.

During the year, improved cowpea lines were screened with and without millet at the Sahelian Center. The total rainfall from May to September was 260 mm – 54% below normal. The cowpea varieties were planted in the third week of June and harvested at the end of August. During this period only 150 mm rainfall was recorded. In spite of such a dry season, yields of 33 lines ranged from 600 to 1500 kg/ha in sole crop and 20 of these produced more than 200 kg/ha in intercrop. Compared with this, the yield from the local farmers' variety was only 185 kg/ha and that of the improved national variety TN 88-63 ranged from 898 to 1011 kg/ha. The local farmers' variety has a long maturity duration (125 days) and was severely affected by the drought.

Because of severe drought, the maturity period of all the lines was reduced by approximately 10 days. The data show that medium maturing lines performed better under Sahel conditions than early maturing varieties and the local line Sadore. Best among all the varieties were IT82D-703, IT82D-716, and TVx 3236 (Table 9). They combine multiple disease resistance, and, in addition, TVx 3236 is resistant to thrips, IT82D-716 to thrips and bruchids, and IT82D-703 to bruchids.

Because farmers in the Sahel grow cowpeas for grain as well as forage, IITA scientists identified 13 promising lines for this dual purpose.

Results of the cooperative program are expected to be of value not only in Niger but Burkina Faso (formerly Upper Volta), Mali, Senegal, Cape Verde, Mauritania, and Chad.

TABLE 9. Performance of improved cowpea lines in an unusually dry season at Niamey in Niger (1984).

Variety	Days to maturity	Yield (kg/ha)
Extra-early		
IT82E-60	56	991
IT82D-789	57	979
IT82D-885	56	917
S.E. ±	1	136
Medium maturity		
TVx 3236	**65**	**1305**
IT82D-752	61	1121
TVx 4659-03E	67	1019
TN 88-63 (Improved local)	67	898
S.E. ±	1.5	112
Bruchid resistant		
IT82D-703	**64**	**1598**
IT82D-716	**65**	**1424**
IT82D-1032	62	1120
Sadore (Unimproved local)	78	185
S.E. ±	3	265

Cowpea Adaptation to Drought Conditions in the Sahel

Crop production in the extreme north of Burkina Faso (formerly Upper Volta) in the Sahel is subject to high temperatures, drought, and violent winds blowing sand across the land. Under these conditions, IITA and national scientists conducted experiments at Pobé/Djibo in 1983 with six different cowpea varieties.

They planted the varieties obtained from various sources on June 22, July 7, and July 16. The four highest yielding varieties which were planted on the earlier date produced grain yields ranging from 782 to 992 kg/ha, but lost an average of 14 kg/ha for each day the planting was delayed beyond June 22 (Table 10).

Two extra-early maturing varieties – IT 82E-60 and KVu 55 – performed poorly in this one-year experiment. Two weeks after all six varieties were first planted, a sand blow generated by violent winds hit the area. The extra-early maturing varieties were severely damaged and did not recover like the other four.

In the Sahel savanna, chances of obtaining larger cowpea yields are better if the crop is planted as soon as rains become

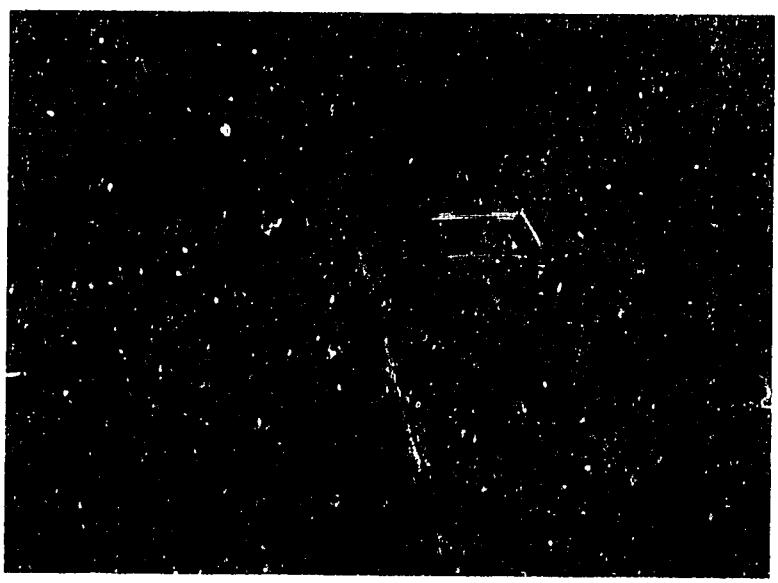
	Planting dates		
	June 22	July 7	July 16
	Yields		
Variety	kg/ha		
TVx 3236	**992**	779	707
SUVITA-2	**953**	639	629
TN 88-63	**782**	566	532
58-57	**951**	623	519
IT 82E-60	**202**	295	321
KVu 55	**257**	509	406

TABLE 10. Grain yield of six varieties of cowpeas planted on different dates at Pobé/Djibo in the extreme northern part of Burkina Faso in the Sahel (1983).

TABLE 11.
Average number of cowpea flowers per day (AFD), maximum number per day (MFD), and total number (TF) at Pobé/Djibo in the extreme northern part of Burkina Faso in the Sahel (1983).

Variety	AFD	MFD	TF
	Flowers/m²		
TVx 3236	14	28	190
SUVITA-2	13	27	167
TN 88-63	13	29	179
58-57	16	31	217
IT 82E-60	6	10	73
KVu 55	8	14	116
LSD (5%)	3	6	51
CV (%)	34	31	39

established in the latter part of June. An extra-early maturing characteristic *per se* is not sufficient to achieve a high grain yield. The variety must adapt itself to the Sahel environment by growing and flowering profusely and setting pods that reach maturity. This lack of adaption of extra-early varieties originating from the south and from areas with more rain is shown in Table 11. Note the low number of flowers for IT 82E-60 and KVu 55.



The cowpea variety in the background (SUVITA-2) has adapted itself to the Sahel's high temperatures and drought; the one in the foreground has not and is suffering from heat.

Cowpea Production under Drought Conditions with and without In-Situ Mulch in Burkina Faso

Like several other African regions in 1984, drought and high soil temperature stresses caused severe crop losses in the Sudan savanna of West Africa. The alfisol soils in this climatic zone are subject to fast run-off of any rainfall, erosion, and a low soil-water reservoir.

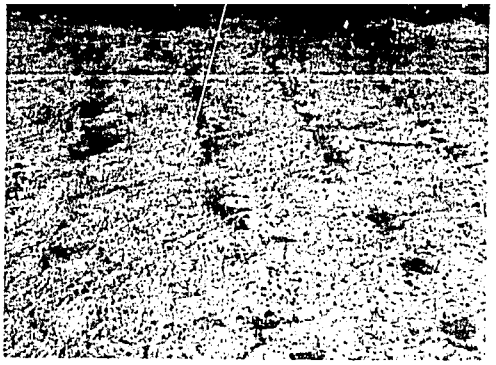
Previous experiments at IITA in Ibadan, Nigeria, with the in-situ mulch technique under a no-tillage system (1983 *Research Highlights*) showed that it was effective in preventing high soil temperature and helped to improve crop establishment, early growth, and maize yields. In 1984, national and IITA scientists in the Semi-Arid Food Grain Development Project (SAFGRAD) tested the technique on cowpea production for the first time at the Loumbila station near Ouagadougou in Burkina Faso (formerly Upper Volta) in the Sudan savanna.

The mulch used in the SAFGRAD tests was the residue of a previous legume cover crop – *Crotalaria*. The yields of cowpeas on the mulched land with no tillage were significantly better than those from plowed, unmulched plots (Table 12). Furthermore, the seed increase due to mulching alone was much larger than

TABLE 12.
Effect of in-situ mulch vs. no mulch at different levels of single super phosphate application on seed yield of cowpeas at Loumbila, Burkina Faso (1984).

	P_2O_5 levels			
	0 kg/ha	50 kg/ha	100 kg/ha	Mean
	Cowpea seed yields (kg/ha)			
Zero-tillage with in-situ mulch	883	1002	1202	1029
No mulch – tractor plowed	176	485	507	389
LSD (5%)				377
CV (%)				34

Poor germination of cowpeas in an unusually dry season without in-situ mulch; soil subject to erosion and fast run-off of any rainfall.



Cowpeas on the left with in-situ mulch. It helped prevent high soil temperature and improved crop establishment and early growth.

that obtained from no-mulched and fertilized plots, indicating that in such a dry season soil physical properties were more critical in achieving seed yield than soil fertility factors. Rainfall in the area was 40% less than the long-term average and the lowest in 25 years.

Soil temperatures, monitored at a 5 cm depth from late August to early September, were markedly lower during the hottest hours of the day in the mulched plots, and this was particularly true as the dry weather continued. Cowpea plants on the mulched land, therefore, were subjected to less moisture stress during the dry spells, and the roots were probably able to continue to perform critical biosynthesis at a reasonable rate. This may explain the early bud initiation and flowering, better fertilizer efficiency, and the higher seed yields.

Cowpea line IT 82E-16 is resistant to brown blotch disease shown here affecting the hybrid in the center and the susceptible parent below. It also possesses a constellation of resistant genes that plant breeders use as a source of multiple disease resistance.

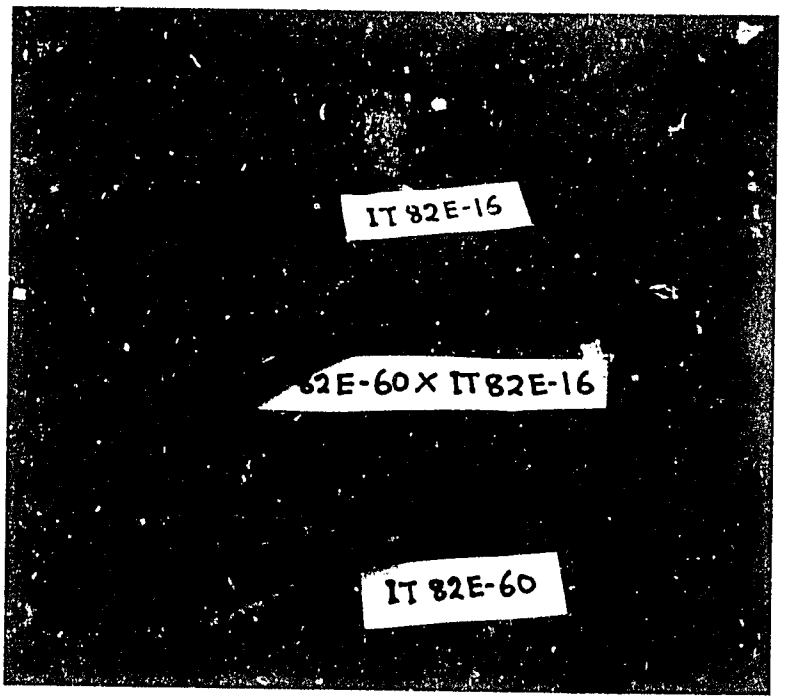


TABLE 13.
Genetic segregation for resistance to different cowpea diseases.

Disease	Resistant sources	F_1 Phenotype	Frequency of F_2 plants: Resistant	Frequency of F_2 plants: Susceptible	Nature of inheritance
Cowpea yellow mosaic	IT82E-16	Resistant	15	1	Duplicate dominant genes
	IT82E-10	Resistant	3	1	Single dominant gene
	TVx 4659-03E	Resistant	3	1	Single dominant gene
Cowpea aphid-borne mosaic	IT82E-10	Susceptible	1	15	Two recessive gene pairs
	IT82E-16	Susceptible	1	15	Two recessive gene pairs
	IT82E-60	Susceptible	1	15	Two recessive gene pairs
Brown blotch	IT82E-16	Susceptible	1	3	Single recessive gene
Septoria	IT82E-16	Resistant	15	1	Duplicate dominant genes
	IT82E-77	Resistant	3	1	Single dominant gene
	VITA-4	Resistant	3	1	Single dominant gene
Scab	TVx 3236	Susceptible	1	3	Single recessive gene
Anthracnose	TVx 3236	Resistant	3	1	Single dominant gene
	IT82E-16	Resistant	3	1	Single dominant gene
	TVx 4659-03E	Resistant	3	1	Single dominant gene

Inheritance of Resistance to Six Major Diseases of Cowpeas

Many diseases reduce cowpea yields, but six are most widespread and devastating: yellow mosaic (CYMV), aphid-borne mosaic (CAMV), brown blotch, septoria, scab, and anthracnose. However, through systematic screening of world germplasm, IITA scientists have identified several sources of resistance, and these are being used in their breeding program.

To plan a more effective breeding strategy, they have conducted genetic studies on the nature of inheritance of resistance to the six diseases. Results showed Mendelian inheritance in all cases involving one or two major genes (Table 13). Resistance to septoria and yellow mosaic is controlled by a duplicate dominate gene, resistance to aphid-borne mosaic by the presence of two recessive gene pairs, resistance to scab and brown blotch by a single pair of recessive genes, and resistance to anthracnose by a single dominate gene.

This information is also useful to national cowpea breeding programs for the development of multiple disease resistant lines with high yield potential. IT 82E-16, an IITA cowpea line which possesses a constellation of resistant genes, can be used as a source of multiple disease resistance in hybridization and backcrossing programs. The simple inheritance makes it rather easy to manipulate resistance traits to these diseases in breeding populations.

One of 16 Nigerian farmers who cooperated with IITA in 1984 to test a new seed yam technology.

Scientists and Farmers Cooperate to Test New Seed Yam Technology

Two questions are often asked of scientists: "Your new technology may work at the experiment station, but is it practical at the farm level and will farmers be interested in it?" The answers turned out to be "yes" when IITA scientists and farmers cooperated during 1984 to farm test a "revolutionary" system of producing seed yams.

The new system, described in the 1983 edition of *Research Highlights*, involves cutting "mother seed yams" into small pieces called minisetts, planting them in nursery beds to sprout, and then transplanting them to ridges or mounds covered with polyethylene plastic. The number of "mother seed yams" needed to produce seed yams by this method is substantially less than with the traditional method of planting large pieces. For example, under the traditional method, it takes 4 million tons of Nigeria's annual yam production of 15 to 20 million tons to plant 1.5 million hectares. If minisetts were used, only 750,000 tons of yams would be needed to produce seed yams to plant 1.5 million hectares. The amount which could be saved for food is enormous, not to mention the savings in farmers' production costs.

Many farmers near IITA's headquarters expressed an interest in collaborating with on-farm tests of the new system, but the number was limited to 16 so scientists could work more closely with them and monitor their progress. The farmers paid for the "mother seed yams" and for labor to plant the minisetts. They came to IITA to participate in the preparation, treatment, and planting of their own minisetts in the nursery for sprouting. Then they planted the sprouted minisetts of two white yam (*D. rotundata*) varieties on their own farms in May and June 1984.

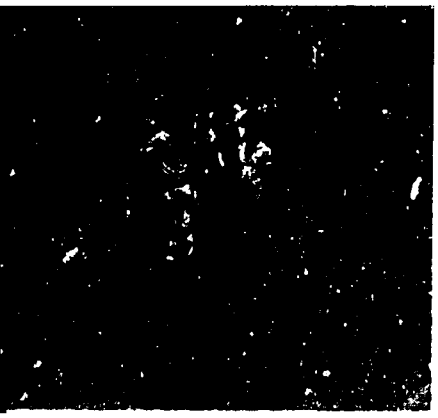
Before the harvest about six months later, IITA and the National Root Crop Research Institute organized a seed yam production technology field day attended by more than 200

Above, 10,000 seed yams needed to plant one hectare. Right, farmers from 17 of 19 states in Nigeria attend a field day to see on-farm results of planting sprouted minisetts to produce seed yams.

farmers from 17 of 19 states in Nigeria. They saw demonstrations and yam fields at IITA and then visited farmers' fields. At the end of the day they formed the Nigerian Seed Yam Growers Association. Soon thereafter, about 150 farmers deposited money for "mother seed yams" and plastic mulch.

Data from the on-farm harvests showed that yam variety TDr 179 was superior in yields per hectare and tuber size. It produced the most tubers weighing more than 1 kg. Farm yields ranged from 12,000 to 99,900 seed yams per hectare. The other variety - TDr 205 - produced more seed yams per plant and per hectare, but as the number of seed yams per plant increased, the weight, length, and circumference decreased. Yields ranged from 18,000 to 47,000 seed yams per hectare. The farm tests showed that TDr 179 is the best line for farmers to use. They plant a whole small seed yam (about 500 g) under the new system.

Cooperators said they believe this recently developed technology holds a real potential for farmers, and some of them plan to expand their yam production with the new system in 1985.



On-farm trial in Cameroon with improved sweet potato clones.

Improved Sweet Potato Clones Tested in Farmer-Managed Trials in Cameroon's National Root Crops Improvement Program

Recent on-farm research in Cameroon has created a continuous flow of information between those who generate new technology (scientists), those who transfer it (extension workers), and those who use it (farmers). Cameroon's National Root Crops Improvement Program (CNRICP) has launched an extensive effort to move the results of experiment station research onto farmers' fields through researcher-managed verification trials, farmer-managed demonstration trials, and farmer-managed multiplication of improved clones.

Last year 430 sweet potato trials were conducted on farmers' fields in three agro-ecological zones; 203 individual farmers, plus groups of farmers in 79 villages, cooperated. Only about 5% of the trials failed because of the lack of care.

Improved sweet potato clones from IITA used in the trials (TIb 1 and 527034) produced two to five times more yield than the best available local clones (Table 14), and their taste rating was "good" to "very good." Moreover, the improved clones showed greater tolerance to prevailing diseases and pests. Farmers are now planting these improved clones on a large scale during the dry and early rainy seasons. Extra planting material is

TABLE 14. Average performance of sweet potato clones in farm trials in three different agro-ecological zones in Cameroon.

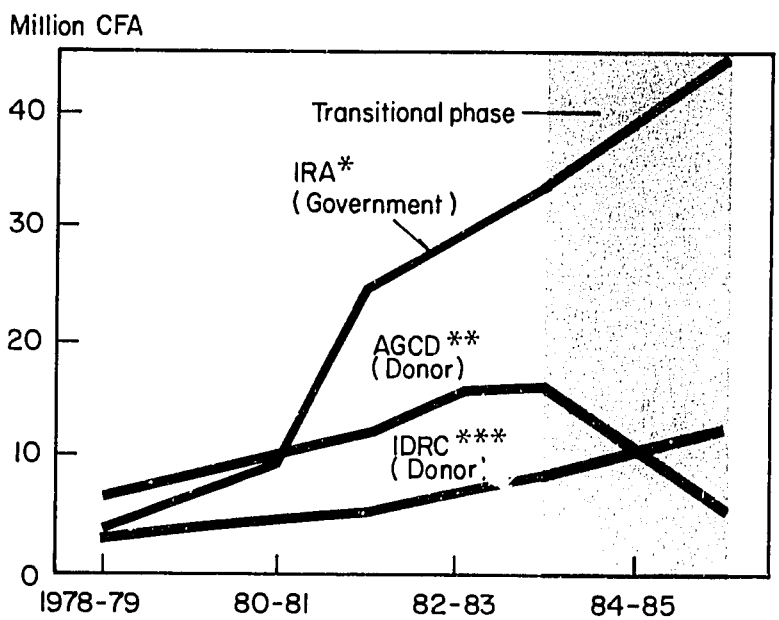
Agro-ecological zones	Yield (t/ha)			Number of storage tubers per unit area (10m²)		
	TIb 1	527034	Local	TIb 1	527034	Local
IIIa	18.9	20.6	4.0	131	181	39
IV	15.1	15.7	7.2	132	207	80
Va	12.8	14.1	7.9	169	223	116

Farmers in Cameroon are planting improved sweet potato clones on a larger scale than ever before.

sold to other farmers and multiplication plots left to grow until the mid-rainy season when the tubers are harvested and marketed. This is normally the time when there are no sweet potatoes in the markets.

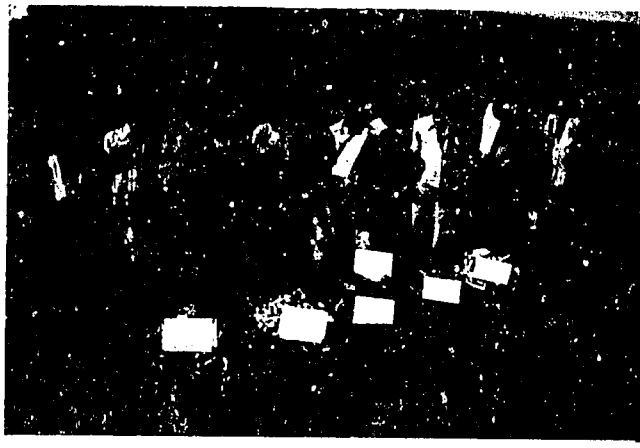
Farmers provide the land and labor for the trials and receive the production for participating. At harvest time, field days are held at which farmers report on sweet potato yields, cooking quality, and the pros and cons of various cultural methods. Production constraints identified at recent field days included poor crop management due to overlapping of several other farming operations during the same period, poor soils (highly weathered and eroded), shallow ridging, careless planting, and grazing animals.

CNRCIP is a cooperative venture involving Cameroon's Institute of Agricultural Research (IRA), IITA which provides technical assistance, and two donors – Canada's International Development Research Centre (IDRC) and Belgium's General Agency for Development and Cooperation (AGCD). From the beginning of the program, strong financial support has been given by the two donors and the Cameroon government through IRA. The government's share of the research operating costs is rapidly increasing – evidence of the value placed on the program by the government (Figure 4).



* IRA: Institut de la Recherche Agronomique, Cameroon.
** IDRC: International Development Research Centre, Canada.
*** AGCD: Administration Générale de la Coopération et Développement, Belgium.

FIGURE 4.
Trend of financial support provided for research operating costs of Cameroon's National Root Crops Improvement Program.



Above, both women and men farmers harvest sweet potatoes from a farmer-managed trial at Rwanda to test the performance of improved varieties; right, farmers display five varieties of sweet potatoes after the harvest.

Sweet Potato Varieties Tested and Farmer-Rated in Rwanda

As part of an applied research program to improve food production by small farmers in Rwanda, the Institut des Sciences Agronomique du Rwanda (ISAR), with the technical assistance of IITA, started on-farm trials a year ago in the Bugesera region using both IITA and local improved sweet potato varieties. This crop is suitable for planting in a wide range of tropical and sub-tropical environmental conditions, including land of low soil fertility. Furthermore, it has a high production potential and provides food at a time when the staple diet is in short supply.

The first set of 17 farmer-managed trials started at the end of October 1983 and the harvesting of the crop was completed in March 1984. Farmers were asked to follow only their normal cultural practices and maintenance. At harvest time, the participating farmers told their neighbors in surrounding villages about their experiences with the trials, described the performance of the different varieties, and rated them at the field sites. They ranked the varieties based on yield, tuber size and shape, and potential market appeal. All farmers in attendance

were asked to indicate their taste preference for each variety which had been steam cooked.

In the Bugesera region, two local improved varieties Nyiramujuna and Rusenya gave the highest yields followed by a local unimproved variety, TIS 2498 from IITA, and Caroline Lee from the USA (Table 15). Farmers showed considerable interest in TIS 2498 because it produced a good yield in spite of low vegetative cover due to an early drought and the tubers were large and uniform which would bring a higher price in the market. Farmers chose TIS 2498 and Rusenya as the most preferred varieties followed by Nyiramujuna and Caroline Lee. They did not like the size, shape, and surface cracks (appearance) of the Caroline Lee tubers. At several sites, the farmers asked for cuttings of TIS 2498 vines for multiplication and later planting on their own farms.

Based on the results of the taste tests, Rusenya was the most preferred variety followed by Nyiramujuna, the local check, TIS 2498, and Caroline Lee. Tubers of the latter variety took longer to cook (30 minutes) compared with the other varieties.

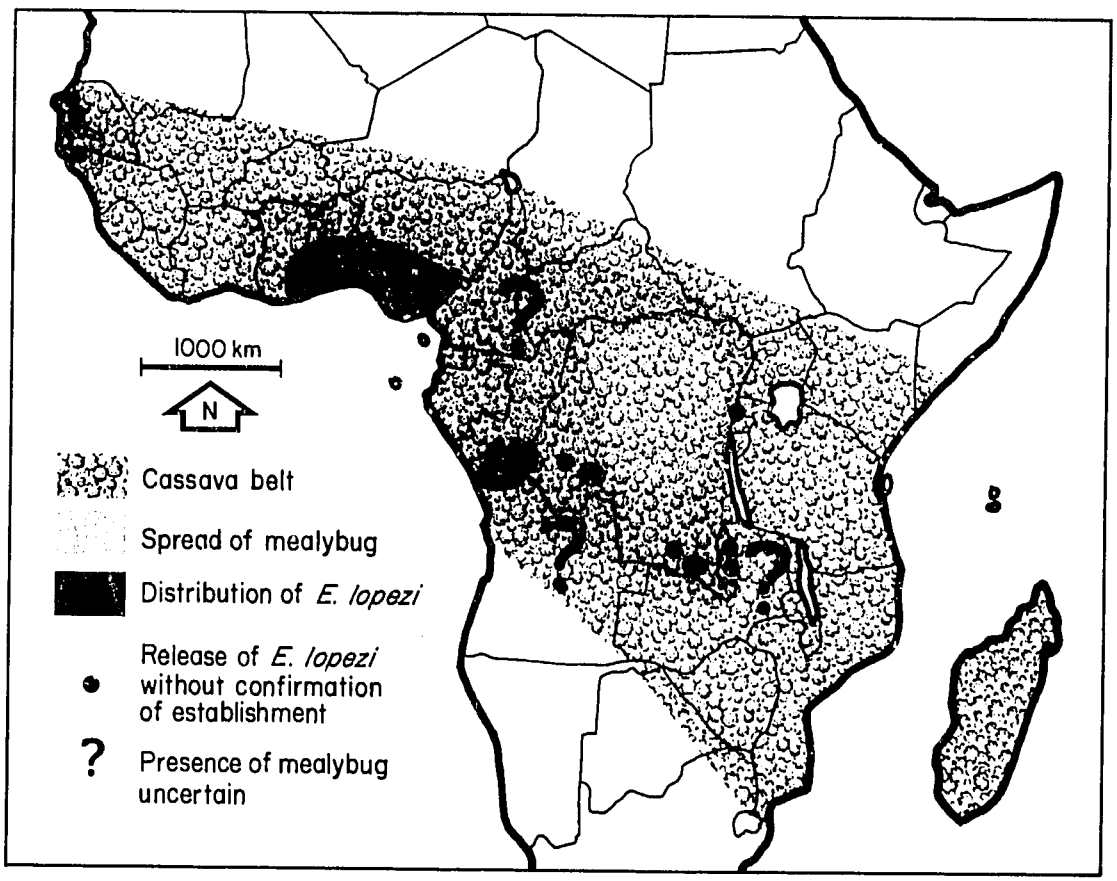
TABLE 15.
Results of sweet potato on-farm trials conducted in the Bugesera region of Rwanda during 1983/84.

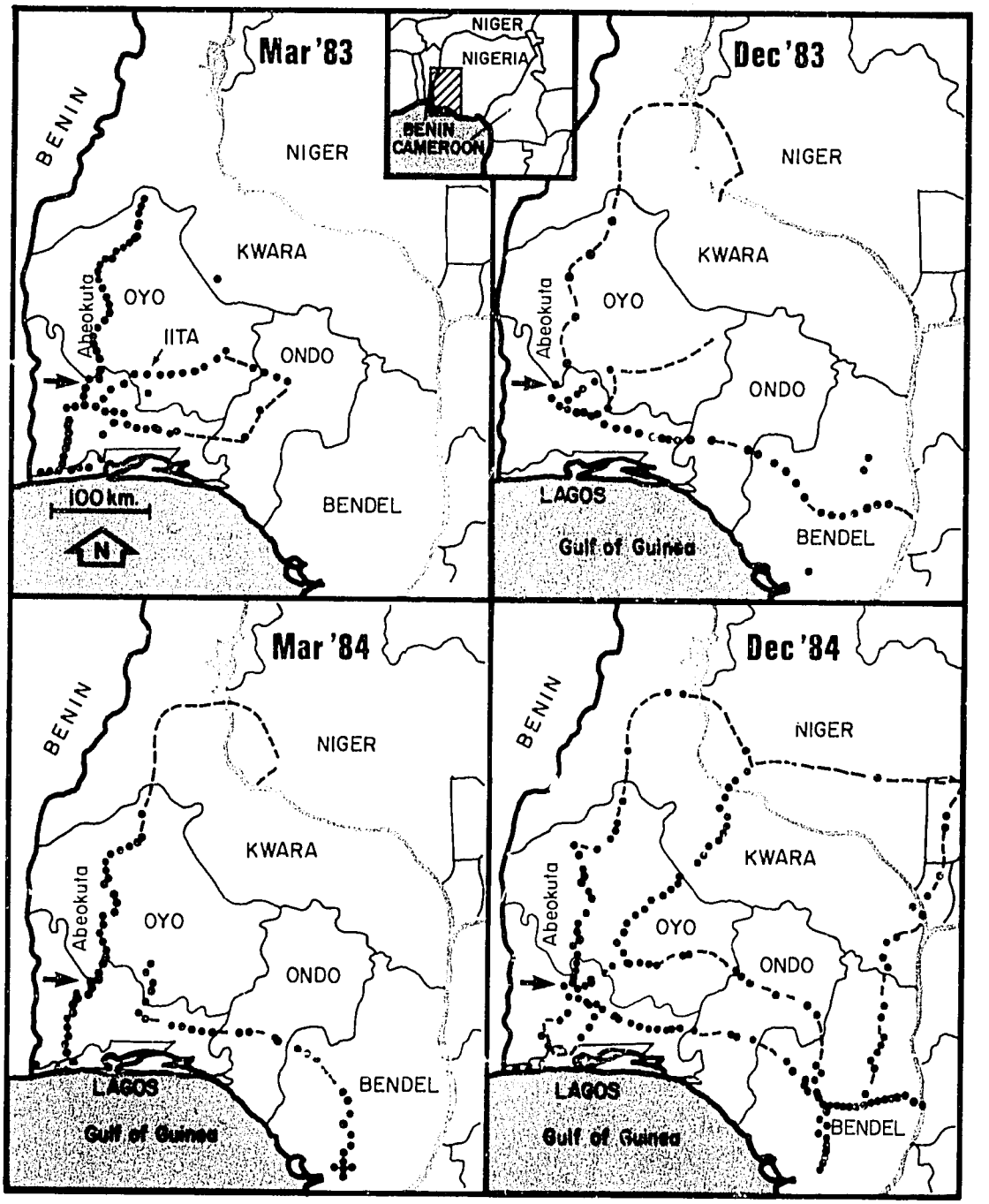
Variety	Ground cover (%)	Mean yield (t/ha)	Cooking time (min.)
Caroline Lee	60	10.2	30
TIS 2498	47	10.8	18
Rusenya	84	12.4	22
Nyiramujuna	89	12.9	22
Local check	88	11.6	–
LSD (5%)	–	N.S.	–

Dissemination, Dispersal, and Impact of *E. lopezi* – a Natural Enemy of the Cassava Mealybug

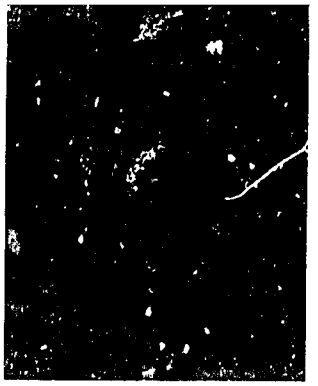
The cassava mealybug (*Phenacoccus manihoti*) causes severe cassava yield losses across large areas in Africa south of the Sahara, and efforts are being made by IITA and its national collaborators to control it through biological means. (See 1982 and 1983 *Research Highlights*). From November 1981 to the end of 1984, approximately 50,000 of the cassava mealybug's

FIGURE 5.
Distribution in Africa of cassava mealybug and its newly introduced natural enemy E. lopezi.





● *E. lopezi* found ● *E. lopezi* not found ---- No mealybug found



Above, severe mealybug damage in a cassava field in Senegal. (Center photo.) Growing tip of a once healthy cassava plant covered with mealybug colonies. (Right photo.) After a natural enemy of the mealybug is released in a cassava growing area, scientists evaluate its establishment and effectiveness.

natural enemy *Epidinocarsis* (= *Apoanagyrus*) *lopezi* were released in 10 African countries: Congo, Gambia, Ghana, Guinea-Bissau, Nigeria, Rwanda, Senegal, Togo, Zaire, and Zambia. The establishment of *E. lopezi* — a wasp that parasitizes the mealybug — has been recorded in eight (Figure 5). A natural enemy is considered established when it has survived a full rainy season — the period of low mealybug population — and has been located again 12 months after release.

All releases in the 10 countries were made from the ground with the assistance of national program personnel using adult wasps transported to the release sites in cold storage boxes. Quarantine regulations within Africa require the release of adult parasitoids since no plant or insect host material can be carried across national borders.

The spread of *E. lopezi* has been comprehensively documented in a large cassava growing area of Nigeria (Figure 6). Data show the capability of this parasitoid to spread throughout the year, even in the rainy season when mealybugs are scarce, as well as the speed of this spread — 50 to 170 km per year. Also, its impact on mealybug populations has been well documented by a series of studies from 1981 through 1984 on IITA's cassava fields and at Abeokuta in southwestern Nigeria (Figure 7). A significant reduction in the number of cassava mealybugs to below the injury level has been observed in every zone colonized by *E. lopezi*. In those zones, the mealybug now reaches peak population densities of only 10 to 20 per terminal cassava shoot and often less than this number compared with a peak population of more than 1,500 per shoot before the introduction of the wasp.

FIGURE 6.
Left, spread of E. lopezi on cassava fields from the release site at IITA in November 1981 and from Abeokuta, Nigeria in November 1982. Samples were taken every 10 kilometers in cassava areas.

In addition to this monitoring, experiments in the laboratory and in the field are carried out to understand and assess the impact of *E. lopezi* on mealybugs. The parasitoid has been excluded by applying sleeves to terminal shoots of cassava plants. Where the wasp is excluded from a mealybug inoculum, the mealybug develops the high populations that were observed before *E. lopezi* was introduced (Figure 8).

The presence of local natural enemies and hyperparasites continues to be monitored both in the experimental plots and on

FIGURE 7.
Impact of the release of E. lopezi in IITA and Abeokuta, Nigeria cassava fields from 1981 through 1984.

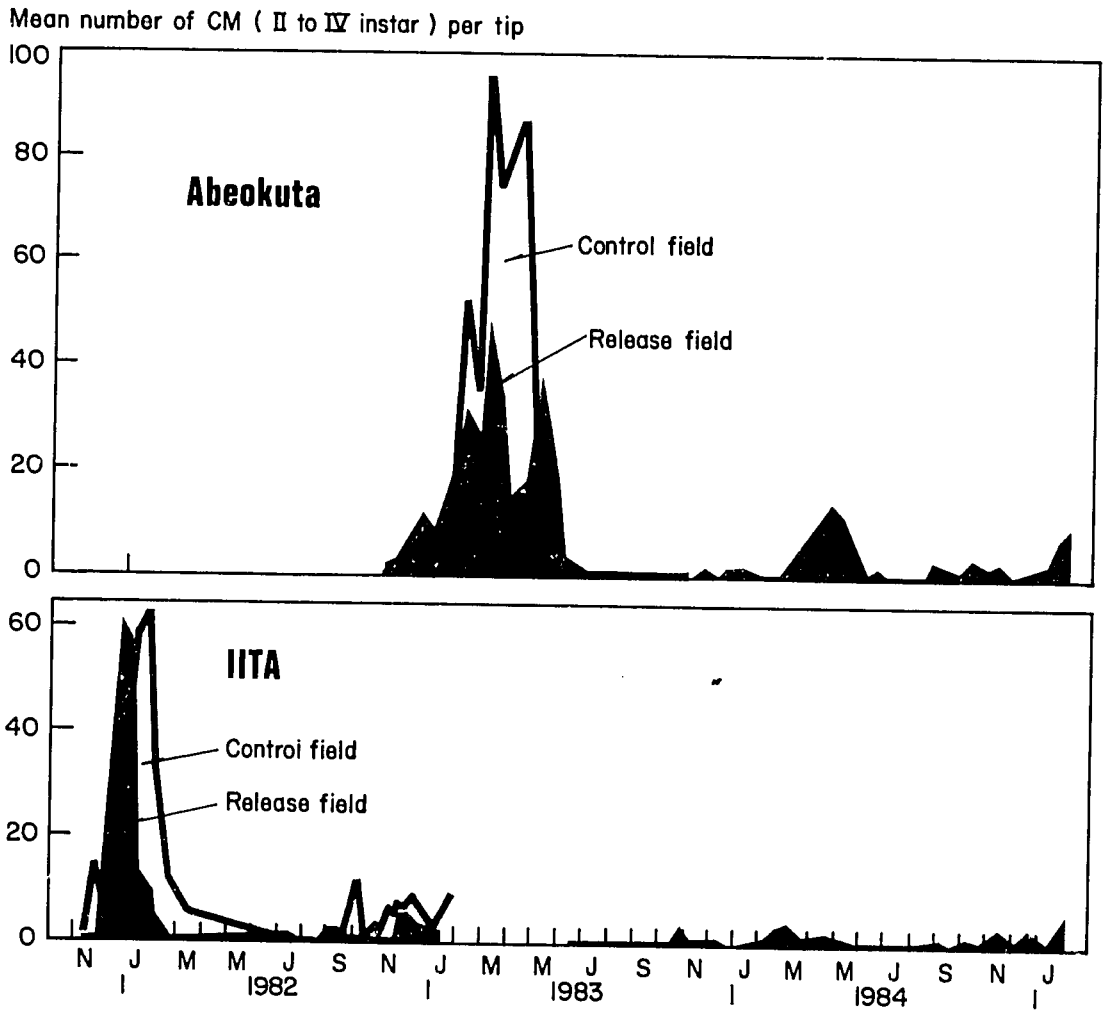
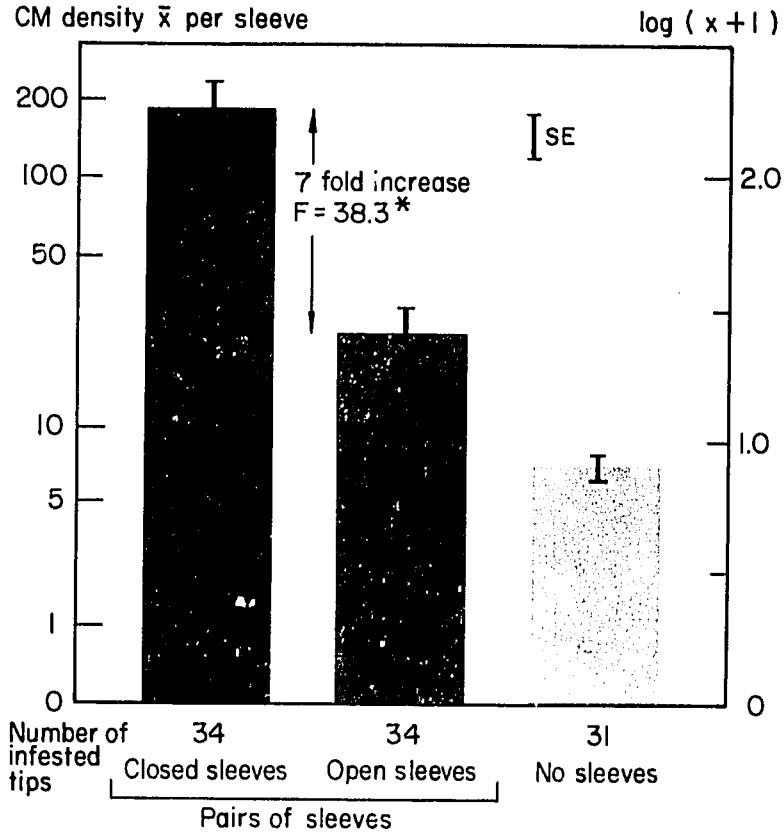


FIGURE 8.
In a natural enemy exclusion experiment using open and closed sleeves attached to terminal shoots, cassava mealybug numbers were about seven times lower where E. lopezi had access to the shoots (open sleeves) than where the wasp was excluded.



field surveys. Where mealybug population levels are low, *E. lopezi* has become the dominant natural enemy, whereas the local ones have become fewer in number.

During three weeks of 1984, IITA scientists, in collaboration with the National Manioc Program, carried out a survey in Zaire to determine the extent of mealybug infestation and the spread of already released natural enemies, using the biological control program airplane to transport the scientists and a motorcycle for ground observations in remote areas. Locations for additional releases of *E. lopezi* in 1985 were identified.

New attempts are being made to find additional effective natural enemy species. A complex of species would be more desirable to assure a permanent and reliable suppression of the mealybug.

Encapsulation and Melanization: Cassava Mealybug Defends Itself Against a Natural Enemy – but Loses

Even though the cassava mealybug apparently has a special defense mechanism against its natural enemy *E. lopezi*, this parasitic wasp continues to be very effective in the context of IITA's biological control program.

When entomologists dissected mealybugs taken from cassava plants where *E. lopezi* had been released, they sometimes found "black particles" in their body cavities which turned out to be the dead eggs and larvae of the wasp. This was significant because the female wasp attacks the mealybug by laying her eggs inside the mealybug. The egg normally hatches into a wasp larva that feeds internally on the mealybug over a period of 8 to 10 days. Eventually, the mealybug is killed, and the wasp larva metamorphoses into a pupa and finally emerges from the dead mealybug as an adult wasp ready to repeat the cycle again.

Dead and blackened eggs and larvae of the wasp indicated that this was a defense reaction against the attack of the parasitoid – a phenomenon known in many insects attacked by parasitic wasps. The defense reaction involves the mealybug's blood cells first surrounding or encapsulating the wasp's egg or larva. This is followed by a blackening or hardening of the capsule called melanization that results in suffocation and death.

Such a defense reaction is a good example of the continuing co-evolution between a parasitoid and its host, wherein the parasitic wasp attacks the mealybug which in turn uses this defense reaction to kill the egg and larva of the wasp. Preliminary experiments, however, indicate that this is not the end of the story because the wasp can overcome encapsulation and melanization by laying more than one egg. Apparently, the mealybug's blood cells are not capable of killing several eggs or larvae so that one survives to kill the mealybug.

Female wasp, E. lopezi, and parasitized mealybug showing "black particles."

The "black particle" is the melanized egg of the wasp. (From a dissected mealybug.)

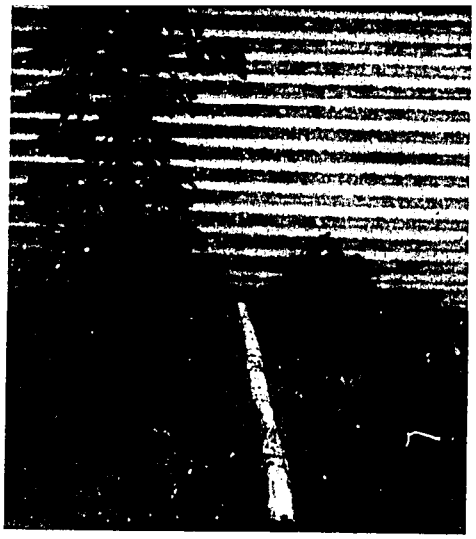
Larva of the wasp is almost completely melanized. (From a dissected mealybug.)

Tests in Zaire show that cassava clone 70453 is resistant to mealybugs. It slows the build-up of mealybug population and tolerates the attack by the pests which survive on the plant.

Cassava Clone Resistant to Mealybugs Now Being Used in Intensive Breeding Program in Zaire

Since 1981, when a cassava clone 70453 was discovered in Zaire to be resistant to the mealybug (*Phenacoccus manihoti*), additional tests have been made which confirm earlier research results. Development of varieties resistant to the cassava mealybug is of major importance because large areas of Zaire lie under constant threat of destruction by this pest. In years of normal rainfall it causes only minor damage, but with rainfall less than normal losses have been extremely severe.

The resistant clone 70453 both slows the build-up of the mealybug population and tolerates well the attack by the pests that survive on the plant. It is now being used in the Zaire National Cassava Program (supported technically by IITA scientists) in an intensive breeding effort to incorporate these two desirable traits into existing high yielding varieties.



Left, the mealybug resistant cassava clone 70453 compared with a susceptible plant (right).

Initial test of the clone three years ago (1981 *Research Highlights*) included only a few plants in greenhouses, but later tests were conducted with many plants under more natural conditions. As in the first test, mealybug colonies grew much more slowly on clone 70453 than on the controls. Eight weeks after the initial infestation, an average of only 11 mealybugs/plant were counted on the resistant clone compared with 420/plant on the controls.

To measure the plants' reaction to attack (i.e., degree of tolerance) scientists attempted to add mealybugs to a group of resistant plants until they supported approximately the same number as a group of susceptible controls. The attempt was unsuccessful. Mealybug colonies on the resistant plants could not be increased significantly in size even when hundreds of new mealybugs were added each week. Ordinarily, even a few mealybugs feeding on a plant over a period of one or two weeks will produce the characteristic symptoms of leaf curl and bending of the stem. By contrast, the most heavily infested plants of clone 70453 showed no leaf curl and only occasionally a very slight and transitory bending of the stem.

Clone 70453 is a non-pubescent type and the resistance to mealybugs appears to be due to antibiosis. This resistance characteristic is being incorporated into cassava breeding populations for further improvement.

Kinuani – a new superior cassava variety – is being multiplied on a large scale in Zaire.

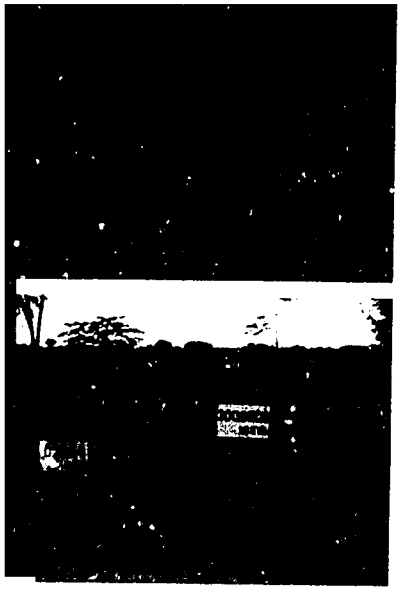
Cassava planting material (Kinuani variety) being loaded on a truck for distribution to farmers.

Superior Performance of New Cassava Variety Confirmed in Zaire

After several years of multilocational trials, the Zaire National Cassava Program (PRONAM), which is supported technically by IITA, released in early 1983 a new superior, stable, and disease resistant variety (formerly known as clone number 30085/28) and named it Kinuani. The word means "fighter" in the Kikongo language.

The strategy used to get wide dissemination of this improved variety involved a large number of demonstration trials on farmers' fields in collaboration with several agricultural and rural development agencies that are able to reach farmers with new technology. (They include the extension service of the Department of Agriculture, National Fertilizer Program, Agricultural Production Project of Mvanza-Ngungu, Integrated Rural Development Project of Luala in Luozi, Oxfam, Salvation Army, and church groups.)

Results of the trials in 1984 showed that Kinuani consistently produced larger yields than local varieties. For example, at 52 on-farm locations in Bas-Zaire, Kinuani outyielded the local variety by more than 30% with no fertilizer, as well as with two different rates of application (Figure 9). Because of a rapid multiplication program, PRONAM officials estimate that approximately 2,125,000 meters of Kinuani planting material (enough to cover 850 ha) will be available for the 1984/85 planting season.



(Top photo.) Waterlogged cassava field. This crop is extremely sensitive to excessive water. (Lower photo.) A comparison of the yield of Kinuani cassava (right) with a local improved variety after standing in water for two to five days during the growth cycle.

Cassava – a crop extremely sensitive to excessive water – may die if it stands in water for only a few days. Tops wilt and roots become rotten. In the later stages of selection, Kinuani was tested on both well drained soils and on those subject to periodic waterlogging.

In a multilocational yield trials at a site in which there was standing water for periods of two to five days during the growth cycle, Kinuani produced a yield of 16.5 t/ha compared with only 5.7 t/ha for the standard variety 02864. A yield of 30.8 t/ha for Kinuani was also recorded on a two hectare production plot which was flooded three times with water standing three to five days.

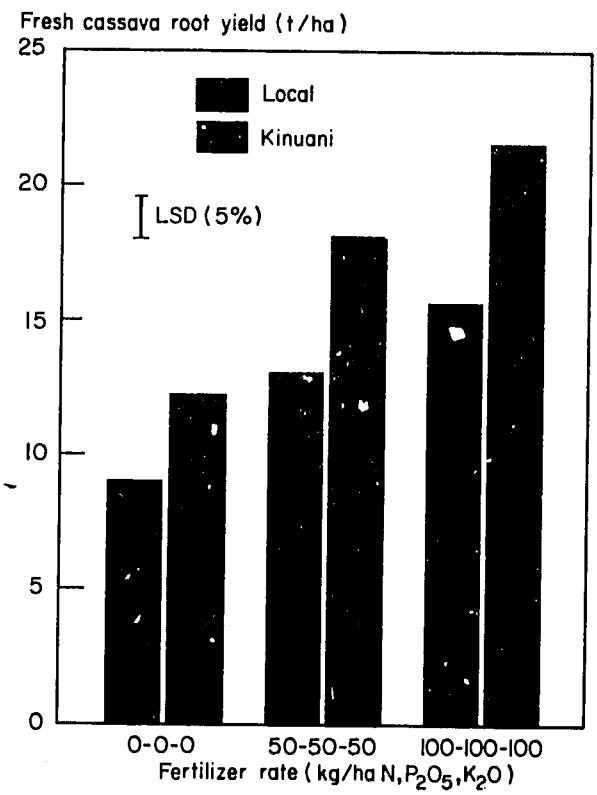


FIGURE 9. Comparison of the fresh root yield of Kinuani cassava with a local variety at 52 on-farm locations in Bas-Zaire (1983–84).

Wide Yield Differences in Cassava Clones Grown at Initial Site Selection vs. a Different Environment in Cameroon

Evaluation of cassava material in two different environments in Cameroon in 1984 showed that clones produced substantially higher yields at locations from which their initial selections were made. Yields and storage root numbers of Babungo-selected material were halved when evaluated at Mujuka. Yields were also cut in half when Mujuka-selected material was evaluated at Babungo, but storage root numbers remained the same (Table 16).

The incidence of disease of Babungo-selected cassava was very high at Mujuka (80 m above sea level). The initial selection had been made under low cassava mosaic disease pressure at Babungo (1130 m above sea level).

This evaluation is part of Cameroon's National Root Crops Improvement Program to develop high yielding, pest resistant cassava varieties adapted to different environments. National

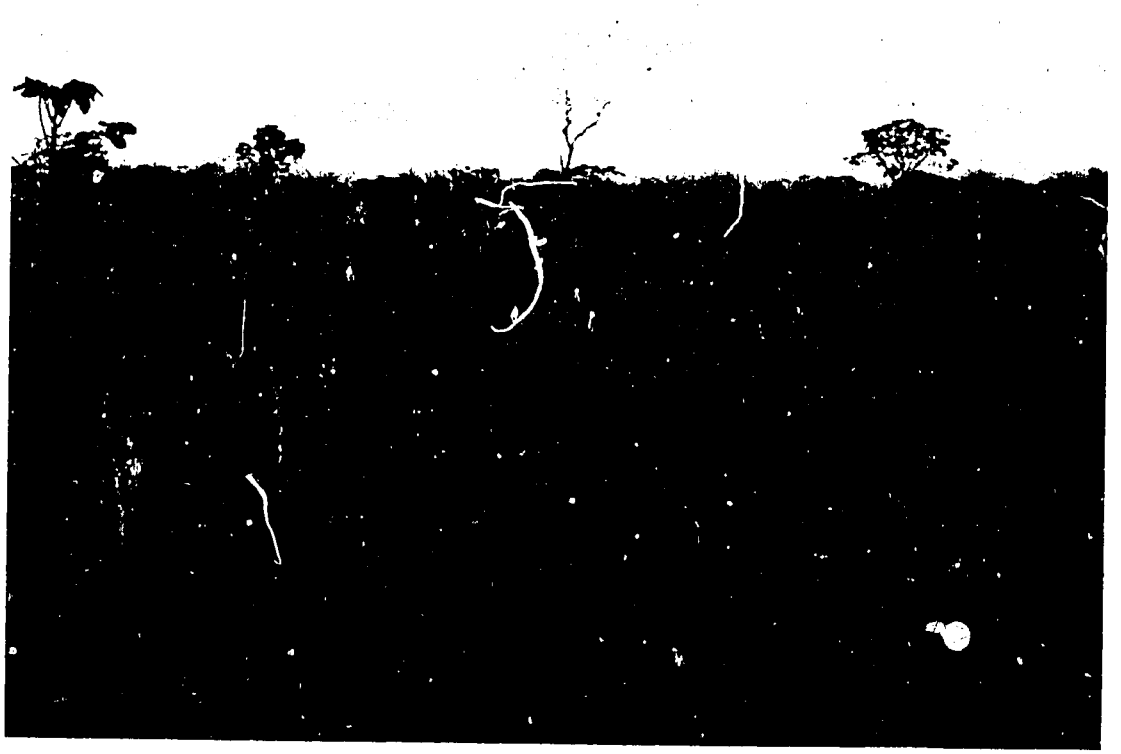
Selection site	Yield (t/ha)		Storage root no. per unit area (10m²)		Mean disease scores* CMD**		CBB**	
***	M	B	M	B	M	B	M	B
Mujuka (M) (Elevation 80 m)	23.1	12.1	64	59	1.0	0.6	1.0	0.7
Babungo (B) (Elevation 1130 m)	15.4	24.5	51	100	3.0	0.1	2.0	0.7

Scores: Rated on a 0 to 4 scale; 0 = no damage and 4 = severe damage.
***CMD = cassava mosaic disease; CBB = bacterial blight.*
****Evaluation site.*

TABLE 16. Performance of cassava clones selected and evaluated reciprocally at two locations with different elevations in Cameroon.

and IITA scientists involved in the program used improved clones in 1984 trials which produced up to 100% better yields than local cultivars in each of the five major agro-ecological zones of the country.

A cassava variety initially selected in the highlands of Cameroon does poorly in a lowland environment shown here mainly because of disease pressure.



Harvest of improved IITA cassava clones in a high altitude area (1650 m) in Rwanda.

Cassava Lines for High Altitude Dry Ecologies in Eastern Africa

Throughout various parts of Africa in 1984, drought caused huge crop losses and hunger, emphasizing the urgent need to grow crops which can withstand long periods of drought. Cassava is one crop that does well under these conditions.

Although many high yielding, disease resistant cassava varieties acceptable to farmers and consumers have been widely distributed and grown in some areas, varieties for high altitude dry ecologies need to be improved. Therefore, IITA scientists, in collaboration with national programs, have initiated efforts to accomplish this by screening IITA genetic source material in such agro-ecologies in Rwanda.

Local varieties have produced moderate yields at these high altitudes when rainfall distribution is normal, but they suffer yield losses and severe green spider mite damage in prolonged dry seasons. In 1984 field tests in three different Rwanda drought locations at high altitude (Table 17), IITA source material demonstrated the ability to withstand these conditions and improve yields. A low cyanide (HCN) clone UYT Bulk 1977/11 gave yields of 16.8, 31.2, and 73 t/ha and a high cyanide clone PYT Bulk 1977/69 yields of 20.7, 19.1, and 61.5 t/ha at the three locations, respectively. (Karama, Rubona, and Mutara.)

TABLE 17.
Characteristics of test sites in Rwanda.

Station	General description	Mean temp (°C)	Dry season duration (months)	Annual rainfall (mm)	Altitude (m)
Karama	Dry, red, and generally poor soils; low rainfall with short period of distribution and high year-round temperature and long dry season.	22	4–5	853 bimodal	1403
Rubona	Red and generally poor soils; cool highland area with moderate dry season and rainfall.	19	3	1171 bimodal	1650
Mutara	Fertile soils; low rainfall with short period of distribution; high year-round temperature.	21	3	831 bimodal	1450

Virologists Find Further Evidence that Geminivirus Is the Causal Agent of Cassava Mosaic Disease

Although the exact etiology of African cassava mosaic disease (CMD) transmitted by the whitefly (*Bemisia tabaci*) has been a mystery for about 50 years, recent research by IITA's virologists and others provides further evidence that it is caused by a geminivirus. Reports from many African countries indicate that cassava yield losses from the disease range from 20 to 90%, thus reducing supplies of this food which is a major carbohydrate source for millions of people.

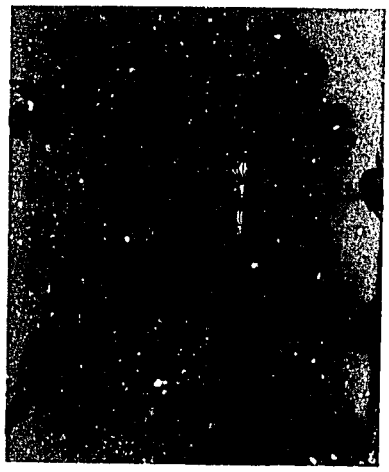
The greater certainty now about the etiology of the disease should make possible the development of suitable and reliable virus indexing and the transfer of cassava vegetative materials across national boundaries. Government quarantine regulations governing the import and export of plant materials usually do not allow for the presence of any virus.

Scientists who did pioneering work as far back as the 1930s on the etiology of the disease presumed that it was caused by a virus, but results of further research supporting this view did not appear until many years later.

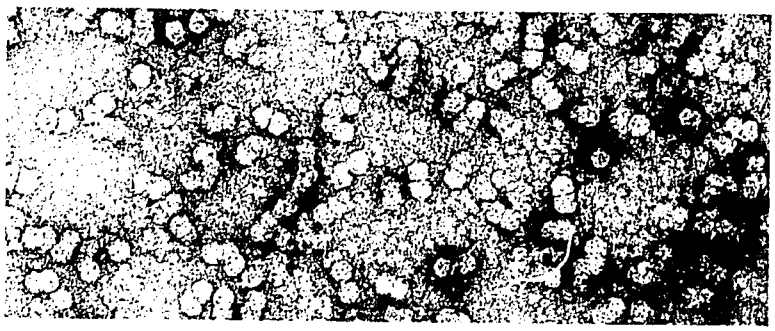
In the late 1970s, several laboratories, including those at IITA, transmitted a geminivirus from mosaic infected cassava to test plants such as *Nicotiana clevelandii* and *N. benthamiana*, but all attempts to transmit the isolated geminivirus back to healthy cassava to try to prove that the geminivirus was the causal agent of CMD proved unsuccessful.

However, IITA virologists have now achieved a low but consistent incidence of infection (about 10%) among cassava seedling populations inoculated with a particular isolate in the form of crude or concentrated sap. This isolate was obtained by using *N. clevelandii* × *glutinosa* as the experimental host for initial isolation. The *N. clevelandii* × *glutinosa* isolate had been

Right, a healthy cassava seedling being inoculated with a crude juice from N. benthamiana infected with the geminivirus. Left, cassava plant with cassava mosaic disease.



Purified preparation of geminivirus – the causal agent for African cassava mosaic disease – as seen under the electron microscope. (Magnified 45,000 times.)



maintained in *N. benthamiana* ever since its initial isolation. In that species it induces symptoms identical to those obtained by direct infection of *N. benthamiana*. Moreover, the new isolate proved to be serologically identical to the previous ones.

Inoculation of healthy cassava seedlings with purified geminivirus preparations also resulted in 10% of the plants showing typical CMD symptoms and were indistinguishable from those observed in the field. This confirms recent findings of scientists at the Kenya Agricultural Research Institute.

Unpeeled Cassava Tubers for "Gari"?

Peeling cassava tubers by hand is likely to continue as the first step in making "gari" because of the relatively high tannic acid content in the peel.

West African consumers of a traditional and popular cassava food – "gari" – prefer a white or slightly yellow product, but this requires peeling the tubers by hand which takes a lot of labor. Also, slicing off the peeling with knives, which is done in many villages, results in some final weight loss. So far there is no efficient peeling machine on the market even for commercial processing plants.

In an effort to find out if white-skinned IITA improved lines could be used without peeling and still meet consumer requirements, scientists started a series of investigations in 1984. Results: The "gari" prepared from the unpeeled cassava tubers always had a grayish or brownish color, and it darkened as the storage period increased.

The scientists suspected that the discoloration was due mainly to a relatively high tannic acid concentration in the peel, and tests proved this to be true. "Gari" processed with the peel on the tubers always had a higher tannic acid concentration – at least five times higher in the 15-month old samples and two times higher in the 15-day-old materials (Figure 10). However, the HCN content (hydrogen cyanide) is always very low after fermentation for three days.

Although commercial processing plants may be able to use a bleaching agent to prevent discoloration due to the higher tannic acid concentration in the peel, it is not yet possible for villagers to prepare acceptable "gari" from unpeeled cassava tubers. The tannic acid concentration in the peel and flesh of 10 local varieties was similar to that in 21 IITA improved cassava clones.

Samples of 15-month old "gari" from unpeeled and peeled IITA cassava varieties. Note the grayish or brownish color of the "gari" from unpeeled tubers caused by a relatively high concentration of tannic acid in the peel.

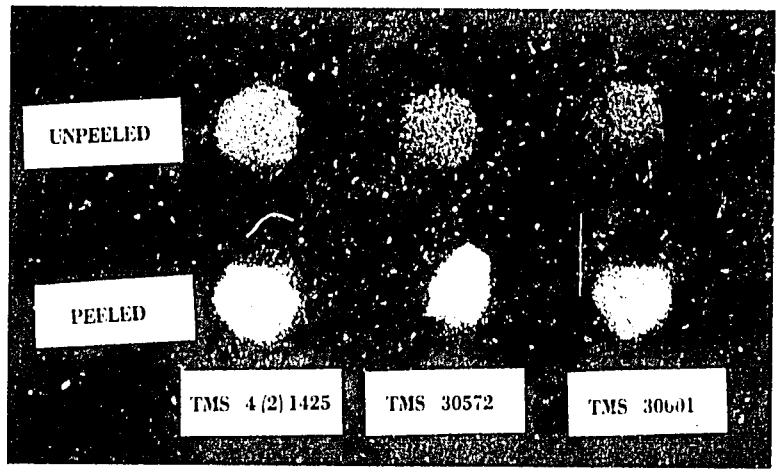
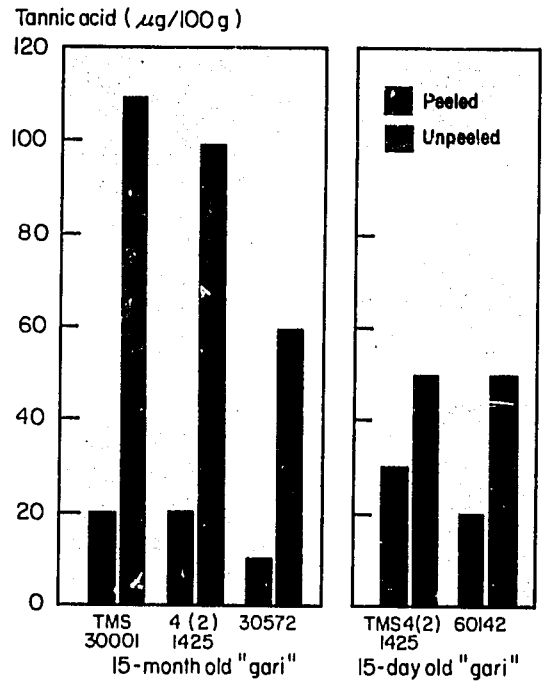


FIGURE 10. Comparison of tannic acid concentration in "gari" made from white-skinned peeled and unpeeled cassava tubers. (IITA improved varieties).



Quality of Bread from Cassava Flour

Many African countries import large amounts of wheat for bread making, and, with increasing foreign exchange problems, they are interested in substituting or blending flour from local tropical crops such as cassava. During 1984, IITA scientists tested various cassava varieties and baking formulas to determine the best ones for cassava breads.

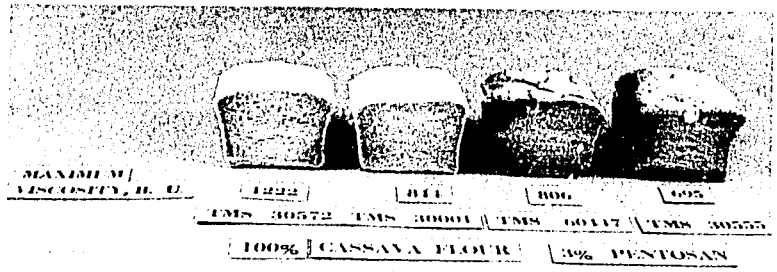
Because starchy crops such as cassava lack proteins which have the properties of wheat gluten, a bread improver (pentosan) must be added or the flour cannot be used for baking. Therefore, either pure or technical grade pentosans from rye or wheat endosperm were added to cassava flour. (Pentosans are polysaccharides consisting of the sugar arabinose and xylose.)

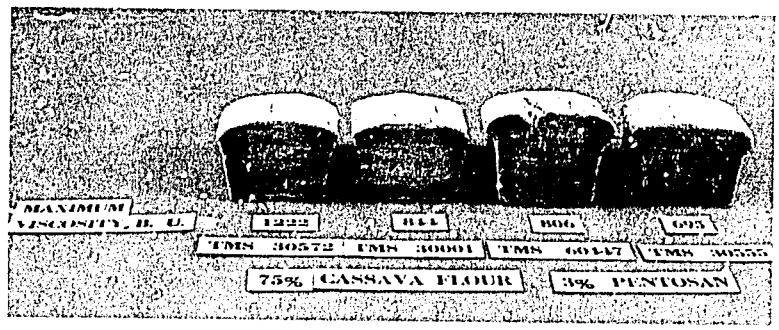
During the laboratory testing, the scientists noted that the quality of the cassava breads depended on the cassava variety. Those IITA improved varieties with a high maximum paste viscosity value – TMS 30572, TMS 30001, and a Nigerian variety 60447 – produced breads with normal crumb structure, but those with low value were not suitable for bread making. TMS 30555 had damp gelled portions at the sides and bottoms of the loaves. Both TMS 518 and TMS 91142 with low maximum paste viscosities also had gels in the same parts of the bread loaves and the centers were too wet, forming a clump when sliced. TMS 50395 produced the poorest quality bread. It was all gel with an air space between the main part of the loaf and the top crust.

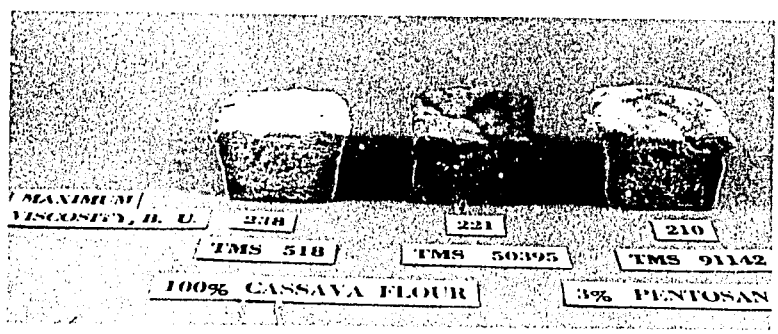
When wheat flour was added at 25% concentration, only the cassava varieties with high maximum paste viscosities formed breads with normal bread structure.

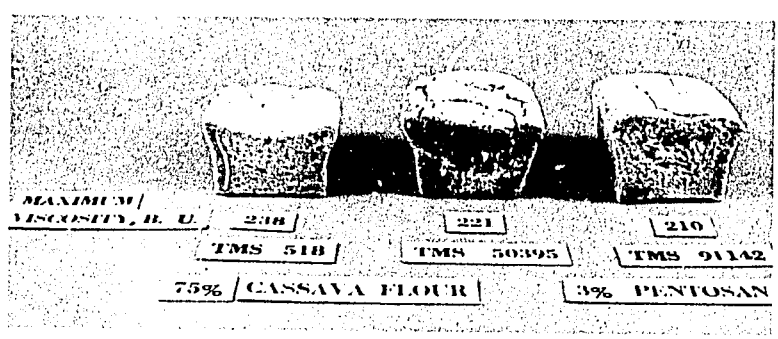
Based on these results, the suitability of cassava lines for baking bread using 75 to 100% cassava flour and pentosan can be determined using maximum paste viscosity values.

(Top two photos.) The best quality bread was made from cassava flour originating from three cassava varieties with high maximum paste viscosity. (Lower two photos.) Varieties with a low viscosity value were not suitable for bread making.









Hybrid maize in experimental plots at IITA (left) and a farmer's field of hybrid maize (right) in Oyo State, Nigeria.

Hybrid Maize Moves from Experimental Plots to Farmers' Fields in Nigeria

Following the selection and testing of high yielding hybrids by an IITA research team last year, farmers in nine states of Nigeria were given seed and a production guide to participate in 1984 on-farm demonstrations organized by national program personnel. Approximately 85% of those participating were small-scale farmers growing less than five hectares of maize.

These on-farm demonstrations were conducted in both forest and savanna zones. In the former (at 79 locations), three maize hybrids yielded an average of 6 t/ha in the first season – 25% more than the improved open-pollinated variety TZSR-W-1 which is one of the principal varieties grown by Nigerian farmers

TABLE 18.
Grain yields of selected maize hybrids compared with improved open-pollinated varieties in on-farm demonstrations located in the forest zone of Nigeria during the first crop season (1984).

Variety	Maize grain yield (t/ha)	Range (t/ha)	No. of Locations
Hybrid			
8326-17	6.0	4.0–8.4	10
8322-13	5.9	5.0–9.4	4
8329-15	6.0	4.4–7.5	24
Open-pollinated			
TZSR-W-1	4.8	2.2–6.7	23
TZPB	4.7	4.4–5.1	3
Local	2.3	1.0–3.5	15

TABLE 19.
Grain yields of selected maize hybrids compared with improved open-pollinated varieties in on-farm demonstrations in the savanna zone of Nigeria (1984).

Variety	Maize grain yield (t/ha)	Range (t/ha)	No. of Locations
Hybrid			
8322-13	8.8	6.9–11.8	6
8321-12	7.9	6.1–11.1	12
8321-18	7.3	4.9–10.3	11
Open-pollinated			15
TZSR-W-1	5.6	3.6–7.7	15
TZB	4.1	1.9–5.1	5

(Table 18). During the second season, hybrids were planted again in the forest zone and yields averaged 4.7 t/ha.

In the savanna zone – the best potential area for maize production – the average yield of three hybrids at 49 locations was 8 t/ha or 43% more than the improved open-pollinated variety (Table 19). The record yield reached 11.8 t/ha in Funtua with the hybrid line 8322-13. All the promising hybrids for the savanna zone carry resistance to streak virus. In field tests at Mokwa, Nigeria during 1983 and 1984, these hybrids showed resistance to *S. hermonthica*, one of the species of *Striga* infesting maize in Nigeria. They have not been tested for *Striga* resistance in other areas where this parasitic weed is a problem.

Growing hybrid maize was profitable for the farmers participating in the on-farm demonstrations according to an analysis by IITA's agricultural economists. The average cost of producing one hectare amounted to 877 Naira (Table 20). Gross

TABLE 20.
Costs of producing one hectare of hybrid maize under good management in Nigeria (1984).

Item	Cost (₦/ha)
Hybrid seeds	70
Land preparation	98
Planting	130
Fertilizers	72
Weed control	297
Harvesting	210
Total	₦877*

** 1 Naira (₦) = $1.30 at the official exchange rate.*

income totalled 2,500 Naira based on a sale price of 500 Naira per ton with an average yield of five tons per hectare. Net profit was 1,623 Naira per hectare. (One Naira equals $1.30 at the official exchange rate.) A farmer in Kaduna State said his figures indicated an expected net profit of 2,371 Naira per hectare based on an average yield of 6 t/ha. Speaking before "distinguished guests and indispensable farmers" at his farm in mid-October, he said that participating in the hybrid maize program is "a unique responsibility because of the hope it holds for helping to feed the masses of this country."

For the first time in Nigeria, a private firm (Agricultural Seed Ltd.) produced hybrid maize seed under the supervision of IITA and the National Seed Service. Approximately 80 tons of single cross hybrid seeds were produced in 1984, and it is expected that the F_1 seed will be planted on approximately 5,000 hectares in 1985

IITA's hybrid maize program is supported by the Federal Government of Nigeria. Cooperators include the Agricultural Department of the Ministry of Education, Science, and Technology, Federal Department of Agriculture and its agencies, National Accelerated Food Production Project (NAFPP), state agricultural development projects, National Cereals Research Institute (NCRI), University of Ife, and Ahmadu Bello University. IITA's scientific work on maize is also a cooperative program with the International Center for Wheat and Maize Improvement (CIMMYT).

Chief of Staff of the Nigerian Supreme Military Headquarters (next to the IITA scientist) and other officials visit hybrid maize demonstrations at IITA and on farmers' fields. The Institute's hybrid maize program is supported by the Federal Government of Nigeria.

A display of IITA's high yielding hybrid maize variety 8321-18 by a farmer (center) from Kaduna State and two Nigerian agricultural representatives.

(Top photo.) A farmer's maize wiped out by a downy mildew epidemic. (Lower photo.) IITA maize variety DMR-LSRW on the right resistant to both downy mildew and streak; variety TZB on the left is susceptible to both diseases.

Maize Varieties with Combined Resistance to Downy Mildew and Streak Diseases

Over the past few years, IITA scientists have put major emphasis on the development of maize varieties resistant to streak – a yield-depressing virus disease in Africa. As a result, several resistant varieties have been made available to national programs. (See 1980, 1982 and 1983 *Research Highlights.*) Now another disease – downy mildew (*Peronosclerospora* spp) which is the most economically important disease of maize in Asia – threatens the crop in some African countries. It co-exists with streak in parts of Burundi, Mozambique, Nigeria, Somalia, Sudan, Uganda, Zaire, and Zambia (Figure 11).

Unfortunately, resistance to streak is not linked with resistance to downy mildew. For instance, an international trial of an early maturing, streak resistant population (TZESR-W) planted in Gandajika, Zaire in 1982 was completely wiped out by downy mildew. Five years earlier, scientists found that all available varieties tested in a downy mildew endemic site in Nigeria were susceptible to the disease. They then crossed downy mildew resistant cultivars from Thailand and the Philippines with streak resistant IITA and Nigerian varieties, and an intensive breeding program to combine resistance to both diseases was underway.

From 1980 through 1982, selected maize populations were subjected to three cycles of an S_1/half-sib shuttle breeding scheme. A cycle involved evaluation for downy mildew at the National Cereals Research Institute's sub-station at Owo, Nigeria, followed by screening for streak resistance at IITA in Ibadan and recombining the resistant plants. In 1983, half sib families of the late maturing populations (DMR-LSRW and DMR-LSRY) were evaluated in three environments: a downy mildew site at Owo and two downy mildew-free locations at Akure and Ikenne in Nigeria. For each population, the top 10 families were selected at each site based on grain yield and

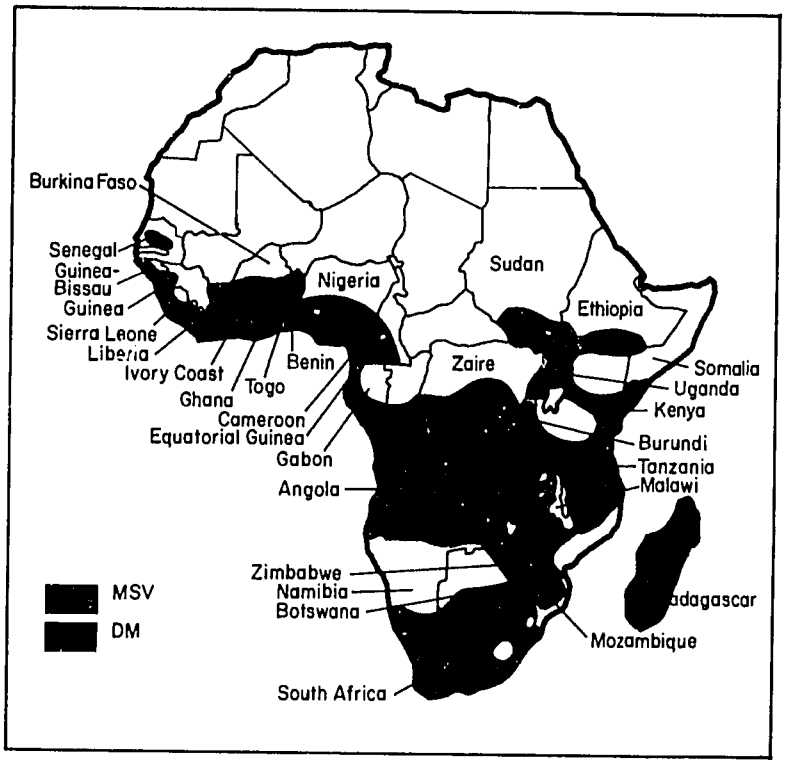


FIGURE 11.
Distribution of maize streak virus (MSV) and downy mildew in Africa.

agronomic characters. Four experimental varieties were formed from each population consisting of three from the different locations and an across-location variety based on performance of the families across the three locations.

These varieties were evaluated in 1984 along with check varieties at six locations in Nigeria: Kabba and Owo for downy mildew evaluation, Ibadan for streak pressure and locations at Ikenne, Samaru, and Funtua which were virtually free of either streak or downy mildew infection.

Data on disease scores and grain yield are presented in Table 21. The DMR-LSR varieties demonstrated resistance and good yield performance in both streak and downy mildew environments and are available for further testing and introduction to areas infected by either or both diseases. The base

populations will be further improved using an intensive full-sib family testing approach in international multilocation experiments.

Collaborators with IITA in this maize program are the Nigerian National Cereals Research Institute and the International Center for Wheat and Maize Improvement (CIMMYT).

TABLE 21. Performance of maize varieties with combined resistance to downy mildew and streak in disease environments and across six locations in Nigeria (1984).

	Downy mildew pressure		Streak pressure		Across disease-free locations	Across all locations	
Variety	Grain yield (t/ha)	DM incidence (%)	Grain yield (t/ha)	Streak score*	Grain yield (t/ha)	Grain yield (t/ha)	% Best check**
Across 83 DMR-LSRW	3.2	8	4.2	2.8	5.6	4.3	119
Akure 83 DMR-LSRW	3.5	18	3.5	1.5	5.4	4.1	114
Ikenne 83 DMR-LSRW	3.5	18	3.5	1.5	6.3	4.4	122
Owo 83 DMR-LSRW	3.7	12	4.3	1.5	6.2	4.7	131
Across 83 DMR-LSRY	4.0	10	3.3	2.8	5.3	4.2	114
Akure 83 DMR-LSRY	3.7	13	4.1	2.0	5.9	4.6	124
Ikenne 83 DMR-LSRY	3.6	17	3.8	1.3	5.8	4.4	119
Owo 83 DMR-LSRY	3.3	13	3.7	1.8	5.6	4.2	114
Checks							
Across 81 TZSR-W-1	0.3	91	4.9	1.8	5.6	3.6	100
TZB	1.4	73	1.1	5.0	7.1	3.2	89
Ikenne 81 TZSR-Y-1	0.2	91	4.5	1.8	6.4	3.7	100
Western Yellow	0.4	93	0.9	5.0	6.1	2.5	68
LSD (5%)	1.2	16	1.2	0.9	-	-	
CV (%)	31	44	25	21	-	-	

**1 = very resistant; 5 = very susceptible.*

*** Figures are computed within white and yellow varieties separately, using appropriate checks.*

Early Maturing, Streak Resistant Maize for African Cropping Systems

Early maturing, streak virus resistant maize varieties can perform many useful roles in African cropping systems. Not only are they important for areas with short rainy seasons, but they give farmers more flexibility in areas with longer growing seasons. This flexibility allows farmers to schedule operations such as planting, weeding, and harvesting at times when labor is more available. The second rainy season in West Africa's forest zone is short, and only streak resistant, early varieties can provide high and stable maize production.

The beginning of the rainy season is called the "hunger season" in many parts of Africa. Food stored from the previous season's crops begins to run out and the current season's crops are not yet harvested. Maize, eaten as roasted or boiled ears, is one of the few products available during the "hunger season," and early maturing maize can produce ears 15 to 30 days before full season varieties. However, the problem with early maturing maize is that it cannot yield nearly as much – or grow as tall – as full season maize when rainfall is not limiting. But shorter stature and earlier harvest has proven useful when farmers intercrop maize with cassava, cowpeas, and other crops.

IITA has developed a wide range of early maturing, streak virus resistant varieties for African farmers. These varieties were made available in 1984 to cooperating African national programs in the form of an Early Streak Resistant Experimental Variety Trial (ESR-EVT). A total of 69 sets of this trial was sent to cooperators in 23 African nations. Results from six of these countries are shown in Table 22.

Most of the varieties in the ESR-EVT trial were developed through International Progeny Testing Trials (IPTT). An IPTT is a set of 250 full-sib families from a single open-pollinated maize population. IPTT trials are requested and grown by national

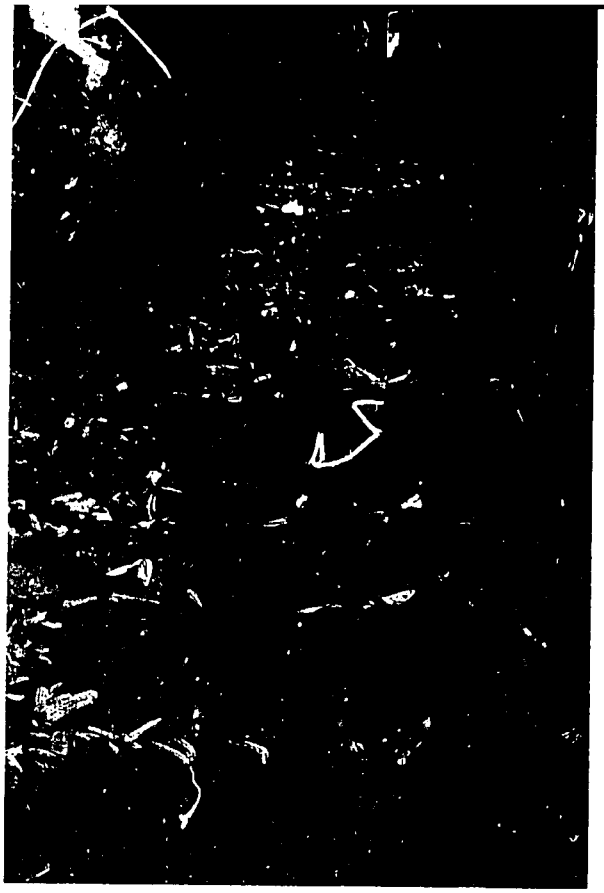
programs. The best families at each testing site are recombined to form an experimental variety with the name of the cooperating site. These are the varieties which are tested in the ESR-EVT trials. In addition, families which perform well across all sites are selected, recombined, and form an improved population from which a new set of IPTT are produced.

IITA maize scientists began to develop early maize varieties in 1977. The maize streak virus resistant populations TZESR-White and TZESR-Yellow were formed in 1980 and sent as IPTT trials in 1982 to sites in Burkina Faso, Cameroon, Nigeria, Tanzania, and Zaire. Experimental varieties formed from these trials are now available, and a second series of IPTT's was sent in 1984. Pool 16 is an early maturing CIMMYT germplasm pool which performed well in SAFGRAD trials (Semi-Arid Food Grains Research and Development Project). IPTT trials of Pool 16 were distributed by SAFGRAD in 1981 but some trials failed because of susceptibility to streak virus. In 1982, Pool 16 was brought to IITA to incorporate streak resistance. The 1984 Pool 16 IPTT, in which one-third of the families carry resistance to streak, was sent to sites in Burkina Faso, Cameroon, Ghana, Nigeria, and Zimbabwe. In addition, a fully streak resistant experimental variety from Pool 16 will be available for testing in 1985. EV. 8330-SR, EV. 8331-SR, and EV. 8335-SR are streak resistant versions of CIMMYT Experimental Varieties from

TABLE 22
Results of an early maturing, streak resistant maize variety trial; summary of 17 locations in six African countries (1984).

Variety	Grain type*	Grain yield (kg/ha)	Days to silk	Moisture at harvest (%)	Plant height (cm)
Ikenne-82 TZESR-W	WF	4140	53	20	187
Gusau-82 TZESR-W	WF	3950	53	20	189
M. Galke-82 TZESR-W	WF	4220	53	20	190
Pool 16 Gusau-81	WD	3810	50	20	163
EV. 8330-SR	WF	3720	51	20	168
EV. 8331-SR	YF	3830	50	19	167
EV. 8335-SR	YD	4570	54	21	183
Best check	–	3660	55	20	197

** Grain types: W = white, Y = yellow, F = flint, D = dent.*



International Progeny Testing Trial (IPTT) with maize variety TZESR-W at Samaru, Nigeria (1984). An IPTT is a set of 250 full-sib families from a single open-pollinated maize population. The best families are recombined to form an experimental variety.

Populations 30, 31, and 35, respectively, which have performed well in African environments. These varieties were developed by a CIMMYT liaison scientist based at IITA.

In addition to the best of the 1984 entries, the 1985 ESR-EVT will contain experimental varieties from the TZESR-Yellow population, a streak resistant version of CIMMYT Population 49, and yellow and white grain varieties resistant to both streak and downy mildew.

All of IITA's early maturing, streak resistant maize varieties have proven popular with farmers whenever they have been tested. Varieties from TZESR-W performed well in mini-kit and on-farm trials in Nigeria in 1984. Nigerian farmers are becoming increasingly interested in TZESR-W, and seed producers already know what farmers mean when they say they want "the early one."

Identifying and Selecting *Cicadulina* Species for Effective Mass Rearing and Maize Streak Resistance Screening

When scientists of several national programs in Africa recently attempted to develop their own colonies of leafhoppers to be used for maize streak resistance screening, they ran into problems. They found serious knowledge gaps on several fronts: (1) suitable techniques for the collection of the live virus vector leafhopper (*Cicadulina* spp); (2) the distribution pattern of the species; and (3) the relationships between various *Cicadulina* species and the maize streak virus (MSV) disease. Each of these may affect the mass rearing of leafhopper vectors and the efficiency of maize streak resistance screening.

IITA entomologists have developed a simple technique for the collection of living *Cicadulina* leafhoppers directly from grasses or maize plants and for the identification of those that transmit the streak virus. Details of this technique have been made available to national programs.

A survey of some maize growing areas in Nigeria and Togo showed significant differences in the species composition of local *Cicadulina* populations in various climatic zones with *Cicadulina mbila* as the dominant species for most areas sampled in Nigeria and Togo (Figure 12). The highest numbers were always found at the end of the rainy season and on maize, wheat, or grasses. *C. mbila* populations showed ecological plasticity by occupying both lowland and mid-altitude ecologies but not areas where the daily temperature was higher than 28°C. In thoses areas with higher temperatures, the portion of *C. triangula* species rose to 49% in northern Nigeria and 57 to 61% in central and northern Togo. Two other species – *C. arachidis* and *C. similis* – were identified in a few samples. Their portion never surpassed 12% of the total number of *Cicadulina* leafhoppers.

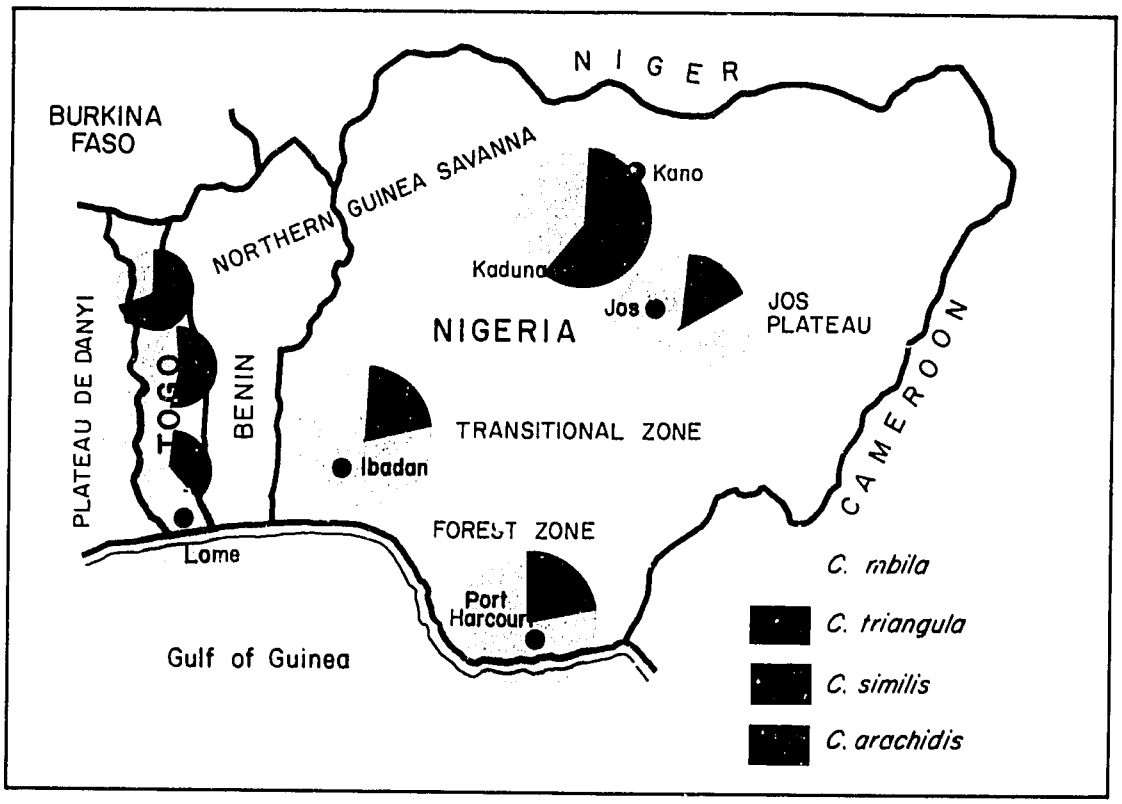
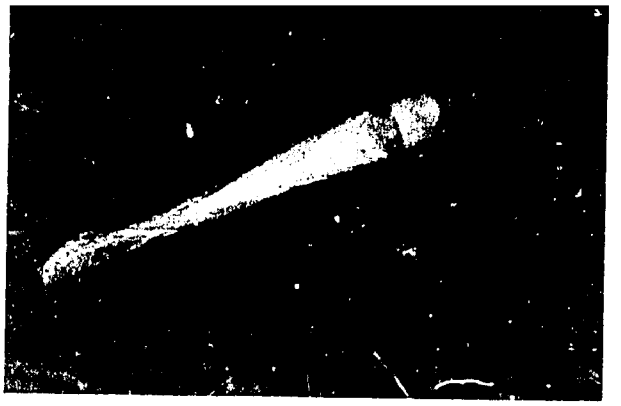


FIGURE 12.
Differences in species composition of** Cicadulina **leafhoppers in various climatic zones in Nigeria and Togo. They are capable of transmitting maize streak virus (MSV) disease.

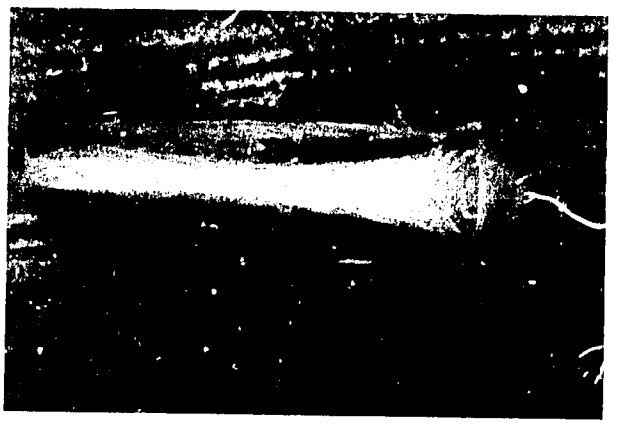
In all populations sampled, females were always more abundant – 65 to 80% of the total *Cicadulina* individuals collected from the field. Although only males are used for taxonomic identification of species, females are individually caged on maize plants for further species identification of their progeny and for initiation of colonies. (See 1983 *Research Highlights*.).

Caging individual wild insects on young maize seedlings also allowed the IITA scientists to monitor the percentage of active virus transmitters in native populations. They select only *Cicadulina* species and populations with a short development period and high fertility for mass rearing. Millet was found to be the best host plant for mass rearing, and in 1984 experiments *C. triangula* colonies reared on millet under 26°C constant

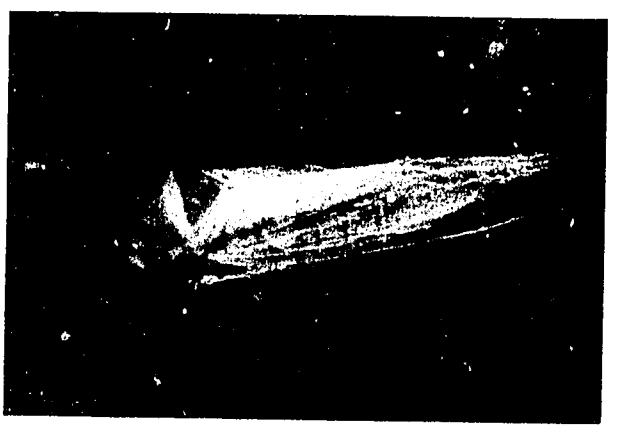
Four species of** Cicadulina **leafhoppers that can transmit maize streak virus (MSV) disease:



Cicadulina mbila ***female common in most sampled sites in Nigeria and Togo.***



Cicadulina triangula ***female common in warmer parts of Nigeria and Togo.***



Cicadulina arachidis ***female. Scientists proved that this species and*** *C. similis* ***transmit MSV. They were added to the list of six other species reported previously in the literature as MSV vectors.***

Cicadulina similis ***remains*** *C. mbila* ***but is somewhat smaller and has less extensive markings.***

temperature at IITA showed significantly higher fecundity than *C. mbila* which originated from Jos or Kadawa (Figure 13).

All four species of Cicadulina identified in West Africa are capable of transmitting the streak virus. Two additional species – *C. arachidis* and *C. similis* – have been added to the list of other *Cicadulina* species previously identified in East Africa as vectors of the disease. Comparative experiments on maize streak virus transmission by various *Cicadulina* species and local populations indicate that only a species with high efficiency in virus transmission may be effectively used in screening for resistance under artificial infestation.

Virologists at IITA found that adults of the *C. triangula* species could pick up the virus from diseased maize after feeding 30 seconds and become viruliferous within 12 to 14 hours. Females were more efficient than males in maize streak virus transmission. In six trials, the average transmission for females was 43% but only 23% for males.

IITA's scientific work on maize is a cooperative program with CIMMYT.

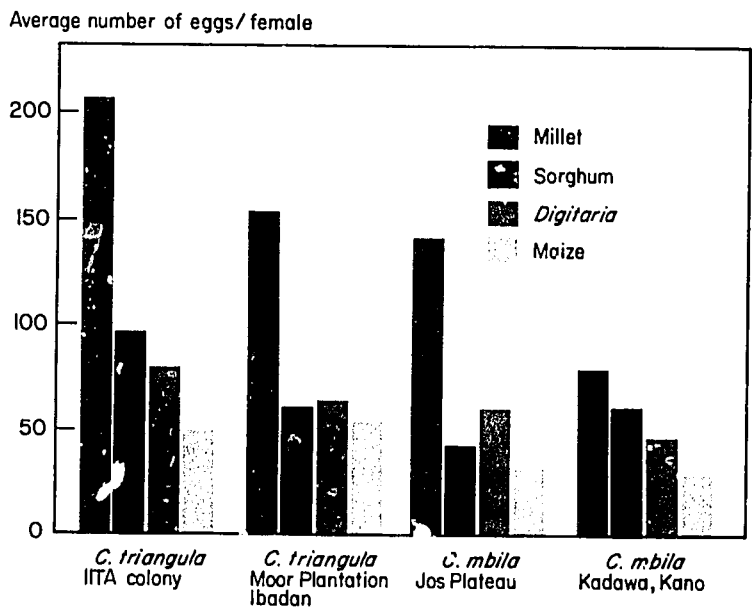


FIGURE 13.
Average number of eggs laid by females of two different populations of two Cicadulina leafhopper species on four host plant species at 26°C constant temperature (Nigeria 1984).

Above, the pink-flowered parasitic weed, Striga hermonthica, has infected maize. Right, 10 hectares of land in Kaduna, Nigeria which had to be abandoned in 1984 because of Striga.

Striga on Maize in West Africa

Thirty species of *Striga* (witchweed, fireweed) belonging to the family *Scrophulariacea* have been described and 23 of them occur in Africa. All are parasitic on other plants, and a single *Striga* plant in some species can produce up to half a million seeds which may remain viable in the soil for up to 20 years.

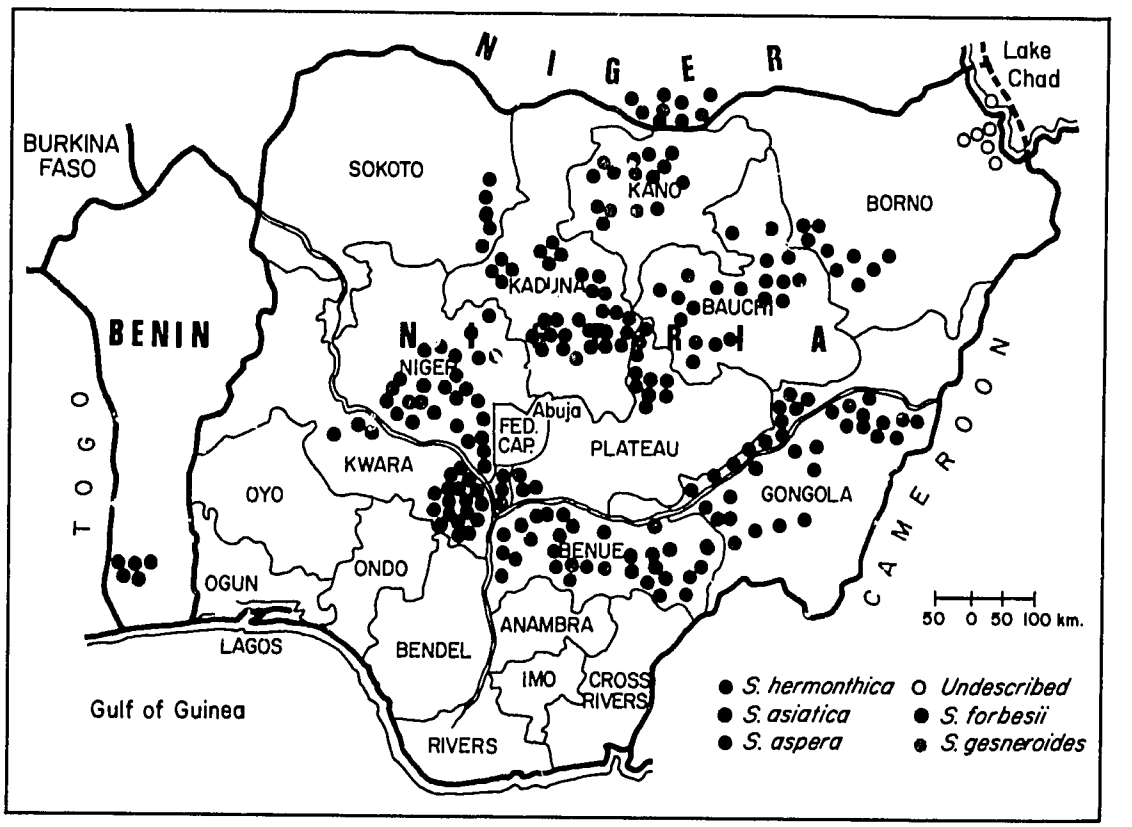
Symptoms of *Striga* infestation on maize may appear before emergence of the weed during the latter stages of vegetative growth of the maize plant. Infested leaves show chlorotic blotches followed by scorching from the leaf tips and margins. The entire plant becomes scorched resembling signs of acute drought, even under adequate moisture. Severe infestation may cause stunting and death before tasseling.

A survey of *Striga* species was conducted in Nigeria and parts of the Republic of Benin from June to October 1984 (Figure 14).

This parasitic weed is a widespread problem in all the major cereal crops in the Guinea and Sudan savannas. The intensity of infestation varies but the middle part of Nigeria – Bauchi, Jos, Niger, and southern Kaduna – appears suitable as a "hot spot" for screening maize for resistance to *Striga*.

Five species were found infesting maize in Nigeria. *S. hermonthica* and *S. aspera* were of economic importance on maize and other cereal crops – millet, sorghum, and rice. (They were also seen on other hosts – groundnuts, sesame, and wild grasses.) *S. hermonthica* was predominant in the drier areas in Niger, Kaduna, and Kano states, but *S. aspera* was more important in the wetter Bauchi, Jos, Benue, and Kwara states. Damage caused by these species was more severe on maize than on sorghum and millet, but the intensity of attack on maize was variable, ranging

FIGURE 14.
Locations of Striga species based on a survey in parts of Nigeria and the Republic of Benin in 1983–84. (All species except S. gesneroides attack maize; it attacks cowpeas). The rest of Nigeria and Benin will be surveyed in 1985.



The yellow-flowered specie of** Striga (S. asiatica) **was reported for the first time in Nigeria in 1984.

from severe infestation resulting in abandoned fields to very slight. Maize fields visited in central Bauchi were not heavily infested, but there was wide scale and severe infestation on wild grasses and groundnuts.

Other *Striga* species of less importance are *S. forbesii* from Jos, (mid-altitude ecology), a yellow-flowered *S. asiatica* from Benue and Kwara States, and a white flowered specie from the Lake Chad Basin, Borno State. The taxonomic position of the latter is still under investigation.

In the Republic of Benin, *S. hermonthica* and the yellow-flowered *S. asiatica* were seen on maize in the Zou Province.

From observation on maize intercropped with other cereals, legumes, and tubers, it was generally apparent that *Striga* was suppressed in a maize/soybean intercrop.

Yield trials at Mokwa, Nigeria during 1984 to test resistance to *Striga* under heavy infestation indicated a negative correlation between *Striga* rating and grain yield. IITA-developed hybrid varieties with the lowest *Striga* ratings gave higher yields than the best open pollinated checks (Tables 23 and 24). Two of these hybrids – 8322-13 and 8341-12 – were resistant to *Striga* in 1983 at Mokwa and maintained a stable resistance in 1984.

Preliminary studies indicate that additive and partially dominant genes play a major role in the inheritance of resistance to *Striga*. Populations involving resistant materials are being formed and will be recurrently selected to accumulate resistance

genes. Future efforts will be directed toward confirming the inheritance of resistance and incorporating it into adapted high yielding varieties.

IITA's scientific work on maize is a cooperative program with CIMMYT.

TABLE 23.
Grain yield and *Striga* ratings of *white* maize varieties in IITA experimental plots at Mokwa, Nigeria (1984).

Variety	Yield (t/ha)	*Striga* ratings (1–5)*		
		F_1	P_1	P_2
Hybrids				
8322-13	7.2	1.5	3.4	2.0
8321-18	6.5	1.9	3.4	1.9
8338-1	4.3	4.3	2.0	4.6
Open pollinated				
TZB	5.2	3.3	–	–
LSD (5%)	1.7	0.7		
CV (%)	24	18		

*Striga *rating: 1 = resistant; 5 = susceptible.*
F_1 = single cross hybrid.
P_1, P_2 = inbred parental lines.

TABLE 24.
Grain yield and *Striga* ratings of *yellow* maize varieties in IITA experimental plots at Mokwa, Nigeria (1984).

Variety	Yield (t/ha)	*Striga* ratings (1–5)*		
		F_1	P_1	P_2
Hybrids				
8341-5	5.6	1.8	2.6	1.8
8341-12	5.6	1.8	1.8	4.0
8329-15	4.9	2.6	2.1	2.0
Open pollinated				
Western yellow	3.4	3.8	–	–
LSD (5%)	1.6	1.1		
CV (%)	24	32		

*Striga *rating: 1 = resistant; 5 = susceptible.*
F_1 = single cross hybrid.
P_1, P_2 = inbred parental lines.

Rice Lines with Durable Resistance to Blast under African Conditions

Blast disease of rice (caused by *Pyricularia oryzae* Cav) is a serious constraint to production in all ecologies in Africa, particularly upland, drought-prone areas. More than half of all rice in Africa – approximately 2,500,000 hectares – is grown under upland conditions.

Because most Asian rice varieties bred for resistance to blast fare poorly under African conditions, farmers on this continent need locally adaptable and drought and blast resistant varieties if they are to increase production

One of the principal objectives of IITA's program is to incorporate blast resistance into all its rice lines using the traditional African specific blast and drought resistant cultivars plus the high yielding dwarf varieties developed by the International Rice Research Institute (IRRI). In the early evaluation of breeding lines under screening nurseries, susceptible lines have been systematically eliminated and resistant ones "moved up" for more elaborate trials with repeated screening for blast, high yields, and desirable plant characteristics.

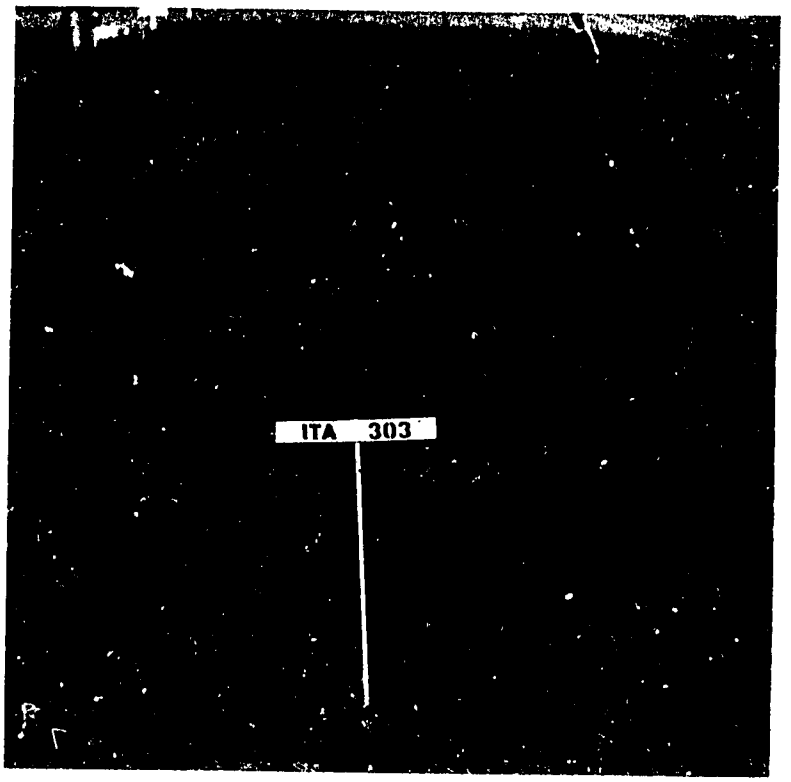
In extensive screening at Ibadan, Ikenne, and Onne, Nigeria, seven IITA lines proved to have the most durable resistance to leaf and neck blast (Table 25). ITA 212 has been released in Tanzania. This variety and ITA 257 are under large-scale testing in several African countries. Where these varieties are grown extensively by farmers, rice production will increase substantially.

Above, blast resistant rice lines on each side of highly susceptible and moderately susceptible lines. Right, screening rice lines at IITA for resistance to leaf and neck blast – a serious disease in rice growing areas of Africa.

TABLE 25.
Elite high yielding rice lines with durable resistance to leaf and neck blast.

Line	Pedigree	Plant height (cm)	Duration days	Average yield (t/ha)
Upland				
ITA 116	TOx 86-1-3-1	115	125	2.0
ITA 117	TOx 356-1-1-1	95	115	3.0
ITA 120	TOx 502-15-118-1-1	115	110	2.0
ITA 150	TOx 502-41-1-1	120	100	2.0
ITA 257	**TOx 1011-4-1**	**95**	**100**	**2.5**
OS 6 (check)		130	125	1.0
Lowland				
ITA 212	**6850**	**100**	**105**	**6.5**
ITA 231	6906	100	120	6.0
FARO 15 (Check)		135	140	4.0

One of the rice cultivars selected at Onne, Nigeria in 1984 as a superior line for acid soil tolerance.



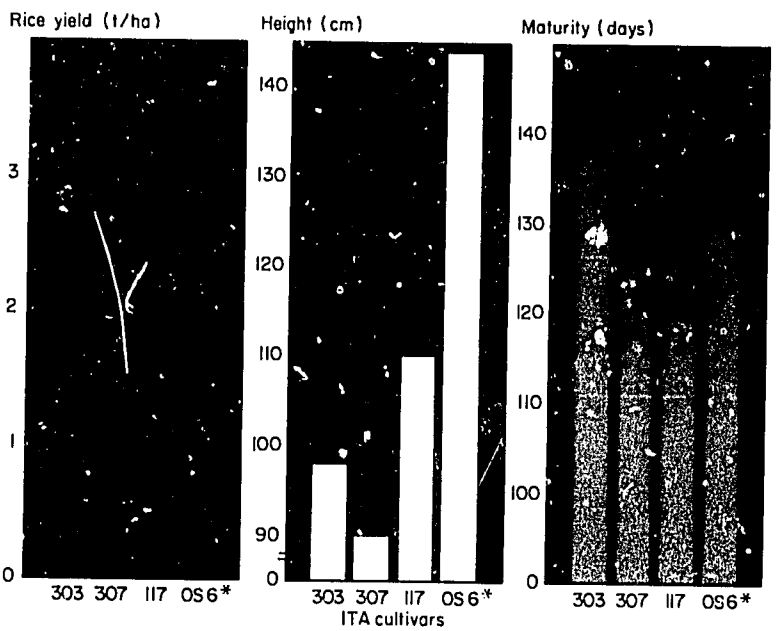


FIGURE 15.
Superior rice cultivars for acid soil tolerance (1983–84).

Upland Rice Varieties Tolerant to Acid Soils in Humid Tropical Rain Forest Regions

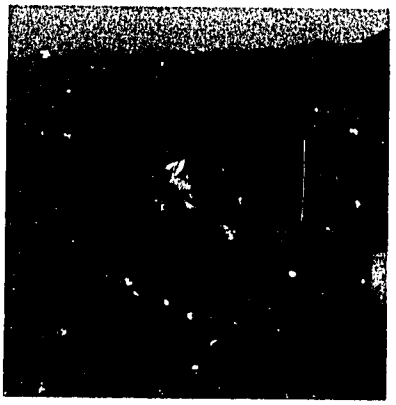
Upland rice is among the few grain crops that can be grown successfully in the humid tropical rain forest regions, but farmers need better yielding varieties more tolerant to soil acidity – a major constraint to increased rice production. Aluminum toxicity and calcium and magnesium deficiencies are the principal soil fertility problems in acid soils.

In the past three years, scientists have intensified their research at IITA's high rainfall sub-station at Onne, Nigeria and screened hundreds of rice varieties for tolerance to acid soils. Earlier work on this problem was done in collaboration with national programs in Liberia and Sierra Leone.

A total of 733 cultivars – originating from many parts of the world – were screened last year at Onne under acid soil conditions, and promising varieties were selected based on their early vegetative vigor, tillering ability, reaction to diseases and insects, and grain yield.

Rice grain yields for tolerant varieties in the highly acid plots at Onne generally ranged from 2 to 3 t/ha and the susceptible varieties 0.5 to 1.5 t/ha. Under normal acid soil conditions with good management (including lime), yields have been as high as 4 t/ha. The most promising IITA varieties were distinctly superior in yield, shorter in height, and earlier in maturity compared with the local check (Figure 15). These also possessed high levels of tolerance to blast and grain discoloration.

Also, results from evaluations in various parts of the world under the International Rice Testing Program (IRTP) confirm the superiority of ITA numbers 117, 118, and 235.



A rice line from IRRI with acceptable grain quality and tolerance to cold temperatures in Cameroon.

Cold Tolerant and High Yielding Rice Lines for Northwestern Cameroon

After testing a large number of rice lines at low temperatures in the 1100-meter-high Ndop Plain of northwestern Cameroon, two have been selected as most promising. One came from the International Rice Research Institute (IRRI) in the Philippines, the other from Indonesia.

In three years of tests conducted from 1982–84, the two lines produced average yields ranging from 5.5 to 6 t/ha (Table 1) with acceptable grain quality and tolerance to temperatures that dropped as low as 13°C. The variety Tainan-5 grown by many farmers in the area averaged only 3.8 t/ha.

Because of its overall performance, the IRRI line (IR 7167-33-2-3) is the most likely candidate for release by the Upper Noun Valley Development Authority (UNVDA) which has the responsibility for rice cultivation in the Ndop Plain with 3,000 hectares suitable for this crop.

A breeding program and evaluation of other rice lines for tolerance to low temperatures and associated stresses are being intensified with the following cooperators: UNVDA, Cameroon Institute of Agronomic Research, National Cereals Research and Extension (NCRE) project, and IITA.

TABLE 26. Characteristics of two promising low temperature rice lines for the Ndop plain in northwestern Cameroon; three year trials under irrigation (1982–84).

Pedigree	Height (cm)	Days to 50% flowering	Average yield* (t/ha)
B 2161-C-MR-57-1-3-1 (From Indonesia)	100	115	6.0
IR 7167-33-2-3 (From IRRI)	95	110	5.5
Tainan-5 (Check)	95	111	3.8

** Yields averaged over 6–10 trials at fertilizer rates per ha: 50 kg N, 30 kg P_2O_5, and 30 kg K_2O.*

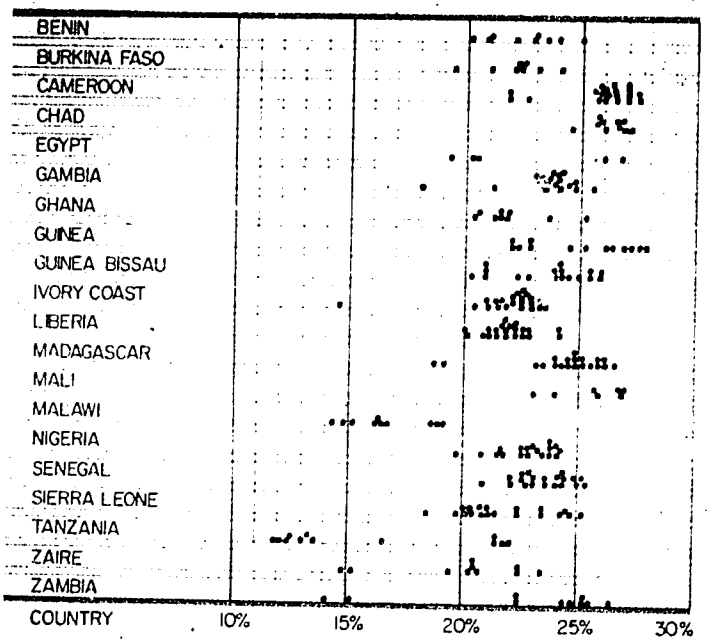
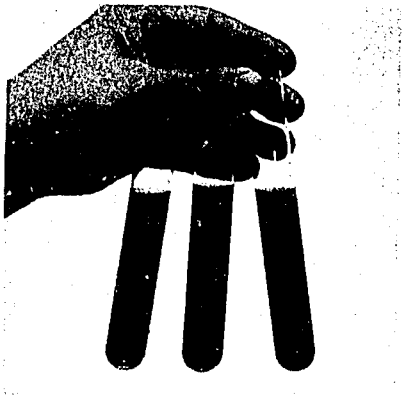


FIGURE 16.
Scattergram of amylose content of selected rice varieties from various sources in Africa.

Amylose Content of Rice Selections from 20 African Countries

Approximately 290 accessions of rice (*O. sativa*) originating in 20 African countries were analyzed for amylose content during 1984 in IITA's rice quality laboratory. The results add to the limited information about African consumer preferences for rices with different cooking and eating qualities. Most of the samples represented varieties selected from IITA's large germplasm "banks," but some were randomly selected from farmers' fields.

Amylose content is the major factor influencing cooking and eating properties of rice. Low-amylose varieties are moist, sticky, and glossy when cooked. In contrast, high-amylose rices cook dry



Amylose content of rice is readily measured by its characteristic blue-colored complex with iodine; left to right: low, intermediate, and high content.

and fluffy and have a harder texture. The amylose content of milled rice is classified as low (10 to 20%), intermediate (20 to 25%), and high (above 25%).

Most of the rices grown in Africa are classified as either intermediate or high amylose content (Figure 16). For example, the laboratory found that Nigeria's samples ranged from 19.7 to 25.2%, Cameroon's from 21.7 to 27.2%, Sierra Leone's from 23.7 to 25.3%, Republic of Benin's from 20.2 to 25%, and Ghana's from 20.6 to 25.6%. However, several of the samples from Malawi were in the low 14.1 to 16.6% range. The sample with the lowest amylose content (11.8%) came from Tanzania.

The high correlation between texture of cooked rice and amylose content limits the extent to which any one variety can meet the different quality preferences in various countries.

Elite rice lines are available from IITA with a wide range of amylose contents to suit the taste or quality preference of any of the 20 African nations included in the survey. ITAs 117, 118, 128, 135, and 235 in the low-amylose range; ITAs 141, 150, and 257 in the intermediate range; ITAs 121, 123, 212, 222, 230, 231, 245, 247, 249, and 306 in the high range.

Right, both men and women farmers meet with IITA farming systems staff members in a Nigerian village before the start of the survey. Above, an IITA socio-economist (left) interviews a woman farmer.

Exploratory Field Survey: Role of Women in Agricultural Production, Marketing, and Processing

Considering women's major role in all stages of agricultural and household production, on-farm adaptive research should consider household and gender factors with a review of the total farm unit. Consideration of these factors requires more emphasis as farming systems strategies and national food policies are developed.

In recent years, IITA's socio-economists have completed several studies to more specifically determine women's role in agriculture, and they share these facts with their scientific associates in crop improvement and farming systems programs. The latest exploratory study was completed in November 1984 among 62 women in five villages in Oyo State, Nigeria. At least

25 of the 62 women were independent owners of land primarily inherited from their fathers or husbands.

All the women interviewed were involved in marketing food products which took about 25% of their time. At least 50% of their time was spent in agricultural work in the fields. They had to be good managers with their lives compounded by field, marketing, and household work, plus processing cassava for extra income. The IITA team found it more difficult to arrange interviews with the women than with men because their days were full and carefully planned. No interviews could be scheduled on the day prior to the market or on market day. There was too much preparation involved with early market arrivals, bartering for goods, and the trek home with items for the household.

Contrary to many studies on women and agriculture, the IITA team did not find that women planted different crops than men. A multiple cropping system was the norm and crop decisions were apparently based on preferences and market prices. The farms had a delicate balance among crops. The field crops were primarily cassava, maize, yams, egg plant, okra, peppers, tomatoes, sweet potatoes, melons, and leafy green vegetables; in the forest areas a selection of pineapple, papaya, bananas, guava, plantains, oranges, kolanuts, and some cocoa.

Processing cassava into two food products – "gari" and cassava flour – and selling them was a major activity of the women of these villages. Some of them purchased whole cassava fields from farmers and then organized both the harvesting and processing for market sales. The interviews consistently indicated that about half of the food produced on the farm was marketed, the other half consumed at home. Within the culture of the Yoruba survey area, husbands and wives have certain financial duties which are their respective responsibilities. It is the husband's traditional duty to house his family, provide basic items of clothing, and pay his children's school fees. However, many of the women commented on the high food costs and other economic demands on them and indicated that their income and that of their husbands now went almost entirely for food purchases for the household (milk, rice, sugar, coffee, tea, cowpeas, and oil) and for clothing.

Women who owned their land hired more labor than men farmers with comparable farm size, primarily for land clearing and weeding. Children also helped with the latter task after school and on holidays.

Earlier studies in different areas support and complement this survey, but some major gaps still exist, including a comparison between men and women farmers on the acceptability and management of new technologies, the use of hired labor, and intra-household resources allocation.

Some women in the survey reported that they jointly buy entire fields of cassava. Then they organize the processing of the cassava for "gari" or flour. Here they peel the cassava in a village compound as one of the first steps in the process.

Changes in Sources of Future Food Supplies for Nigerian Cities

Field surveys started in 1983 and completed in 1984 by IITA and the University of Nigeria indicate that major changes are taking place in the production of food crops for sale in markets in the larger population centers and that these changes need to be considered in developing strategies for farming systems research and technology transfer.

The results show that future food production will come mainly from farms located 45 or more kilometers from city markets. Smallholder production near the cities presents only limited chances for expansion.

Information on the proportion of food crop production marketed in the past decade was collected from 300 farmers in six states – Anambra, Benue, Bornu, Kaduna, Kwara, and Ondo. Data on 30 food crops showed that the proportion marketed increased from an average of one-third to about one-half of their total output.

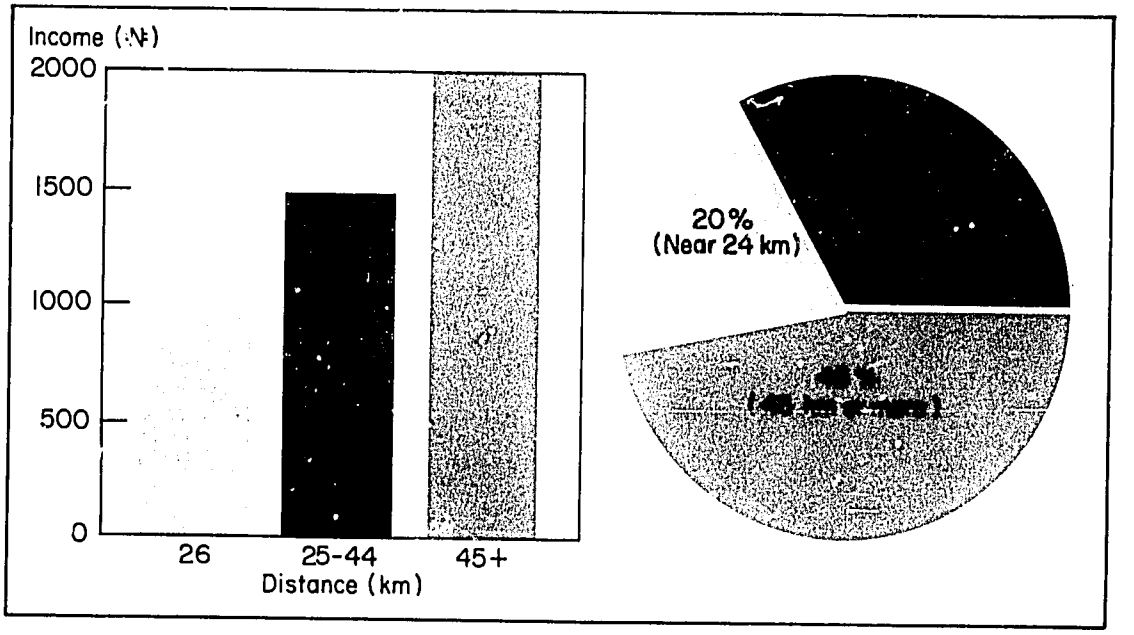
An analysis of interviews with 1,290 other farmers in Anambra, Imo, Cross River, Bendel, Rivers, and Ondo states indicated that the amount of food products sold increased with the distance the farms were away from the city markets. Persons in charge of the survey selected three farmer groups of equal size (430) with farms located at three different distances from the cities – up to 24 km, 25–44 km, and 45 km or more. The percentage of total production from each area sold in different markets – local, regional, and long distance – was only 20% in the near city zone, 34% in the medium zone, and 46% in the more distant zone (Figure 17). Average income from market sales in each zone is shown also in Figure 17.

The proportion of total production sent to market from the three distances differed, of course, for individual crops. Some of the more perishable items such as breadfruits and leafy

Tomatoes produced on farms far away from the city are unloaded at a market. The amount of food products sold has been increasing with the distance of farms from city markets.

vegetables were grown and marketed near the cities, but these were mainly subsistence crops in the far zone. The major production for market of crops such as cocoyam, seed yam, peppers, bananas, palm oil, and oranges came from the medium zone (25–45 km). However, nearly half of the total production for sale took place in the far zone and consisted mainly of late maize, rice, yams, cassava, groundnuts, tomatoes, plantain, and seed melons. For the longer distances, grains and cassava (processed as "gari" and flour) have gained a greater share of the market. More land was available for their production and transportation facilities had improved.

FIGURE 17.
Right, percent of total food production marketed by farmers at varying distances from Nigerian cities. Left, average income per farmer from marketed food products in three distance zones. (1 Naira = $1.30 at official exchange rate).



An IITA economist (right) and an extension worker (left) listen to a small-holder farmer tell about his cowpea yields obtained in a cassava intercropping system.

On-Farm Adaptive Research in Four Cropping Systems and Farmers' Responses to New Technologies

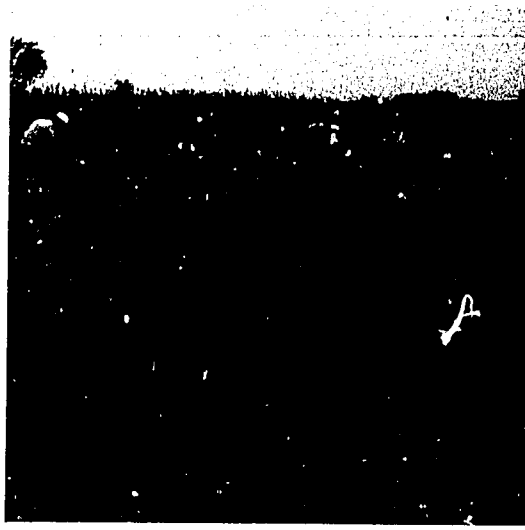
Three years of experience with on-farm adaptive research in the Bida Agricultural Development Project (BADP) in Niger State, Nigeria have shown the possibilities of quickly identifying areas of improvement in local farming systems and the willingness of farmers to accept practical new technologies.

The adaptive research strategy used by IITA and the agronomy section of BADP includes five stages: (1) diagnosis of constraints and opportunities; (2) design or identification of improved technologies that fit local farming systems; (3) testing and evaluating the technologies under farmer conditions; (4) dissemination of information to farmers; and (5) reporting back to research stations those technologies that should receive further refinement.

After aerial reconnaisance of the project area (17,000 square kilometers) and an agro-economic survey of 225 farmers, four dominant cropping systems were designated for on-farm adaptive trials: lowland rice-based, upland yam-based, upland cassava-based, and upland sorghum/millet-based.

Among the four cropping systems, farm productivity measured in terms of caloric value of food produced, total farm income, and returns to farm inputs varied considerably. The root crops-based systems of yams and cassava yielded greater quantities of food compared with the rice and sorghum/millet-based systems. Farmers growing root crops contributed not only more to the market (about 45% of the total food produced) but still had more food available per capita than farmers in the rice and sorghum/millet-based systems.

Results of trials in the lowland rice-based systems showed the importance of an earlier planting date for rice. In a season when



An on-farm adaptive research trial. Cowpeas were planted in August for an upland cereal-based system.

After the harvest, members of the farmer's family carry sacks of dried cowpea pods to the house for storage. Right, a woman sells cowpeas in a local market in the Bida project area.

the rains came late and planting was delayed two to three weeks, yields of improved varieties were less than those of local determinate varieties which averaged 2.3 t/ha. However, at one site where water management was good and irrigation through seepage water continued after the rains ceased, yields of the improved varieties were 32 to 40% higher. Farmers reported that they liked the grain color, size, and cooking quality of the improved varieties and would plant them on part of their land where water control was better and weeds less of a problem.

Although increasing rice plant density from 100,000 to 150,000 per hectare at trial sites which did not have a flooding problem produced an extra 300 kg/ha of paddy rice, farmers' reactions were mixed. Some feared the practice would reduce

tillering and closer spacing would make it more difficult to weed the crop with their wide hoes. Smaller hoes are not easily available in the area.

One of the most successful innovations in the lowland fields of the project area has been the planting of early maturing cowpeas after the rice harvest on land usually left fallow until the next rainy season. Confined flow of seepage water from surrounding uplands into the inland swamps (fadamas) during the dry season offered the possibility of increasing food production by growing a "catch crop" using the residual moisture. Furthermore, surplus labor in the dry season and a minimum spray regime for insect control were "plus features."

Farmers said they welcomed any innovation that would increase their food supply by using slack period resources. In a survey sample of 85 farmers, 76% planted dry season cowpeas in 1984/85 compared with only 45% the year before and none in 1982. Demand for seed far exceeded the supply.

Total crop value of the two early varieties planted in 1983/84 dry season trials averaged $1,096 per hectare (Table 27). Yields ranged from 600 to 700 kg/ha with two sprayings for insects.

With the success of dry season cowpeas in the lowland rice-based systems, farmers in the other cropping systems showed increasing interest in growing the crop in the main season. During the 1984 main season, about 25% of all project farmers grew cowpeas. Those in the cassava and sorghum/millet-based systems planted the crop in July/August using surplus labor (Figure 18), and reported an average yield of approximately 600 kg/ha for IT 82E-60 (popularly known as 60-day cowpea) and 700 kg/ha for TVx 3236. Several farmers in the four cropping systems expressed the view that the early maturing cowpea varieties may be a crop that can reduce hunger.

Farmers report that insect control is the biggest production problem they have and many were not able to buy the Electrodyn sprayer. The project's 100 sprayers and insecticide supply did not meet farmers' requests. They placed orders for 100 additional sprayers and 1,000 containers of insecticides for next season.

The Bida Agricultural Development Project is funded by the Federal Government of Nigeria, the Niger State Government, and a World Bank loan.

FIGURE 18.
Average household labor input for agricultural activities by four cropping systems in the Bida Agricultural Development Project in Niger State, Nigeria.

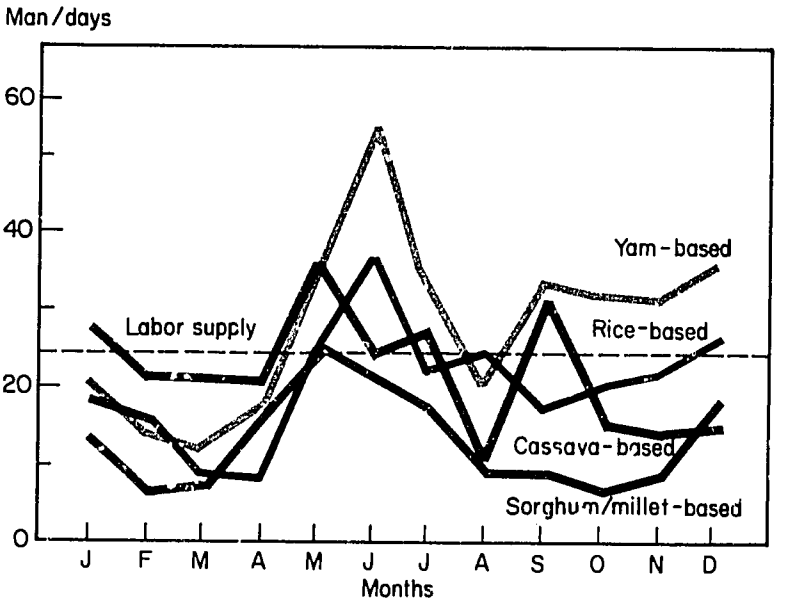


TABLE 27.
Economic returns from two short season cowpea varieties; on-farm trials, Bida Agricultural Development Project in Niger State, Nigeria (1983/84).

Cowpea variety	Yield (kg/ha)	kg/ man-day*	Total crop value ($/ha)**	Net benefits ($/ha)***	Benefit/ cost ratio
IT 82E-60	608	9.4	1026	901	8.2
TVx 3236	691	10.6	1166	1041	9.3

**Based on 65 man-days/ha.*
***Based on net field price of 1.25/kg. (₦1 = US$1.30 at the official exchange rate.)*
****Assuming total cash costs of $125/ha; cost of family labor not included.*

A national on-farm research team in the Ivory Coast interviews a farmer as part of an exploratory survey in 1984.

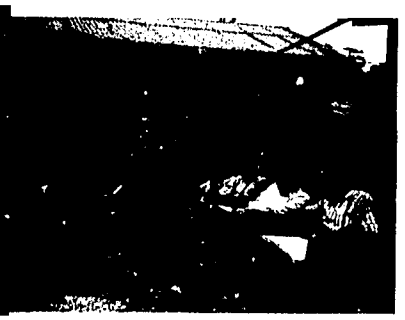
Establishment of Permanent On-Farm Research Teams by National Systems

Two countries in West Africa – Ivory Coast and Nigeria – have established their own on-farm research teams with 100% national staffing, and others are planning to do so in the near future. These multi-disciplinary teams of experienced scientists have become a key element in strengthening agricultural research and extension in their countries. They operate on the premise that new technologies cannot be really effective until adopted by farmers and that the testing and evaluation of these technologies must involve the farmers themselves.

Nigerian teams conducted their first exploratory surveys in 1983 and completed the first year of on-farm testing in 1984. Both their own and IITA technologies were tested, and farmer adoption of any of them is being monitored. Feedback to scientists at the experiment stations has resulted in new directions for research. These Nigerian teams come from the following institutions: Institute of Agricultural Research and Training, National Cereals Research Institute, National Root Crop Research Institute, Institute of Agricultural Research at Zaria, and the University of Nigeria at Nsukka.

Ivory Coast scientists from the Institut des Savannas and a group of institutes in the forest belt conducted exploratory surveys in 1984. They will start field testing in 1985. One of their research areas was used as a case study during a joint training workshop held in September 1984 in Bouake for both Ivory Coast and Nigerian on-farm research (OFR) scientists.

The different country teams have linked up into national Farming Systems/On-Farm Research networks that meet regularly to discuss organizational issues, methodology, and field results.



Training workshop held in September 1984 in the Ivory Coast for on-farm research scientists of that country and Nigeria.

IITA scientists conduct training, counsel national program personnel on the set-up of the teams, participate in the design of surveys and on-farm tests, and supply IITA improved varieties and other materials (Figure 19). These activities are partially supported by a Ford Foundation grant.

The creation of institute-based on-farm research has become one of the major objectives of IITA's cooperation with national agricultural research systems. Outreach projects in Cameroon, Zaire, and Rwanda have IITA staff members working with national institutes in Farming Systems/OFR programs. Upon completion of the projects and withdrawal of IITA staff, these units are expected to have permanent national staffing.

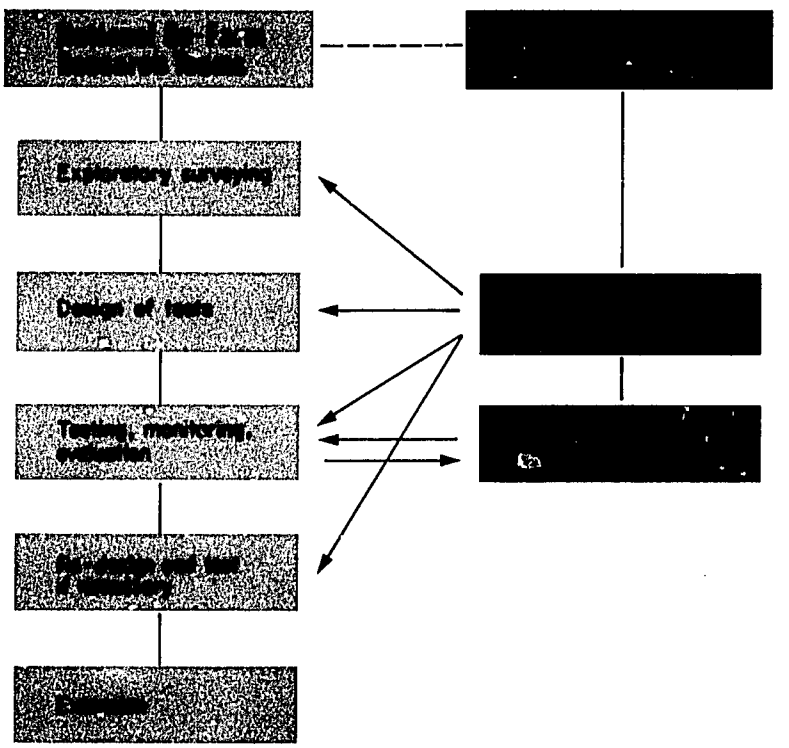


FIGURE 19. Relationship between national on-farm research teams and IITA scientists.

Alley Cropping: Six Years of Experiments and Farmer Use of the System

To develop stable, low-input systems for crop production under rainfed upland conditions in Africa, IITA research teams have experimented with alley cropping over the past six years. The field experiments were established on a loamy sand soil to assess the long-term effect of alley cropping for managing fragile tropical soil. They planted *Leucaena leucocephala* in hedgerows spaced four meters apart, pruned them, and then cropped the alleys. A maize-maize sequential cropping pattern was used at first and later changed to maize-cowpeas.

Results of the long-term experiments showed that when the leucaena prunings were removed and no nitrogen fertilizer applied, main season maize grain yields were very low -- ranging

Alley cropping – one effective means of managing fragile tropical soils and obtaining good crop yields with low inputs. (Photo taken of IITA experimental fields.)

TABLE 28.
Main season grain yield of maize variety TZPB alley cropped with *Leucaena leucocephala* ***on a loamy sand soil as affected by application of leucaena prunings and nitrogen, IITA, Ibadan, Nigeria.***

N rate (kg N/ha)	Leucaena prunings	1979	1980	1981*	1982	1983	1984
			Maize	yield	(t/ha)		
0	Removed	-	1.0	0.5	0.6	0.3	0.7
0	Retained	2.1	1.9	1.2	2.1	1.9	2.0
80	Retained	3.5	3.3	1.9	2.9	3.2	3.7
LSD (5%)		0.4	0.3	0.3	0.4	0.8	0.5

**Maize crop serio[illegible] affected by drought during early growth.*

from 0.3 to 1.0 t/ha (Table 28). But with the use of the prunings yields were stabilized at about 2 t/ha. It is estimated that the prunings contributed about 60 kg/N/ha to the maize crops. Maize yields reached a high of 3.7 t/ha in 1984 when researchers added 80 kg/N/ha along with the prunings (Table 28). Even when higher rates of nitrogen were applied (as high as 160 kg/ha) in another experiment without leucaena prunings, maize yields did not go over 2.5 t/ha (Figure 20). These results provide further evidence that the cumulative benefit from alley cropping helps to maintain soil productivity over time.

To test the acceptance and adoption of this technology by African farmers, several adaptive research plots have been established in Nigeria and Rwanda. Alley cropping maize and cowpeas with leucaena has been tried and accepted by some farmers in southern Nigeria. Also, they use the system to supply fodder for small ruminants. In the yam growing area at Zakibiam in the east-central region of Nigeria, some farmers have adopted alley cropping mainly for soil improvement and production of leucaena stakes for yams. In cooperation with local institutions, testing on a large number of farms is now underway in other parts of Nigeria.

Farmers in Rwanda face a perpetual land shortage and a lack of inputs so their food production is based mainly on organic agriculture. A serious shortage of wood for fuel also exists. One phase of a project in the Bugesera-Gisaka-Migongo area, in which IITA is cooperating with the Rwandan Institute of Agricultural Sciences, involves the introduction of alley cropping

with the emphasis on production of wood for fuel and feed for small ruminants. Several leguminous shrubs and tree species, including *Leucaena leucocephala*, *Cassia spectabilis*, *Calliandra calothyrsus*, and *Sesbania sesban*, have been planted, and preliminary observations indicate that the latter two perform especially well under Rwanda conditions.

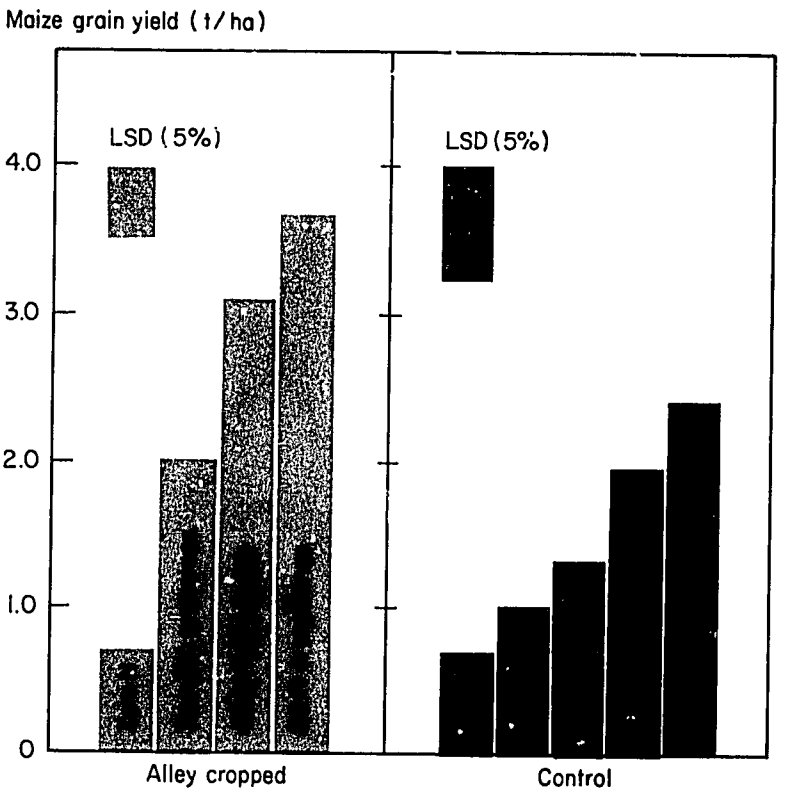
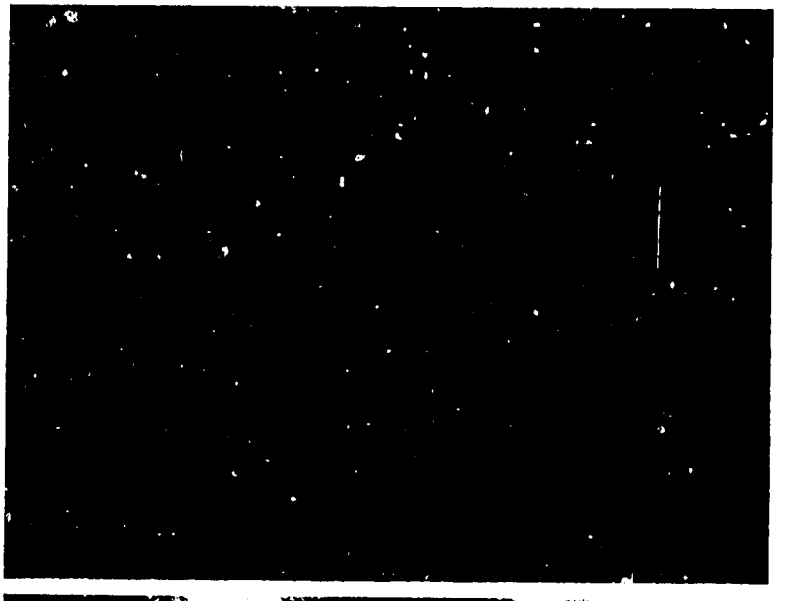


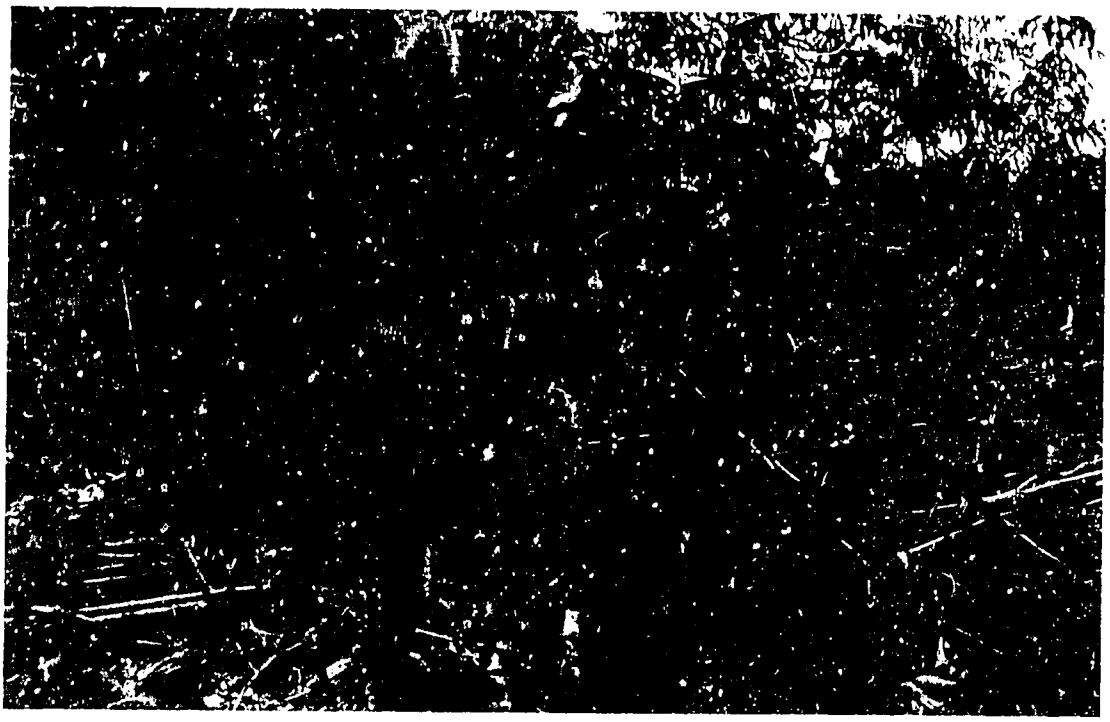
FIGURE 20.
Grain yield of maize variety TZPB grown on loamy sand soil as affected by six years of alley cropping with *Leucaena leucocephala* ***and nitrogen application. (IITA, Ibadan, Nigeria.)***

A farmer has adopted the alley cropping system.



Some farmers have decided on alley cropping mainly for soil improvement and production of leucaena stakes for yams.

Yam staking on a farmer's field.



Maize variety TZSR-W-1 caused lodging of cassava (right) because of its tall height, spreading leaves, and late maturity. This compares with upright cassava plants (left) interplanted with maize variety TZE which is shorter and earlier maturing with a lower leaf area.

Maize Plant "Architecture" Important Factor in Intercropping with Cassava

More than 70% of the food crops consumed in the humid tropics, especially in tropical Africa, comes from intercropping. Therefore, it is important that plant breeders develop appropriate crop types with the best plant "architecture" for mixed cropping, particularly in relation to efficiency in the uses of environmental resources such as light, water, and nutrients required for crop growth. A popular combination with high yield potential in humid/subhumid Africa is a cassava/maize intercrop.

In an experiment conducted over a four-year period, IITA scientists intercropped five improved maize genotypes of varying

growth habits (Table 29) with cassava variety TMS 30572 at two maize populations of 30,000 and 60,000/ha. They found that plant height and leaf display were important in selecting maize for intercropping with cassava because cassava root yields were significantly lower when intercropped with tall, spreading, late maturing maize types such as TZSR-W-1 compared with the shorter genotypes such as Pool 16 (Table 29 and Figure 21). Major reason for the lower cassava yields was a reduction in the amount of light reaching cassava through the maize.

TABLE 29. Yields of intercropped cassava and maize with different plant "architecture."

Maize variety	Characteristics	Cassava (t/ha)*	Maize (t/ha)*	N Returns/ha Total	N Returns/ha Returns from cassava (%)
TZPB	Late maturing (> 120 days) Spreading leaves Tall (271 cm) LAI** (5.1) 8 WAP#	13.4	3.6	3810	53
POOL 16	Early maturing (190 days) Spreading leaves Intermediate height (195 cm) LAI (3.4) 8 WAP	21.2	2.6	4480	71
KEWESOKE***	Late maturing (110 days) Erect upper leaves Moderately tall (223 cm) LAI, (3.7) 8 WAP	29.1	2.1	5415	81
TZSR-W-1	Late maturing (120 days) Spreading leaves Tall (280 cm) 8 WAP	17.2	3.1	4130	62
POPULATION 49	Early maturing (100 days) Spreading leaves Very short (175 cm) LAI (3.5) 8 WAP	27.3	2.7	5445	75
LSD (5%)		4.8	1.2		

** Three season average.*

***LAI = Leaf area index; #WAP = Weeks after planting; Maize population = 40,000/ha; Cassava variety = Tms 30572 at 10,000/ha. Prices: ₦/ton = Cassava root at ₦150; Maize grain at ₦500. 1 Naira (₦) = 1.30 US$ at official exchange rate.*

****Based on one season data only.*

Because the shorter maize types now available usually yield less than tall, highly vegetative types, one of the challenges faced by plant breeders is to produce short, high yielding maize types with erect upper leaves for intercropping with cassava. Evidence that such varieties can be grown at higher intercrop populations is given in Table 30 where grain yield of Pool 16 increased up to 60,000/ha population.

The long maturity gap between maize and cassava (three to four months for maize and more than 12 months for cassava) could have enabled cassava to overcome any depression in growth due to maize, but this is not the case because of a drastic reduction in yield of etiolated, lodged cassava stands.

Because cassava contributed such a large proportion of cash returns from the cassava/maize mixture, maize genotypes which result in reduced cassava root yield may not be attractive to farmers.

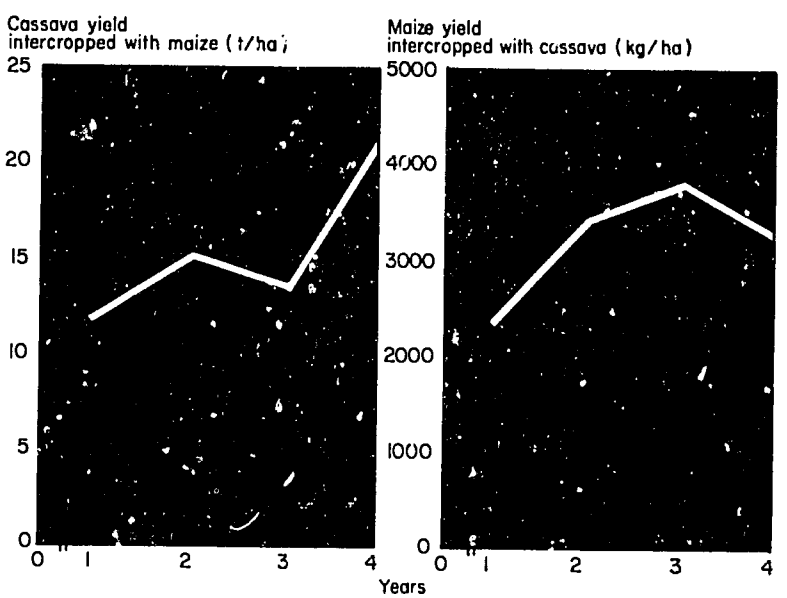


FIGURE 21.
Cassava yield (left) intercropped with two maize varieties (Pool 16 and TZSR-W-1) and maize yields (right) intercropped with cassava; experiment over a four-year period at IITA.

Organic matter for soil maintenance is generated in a cassava/maize intercrop system.

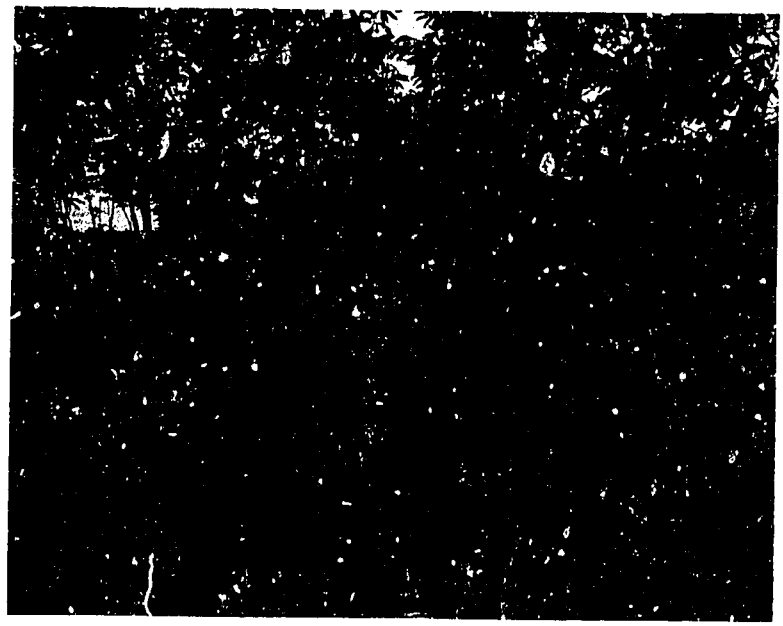


TABLE 30.
Average weight (t/ha/yr) of organic residue produced by intercropped cassava and maize.

Maize Variety	Population × 10^3	Maize stover (dry wt.)	Cassava leaves & twigs	Total dry weight	Maize grain (t/ha)
TZSR-W-1					
Intercrop	30	5.5	2.1	7.6	3.1
	60	8.4	1.8	10.2	2.8
Sole	30	6.1		6.1	3.0
	60	7.8		7.8	3.3
Pool 16					
Intercrop	**30**	**3.7**	**2.5**	**6.2**	**2.3**
	60	**5.1**	**2.5**	**7.6**	**2.7**
Sole	30	4.4		4.4	2.1
	60	5.9		5.9	2.9
LSD (5%)		0.95	0.8	1.1	0.4
CV %		9.1	19.5	7.5	

Clearing the experimental site in the forest in southern Nigeria.

Effects of Deforestation and Landuse on Soil, Micro-climate, and Productivity: First Phase of a Long-Term Study

Beginning in early 1984, part of a 75-hectare forest southeast of Benin City, Nigeria was cleared so an experimental project could be started with the aim of obtaining a better understanding of the ramifications of the delicate equilibrium between soil, climate, and vegetation in an undisturbed forest ecology in the humid tropics.

The overall objective of the project is to better understand the magnitude and trends in alterations of soil, hydrology, micro-climate, and biotic environments by deforestation, different landuse systems and agricultural practices. Specifically it is aimed at:

- Strengthening a basic scientific body of knowledge that enables the rational use of land and water resources.

- Developing guidelines for the management of land resources for economically viable and sustained productivity.
- Creating awareness of the food production potentials and limitations of the humid tropics.
- Providing training opportunities for scientists in the tropics.

Existing vegetation is high forest with a tree density (exceeding 15 cm in girth at 1 m) varying from 1,300 to 2,100 per hectare. The height of tall trees ranges from 37 m to 46 m. Mean annual rainfall of this forest area is about 2,400 mm with a range of 1,800 to 2,900 mm. Forest canopy effectively intercepts solar radiation and rainfall. On an average, rainfall through the canopy is estimated to be about 12% less than in open land. Radiation reaching the forest floor is only a fraction of that in the cleared area.

As a result of these differences in radiation, both soil and air temperatures and relative humidity are drastically different under high forest than in cleared land (Figure 22). The air temperature at 1 m height and the soil temperature at 5 cm depth are always lower by 3 to 6°C under forest than in the open. The relative humidity in the cleared land is decreased more than under forest. Accordingly, the evaporation rate under forest canopy is only 25% of that in the cleared land (Figure 22).

Productivity and alterations in soil, microclimate, and hydrology are being evaluated for the following landuse systems: forested control; traditional farming systems; improved forestry; oil palm plantation; plantain; grazed pastures; food crops alone and food crops in association with woody perennials.

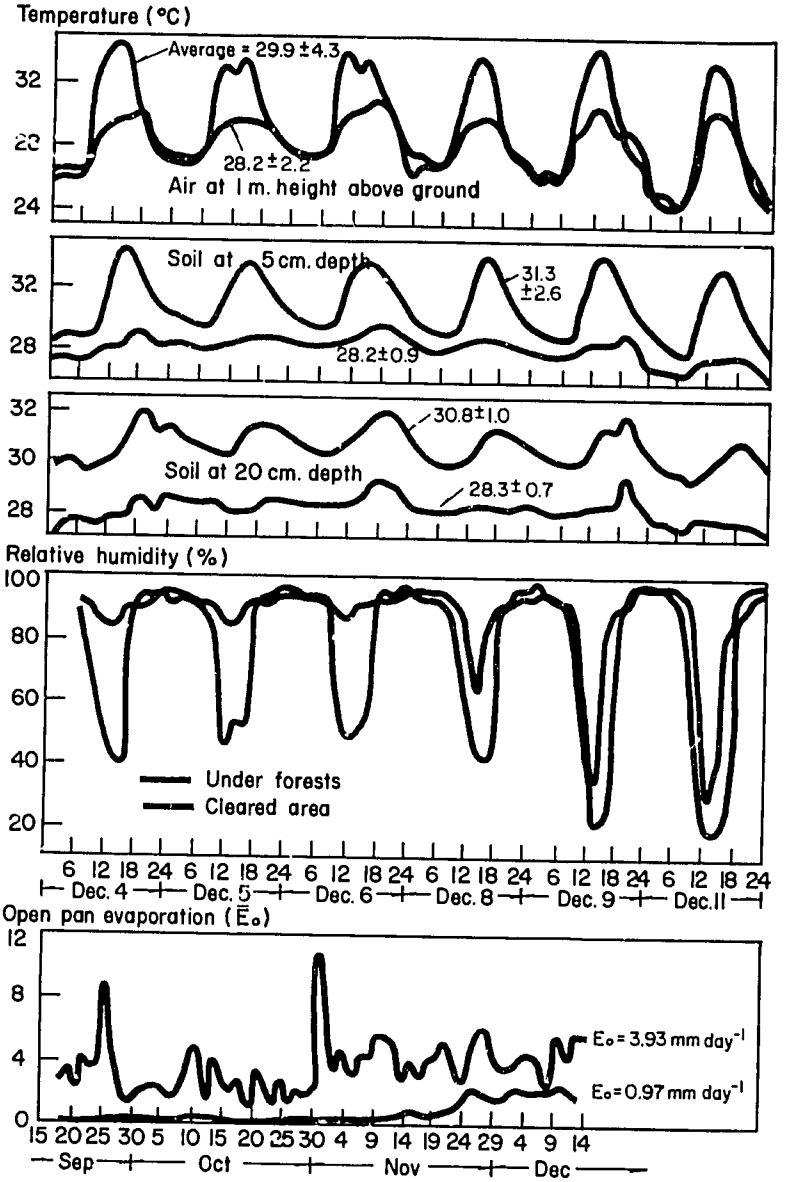
The principal collaborator in this long-term project is the United Nations University. The experimental forest land was provided by the Okomu Oil Palm Company Limited.

FIGURE 22.

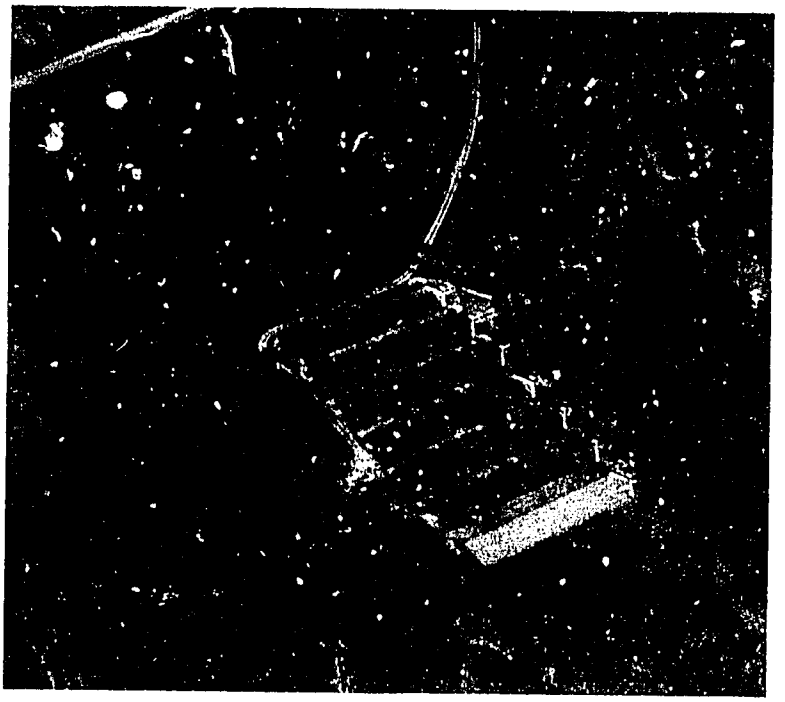
(A)
Soil and air temperatures under and outside the forest for six days during the dry season.

(B)
Relative humidity decreases with the advancement of the harmattan season from December 4–11. Decrease is greater in the cleared area than in the forest.

(C)
Open pan evaporation in the cleared area and under the forest.



Experimental site at Ilore village, Nigeria with seven field plots surrounded by farmers' traditionally managed land.



Evaluating Conservation-Effective Cropping Systems for an African Savanna Soil

Soils in the humid and subhumid regions of West Africa are structurally unstable, prone to crusting, susceptible to accelerated erosion, and of low fertility. Some soils with so-called iron pans at shallow depth cover an estimated 243 million hectares of the West African landscape and when put to intensive landuse may undergo irreversible degradation.

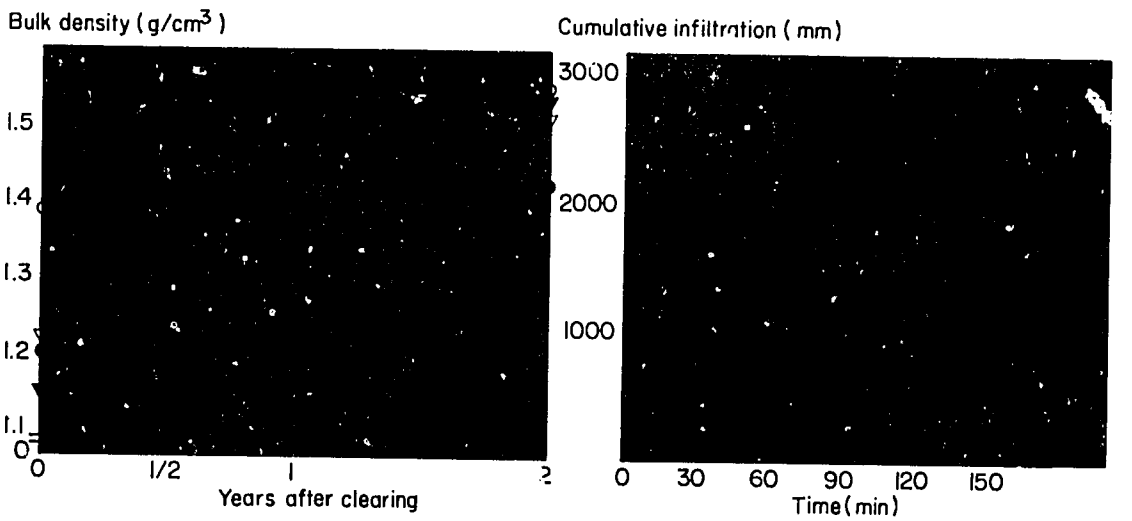
To evaluate the effects of cropping systems and soil surface management on water runoff, erosion, and alterations in soil properties and to assess crop production under traditional and intensive landuse, scientists selected a site at Ilore village about 20 km northwest of IITA's main campus. The experiment,

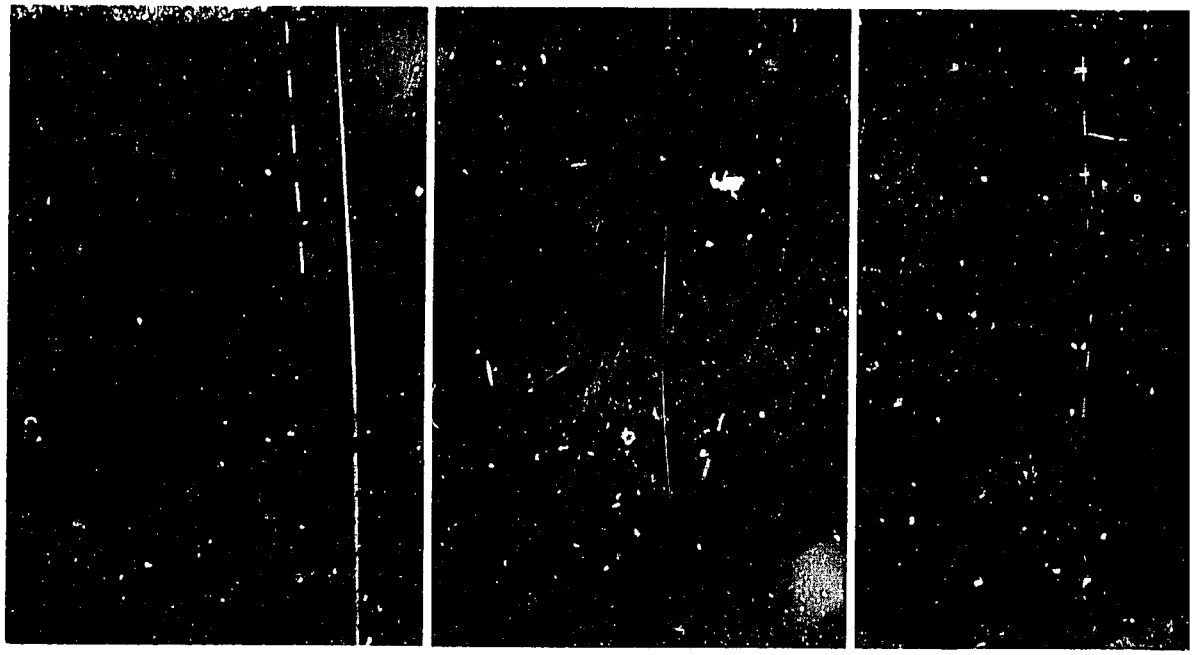
started in 1983, consists of seven plots where the scientists are comparing the effects of a traditional farming system with that of maize-cowpea rotation under no-till, conventional plowing, and bare fallow. The soil (on a slope of 4 to 5%) is a Psammentic Ustorthent, sandy isohyperthermic, and siliceous with plinthite (iron pan) at depths varying from 20 to 100 cm.

Soil bulk density of the 0 to 5 cm layer increased with time after initiating cultivation (Figure 23). Iron pan is formed by hardening of plinthite upon deforestation and exposure by cultivation in the humid regions, but it is already formed in a savanna ecology due to frequent fires and low vegetation cover. Two years after starting the study, the bulk density was in the decreasing order of bare fallow, plowed, no-till, and traditional treatment, respectively. Treatments involving plowing were characterized by the development of a thin crust that inhibited the infiltration rate, increased surface runoff, and speeded up soil erosion. Water infiltration rate was the maximum under natural vegetation, followed by under cultivated plots in the order of traditional, no-till, plowed, and bare fallow treatments, respectively (Figure 23).

Data in Table 31 show drastic differences in runoff and soil erosion among the treatments investigated. The traditional

FIGURE 23.
Left, change in soil bulk density with time for four soil management systems; right, cumulative infiltration rate two years after imposing soil treatments on a savanna soil. (Ilore, Nigeria.)





Sequence of three predominant soils of the region: Left, gravel layer at top but no iron pan below; center, no gravel layer at top but iron pan at about 30 cm depth; right, iron pan at 10 cm depth. If erosion removes the top soil, productivity is lost forever.

treatment in 1983, which was managed entirely by a farmer, included maize-yams grown on mounds. Soil erosion was more severe on this plot than from a flat-seeded maize-cowpea rotation grown with no-till or the plowed system. In 1984, however, traditional systems consisted of maize-cassava grown on ridges made across the slope that reduced water runoff and soil erosion. The least soil erosion was observed on no-till plots. Compared with the no-till system, water runoff, and soil erosion, respectively, were 3.3 and 2.5 times greater in the traditional system,

TABLE 31.
Effects of soil and crop management on water runoff and soil erosion at Ilore, Nigeria (1983–84).

Treatment	Soil erosion t/ha 1983	Soil erosion t/ha 1984	Runoff mm 1984
Traditional	5.1	1.5	23.8
No-till	**2.3**	**0.6**	**7.2**
Plowed	5.4	10.1	154.9
Bare fallow	33.9	261.6	327.1

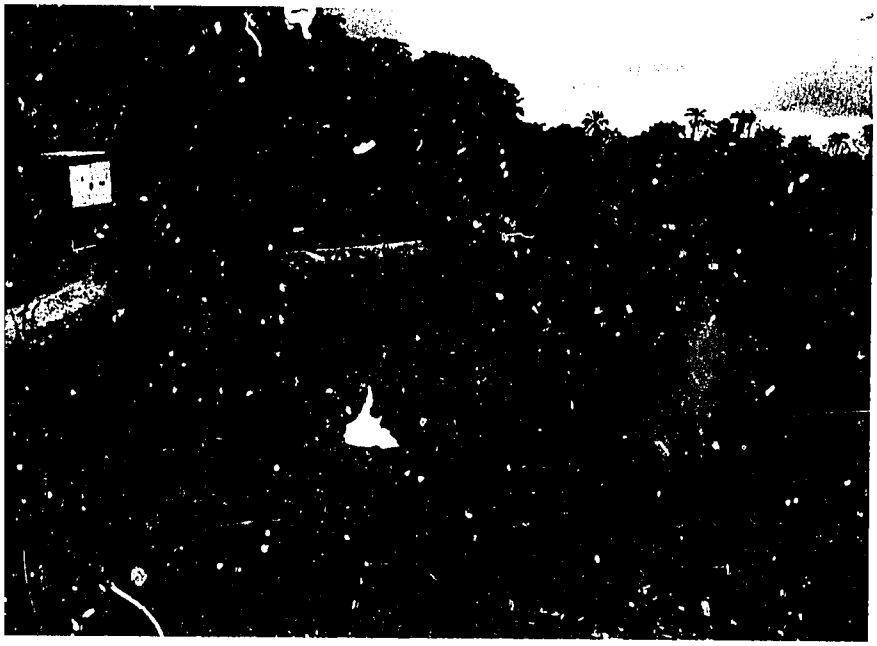
21.5 and 16.8 times greater in the plowed treatment, and 45.4 and 436 times greater in the bare fallow plot.

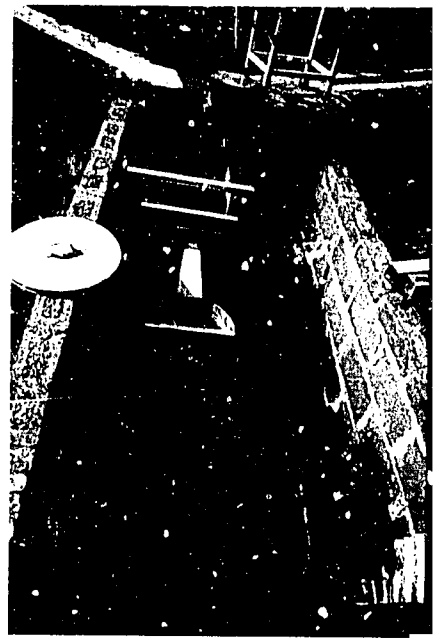
Because the depth of soil and occurrence of iron pan were highly variable along the slope, crop growth can be interpreted only by comparing the yields in corresponding sub-plots (Table 32). In 1983, the first season maize yields were higher in the plowed than in the no-till treatment. In the second season, when the no-till was mulched with the maize residue, the cowpea yields did not differ significantly between the treatments. Similar yield trends were observed in 1984.

This experimental program was established in collaboration with the University of Munich, West Germany and partially funded by the German Agency for Technical Cooperation (GTZ).

TABLE 32.
Crop yields on three different slopes at Ilore, Nigeria (1983). Maize yields downslope are low because of the shallow depth of iron pan.

Treatment	Upslope	Midslope	Downslope
		(t/ha)	
Traditional			
Maize	0.8	1.0	0.2
Yams	0.5	5.1	3.4
No-till			
Maize	3.0	2.9	2.2
Cowpeas	0.5	0.5	0.4
Plowed			
Maize	4.0	3.8	3.3
Cowpeas	0.5	0.4	0.4





Above, experimental set-up showing field plots at the site with tensiometers and water runoff collection system; right, water runoff and sediment collection system, including storage tank, divisor tank, HS-flume, and water stage recorder.

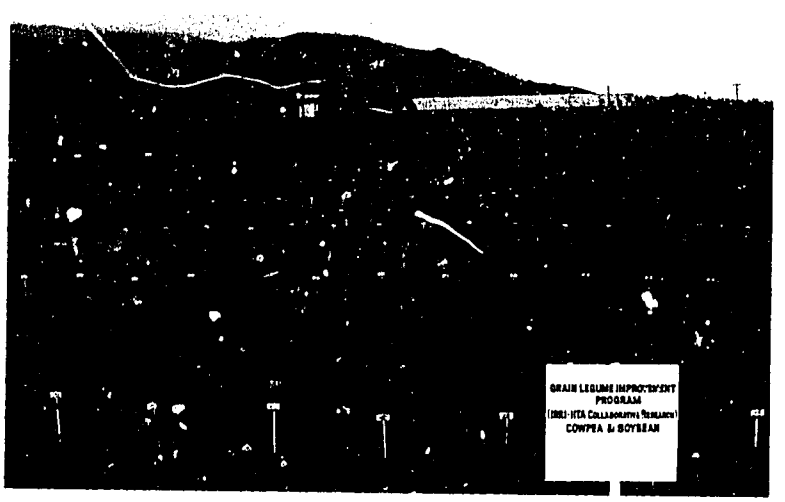
Severity of sheet and rill erosion on bare plowed land.

Research and Training Activities Move Closer to Recipients

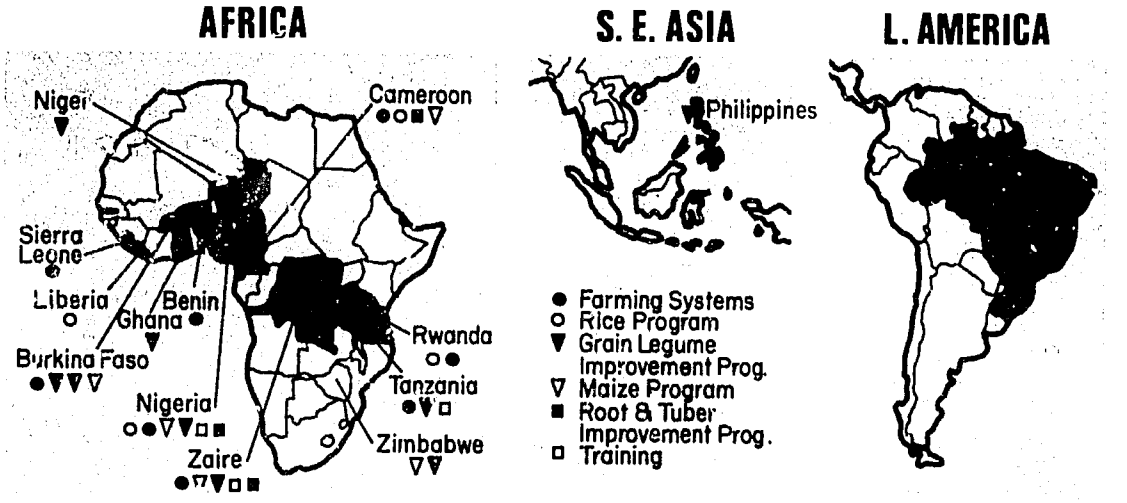
Under a new master plan, IITA has stepped up efforts to conduct more research and training outside its headquarters at Ibadan, Nigeria.

A new substation in the Republic of Benin was opened in 1984 on a 50-hectare site contributed by that nation, and scientists and support staff were assigned there and in several other African areas to join already active or newly created regional or national teams to help speed up food production and agricultural development (Figures 24 and 25). The principal thrust of this new direction involves on-farm adaptive research and training.

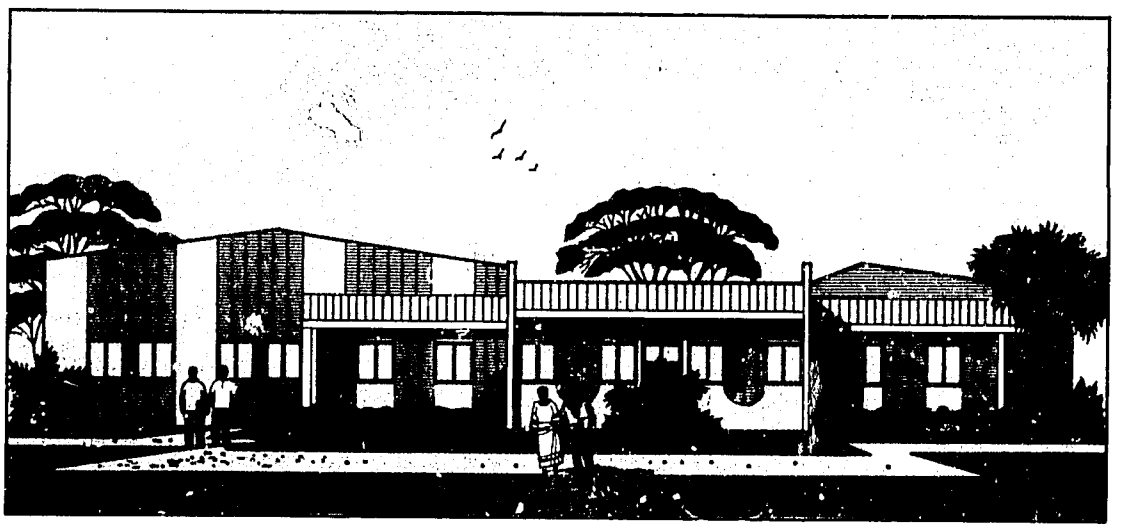
Although IITA is concerned primarily with humid and subhumid Africa, it has a worldwide mandate for research on farming systems and on cowpeas, yams, and sweet potatoes. As part of this broader responsibility, the Institute has posted two grain legume scientists in Brazil at EMBRAPA to work in Latin America and in the Philippines at IRRI to work in Southeast Asia.



Collaborative grain legume research between IITA and IRRI for Southeast Asia is underway with the posting of an IITA scientist in the Philippines.



FIGURES 24 & 25.
Above, locations of IITA scientists and their program connections in Africa, Southeast Asia, and Latin America; below, an artist's sketch of the new IITA substation headquarters building under construction in the Republic of Benin.



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